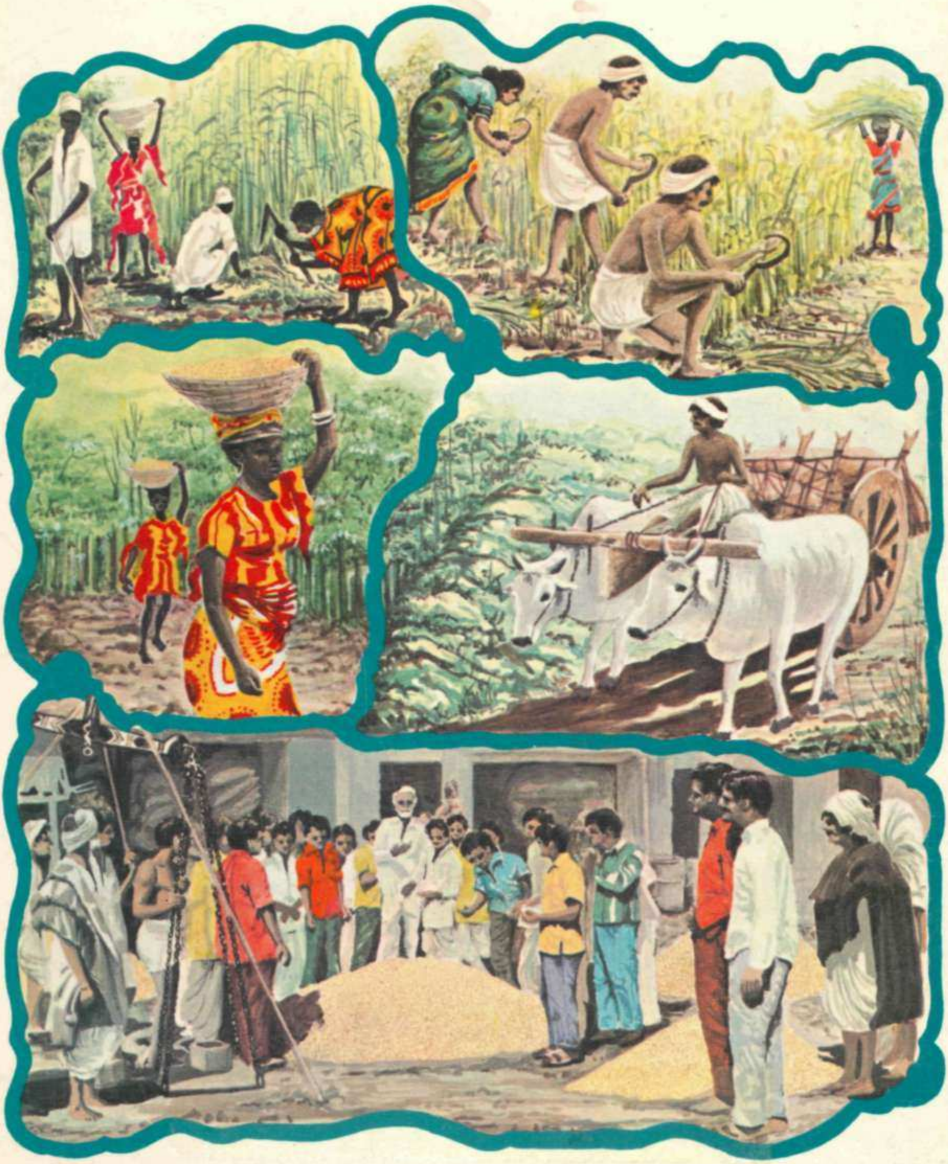
Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture



International Crops Research Institute for the Semi-Arid Tropics

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Foreword

Since ICRISAT's earliest days, socioeconomic research has played an important role in the Institute's efforts to improve crops and farming systems in the semi-arid tropics (SAT), and the lives of the people who depend on these crops for their basic food supply.

Our Governing Board was aware that new technologies, and even seeds, could not be distributed and adopted for use without an understanding of the social and economic conditions in which the people of the region lived. The following objective was written into ICRISAT's mandate in 1974, two years after the Institute was started:

> To identify socioeconomic and other constraints to agricultural development in the semi-arid tropics and to evaluate alternative means of alleviating them through technological and institutional changes.

The constraints to agricultural development in the SAT are many: harsh climate; limited, erratic, and unpredictable rainfall; poor soils; widely varying resource endowments, such as an abundance of labor and scarcity of land and capital in India, an abundance of land and scarcity of labor and capital in Africa, and — especially in Africa — limited market facilities. Most of the 600 million people populating the SAT regions of 49 countries live at a subsistence level, and the crops researched by ICRISAT (sorghum, pearl millet, pigeonpea, chickpea, and groundnut) are among their most important food crops.

The principal target of ICRISAT's research is the small farmer of limited means, who often has poorest access to technology and the markets that can help him effectively benefit from it. ICRISAT's economists and social anthropologists are working closely with biological and physical scientists to better identify the needs of the small farmer and devise improved crops and farming systems that will enhance his welfare and that of the labor he employs, as well as those who depend on him for food supplies.

As part of our effort to learn more about the socioeconomic problems affecting this region, ICRISAT sponsored the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture at Hyderabad, 19 to 23 February 1979. This conference brought together economists and social scientists from 16 countries, all with an interest in and experience with the problems of the SAT.

Their contributions and the results of their deliberations will be found on the following pages. We at ICRISAT have found these contributions to be valuable in our work; we believe that you also will find them interesting and useful.

L. D. Swindale
Director General

Preface

The primary objective of the Workshop was to consider ways and means of overcoming the various socioeconomic constraints identified during the course of the participants' research in the semi-arid tropics. In particular we asked them to focus their papers and discussions on the role that new technologies and/or policies could play in alleviating the constraints to the development process in the SAT.

The Workshop comprised three basic segments : (1) subject matter sessions, (2) country reports, and (3) field trips.

The subject matter sessions addressed issues particularly relevant to the SAT and on which research is currently under way, both at ICRISAT and in other institutions. Topics chosen included the analysis of existing farming systems and practices, socioeconomics of prospective technologies, field assessment of prospective technologies, issues in foodgrain marketing, nature and significance of risk, rural labor markets, and the economics of improved animal-drawn implements and mechanization. Papers were invited from colleagues working on these topics in other institutions in SAT regions as well as those in the ICRISAT Economics Program. A large amount of time was allowed for open discussion, following the prepared commentary by the discussant assigned for each session.

Country reports were presented by invitees from major SAT countries of primary concern to ICRISAT. The objective was to obtain a set of meaningful socioeconomic data on the SAT regions of these countries to enable cross-country comparative analyses to be made and to better identify technological and institutional potentialities and priorities. These papers, listed in Appendix 2, will be assembled in a companion volume to these proceedings. In the meantime, copies of the papers can be obtained from the Economics Program at ICRISAT.

Workshop sessions were held in Hyderabad, since ICRISAT Center was then still under construction on the research farm at Patancheru, 25 km northwest of the city. A field trip was made to the Center to familiarize participants with the two main research programs of ICRISAT, Crop Improvement and Farming Systems. Scientists from the five breeding programs included in Crop Improvement — sorghum, pearl millet, pigeonpea, chickpea, and groundnut — discussed the objectives and progress of their research to develop new cultivars with higher yield potential, pest and disease resistance, improved quality, etc. Scientists from Farming Systems discussed and demonstrated the various approaches in cropping systems and land and water management they are investigating in order to develop viable technologies that will help increase and stabilize crop production in the SAT.

A second trip was made to Aurepalle, one of the six selected villages in ICRISAT's socioeconomic studies that have been under way since May, 1975 in the SAT of peninsular India. This visit, together with the one to ICRISAT Center, served to illustrate how the work of the Economics Program directly relates to the work of the Crop Improvement and Farming Systems Programs, and the extent to which close collaboration exists between scientists of these three programs.

The Workshop program was designed to maximize time for discussion. The rapporteurs recorded major highlights of each session, including both the formal presentations and the discussions. These were used, along with the written versions of questions and answers that we asked each questioner/commentator to complete, to help the session chairman prepare a short summary of highlights and recommendations on the session for presentation at the concluding session of the Workshop. It was requested of the session chairmen that their recommendations pay particular attention to questions of (1) technology design, (2) agricultural policy, (3) future socioeconomic research both in national programs and at ICRISAT, and the relationship of these programs to one another. For the convenience of readers, the session summaries presented by the chairmen at the concluding session are found at the end of each chapter in this report.

This volume includes edited versions of all subject matter papers that were submitted in writing for the Workshop, and the Discussant's comments and Chairman's summaries of each session. We have not included invited presentations made orally unless these were later submitted in writing.

Five of the papers were presented in French. They appear herein with English translations, which have been edited. The original French text will be found in Appendix 1, along with French abstracts of the papers that were presented in English.

I would like to thank all of my colleagues in the Economics Program and other units of ICRISAT for-their active assistance in the planning, preparation, and conduct of the Workshop. Especially appreciated were the efforts of Information Services in the editing, printing, and distribution of the large volume of papers for the Workshop and in the preparation and printing of these proceedings. The editorial assistance of Mrs. Vrinda Kumble is also gratefully acknowledged.

I deeply appreciate the guidance and strong support of Dr. R. C. McGinnis, former Associate Director for Cooperative Programs at ICRISAT, who at that time had responsibility for international conferences and symposia.

James G. Ryan
Workshop Chairman

Chapter 1

Socioeconomic Analysis of Existing Farming Systems and Practices

Socioeconomic Analysis of Existing Farming Systems and Practices in Northern Nigeria

G. O. I. Abalu and B. D'Silva*

Abstract

Microlevel studies of existing farming practices in northern Nigeria show a clear-cut socioeconomic rationale behind the practices adopted by farmers in the area. Mixed cropping is favored because returns per acre are high and risk is minimized. Only those technologies that encourage and support the strategies behind the farming practices in this region will have a good chance of being successful. Conventional research approaches emphasizing single-crop technologies should be discouraged; an approach that examines all crops in the farming system and considers the felt needs of farmers should be evolved. The importance of multidisciplinary work and the ex ante role of the social scientist in the research effort are emphasized.

The principal variations in agricultural production in Nigeria arise from climatic differences. Four major ecological areas with homogeneous agricultural conditions can be identified: two savanna areas in the northern part of the country (Sudan savanna and Guinea savanna), the forest savanna in the middle belt, and the rain forest areas in the southern part of the country. The general pattern of these ecological areas consists of horizontal bands proceeding from east to west.

The farming systems that have emerged over the years have been shaped by the interaction of factors such *as* (1) tradition, (2) level of technology (hand labor, use of oxen, etc.), (3) resource availability (land, labor, capital, managerial skill, etc.), (4) physical environment (temperature, water availability, etc.), and (5) economic conditions (markets, storage facilities, transportation, etc.). Any effort to change the levels of production and standards of living of farmers, if it is to be successful, would have to closely study these indigenous farming systems.

In this paper, we examine the salient characteristics of farming systems in northern Nigeria and evaluate the economics of existing practices and cropping patterns, as revealed by microlevel studies carried out in the Department of Agricultural Economics and Rural Sociology at Ahmadu Bello University, Nigeria over the last 12 years.

These studies — interdisciplinary in nature — have concentrated on describing, explaining, and understanding the agricultural environment of small-scale farmers in northern Nigeria and in identifying the economic, social, political, and institutional factors impeding agricultural and rural development in the area. Considerable work has been done and documentation now exists on what farmers are doing. Emphasis is now being directed towards studies of alternative strategies for increasing agricultural production and rural welfare and the economic, social, and political implications and consequences of these strategies.

Farming Systems in Northern Nigeria

The bulk of agricultural production in northern Nigeria is undertaken by small-scale farmers. Their agriculture is characterized by a situation where:

1. the bulk of the labor force, management, and capital come from the same household;
2. production is either consumed on the farm and/or traded in local markets;

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3. the decision-making process is hampered by limited access to marketing and political institutions; and
4. most of the farmers do not live much above the culturally determined subsistence level. (Abalu and D'Silva 1978).

There is a marked seasonal distribution of rainfall in northern Nigeria. The rains generally begin in April or early May and continue to the end of September or middle of October. During the rainy season, upland fields are cleared, plowed, planted, weeded, and ridged. The first crop to be harvested is millet, in August-September. Other crops (groundnuts, cowpeas, cotton, peppers, etc.) are harvested as they mature, with the major grain crop, sorghum, being harvested last, around January (Simmons 1978).

A significant aspect of the cropping system that has emerged in northern Nigeria is that crops are grown in mixtures. Norman (1972) found 24 different crops on rainfed *(gona)* land, in a total of 174 different crop mixtures. Sole crops accounted for only about 17% of the total cultivated acreage (Table 1). More recent studies have indicated a slight shift in favor of sole crops (Ukpabio 1978).

The crops that farmers have chosen to grow in the area have depended not only on physical factors such as rainfall, temperature, soil fertility, etc., but also on economic, social, and political considerations (Baker and Norman 1975). The cropping system that has emerged is complex and dynamic. Given the available factors of production, farmers allocate or withdraw these factors from their farming activities depending on their goals, management abilities and expectations, as well as on how the season unfolds. Palmer-Jones (1978), for example, quotes Mike Watts as to the description given by some farmers of their farming system in Katsina Emirate in northern Nigeria.

> There are three types of land, *jigawa,* upland soils where cereals and beans are grown; and two types of *fadama,* one has a high water table in the rainy season and sometimes floods, and allows us to grow a tobacco crop in the dry season; the other floods every year but we can grow irrigated vegetables in the dry season on it. If there are good early rains, most of us (farmers) plant the millet variety *zango* on the *jigawa* at wide spacings, some put the guinea corn variety *jadawa* in between, others wait until the next rains. If these follow the first rains within say 10 days we will all plant *jadawa* and later we will interplant the cowpea variety *dan baranda.* However, if there is a drought after the first rains, or if they come late, we will replant with the millet variety *dan hawa* and the guinea corn variety *yar*

Table 1. Common crop combinations In the Zaria area.[a]

Crop Specification	Percent of total cultivated acreage
Sole crops	
Sorghum	8.4
Groundnuts	1.8
Cotton	3.1
Other crops	3.3
Subtotal	16.6
Two-crop mixtures	
Millet/sorghum	25.8
Sorghum/groundnuts	2.8
Cotton/cowpeas	3.9
Other crop combinations	9.6
Subtotal	42.1
Three-crop mixtures	
Millet/sorghum/groundnuts	5.0
Millet/sorghum/cowpeas	3.9
Cotton/cowpeas/sweet potatoes	4.3
Other crop combinations	10.5
Subtotal	23.7
Four-crop mixtures	
Millet/sorghum/groundnut/ cowpeas	5.4
Other crop combinations	6.7
Subtotal	12.1
Five- and six-crop mixtures combinations	5.5
Total	100.0

Source: Norman (1975).
a. The survey included a total of 890.7 cultivated acres of rainfed land, (i.e., upland).

bazerga, at wider spacings. Also if the rains are poor we will plant more guinea corn *(jadawa)* on the first type of fadema and less rice because our guinea corn will not do so well on *the jigawa* and because the *fadama* is less likely to flood, so rice will not do so well and guinea corn will do better.

Faced with this type of scenario every year, the farmer is forced to plan purposefully if he is to meet his production targets. In the section that follows, we attempt to evaluate the economic rationale behind the existing cropping systems in the area.

The Economics of Existing Practices

The farmers of northern Nigeria choose from a wide range of technical possibilities the practices that will lead them to achieve their specific goals. With the aid of an income model, a risk aversion model, and a minimum nutrition model, this section examines the rationality behind existing farm practices in the area.

Maximizing Income[1]

In his study of the rationale behind mixed cropping under indigenous conditions in northern Nigeria, Norman found that individual yields of sorghum, groundnuts, and cotton are depressed when grown in mixtures rather than in sole stands. However, this was not always true for crops that are normally grown in mixtures, such as cowpeas and millet. Sole-stand cowpea appears to be more prone to insect and disease attack than cowpea grown in mixtures; millets, which are the first seeds planted at the beginning of the rains and the first crop harvested in the growing season, are unlikely to suffer greatly from competition with other crops.

Average gross and net returns from sole crops and crop mixtures are presented in Table 2. Average gross returns per acre are about 62% higher for crop mixtures. Average net returns per acre show the same trend. It is obvious from this that crop mixtures bring higher returns per unit of land than sole cropping.

Since the farmer who is interested in maximizing his income will most likely achieve that goal by maximizing returns from his most limiting resource, return per unit of land may not be the most relevant criterion for his allocation of resources. In northern Nigeria, the amount of labor available during the period between June and July is of crucial importance to the type and amount of crops that can be grown. During this period land preparation, weeding and planting are taking place simultaneously; consequently, the amount of labor that can be made available at this time will greatly influence the crops that are grown. Norman (1975) found that returns to June-July labor were higher for all crop mixtures than for

1. This section draws from Norman's (1975) work on crop mixtures.

Table 2. Average gross and net returns from sole crops and crop mixtures.

Variable	Sole crops	Crop Mixtures: Two crops	Three crops	Four crops	All mixtures	Overall
	Shillings					
Gross return per acre	153.6 ±22	240.6 + 19	229.8 ±30	340.9 ±80	248.3 ±16	228.5 ±13
Net return per acre						
Labor:						
Not costed	148.9	235.7	220.3	322.9	240.8	221.6
Hired costed	135.2	213.6	199.1	297.4	218.6	201.2
June-July costed	133.7	204.7	189.0	276.8	208.2	190.2
All costed	74.1	115.5	105.3	184.6	119.8	110.1

Source: Norman (1975).

sole crops. Using the same data, Ogunfowora (1972) also concludes that the scarcity of resources on traditional farms in the area was consistent with the preference for mixed cropping.

Minimizing Risk

Numerous writers have incorporated yield and price variability into models representing the decision framework of small-holder farmers (Wharton 1968).. Farmers in northern Nigeria are faced with a limited growing season and are constrained by limited resources. It is therefore logical for them to be concerned with ensuring a stable income in the face of biological and economic occurrences whose effects they cannot exactly determine in advance. Consequently, their cropping patterns are influenced by subjective formulations of expectations about future price and production situations. On the basis of long-established traditional procedures, they are able to arrive at complex calculations concerning probable future prices and yields. On this basis, they may choose not to cultivate single crops over time, even where substitution ratios and price ratio expectations may so dictate, but to cultivate crop mixtures in somewhat fixed proportions. The rationale behind their strategy here is simply not to "put all of their eggs in one basket."

The use of crop mixtures as a diversification precaution against uncertainty can be accomplished in two ways:

1. The amount of resources can be increased so as to be able to produce both products A and B, for example, or
2. The amount of resources can be held constant while part of them are diverted to other products.

Since factors of production have been shown to be limiting in the agriculture of the area, it is the latter method that seems to be more applicable. Because of the marked seasonal distribution of rainfall, the diversification strategy has tended to be pursued through mixed cropping rather than through multiple or relay cropping (Baker et at. 1975).

The question may be raised that if the farmer is dealing with risk aversion, why should he, for example, mix crop A and crop B *over* his entire field rather than divide his field between crop A and crop B? The answer lies in the fact that the farmer, realizing that he is faced with a limited and uncertain growing season, finds it attractive to grow different crop species in the same plot — provided that the relationship between the species is complementary. Factors such as complementary growth cycles, noncompeting rooting habits, and compatible labor demands may enhance the desirability of growing crops together in the same plot rather than on different parts of the plot.

Using a mean-variance framework, an attempt was made to test the hypothesis that risk aversion is a critical item in explaining farmers' decisions concerning choice of cropping pattern.[2] Information was obtained on the average value, range, and standard deviation of income derivable from a unit of agricultural land in the area over a 5-year period, 1971 to 1975. Total income variance equations were calculated for pairs of identified farm enterprises including variances and covariances. These equations then provided a basis for calculating the optimum proportion of resources, P, that should theoretically be allocated to each crop enterprise in the pair so as to enable minimizing the variability of income over the period. These proportions were then compared with the actual observed proportions of resources devoted to the pairs of crop enterprises. The results are presented in Table 3. Paired comparisons on the two series using a t-test revealed no statistical difference between the model and the observed proportions at the 95% confidence level.[3]

The results of the analysis indicate that the cropping system in the area reflected a risk-aversion strategy.

Meeting Protein and Calorie Requirements

Malnutrition has very serious repercussions for the small-holder farmer. There is always a balance between the nutritional resources available to him (which depend largely on how much food was produced during the preceding harvest) and the nutritional requirements to maintain the existing and future livelihood of his

2. Details of the methodology employed can be found In Abalu (1976).
3. It Is realized that a t-test of differences in proportions is not strictly valid.

Table 3. Proportion of resources allocated to pairs of crop enterprises.[a]

Crop enterprises		Allocation of resources to crop A[b]	
A	B	Model solution	Observed
Sorghum	Millet/Sorghum	0.27	0.25
Sorghum	Groundnuts/Sorghum	1.00	0.75
Sorghum	Millet/Groundnuts/Sorghum	0.70	0.62
Sorghum	Millet/Cowpeas/Sorghum	0.48	0.68
Sorghum	Groundnuts/Cowpeas/Sorghum	0.97	n.a.[c]
Sorghum/Groundnuts	Millet/Sorghum/Groundnuts	0.26	0.39
Sorghum/Groundnuts	Cowpeas/Sorghum/Groundnuts	0.18	n.a.
Sorghum/Groundnuts	Millet/Cowpeas/Sorghum	0.69	0.71
Sorghum/Millet	Groundnuts/Sorghum/Millet	1.00	0.84
Sorghum/Millet	Millet/Cowpeas/Sorghum	0.53	0.86
Groundnuts	Groundnuts/Sorghum	0.66	0.40
Groundnuts	Groundnuts/Cowpeas	0.48	n.a.
Groundnuts	Millet/Groundnuts/Sorghum	0.37	0.27
Groundnuts	Groundnuts/Cowpeas/Sorghum	0.20	n.a.
Groundnuts/Cowpeas	Groundnuts/Cowpeas/Sorghum	0.11	n.a.
Groundnuts/Cowpeas	Millet/Groundnuts/Sorghum	0.66	n.a.
Groundnuts/Cowpeas	Millet/Cowpeas/Sorghum	0.53	n.a.

a. Proportion is computed as the quantity of land devoted to an enterprise relative to the total land devoted to the pair of enterprises.
b. Refers to the proportion of resources allocated to crop enterprise A. The proportion of resources allocated to crop enterprise B is one minus the proportion shown here.
c. Not available.

family. This ratio of available resources to required inputs will vary depending on the crops that the farmer chooses to grow on his limited land base.

In the face of threats of malnutrition to him and his family, the farmer would be expected to adjust and reallocate agricultural resources available to him and adopt or discard land use practices. The beginning of the rains witnesses an increase in agricultural activities associated with land preparation, planting, weeding, and harvesting. This is also the period when many people are in a negative nutritional balance because of the shortage of food. It has been suggested that some of the most serious debilitating diseases, such as malaria, diarrhea, guinea worm, and infections of the skin, peak during this time as well (Longhurst 1978). Coinciding with a peak labor demand — when failure to cultivate, plant, weed, or harvest may critically affect future income and food supplies — these infectious diseases increase the risk and vulnerability of small-holder farmers in the area (Longhurst 1978). Hill (1972) has suggested that the ability of the farmer to survive this period determines to a large extent the welfare of the family during the rest of the year.

With the aid of a linear programming model, we attempted to find out whether the cropping system that the farmer has come to prefer is consistent with his body requirements and the nutritional requirements of his family. The model had as an objective the maximization of farm income in the face of a minimum nutrition constraint. Constraints were also imposed on available farm labor and farm land. Nine different cropping activities, reflecting those most common in the area, were considered. The data used in the analysis are derived from work by Simmons (1976) and Norman (1972).

Yearly requirements of protein and calories for an average family in the Zaria area are shown in Table 4. The program was analyzed.

Table 4. Calorie and protein requirements for an average family, Zaria, Nigeria.

Age category	Average number of persons per family	Annual requirements: Calories ('000 kilo cal.)	Annual requirements: Protein (kg)
Under 7 years	2.18	1252	13.89
Between 7-14 years	1.54	1313	16.92
Female over 14 years	2.62	1913	33.94
Male over 14 years	2.15	2119	30.64
Total		6597	95.39

using farm sizes of 3, 5, 10, 12, and 18 acres (average farm size in the area is 7.9 acres, Norman 1972). The results thus obtained would show a relationship between farm size, labor use, and nutritional balance.

The results of the analysis *are* presented in Table 5. A farm size of 3 acres resulted in an infeasible solution. All the other farm sizes, however, were able to meet the nutritional constraints. In fact, a surplus of both protein and calories was found to exist in all cases. Over 70% of the protein and 40% of the calories supplied by the crop activities in the plan were in surplus. We have not here compared these balances with the actual balance as revealed from the existing farm plans. This would be a valuable exercise.

Of significant interest in Table 5 is the fact that all crop activities in the optimal plans for all farm sizes are crop mixtures. This is all the more striking since the model provided for nonprotein and noncalorie-generating crop activities to enter the optimal plan, if they generated enough income to purchase the minimum protein and calorie requirements.

The analysis also showed that a strong relationship existed between income, farm size, and the hiring of labor. Thus, as farm size increased and if labor was available to be hired, incomes for farmers would also increase and all farms, except those less than 3 acres in size, met the nutritional requirements of the work force. It should be emphasized that the major constraint here would be labor availability.

It is also interesting to note that the farm size of 3 acres resulted in an infeasible solution, suggesting that only a larger acreage is capable of meeting the protein and calorie require-

Table 5. Solutions of program for different land sizes.

Land constraint (acres)	Crop activities in the plan	Production of nutrients: Calories ('000 kilo cal.)	Production of nutrients: Protein (kg)	Net farm income (£ N)	Month of labor hiring
3	Infeasible	NS	NS	NS	NS
5	Millet/Sorghum/Cowpeas	6959	220	855	May
10	Millet/Sorghum/G'nuts (5.99 acres)	5700	148		May, June
	Millet/Sorghum/Cowpeas (4.01 acres)	5581	177	1382	July, Aug.
12	Millet/Sorghum/G'nuts (9.64 acres)	9174	238		May, June, July
	Millet/Sorghum/Cowpeas (2.36 acres)	3660	116	1540	Aug, Nov
18	Millet/Sorghum/G'nuts (15.99 acres)	15217	395		Apr, May, June
	Millet/Sorghum/Cowpeas (2.56 acres)			1868	July, Aug Oct, Nov

NS = No solution obtained.

ments. Consequently, a farmer confronted with a limited land base would have to take alternative action if he is to feed his family adequately. One such action is for him, knowing that the land available to him is too small to meet the minimum nutritional requirements of his family if he grew food crops, to choose to grow the most profitable crop compatible with his low income. In most cases, this would be a cash crop. Revenue received from the sale of the crop would thus allow a higher level of food consumption (as well as meet the minimum nonfood cash needs) than if the entire land base had been allocated to less profitable food crops.

Although this paper does not further analyze the protein strategy of farmers who own 3 acres or less, another study near the area does provide some information on the nutritional strategy of land-scarce farmers. Matlon (1977) finds that groundnut production was given relatively greater emphasis by low-income farmers. Their food production was inadequate to meet their minimum nutritional requirements, yet groundnut (a cash crop) constituted a disproportionately large component of the crops they produced. The optimum plans from the linear programming exercise would therefore appear to support the hypothesis that the emphasis on crop mixtures in the agriculture of the area is consistent with the nutritional requirements of the farmer's family.

Improving Cropping Systems in Northern Nigeria

What emerges from the foregoing analysis is the fact that existing farming systems and practices in northern Nigeria have a clear-cut rationale behind them. This does not imply that farmers are organizing their resources in the best manner and making the best use of their land. But it is obvious that efforts to improve upon the existing farming systems should aim at (1) examining the rationale behind existing practices, (2) avoiding actions that weaken the strategies underlying these practices, and (3) encouraging measures that support and strengthen these strategies.

To this end, suitable technologies have to be developed, accompanied by the creation and maintenance of relevant infrastructural support systems and the undertaking of honest research on farming systems.

Most of the technologies that have been developed in northern Nigeria so far have been designed to improve single crops rather than the complete farming system. This is because of the long-standing tendency to associate progressive agriculture with sole cropping and the selfish quest to promote the development of certain crops. Consequently, efforts at applying new technologies have resulted only in isolated and haphazard introduction of single-crop modern technology. This has resulted in a few isolated public and private farms using modern technology while the vast majority of farms in surrounding villages continue to use primitive and crude implements.

A systems approach to the development of new technologies appears to be needed to increase agricultural production and the welfare of farmers in the area. For example, it would be necessary to be aware of the effect of any new practice on the entire farming system and, as such, to balance the effect in such a way that the new farming system that emerges does not lose its logic and rationality. New technologies, therefore, would be judged not only by their technical feasibility but also by their technical compatibility. These technologies would be expected not only to be able to increase productivity given the prevailing technical environment but also to be compatible with the technical environment in which other technologies operate or are expected to operate. While the technologies must return fair profit to the farmer, they must also exhibit a level of risk the farmer can accept and meet the nutritional requirements of the farming family. The new technologies would also need to be compatible with existing structures and norms, as well as the prevailing or possible levels of infrastructural support.

Considerable research on farming systems would be needed to ensure that appropriate farming systems evolve in the future. This research must emphasize the present status of farming systems in the area and their potential for improvement. The research effort must deal with the dynamic nature of the farming system and be done from the "bottom-up." This underscores the need for the research to be multidisciplinary and for the social scientist to play not only an ex post but also — perhaps more importantly — an ex ante role in the research effort. Above all, research on existing farming systems and how to improve them should reflect a sincere concern for the welfare of the masses in the area rather than the personal and — as experience has shown — selfish goals of researchers and sponsoring agencies.

Summary and Conclusion

This paper has attempted to evaluate the economics of existing farming practices in northern Nigeria as revealed by microlevel studies of the area. We have tried to show that there is a clear-cut socioeconomic rationale behind the practices adopted by farmers in the area. This rationale and logic would suggest that only technologies and institutions that encourage and support the strategies behind the farming practices would have a good chance of being successful. We suggest that conventional research approaches that emphasize single-crop technologies should be discouraged and, in their place, a research approach that examines all crops in the farming system and takes into account the felt needs of farmers should be evolved. The importance of multidisciplinary work and the ex ante role of the social scientist in the research effort are also emphasized.

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Some Dimensions of Traditional Farming Systems in Semi-Arid Tropical India

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Abstract

This paper summarizes some results of village-level studies conducted since 1975 by ICRISAT in six villages in three agroclimatic zones of peninsular India. Results that are of direct relevance to the research strategy for generating new technology for SAT areas are discussed. The paper analyzes the rationale behind the practices of monsoon fallowing of deep Vertisols and intercropping in rainfed agriculture. Constraints on the spread of prospective watershed technology are also discussed. Because small farms have a relatively greater extent of monsoon fallowing and intercropping, any low cost technological advance in these research areas may help less-endowed farmers. Under the existing pattern of land distribution and utilization, prospective watershed technology is likely to face severe institutional constraints.

This discussion of traditional farming systems in semi-arid tropical (SAT) areas of peninsular India is based on data from village-level studies undertaken by ICRISAT in three agroclimatic zones since May 1975. The principal objective of the village-level studies was to understand the constraints and potentials of traditional farming systems and to use this understanding as an input in the generation of new technology for SAT agriculture. Guided by this consideration, the paper addresses itself to a few key aspects of traditional farming systems that are of direct and immediate relevance from the standpoint of technology generation.

The paper makes use of data for 3 agricultural years (1975-76 to 1977-78) collected regularly at intervals of about 20 days from 30 sample farms (10 small, 10 medium, and 10 large) from each of the six villages.[1]

Table 1 provides some information about the selected villages and the sample farms and also broadly differentiates the three agroclimatic zones. The three zones considerably differ in terms of soil types, rainfall and extent of irrigation. The differences influence the farm level availability as well as pattern of resource use in these regions.[2]

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1. For sampling procedure and other methodological details of ICRISAT village studies see Jodha et al. (1977). During the period of 3 years some households belonging to the sample of labor households (10 in each village) acquired land. However, they have not been included in the present analysis. In keeping with the different land: man ratios prevailing in the villages, different ranges of operational landholding (in hectares) were used to define small, medium, and large farms as indicated below (for details see Ghodake and Asokan 1978).

Village	*Small*	*Medium*	*Large*
Kanzara	0.21-2.25	2.26- 5.60	> 5.60
Kinkheda	0.21-3.00	3.01- 5.60	> 5.60
Kalman	0.21-6.00	6.01-10.75	>10.75
Shirapur	0.21-2.50	2.51- 6.00	> 6.00
Aurepalle	0.21-2.50	2.51- 5.25	> 5.25
Dokur	0.21-1.00	1.01- 3.00	> 3.00

2. This paper deals with some aspects of the use pattern of land and water resources and their implications. For a discussion of the labor resource and its use see Ryan et al. (1979a).

Table 1. Details of operational land holding and its use pattern on sample farms in six SAT Indian villages from 1975-76 to 1977-78.[a]

Village (Location, soils, annual rainfall)	Farm size group[b] (ha)	Average size of land holding (ha)	Land use intensity[c] (%)	Cropping intensity[d] (%)	Irrigated area[e] (%)	Rainy season Fallow[f] (%)	Rainy season Cropped area[g] (%)
KANZARA	Small	1.4	99	103	6	2	98
(Akola Dist.; medium deep Vertisols;	Large	14.2	97	103	5	2	98
820 mm)	Total[h]	6.5	97	103	5	2	98
KINKHEDA	Small	1.6	97	104	4	2	98
(Akola Dist.; medium deep Vertisols;	Large	13.2	92	106	5	3	97
820 mm)	Total	6.7	93	106	4	3	97
KALMAN	Small	3.5	98	105	7	66	34
Sholapur Dist.; deep and medium-	Large	13.8	95	108	11	59	41
deep Vertisols; 690 mm)	Total	8.5	98	108	10	61	39
SHIRAPUR	Small	1.7	100	108	22	77	21
(Sholapur Dist.; deep and medium-	Large	11.3	91	114	11	71	29
deep Vertisols; 690 mm)	Total	6.5	92	114	13	68	32
AUREPALLE	Small	1.4	93	104	5	5	95
(Mahbubnagar Dist.; shallow and	Large	12.0	70	119	25	7	93
medium-deep Alfisols; 710 mm)	Total	5.6	76	114	21	5	95
DOKUH	Small	0.7	80	120	74	8	92
(Mahbubnagar Dist.; shallow and	Large	8.2	90	113	59	19	81
medium-deep Alfisols; 710 mm)	Total	3.7	82	113	60	18	82

a. Based on details from 180 sample farms in six villages. Village-level studies have been conducted in these villages since May 1975 (Jodha et al. 1977).

b. For the details of farm size grouping see text (footnote 1). All tables in this paper exclude the labor households even if they have acquired land during the reference period.

c. Land-use intensity $= \frac{\text{Net cropped } \textit{area}}{\text{Total operational area}} \times 100$

d. Cropping Intensity $= \frac{\text{Gross cropped area}}{\text{Net cropped area}} \times 100$

a. Gross irrigated area as proportion of gross cropped area.

1. Proportion of total net sown area fallowed during rainy season and planted in postrainy season. In Dokur and Aurepalle the rainy-reason fallow lands consist of tank beds where runoff collection is druring rainy season. These areas are available for planting crops only in the postrainy season once tank water is used up for irrigation.

g. Proportion of gross cropped area. It covers all area planted during rainy season including the double-cropped area.

h. Totals include medium farms besides small and large farms in each case.

Intensity of Land Use and Cropping

From Table 1 it is apparent that irrigation is associated with reduction in the average size of operational landholding and an increase in the cropping intensity. Except in the highly irrigated village Dokur, and to some extent Aurepalle, the intensity of land use during the reference period was found to be very high (exceeding 90%).

Land-use intensity was higher on small farms than on large farms. This is quite understandable as the smaller the land holding, the less the scope for resting land through periodical fallowing.[3] In all villages except Dokur, however, the cropping intensity was higher on large farms. This indicates that resource-rich farmers, instead of spreading their nonland resources thinly oyer all their land, *try* to concentrate their cropping efforts only on part of the total holding. Furthermore, taking farms as a whole, the gap between intensity of land use and intensity of cropping widened with the extent of irrigation available. The Mahbubnagar villages (particularly Dokur) clearly demonstrate this phenomenon.[4] Since the profits from irrigated land are much higher than on nonirrigated land, farmers prefer to keep part of the dryland fallow and concentrate their attention on irrigated land. The low land-use intensity in Dokur, especially on small farms, is thus largely explained by the extensive irrigation in the village. This has implications for rainfed agriculture. Because of the low and uncertain profit characterizing rainfed agriculture, less attention is paid to it and resources are, if possible, diverted to irrigated farming.[5] More about this later.

Rainy-Season Fallows

Another feature of traditional farming is the seasonal distribution of cropping (Table 1). In the two Sholapur villages that have a high proportion of deep Vertisols and a bimodal pattern of monsoon rains, 61 and 68% of the net cropped area was kept fallow during the rainy season and planted in the *rabi,* or postrainy, season.[6] This practice, known as *kharif* (rainy season) fallowing and *rabi* (postrainy season) cropping, is widespread in the deep Vertisol region of SAT India.[7]

The important reasons advanced by farmers for fallowing the deep Vertisols during the rainy season and then planting them in the postrainy season were as follows:

1. In the absence of good soaking rains, the deep Vertisols are too hard to work; once substantial rains begin, it is difficult to enter such fields.
2. Even if some crops are dry sown in deep Vertisols prior to rains, the management of the crop during the subsequent wet period is difficult. Weeds may ruin the crop before the fields are dry enough to permit entry of labor.
3. The rains received during the early phase of the monsoon are less dependable than those received during the later phase. According to the farmers' experience and meteorological data, early rains are inadequate to fully saturate the profile of deep Vertisols. The crops planted during the first phase of the monsoon are exposed to the risk of drought in a prolonged midseason dry spell, and to waterlogging as well as increased disease incidence caused by continuous rains in the second phase of the monsoon when they are at the flowering or ripening stages.

At present, farmers — not aware of crop varieties or land management practices that can

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3. This has been observed at macrolevel also in the case of the arid region of Rajasthan, where the extent of periodical fallowing has declined with a decrease in the farm size. Such increased land use intensity, unaccompanied by measures to protect and conserve the submarginal lands has accelerated the process of desertification in the region (Jodha 1977b).
4. The extent of irrigation reported in Table 1 does not take into account the intensity of irrigation. If this is done, the extent of irrigation in Mahbubnagar villages will increase substantially. See Table 8.
5. ft has been observed in the study villages and elsewhere that several farmers usually ignore such operations as weeding, interculturing, etc., at crucial times - on dryland crops and opt for wage employment on irrigated farms at times - by temporary outmigration. In such circumstances at least a part of the low productivity of rainfed agriculture could be attributed to the attraction of neighboring irrigated farming.
6. In Dokur, the rainy season fallowing was more than 18%. But this represented a different situation from the Sholapur villages. The rainy season fallow areas in Dokur and Aurepalle largely consisted of tank beds where runoff collection took place during the rainy season. Once the water was used for irrigation, these tank beds became available for cultivation. This incidentally, reduces the land lost due to traditional runoff collection tanks.
7. It is estimated that nearly 18 million hectares, or more than 24% of the net sown area in SAT areas of India, is fallowed during the rainy season, to be planted during the postrainy season. [J. G. Ryan, personal communication, using districtwide data from Malone (1974)).

reduce these hazards of rainy-season cropping in the deep Vertisols — continue to follow the traditional practice of fallowing land in the monsoon season. Given the hazards of rainy-season cropping and the nonavailability of viable technology to counter them, the farmer probably makes a rational choice in leaving the deep Vertisols fallow during the monsoon. The irrationality of rainy-season fallow can be demonstrated only by providing a viable alternative, and this constitutes the challenge for agricultural research.[8]

Even if one ignores the benefits of reduced soil erosion when Vertisols are planted in the rainy season (Kampen et al. 1974), the potential payoff from a breakthrough in technology for monsoon-fallow areas, facilitating the raising of *kharif* crops as well as *rabi* crops, will increase the gross cropped area by nearly one-fourth of the current net sown area in SAT India.

Furthermore, as shown by Table 1, since small farmers leave a higher proportion of their land fallowed during the monsoon than do large farmers, the prospective low-cost technology for such areas may help small farmers more than large ones. This indicates one possible direction for achieving egalitarian goals through technological as opposed to institutional means in SAT areas.

Intercropping[9]

Intercropping, or growing crops in mixtures, is an important feature of traditional farming in SAT areas of India and elsewhere. The superiority of intercropping, in terms of higher gross returns as well as higher and more evenly spread employment of labor when compared to solecropping, has been documented by Mathur (1963) and Norman (1974, 1978). Additional reasons for this are given below.

As shown by Table 2, the extent of intercropping as a proportion of gross, cropped area (average of 3 years) varied from 18 to 83% in the six villages under study.

Factors that explain the differences in extent of intercropping in these villages were the amounts of irrigation, postrainy-season cropping, and extent of HYVs, as well as the extent of some specific crops such as paddy, castorbean, and sugarcane (rarely grown as mixed crops in these villages) (Table 2). Table 3 illustrates that increases in the above factors lead to greater emphasis on sole cropping.

Diminution of intercropping with an increase in irrigation, observed also in the command areas of new irrigation projects such as the Chambal canal (Bapna 1973), is not difficult to understand. To the extent that intercropping is a strategy against weather-induced risk, the availability of irrigation reduces this need (Jodha 1977b). The same reasoning applies to the situation where the postrainy season discourages intercropping. Unlike rainy season crops, postrainy crops, are grown on residual moisture stored in the soil profile largely in deep Vertisol nonirrigated areas. Planting of crops in such situations begins with a known state of soil moisture; hence the need for intercropping to adjust to eventual fluctuations in the soil moisture situation becomes less important.

To the extent that HYVs and intercropping are not incompatible, the limited use of HYVs in intercropping systems may hopefully be regarded as a transitional phase. [10]But the real issue is not the technical suitability of HYVs for intercropping." The farmers' decision is largely guided by economic costs involved. From the standpoint of the majority of SAT farmers in India, the HYV technology can be a high-cost technology as it consists of costly inputs

8. The All India Coordinated Research Project for Dryland Agriculture, ICRISAT, and several other institutions are currently engaged in developing technology for traditionally monsoon-fallow areas. Besides the work at experimental stations, ICRISAT initiated in 1977-78 diagnostic experiments on farmers' fields in three of the villages to which this study refers.
9. This discussion on intercropping draws heavily from the discussion presented elsewhere; see Jodha (1979b).
10. This has been amply demonstrated by experimental evidence. See papers presented at an Intercropping Workshop, ICRISAT (1979).
11. Of course there is one technical possibility of HYVs discouraging intercropping. HYVs are generally earlier maturing crops that facilitate sequential or relay cropping, i.e. planting a second crop after harvesting the first crop. Thus any intercropping that may obstruct sequential or relay cropping may be rejected by the HYV-grower (J. G. Ryan, personal communication).

Table 2. Extent of intercropping and related details in six SAT Indian villages from 1975-76 to 1977-78.[a]

Village	Farm size groups	Proportion of gross cropped area devoted to Intercropping[b] (%)	Irrigated crops (%)	HYVs[c] (%)	Specific crops[d] (%)	Postrainy season cropping[e] (%)
Kanzara	Small	87	6	13	–	2
	Large	70	5	16	2	2
	Total'	73	5	16	2	2
Kinkheda	Small	91	4	4	2	2
	Large	82	5	7	2	3
	Total	83	4	7	2	3
Kalman	Small	60	7	–	3	66
	Large	41	11	1	5	59
	Total	47	10	1	4	61
Shirapur	Small	11	22	–	5	77
	Large	19	10	1	7	71
	Total	18	13	-	7	68
Aurepalle	Small	44	5	3	41	5
	Large	34	25	15	57	7
	Total	35	21	12	54	5
Dokur	Small	5	74	77	82	8
	Large	21	59	43	45	19
	Total	21	60	44	50	18

a. Based on details from 180 sample farms in six villages. Village-level studies have been conducted In these villages since May 1975 (Jodha et al. 1977).
b. The small and large farm differences in the extent of intercropping were found to be statistically significant at the one percent level.
c. High-yielding varieties mainly Include hybrid sorghum and hybrid cotton in Kanzara and Kinkheda, and HYV paddy in Aurepalle and Dokur.
d. Includes crops like paddy, castor bean, and sugarcane, more than 90% of which are grown only as sole crops.
e. Net area of postrainy season (rabi) cropping as a proportion of total net sown area.
f. Total includes medium farms besides small and large farms In each case. For the basis of farm size classification, see footnote 1 of the text.

such as fertilizers, pesticides, and better management of the crop. The farmer may not want to divert costly inputs meant for HYVs to intercropped, non-HYV crops.[12] The same consideration tends to discourage the mixing of other crops with high water-requiring, high payoff crops like paddy and sugarcane. Furthermore, crops like paddy, castorbean, and sugarcane may lack strong technical complementarity with other crops. Villages with a high proportion of these crops correspondingly had a lower extent of intercropping (Table 2). On the other hand, villages (particularly Kanzara and Kinkheda) with substantial area under crops such as pigeonpea, cotton, or rainy-season sorghum (largely grown as intercrops) had a higher extent of intercropping.[13]

12. The difficulty of incorporating HYVs into intercropping systems could be one of the factors responsible for a limited spread of HYVs regionally as well as among small farmers who practice extensive intercropping (Table 2).

13. For details of major sole crops and crop combinations in mixed crops see Jodha (1979b).

Table 3. Proportions of area devoted to sole cropping in six SAT Indian villages from 1975-76 to 1977-78.[a]

	Proportions of sole cropping in the total of:			
Village	Postrainy season NSA (%)	Gross irrigated area (%)	HYVs area (%)	Specific crops[b] (%)
Kanzara	99	100	77	–
Kinkheda	100	74	73	-
Kalman	65	83	61	93
Shirapur	79	90	100	91
Aurepalle	100	94	100	95
Dokur	99	100	100	100

a. Based on details from 180 sample farms in six villages. Village-level studies have been conducted in these villages since May 1975 (Jodha et al. 1977).
b. Specific crops are sugarcane in Kalman and Shirapur; paddy in Dokur, and paddy and castor bean in Aurepalle.

Farm Size and Intercropping

Largely because of its risk-reducing potential, intercropping is a more popular system among small farmers.[14] Both because of their poor capacity to take risk and the paucity of land to sow sole crops in different plots, small farmers more often resort to intercropping as a defense against risk than do large farmers.[15] The preliminary results on this aspect reported earlier (Jodha 1977b) are confirmed by data for three crop years (Jodha 1979b); small farmers consistently used intercropping to a higher extent than large farmers in all the villages except Dokur and Shirapur. The difference between proportions of intercropping on small and large farms (average of 3 years) ranged from 9 to 18% in different villages and was found statistically significant. Greater use of sole cropping than intercropping on small farms in Dokur and Shirapur was highly significant because small farmers in these two villages had more irrigation and postrainy-season cropping, which, for the reasons discussed earlier, discouraged intercropping.

This suggests that any advance in intercropping technology may benefit less well-endowed farmers (and areas) more than the relatively better-endowed ones. It offers additional opportunity to explicitly incorporate equity considerations into an agricultural research strategy by means of greater resource allocation to this area of research.

Complexity of Traditional Intercropping Systems

Complexity and diversity are features of traditional cropping systems (Table 4). If sole crops and number of crop combinations in crop mixtures are considered together, their numbers range from 27 to 118 in different villages. Two-crop mixtures were popular in most villages, but mixtures involving five to eight crops were not uncommon.[16] There were considerable interregional differences in terms of the importance of major intercrops. For instance, in

14. Analysis of data for precise quantification of the extent to which intercropping reduce risk is still in progress.
15. Another reason for a higher proportion of intercropping on small farms is that small farmers try to satisfy their profit, subsistence, and security-oriented needs from the same small piece of land. Intercropping serves this purpose better.

16. Mathur (1963) recorded more than 100 crop combinations in fields of crop mixtures in the Vidarbha region of India; Norman (1978) recorded 230 different crop combinations used in intercropping in villages of northern Nigeria. This indicates that complexity of traditional intercropping is a general phenomenon.

Table 4. Sola crops and crop combinations in crop mixtures and their (%) share In gross cropped area in six SAT Indian villages from 1975-76 to 1977-78.*

Village	Sole crops (No.)	Intercrops with mixtures of 2 crops (No.)	3 crops (No.)	4 crops (No.)	5-8 crops (No.)	Total (No.)
Kanzara	22	17	13	11	4	67
	(27)[b]	(26)	(24)	(19)	(4)	(100)
Kinkheda	19	15	14	11	1	60
	(17)	(24)	(41)	(17)	(1)	(100)
Kalman	34	40	28	13	3	118
	(53)	(24)	(15)	(16)	(2)	(100)
Shirapur	44	23	3	1	-	71
	(82)	(15)	(2)	(1)		(100)
Aurepalle	21	4	2	-	11	38
	(65)	(6)	(10)		(19)	(100)
Dokur	17	4	3	2	1	27
	(79)	(5)	(2)	(7)	(7)	(100)

a. Based on details from 180 sample farms in six villages. Village-level studies have been conducted in these villages since May 1975 (Jodha et al. 1977).

b. Figures in parentheses indicate the percentage share of crop/crop combination in gross cropped area during the 3-year period.

Kanzara and Kinkheda (Akola District) cotton-based and sorghum-based intercrops were dominant. In other villages (except Dokur where groundnut-based intercrops dominated) sorghum-led intercrops were more important. Pigeonpea was an important component of mixtures in all villages (Jodha 1979a).

The complexity of traditional intercropping systems is partly an outcome of farmers' informal experimentation with crops that satisfy their requirements and also fit the agricultural environment of the region. The farmer is engaged in agriculture with multiple objectives related to subsistence and employment of his family and cattle, profit from farming, adjustment to drought risk, as well as potential and limitations of his land.

To illustrate the points mentioned above, crop mixtures observed in the villages were classified into six categories on the basis of the specific characteristics of the crops included in each intercrop combination. The categories were defined on the basis of objectives they could fulfill and are briefly described under Table 5, which presents the proportions of intercropped area covered by mixtures satisfying different objectives. Since a given mixture may satisfy several objectives, the six crop mixture categories are not mutually exclusive and the percentages in Table 5 do not add to 100.[17]

In the six villages the most important categories of crop mixtures (indicated by their share in total area of intercrops) were as follows:

C. *Mixtures with different maturity lengths* - The aim being to evenly distribute the labor requirements of cropping and making fuller use of the environment (e.g. sorghum and pigeonpea).

D. *Mixtures of drought-sensitive and drought-resistant crops* - Some examples are pearl millet with groundnut, or pigeonpea with cotton, to guard against moisture risk without foregoing the benefits of good rains.

E. *Cash crop - food crop mixtures* - Some examples are cotton with sorghum or pearl millet with groundnut, in order to simultaneously satisfy cash and subsistence requirements.

17. It is recognized that even if crops are not grown as mixtures but as separate sole crops, some of the objectives listed in Table 5 can still be satisfied.

Table 5. Proportions of different categorise of crop mixtures In the total area of intercropping In six SAT Indian villages (average of 1975-76 to 1977-78).[a]

Crop mixture categories[b]	Proportion of different categories of crop mixtures in total area of intercropping in					
	Kanzara (%)	Kinkheda (%)	Kalman (%)	Shirapur (%)	Aurepalle (%)	Dokur (%)
A. Special situation	2	3	15	12	3	2
B. Self-provisioning	9	11	18	14	36	29
C. Different maturity periods	58	84	46	32	71	79
D. Drought-sensitive-drought-resistant	72	81	18[c]	25	13[c]	41
E. Cash crop-food crop	73	59	44	61	53	50
F. Legume-nonlegume	88	77	59	40	84	38[d]

a. Based on details from 180 sample farms in six villages. Village-level studies have been conducted in these villages since May 197S (Jodha et al. 1977).

b. The crop-mixture categories ere not mutually exclusive. Therefore the percentages are not additive. The basis of crop-mixture categorization is as follows:

Category A - *Special situation:* Mixture resulting from adding to the main crop of the plot a few other crops in order to adjust to physical factors such as patches with salinity, depressions, infertile, gravelly soil, etc. (e.g., paddy combined with sorghum or pigeonpea).

Category B - *Selt-provisioning:* Mixtures having in addition to main crops of the mixtures, some crops like seasonal vegetables, tobacco, fiber crops, etc., seldom grown for the purpose of final harvests. They are harvested as and when family "self-provisioning" demands.

Category C - *Different maturity lengths:* Mixtures involving crops with different growth periods facilitating spread of peak (harvest) period labor requirement (e.g., sorghum and pigeonpea).

Category D - *Drought-sensitive and Drought-resistant crops:* Mixtures involving drought-resistant and drought-sensitive (or less drought-resistant) crops (e.g., groundnut and pearl millet).

Category E - *Cash crop-food crop:* Mixtures Involving cash crops and foodgraln crops (e.g., sorghum and cotton, castor bean and pigeonpea).

Category F - *Legume-nonlegume:* Mixtures involving legumes and nonlegumes (e.g., sorghum, pigeonpea, or green gram).

c. Bulk of the other mixtures consisted of only drought-resistant crops.

d. Bulk of the other mixtures consisted of only legumes.

F. *Legume-nonlegume mixtures* - Examples are sorghum or pearl millet with mung bean or pigeonpea to fulfill fertility and rotation requirements without sacrificing nonlegume crops and for balancing the diet.

The other two mixture categories (A and B), induced by self-provisioning requirements and the need for adjustment to problems of soils, are relatively less important in these villages.[18]

18. Cropping patterns in villages are not rigidly fixed. Depending on the quantum and timing of rains and rotation requirements farmers do adjust their crops and crop combinations. An analysis of the relationship between rainfall and cropping decisions using village level daily rainfall record and cropping patterns on sample farms, is currently under progress.

The above picture demonstrates that traditional intercropping systems are complex and diverse because they involve a conscious and rational attempt by the farmer to adjust his cropping pattern according to his need and resource base. An important implication for research on intercropping follows. While trying to generate new, simple, and more productive intercropping systems, considerations indicated by mixture categories C, D, E, and F should not be completely ignored. This would mean ignoring the very clients for whom intercropping technology is being generated.

Water Resource: The Key Variable

Without belittling the rationale of farmers' wisdom underlying the traditional system of farming in SAT areas, it is clear the system seems to operate more as an adjustment mechanism against factors causing low and unstable production rather than a dynamic enterprise showing possibilities for sustained growth. The circumstantial evidence suggesting an asset depletion/replenishment cycle (Jodha 1978) and aversion to risk associated with investment (Binswanger 1978) indicates the possibility of permanent underinvestment in SAT agriculture. The scope for dynamizing SAT agriculture is limited for want of viable technological options. Fertilizer-responsive HYVs have been the new element that led to a production rise in traditional agriculture in recent years. But HYV-based technology also works best when complemented by the requisite amount of soil moisture. This brings us to a key physical factor that can make traditional agriculture in SAT areas more dynamic. Farmers, scientists, and policy-makers, of course, are not unaware of this.

During British Colonial rule, the traditionally drought-prone areas in India received priority in terms of irrigation projects, largely based on import of water from other catchments.[19] The substantial irrigation investment in SAT areas since the early twentieth century did not help beyond creating a few pockets of prosperity within SAT regions where irrigation schemes, intended to irrigate and protect rainfed crops against drought, ended up being used to irrigate sugarcane and paddy. Realization of the limits on 'imported water' as a solution to the problems of low rainfall areas induced a search for technologies that would ensure maximum conservation and efficient use of available moisture. A limited research effort of the 1930s generated what is commonly known as the Bombay Dry Farming Technology. More concentrated efforts were initiated during the early 1970s when organizations such as the All India Coordinated Research Project for Dryland Agriculture and ICRISAT came into existence to generate relevant technological options for SAT farmers. Of the several approaches being tried, the principal one heavily emphasized by ICRISAT is management of soil and water on a small watershed basis.

Watershed-Based System of Farming

The basic philosophy behind the resource-centered (as against crop-centered) approach to technology research is that the resource use in SAT agriculture should be environment-based rather than individual holding-based. For this purpose ICRISAT considered a watershed or catchment to be the appropriate unit of resource management and utilization (Krantz et al. 1977). To ensure conservation and effective utilization of water—the scarcest of natural resources for agriculture in SAT areas — a variety of measures are considered. Depending upon soil type and slope, these measures broadly include necessary land smoothing; semipermanent graded broadbeds and furrows to ensure full penetration of moisture, reduce erosion, and regulate runoff; grassed waterways for improved drainage; and small dams or tanks to collect runoff water to be used for supplementary irrigation during midseason droughts, or for irrigating crops in the postrainy season. The land- and water-management measures are complemented by improved agronomic inputs (Krantz et al. 1977).

There are three key elements of the watershed-based system of farming relevant to the present discussion. First, if the land management is attempted on a watershed basis it can ensure greater availability of moisture which, when complemented with improved agronomy, can ensure higher and more stable production from the same land resources.[20] Second, since water is the most limiting natural factor in SAT agriculture, it should be used most efficiently — i.e., on crops that do not require large amounts of it — so that a maximum area can be covered with the limited water available from runoff collection tanks in the watersheds.

The full-scale watershed technology is yet to be tried in the villages. However, juxtaposition of some factors characterizing traditional agriculture and the elements of prospective watershed technology can give some idea of

19. For a detailed review of various technological approaches and policies to reduce instability and ensure growth of rainfed agriculture in India see Jodha (1979a).

20. For economic analysis of field-scale watershed experiments see Ryan et al. (1979b).

the potential constraints on the prospective technology.[21]

Problem of Group Action

The first problem arises from the existence of several plots owned/operated by different owners on every miniwatershed in the villages (Table 6). The watersheds actually surveyed in ICRISAT study villages, as well as by the Drought Prone Area Programme (DPAP) in different states, suggest that the number of farmers involved in a single miniwatershed can range from 7 to 93. There is also considerable variation in the size of holdings within the watersheds. Similar variation could be expected in the resource positions of the farmers involved in each watershed. The disappointing experience with cooperatives in India suggests that obtaining the agreement of all farmers in a watershed to its common and integrated use poses a question of group action among the farmers.

Adoption of full watershed-based technology on an individual farmer's land, as against the contiguous plots owned by several farmers involving group action, may be difficult. The reasons are the indivisibility of full watershed-based technology, paucity of individually owned plots or land fragments that are large enough to form a miniwatershed, and the difficulties involved in land consolidation.[22]

21. For a detailed discussion of these issues see Jodha (1975).

22. Of course, some components of prospective watershed technology could be adopted in parts. However the total impact in terms of resource productivity and conservation can be realized only if the whole package of technology is adopted (Krantz et al. 1977).

Table 6. Details of landholdlngs on small watersheds in eight SAT Indian villages.[a]

Village	District (State)	Total area (ha)	Farms represented on watershed (No.)	Average size of plot on given watershed (ha)	Range of plot size on watershed (ha)	Farm holdings smaller than average (%)	Soil types on watershed'	Annual rainfall (mm)
Kanzara	Akola (Maharashtra)	19.9	13	1.5	0.4-4.5	69	MDV	819
Shirapur	Sholapur (Maharashtra)	16.9	13	1.3	0.2-3.9	77	DV	636
Darphal	Sholapur (Maharashtra)	70.5	30	2.4	N.A.	N.A.	MDV, SV	600
Khanderajani	Sangli (Maharashtra)	35.4	10	3.5	N.A.	N.A.	MDV, SV	425
Krishnapur and Takli	Dharwar (Karnataka)	43.4	29	1.5	0.3-4.0	N.A.	MDV	606
G. R. Halli	Chitradurga (Karnataka)	116.0	93	1.3	0.4-6.0	47	DA, SA	612
Bayanapalle	Mahbubnagar (Andhra Pradesh)	20.0	30	0.7	N.A.	N.A.	DA, SA	710
Aurepalle	Mahbubnagar (Andhra Pradesh)	26.7	7	3.8	1.3-10.0	57	DA, SA	710

a. Detaits summarized from Sharma and Kampen (1977) and unpublished reports prepared during Training Program tor DPAP Officers, organized jointly by All India Coordinated Research Program for Dryland Agriculture, Central Soils and Water Conservation Research and Training Institute and ICRISAT, April 10-17, 1977.
b. *Soil types:* MDV - Medium Deep Vertlsols; DV - Deep Vertlsols; DA - Deep Alfisols; SA = Shallow Alfisols; SV - Shallow Vertisols.

In order to justify a water harvesting and supplementary irrigation technology, Ryan et al. (1979b) have estimated that the optimum economic size of catchment or watershed in parts of peninsular India would seem to be between 8 to 16 ha. The size distribution of individually owned land parcels or fragments (Table 7) in ICRISAT's six study villages indicates that there are literally no plots with any farmer that could satisfy the economic (8 to 16 ha) requirements of a miniwatershed for an individual farmer. Even if the size requirement is reduced to 4 to 6 ha, in four out of six villages one does not find more than 7% of individually owned land parcels that could, at least on an area basis, qualify for a miniwatershed.[23] Topographic information about the plots may further reduce the percentage of fragments suited for treatment on a whole watershed basis. Furthermore, practically all the large plots under consideration were owned by large farmers. Hence, for the small and medium farmers there may be no alternative to group action, if the complete watershed-based technology, including provision for a runoff collection tank, is to be adopted.

A review study of several agricultural group organizations by Doherty and Jodha (1977) suggested that besides several other factors an easily perceivable, clear-cut, and high economic payoff is one condition that can induce farmers to participate in group action. It seems from the analyses performed on the research watersheds at ICRISAT Center since 1975-76 that the new watershed technology does offer considerable additional profits, particularly on deep Vertisols.[24]

Allocation of Water Resources

As Table 8 shows, in the villages of Dokur and Aurepalle, where traditional runoff collection tanks are a principal source of irrigation, around three-quarters of their gross irrigated area was occupied by paddy. Even in the villages where the extent of irrigation was only 5 to 13% of gross cropped area, the bulk of the irrigation was devoted to high water-consuming crops such as wheat, sugarcane, cotton, vegetables, etc. If the case of Kanzara, where hybrid sorghum was irrigated, is excluded, Kalman is the only village where sorghum received a substantial proportion (30%) of the irrigation. This was because wells did not have sufficient recharge to support paddy or sugarcane. Intercrops did not receive more than 10% of irrigation in any village, once again confirming the results mentioned earlier.

If the extent of irrigation is defined in terms of intensity of irrigation (area irrigated multiplied

23. It is not area alone but topography of the plot as well that determines its suitability as an integrated miniwatershed. However, such information about land parcels (Table 7) is not available at present.

24. See Ryan et al. (1979b) for economics of watershed technology.

Table 7. Distribution of land fragments by size on the sample farms in six SAT Indian villages during 1976-76.[a]

Village	Total fragments/land parcels (No.)	% distribution of fragments in the ranges (ha) of			
		0.80 (%)	0.81-2.80 (%)	2.81-4.10 (%)	4.11-6.10 (%)
Kanzara	100	28	57	9	6
Kinkheda	71	21	44	15	20
Kalman	216	48	50	2	-
Shirapur	112	53	39	4	4
Aurepalle	87	37	40	9	14
Dokur	83	68	26	4	2

a. Based on details from 180 sample-farms in six villages. Village-level studies have been conducted in these villages since May 1975 (Jodha et al. 1977).

Table 8. Percentage share of different crops in the gross irrigated area in six SAT Indian villages (average of 1975-76 and 1976-77).[a]

Crops	Proportion of different crops in gross irrigated area in[b]											
	Kanzara		Kinkheda		Kalman		Shirapur		Aurepalle		Dokur	
Sorghum	28[c]	(26)	-	-	30	(28)	9	(3)	6	(6)	–	–
Wheat	56[d]	(58)	44[d]	(45)	19	(23)	15	(14)	3	(2).	-	-
Paddy	2	(2)	1	(1)	6	(5)	1	(1)	73	(78)[e]	79[e]	(74)
Groundnuts	6	(5)	10	(9)	4	(4)	10	(10)	-	-	20	(24)
Pulses[f]	5	(4)	25	(27)	9	(5)	2	(1)	-	-	-	-
Vegetables	4	(4)	2	(1)	7	(11)	12	(13)	5	(6)	1	(1)
Sugarcane	-	-	-	-	3	(6)	22	(39)	-	-	-	-
Cotton/Castor bean[g]	-	-	9	(13)	-	-	-	-	5	(2)	-	-
Other Sole Crops[h]	-	-	-		13	(13)	23	(17)	-	-	1	(1)
All Mixed Crops[i]	-	-	9	(4)	10	(7)	6	(3)	10	(6)	-	-
.Total	100	(100)	100	(100)	100	(100)	100	(100)	100	(100)	100	(100)
Total weighted irrig. area as % of GCA	6	(22)	3	(6)	8	(21)	13	(42)	19	(66)	60	(307)

a. Based on details from 180 sample farms in six villages. Village-level studies have been conducted in these villeges since May 1975 (Jodha et al. 1977). The sources of irrigation are tanks and wells In Mahbubnagar and Aurepalle and wells In other villages.

b. Figures in parentheses indicate the proportion of each crop in the gross irrigated area recalculated using the intensity of irrigation. The recalculated weighted gross Irrigated area is based on area irrigated multiplied by number of Irrigations given to the same (whole) plot. All irrigation operations for a given plot taking place within a 10-day period have been treated as one irrigation operation to avoid the possibility of partial coverage of a plot by water being treated as its full coverage. The partial coverage may result from poor and slow recharge in the irrigation well and the water-spreading methods used in paddy fields. In the case of paddy, this method tends to underestimate the irrigation Intensity, because watering of paddy is almost continuous and the field Is always kept wet.

c. Hybrid sorghum.

d. Kanzara over 60 % and Kinkheda over 60 % HYV wheat.

e. HYV-paddy over 60 and 90% respectively in Aurepalle and Dokur.

f. Mung bean in Kanzara and Kinkheda; chickpea in Kalman and Shirapur.

g. Hybrid cotton in Kinkheda; castor bean in Aurepalle.

h. Includes maize, sunflower, garden crops in Kalman and Shirapur villages, end finger millet in Dokur.

i. Excludes all vegetables, mixtures and a limited extent of sugarcane-vegetable mixtures, Included with respective main crops.

by number of irrigations), the tendency towards concentration of the water resource on high water-consuming crops, particularly in villages with little irrigation, becomes more clear. For instance, in Shirapur the share of sugarcane in irrigation increased from 22 to 39% once intensity of water use was considered. Correspondingly shares of sorghum and mixed crops declined from 9 to 3% and 6 to 3%, respectively. The case was similar in Kalman where sugarcane, vegetables, and wheat gained at the cost of sorghum, mixed crops, etc. Among the six villages, Dokur had the highest extent (60%) of gross cropped area receiving water. Once water use intensity was considered, the weighted gross irrigated area exceeded three times the gross cropped area. Practically all of this area was devoted to high water-requiring crops, particularly paddy. One can expect a similar pattern in the allocation of other inputs among different crops.

This raises a basic question about priorities in resource use on irrigated crops and irrigated dry (ID) crops in SAT areas. Social gains from water and other resources when used on ID crops may be higher, but it is private benefit that guides farmers' decisions about their resource allocation. Thus, given the circumstances, coarse grains like sorghum and pearl millet (two of the five ICRISAT crops) will always suffer neglect unless their low-value status is countered by much lower cost of production and their competitiveness vis-a-vis traditionally high-value crops is improved (Jodha 1973). This again is a challenge for researchers. Any breakthrough in crop technology of SAT crops, reflected through low cost and high yield as well as their improved competitiveness with other crops, besides being an achievement in itself, could serve as a means of shifting resource (e.g. water) allocation in favour of these crops. However, to the extent the gap between profitability of high-value and low-value crops persists (partly because of equal or stronger research efforts on the former) one may not be left with any alternative to some form of social control of water to ensure its allocation to low-value crops to better serve equity and efficiency goals.

Conclusions

The results, based on data from 3 crop years from six villages in three agroclimatic zones of peninsular India, have revealed the rationale behind some of the traditional farming practices.

In the deep Vertisol areas the practice of fallowing land during the rainy season and planting it in the postrainy season is a very important practice, more so in the case of small farmers than large ones. Hence any technological advance facilitating rainy-season crops in monsoon-fallow tracts can probably help small farmers proportionately more than large ones, as well as substantially adding to the area double cropped.

In the rainfed regions that do not have extensive deep Vertisol areas the traditional practice of intercropping covers 35 to 73% of their gross cropped areas. The extent of intercropping declines with increases in irrigation in villages. The small farmers again have a significantly higher extent of intercropping than large farmers. This indicates that generation of a low-cost new technology for intercropping may help less-endowed areas and farmers more than the relatively well-endowed ones. This is one of the few opportunities where egalitarian objectives in SAT areas could be achieved by technological means as opposed to institutional means, and it has significant implications for research resource allocation.

As revealed by the number of crop combinations (as high as 84 in a single village), traditional intercropping is highly complex. This is partly an outcome of farmers' informal experimentation with crops that could satisfy their requirements and also fit the agricultural environment of the region. The multiple objectives of the farmer such as security, profitability, employment and subsistence requirements of his family members and cattle etc., should be taken into account when evolving new intercropping technology.

The juxtaposition of requirements of prospective watershed-based technology and the features of the traditional system of farming — particularly the land ownership and usage pattern — gives an idea of the institutional constraints the technology is likely to face. Because integrated watershed-based technology is indivisible and because individually-owned land parcels large enough to constitute a composite miniwatershed are not available, there seems no alternative to group action that can ensure management of land for higher productivity and conservation on a watershed basis. In order to induce group action among farmers, prospective watershed technology will have to be highly profitable.

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Cropping Patterns, Farming Practices, and Economics of Major Crops in Selected Dryland Farming Regions of India

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Abstract

This paper presents an overview of the current level of dryland farming technology in use by the Indian farmer, through a study of the cropping patterns, farming practices, and economics of major crops in selected dryland farming regions of India. It is based on the data collected under the Agro-Economic Research Scheme of the Drought-Prone Areas Program at the All India Coordinated Research Project for Dryland Agriculture. The information, collected from eight centers in the arid and semi-arid regions of India during 1976-77, shows that farmers in those regions operate at a very low level of technology. In many locations, the preparatory tillage is casual and often inadequate. The use of improved seeds, fertilizers, and plant protection chemicals is low. Tractors and threshers are used only in some places. The animal manures available are spread too thinly; cash crops have the first claim on them. Though the new dry-farming technology developed at research centers has been found viable and feasible where the recommended practices have been put to use, and though it is said to be neutral to scale, it has not yet gained popularity with the farmers in the arid and semi-arid regions of the country.

The cropping pattern in any region is essentially determined by experience gained over the years on a given soil type, rainfall and climate, irrigation potential, and economic considerations such as labor availability, prices, and marketing. In dryland areas, however, rainfall — or, more precisely, the amount and period of moisture availability — overshadows other considerations because such areas are characteristically subsistence oriented. There are some exceptions though, where cash crops that influence the local economy are grown. These are discussed using farm-level data for 1976-77 derived from the socioeconomic studies conducted by the All India Coordinated Research Project for Dryland Agriculture at eight of their 16 centers.

The Setting

Soil type and rainfall, two major determinants of the cropping pattern, vary greatly from location to location. Broad features of the regions selected for analysis in this paper are given in Table 1. Their location is shown in Figure 1.

It is evident that cropping patterns in these areas have been developed within the constraints of low and erratic rainfall for a short growing period (75 to 130 days) and soils of low depth and poor fertility.

Basic land statistics in Table 2 reveal that in most of the dry farming areas cultivation has extended to marginal and submarginal lands, raising the cultivated area from 85 to 100% of the total owned area. This is done to meet family needs of food and fodder from their own land resources; it does not involve much cash expenditure. The relatively low proportion of cultivated area in Hyderabad reflects two aspects: (1) as a rule, farmers leave a part of the otherwise cultivable area as grazing land each year, by rotation; (2) during the year 1976-77, some areas could not be sown because of long dry spells during the sowing period. Part of the cultivated area remained unsown at Nagaur as well.

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Table 1. Major soil types and rainfall statistics.[a]

Region	Soil type	Normal annual rainfall (mm)	Normal dates of onset of southwest monsoon	Normal dates of withdrawal of southwest monsoon	Normal seasonal rainfall (mm) Kharif (Jan-Sept)	Rabi (Oct-Feb)
Arid						
Nagaur	Sandy	310(20)	29 June	21 Sept	265(16)	23(2)
Jodhpur	Sandy	366(20)	29 June	21 Sept	328(16)	23(2)
Narnaul	Sandy	428(26)	27 June	23 Sept	341(18)	52(4)
Anantapur	Red loam/Sandy	583(33)	9 June	16 Oct	336(18)	175(10)
Semi-Arid						
Hyderabad	Red chalka	771(50)	9 June	10 Oct	574(37)	130(8)
Bangalore	Red loam	889(58)	5 June	10 Nov	483(32)	244(15)
Rahuri	Black day/Red lateritic	520(31)	10 June	2 Oct	394(23)	102(6)
Sholapur	Black clay	678(41)	10 June	2 Oct	516(31)	120(7)

a. Data on rainfall normals are based on 50 years from 1901 to 1950. Dates of onset and withdrawal of southwest monsoon are also based on 50 years from 1921 to 1970. Figures in parentheses are the number of rainy days.
Source: Meteorological Unit, Dryland Research Project, Hyderabad.

Nagaur, Jodhpur, Sholapur, Anantapur, and Rahuri are the regions where the irrigated area is low and the potential for further development is also limited. At Narnaul, the area under irrigation appears to be relatively high, which is contrary to the situation actually existing. The new minor irrigation/dug well schemes have created only a potential; sufficient water to irrigate the stipulated area is not available, leaving a part of the area nonirrigated. At Hyderabad, on the contrary, the proportionate cropped area under irrigation during 1976-77 was high because a part of the cultivable land was either left fallow for grazing purposes or could not be sown for want of adequate moisture.

Double cropping is confined, either partially or wholly, to areas receiving irrigation in the *rabi* (postrainy) season, i.e., during October-February. Therefore, the intensity of cropping is low, ranging from 84% at Nagaur to 125% at Hyderabad.

Cropping Patterns

Based on the experience gained with the land, soil types, rainfall and irrigation facilities available, a wide variety of cropping patterns have emerged in the different regions under review (Table 3).

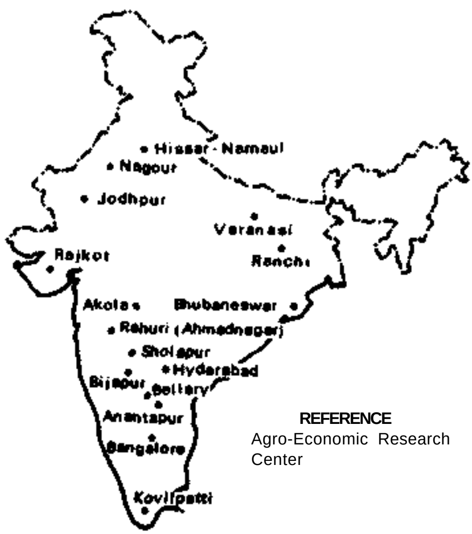

Figure 1. DPAP agro-economic research locations.

Table 2. Average village statistics from socioeconomic surveys 1976-77.[a]

Region	Number of households	Total owned area (ha)	Cultivated area (% to total area)	Irrigated area (% to cultivated area)	Intensity of cropping (%)	Average holding size (ha)
Arid						
Nagaur	99	669	84	2.7	84	6.76
Jodhpur	40	184	88	9.8	105	4.60
Narnaul	81	238	100	23.3	123	2.94
Anantapur	106	778	70	8.8	108	5.16
Semi-Arid						
Hyderabad	101	358	60	27.0	125	3.55
Bangalore	116	354	86	17.3	100	3.05
Rahuri	115	567	85	11.4	112	4.19
Sholapur	96	611	90	7.1	105	5.74

a. Source: Farm structure studies conducted in 4 to 6 villages in each area in clusters of 2 to 3 villages each. Households are represented In proportion to total area.

Table 3. Average village cropping patterns from socioeconomic surveys (1976-77).

Region	Total cropped area (ha)		Percentage cropped area in different seasons (cropwise)
Arid			
Nagaur	469	Kharif:	Pearl millet 45, sorghum 11, moth 6, green gram 6, sesamum 13, cluster beans 6, others 2.
		Rabi:	Wheat 4, chickpea 4.
Jodhpur	171	Kharif:	Pearl millet 56, green gram 10, moth 8, sesamum 7, cluster beans 6, others 9.
		Rabi:	Wheat 3, others 2.
Narnaul	293	Kharif:	Pearl millet 30, pearl millet + cluster beans 13, cluster beans 6, sorghum 1.
		Rabi:	Chickpea 33, wheat 8, mustard 7, barley 1.
Anantapur	590	Kharif:	Paddy 6, groundnut 24, setaria 35, pearl millet 12, sorghum 7, horse gram 5, others 4.
		Rabi:	Paddy 1, groundnut 3, wheat 1, sorghum 1, others 1
Semi-Arid			
Hyderabad	258	Kharif:	Paddy 16, castor 20, sorghum 9, pearl millet 1, sorghum + red gram 22, pearl millet + red gram 2, sorghum + pearl millet 1, others 8.
		Rabi:	Paddy 10, sorghum 6, others 4.
Bangalore	305	Kharif:	Paddy 12, sugarcane 3, ragi 65, horse gram 6, maize 6, others 9.
		Rabi:	No crop is possible.
Rahuri	539	Kharif:	Pearl millet 22, green gram 8, groundnut 2, others 4.
		Rabi:	Wheat 2, sorghum 6.
Sholapur	578	Kharif:	Paddy 4, pearl millet 2, maize 2, red gram 12, groundnut 13, others 6.
		Rabi:	Sorghum 58, wheat 2, chickpea 1.

Neutralizing the cropping pattern variations due either to differences in location in a given area or to farm sizes, it is observed that in the arid regions having sandy shallow soils (Nagaur, Jodhpur, and Narnaul) the predominant *kharif* (rainy season) cereal crop is pearl millet. Sorghum is cultivated mainly to meet fodder requirements. Pulses (green gram and moth) and also sesame — an oilseed crop — are grown only in the Nagaur and Jodhpur areas. Cluster beans are also gaining importance in the agricultural *economy of* the region and cover 5 to 6% of the cropped area. During the *rabi* (postrainy) season, chickpeas are important in the Narnaul region, covering more than one-third of the cropped area. Cultivation of wheat is undertaken on the wet (irrigated) land. If irrigation water is not adequate to cover the entire area, a part is diverted to the cultivation of mustard, which requires in most cases only one presowing irrigation. Other crops of economic importance, though occupying relatively small areas, include castor at Jodhpur and groundnut at Nagaur.

In the Anantapur area, with red sandy loam soils, cultivation of minor millets is more important than pearl millet or sorghum. The main millet crop is setaria, a small-seeded millet of little significance in other arid areas. Groundnut is of importance in the region, covering about one-fourth of the cropped area. Crops of pearl millet or sorghum are usually grown as mixed crops with either red gram or castor. Horse gram is normally cultivated to meet fodder requirements. Paddy is grown on irrigated land.

In the semi-arid Hyderabad region, the oilseed castor and sorghum are important *kharif* (rainy season) crops in the red chalka soils. Sorghum is usually grown as a mixed crop either with red gram or pearl millet, and pearl millet is cultivated as a sole crop on a limited area. Other crops of these drylands include horse gram, *ragi* (finger millet), tobacco, and vegetables such as tomato, lady's finger (okra), and brinjal (eggplant). Paddy is grown on irrigated lands during both rainy and postrainy seasons. Sorghum is cultivated on relatively heavier soils as a nonirrigated crop in the postrainy season.

Ragi is the principal crop in the Bangalore region, covering about two-thirds of the cropped area, mainly on the red loamy soils. Horse gram is the important pulse crop of the area. Maize is an introduced crop and is grown on a limited area. Other dryland crops include cowpeas, castor, groundnut and vegetables. Paddy and sugarcane are irrigated crops. Cropping during the postrainy season is not feasible under rainfall conditions at Bangalore.

In the black soil areas of the Rahuri and Sholapur regions, postrainy-season sorghum is the principal dryland crop. This is grown on medium/deep soils with a large moisture-holding capacity. However, on the red lateritic soils, pearl millet and green gram are grown during the rainy season to meet the cereal and pulse requirements in the Rahuri region. In the shallow soils of the Sholapur area, red gram and groundnut are usually cultivated as sole crops during the rainy season.

On the basis of the above, it is concluded that:

1. In most dryland farming areas, double cropping and relay cropping are not practiced.
2. Rainy-season crops are more important in the economy of Nagaur, Jodhpur, Anantapur, Hyderabad, and Bangalore regions.
3. Chickpea at Narnaul and sorghum at Rahuri and Sholapur are the important postrainy-season crops.
4. The predominant foodgrain crops in each region vary with rainfall and growing season, e.g. pearl millet (Jodhpur, Nagaur, and Narnaul), sorghum (Hyderabad, Rahuri, Sholapur), setaria (Anatapur) and ragi (Bangalore);
5. Intercropping is limited to a few locations only and consists mostly of crops with different durations, e.g. combinations of pearl millet and cluster beans at Narnaul and sorghum and pigeonpea at Hyderabad.
6. Cropping intensity is low; at times, it is not possible to sow the entire area because of long dry spells during the sowing period, as at Narnaul and Hyderabad.

Farming Practices and Economics of Major Crops

Discussion of the farming practices followed, cash investment made, and consequent returns from irrigated lands would be beyond the scope of this presentation. Nevertheless, it is noticed that irrigated lands, irrespective of their share in the cropped *area,* attract more attention in terms of both management and investment, resulting in higher net profits.

Farming Practices

Nagaur. The fields are first cleared of bushes and other vegetation before the onset of the monsoon, which is followed by plowing, harrowing, and planking with a tractor-drawn cultivator when the soil is saturated by rains. Sowing is also done with a tractor-drawn cultivator through a polythene/rubber pipe with iron funnels attached to tillers. This is a recent change and has been accepted widely in the region. Cattle manure is applied to dryland crops but the average rate (400 kg/ha) is very low. Interculture is carried out by manual labor with the help *of kasies* (blade harrows) but there are also instances of running a bullock-drawn plow between the rows. Hardly any plant protection measures are used in the case of rainfed crops. The earheads are picked first and threshed by tractors or cattle and the straw is cut later at leisure.

Jodhpur. Preparatory tillage is carried out more commonly with tractor plows than with bullock-drawn plows from mid-June to early July for rainy-season crops and from late September to the end of November for postrainy-season crops. Local varieties are still predominant but, during the last few years, the use of improved varieties of pearl millet (BJ-104) and green gram (S-8) has been increasing. Farmyard manure in small quantities is applied to dryland crops, but the use of inorganic fertilizer is restricted to a few progressive farmers only. One hand weeding and one hoeing are done in the case of peart millet, but only hand weeding is done in the case of green gram, moth and cluster beans. The common tool used for interculture is known as *kasola. Kharif* (rainy season) crops are harvested from mid-September to mid-October and *rabi* (postrainy season) crops from the end of March to mid-April. Manual labor picks the ears/pods from standing crops first and then harvests the remaining parts of the plants for fodder. Threshing is usually carried out by tractor-operated threshers.

Narnaul. Postharvest tillage is uncommon in the region. The preparatory tillage starts after the onset of the monsoon. Most of the farmers use a wooden *desi* (indigenous) plow for preparatory tillage. Some use tractor harrows also.

Sowing of pearl millet — either pure or mixed with cluster beans and green gram — begins in mid-June and continues into early July. Chickpea, the important dryland crop in the *rabi* season, is sown during late September and early October. Local varieties of seed are mostly used. Sowing is done in almost all the crops by the pora method, using a country seed drill with a *desi* plow.

No farmers use fertilizers on any dryland crops. Farmyard manure is applied, however, to a small area under pearl millet and mustard crops. Interculturing is done commonly in the area for pearl millet and pearl millet mixed with clusterbeans and green gram, but rarely in the case of cluster beans and chickpea. An iron *kasola* is the implement used. In all crops harvesting is done using sickles, with threshing done by human and cattle power.

Anantapur. Preparatory tillage consists of plowing and harrowing after the onset of the monsoon. In this region, some farmers plow the land every year while others plow only in alternate years. The regularity of plowing depends on the depth of the soil, crop to be grown, and availability of bullocks. Local varieties dominate and sowings are done with indigenous seed drills (mostly in August during 1976-77 because of late onset of the rains; in a normal season, sowings occur during June-July). Farmyard manure (FYM) and sheep-penning are the traditional sources of plant nutrients. Groundnut receives preference over other crops in the application of FYM. Fertilizer is rarely used for dryland crops. Interculturing with blade harrows is practiced by most farmers. Handweeding is also practiced in the case of groundnut. Grain crops are harvested with sickles and groundnut with blade harrows. Crops suffer heavily due to moisture stress and this also makes harvesting of groundnut difficult. Threshing is carried out with human and bullock labor.

Hyderabad. Preparatory tillage for sorghum and pearl millet, whether sown as sole crops or as base crops in mixed cropping systems, consists of two to three blade harrowings during premonsoon showers, while castor and *rabi* sorghum receive thorough preparatory tillage with two or three plowings. Sorghum and pearl millet are sown immediately after a good rain, from late May to mid-June. Local varieties of seed for sorghum and pearl millet are common. The improved variety of castor, Aruna, is becoming popular with farmers, although the local variety still occupies almost 50% of the area. Farmers use the same seed rates of sorghum and pearl millet in mixed cropping systems as in pure crops to maintain full plant population. Castor sowings are usually done in July. Sowings are done both by the *khera* method (dibbling seeds in the furrows opened by *desi* plows) and by the *'pora'* method (country wooden seed drill). Fertilizers are not used and application of farmyard manure is mainly restricted to castor and *rabi* sorghum. One or two intercultivations in the case of sorghum and pearl millet, and two to three in the case of castor, are done with blade harrows. Handweeding is not done for cereal *crops.* About one-third of the area under castor is subjected to handweeding. Generally, no plant protection measures are used. Harvesting of castor is done in three to six pickings.

Bangalore. Preparatory tillage for *kharif* crops is undertaken with the rains received from April to June, using implements such as iron plow, wooden plow, *heggunta* (wooden implement with two to six spring plated tines), or harrow. Use of local seed varieties is common in the case of all the crops except maize. The seed rate per hectare of ragi varies with the method of sowing — 25 kg for broadcasting, 15 to 20 kg for drill sowing, and 8 to 10 kg for transplanting. Farmyard manure is regularly applied by farmers, but fertilizer use is limited to improved varieties and to less than 50% of the recommended levels. Thinning in ragi is widely practiced by passing a *kunte* (a harrow with two to four closely spaced tines) across the rows. Normally, ragi is harvested at one time, but whenever improved varieties are used, harvesting is spread over several periods.

Rahuri. Flowing is done as a rule from March to June followed by two or three blade harrowings *for kharif as* well *as rabi* crops. Mostly, local varieties are used. Green gram is sown first and then the farmers move to pearl millet. *Rabi* sorghum sowings are completed during the first fortnight of September. The green gram crop receives more farmyard manure than pearl millet and *rabi* sorghum. One hoeing is commonly done in the case of pearl millet and *rabi* sorghum and *one* handweeding is widely practiced in the case of *rabi* sorghum and green gram. Plant protection and fertilizer applications are conspicuous by their absence in all crops.

Sholapur. Preparatory tillage starts in summer with surface tillage using a blade harrow. Plowing is done only in fields where groundnut is to be sown, using a reversible iron plow or improved country plows. Farmers generally use local varieties except in the case of pearl millet (occupying a small area) whose hybrid cultivars are accepted by farmers. Sowing is usually done with a three-coulter local seed drill. Organic manures are used for cash crops like groundnut; fertilizers are not used at all. *Rabi* sorghum sowings are evenly distributed over three periods, late August to early September, mid-September, and late September to early October. One or two intercultivations are done with slitblade hoes drawn by a pair of bullocks. Handweeding is restricted to groundnut. Harvesting is done by cutting out the plants and threshing with manual beating or animal trampling.

From the above review of cropping patterns and practices, it is evident that farmers in the arid and semi-arid tropical regions are still tradition-bound and are operating at a very low level of technology. In many regions, preparatory tillage is casual and often inadequate. The use of improved seeds, fertilizers, and plant protection chemicals is extremely low. Use of tractors and threshers is popular in the arid regions of Jodhpur and Nagaur. At other places, farmers depend largely on bullocks, which may be in short supply. The animal manures available are spread thinly and cash crops have the first claim on them.

Costs and Returns

With this background of the cultural and associated cultivation practices followed by farmers in different regions, it would be of interest to examine the investment level for different crops/regions and the consequent returns. Details of average costs and returns for major dryland crops per hectare are given in Table 4.

Investment in seed, manures, fertilizers and plant protection measures is generally very low, though there are wide variations between crops and regions. As a proportion of working capital, the value of these cash inputs varied from 6 to 22% at Nagaur, 20 to 30% at Jodhpur and 5 to

Table 4. Average costs and returns from major dryland crops under present practices in 1976–77 (per hectare).

Region	Crop	Area sown (ha)	Value of cash inputs[a] (Rs)	Working capital[b] (Rs)	Total cost[c] (Rs)	Output (grain) (kg)	Gross output value[d] (Rs)	Net profit based on Working capital (Rs)	Net profit based on Total cost (Rs)
Arid									
Nagaur	Pearl millet	214	34	237	294	372	427	191	134
	Sorghum	52	13	215	271	203	298	83	27
	Sesamum	60	57	256	315	169	997	742	682
Jodhpur	Pearl millet	96	48	161	215	477	613	453	399
	Green gram	17	41	155	211	312	796	641	585
	Cluster beans	11	22	113	169	330	486	373	317
Narnaul	Pearl millet	89	18	454	736	668	700	246	−36
	Pearl millet + Cluster beans	37	25	517	800	850	1016	499	216
	Cluster beans	17	33	421	686	894	1143	722	458
	Chickpea	98	58	440	712	893	1341	907	629
	Mustard	22	35	638	915	621	2016	1378	1101
Anantapur	Setaria	208	10	246	673	20	40	−205	−632
	Groundnut (Kharif-nonirrigated) }	158	292	697	1098	140	455	−242	−643
	Groundnut (Rabi-irrigated) }		644	1545	3361	1276	4472	2927	1111
Semi-Arid									
Hyderabad	Castor	52	142	365	563	188	470	105	−93
	Sorghum	38	125	444	732	411	591	147	−141
	Pearl millet	3	69	506	814	147	170	−336	−644
	Sorghum + Red gram	58	111	356	545	186 + 16	378	22	−167
Bangalore	Ragi	199	257	NA	1030	544	1457	NA	427
Rahuri	Pearl millet	119	6	189	303	117	271	82	−32
	Green gram	45	54	341	440	282	456	115	16
	Sorghum (Rabi)	327	18	208	327	212	429	227	102
Sholapur	Groundnut	78	363	721	895	378	1272	551	377
	Red gram	67	21	157	295	293	722	565	427
	Sorghum (Rabi)	335	24	181	313	348	697	516	384

a. Includes the value of seed, manure, fertilizer, plant protection measures whether owned or purchased.
b. Includes the above plus the value of family and hired human labor and draught power (bullock/machinery). Prevalent wage rates have been considered.
c. Includes 2 above plus interest on working capital @ 14% for half the crop days and land rent @ 2.5% of the present land value.
d. Includes the gross value of main and by-products at the prevalent market rate immediately after the harvesting season.

13% at Narnaul in the arid region. Pearl millet, the major cereal crop, accounted for 30% of the total working capital at Jodhpur, about 15% at Nagaur and nearly 5% at Narnaul. The proportionate expenditure on cash inputs for cluster bean was also higher at Jodhpur than Narnaul. Cash costs for sesame at Nagaur and chickpea and mustard at Narnaul accounted for 22%, 14%, and 6%, respectively, of working cost. At Anantapur, the cash investment for setaria was nearly 7% of working cost and varied between 32 and 58% for groundnut.

In the semi-arid region of Bangalore, the cash investment for ragi was nearly 25% of the total working cost, varying between 20 and 28% in different villages. In the Hyderabad region, cash expenditures were nearly 40% for castor, 28% for sorghum, 14% for pearl millet, and nearly 34% in the case of sorghum plus red gram. Interestingly, variations across locations were higher at Hyderabad than elsewhere. Cash investment varied between 26 and 55% for castor, 7 and 33% for sorghum, and 20 and 59% for sorghum plus red gram. At Rahuri and Sholapur, which are principally *rabi* sorghum areas, cash investment was nearly 9% of the working cost at Rahuri and about 13% at Sholapur for sorghum. No great variations were noticed. Further, the expenditure was limited to only 3% for pearl millet. It varied between 7 and 28% (average 16%) for green gram. At Sholapur, cash expenditures on groundnut and red gram accounted for 50 and 15% of total working costs, respectively. This varied between 28 and 70% for groundnut and between 9 and 29% for red gram over locations in the region.

Considering the overall situation, cash investment ranges between 39 and 45% of total working capital for oilseed crops such as groundnut and castor. It ranges between 12 and 16% for cereals and between 13 and 19% for pulses. It is as low as 3 to 4% for millets. Surprisingly, it is also low (5%) for mustard (oilseed crop) at Narnaul.

The investment in cash does not appear to have any relationship to the size of the farm. However, the high-value crops of the regions — such as sesame at Nagaur, pearl millet at Jodhpur, chickpea and mustard at Narnaul, groundnut at Anantapur and Sholapur, castor and red gram at Hyderabad, red gram at Hyderabad and Sholapur, and green gram at Rahuri — were subjected to relatively higher cash expenditures than the other crops. The breakup of cash investment into various components such as seed, manures, fertilizers, and plant protection measures also suggests that the high-value crops generally received more manure/fertilizer and plant protection measures than other crops — even the cereals — in the region (Table 5).

Thus it seems that plant protection measures were not used for most crops and, wherever adopted, were inadequate. The amount spent on manures/fertilizers was also small when viewed in relation to the corresponding prices of manure and/or fertilizers. In some cases it appears that application of manure was nothing more than an apology. At Hyderabad, crops were better fertilized than in the other regions, though not adequately.

Under farmers' management, as reflected by the cultivation practices followed and the level of inputs used, the yields of all crops considered at all locations were extremely low. However, in the arid region, yield levels obtained at Narnaul were higher than those obtained either at Nagaur or Jodhpur. Crops at Anantapur virtually failed because the season was extremely unfavorable. Further, the yields of pearl millet, though low in the arid region, were two to three times higher than those obtained either at Hyderabad or Rahuri in the semi-arid region. But the yields of sorghum in the arid region were about half of those obtainable in the semi-arid region even though these were low.

Thus it is clear that farming in these dryland areas has been designed for low investment in terms of practices followed and inputs used, resulting in low yields. Based on the economic rationale, such low yields hardly have a margin of profit sufficient to sustain a farmer and his family.

Recommended Technology

The remedy for the malady of low crop yields and low profits in dryfarming areas lies in recent technological advances, which have convincingly established the superiority of the recommended package of practices over the traditional practices. Table 6 gives the details of average yields obtained, costs incurred, and consequent returns per hectare with the re-

Table 5. Composition of cash Inputs under farmers' present practices.

Region/Crop	Value of inputs (Rs/ha)			
	Seed	Manure/fertilizer	Plant protection	Total value
Arid				
Jodhpur				
Pearl millet	9	39	Nil	48
Green gram	21	20	Nil	41
Cluster beans	13	9	Nil	22
Narnaul				
Pearl millet	13	4	Nil	17
Cluster beans	33	Nil	Nil	33
Pearl millet + Cluster beans	23	2	Nil	25
Chickpea	57	Nil	Nil	57
Mustard	29	6	Nil	35
Semi-Arid				
Hyderabad				
Sorghum	23	103	Nil	126
Castor	55	86	1	142
Pearl millet	32	37	Nil	69
Rahuri				
Sorghum	15	3	Nil	18
Green gram	27	27	Nil	54
Sholapur				
Sorghum	20	3	1	24
Groundnut	329	34	Nil	363
Red gram	21	Nil	Nil	21

commended practices under similar agroecological and socioeconomic environments as are considered in the preceding pages.

It is observed that, in all cases, the recommended practices gave yields many times higher than those obtained with the traditional methods of farming (Table 4). Even in Anantapur where, because of an extremely poor season, crops under the farmers' level of management almost failed, crop yields with the recommended practices were higher — though not enough to cover the cash inputs or the charges for the use of human/bullock labor, etc.

As one would expect, the share of cash inputs in total working costs with the recommended practices was much higher than with traditional practices, ranging between 35 and 67% considering crops and locations together. It may also be relevant to point out that in the additional cost, the share of fertilizers was considerable, ranging from 60 to 70%. The seed cost was also higher with the recommended practices — 12 to 15% of the additional cost. The share of the plant protection measures was 5 to 7% and the rest of the additional cost was accounted for by the use of extra labor needed for adequate preparatory tillage, interculturing, harvesting, and threshing the additional output. A perusal of investment in inputs and the output obtained reveals that, in the arid region alone, cash inputs were more intensively used at Narnaul than at either Nagaur or Jodhpur. Consequently, the output per hectare was much higher at Narnaul. For example, the additional investment in pearl millet ranged between Rs 250 and 300 per hectare, with an average additional output of 650-675 kg at Nagaur/Jodhpur. The additional investment in inputs at Narnaul for pearl millet was over Rs 700/ha with an average additional yield of 1250 kg.

At Hyderabad, the additional investment in inputs was about Rs 250/ha for sorghum and

Table 6. Average costs and returns per ha from major dryland crops with recommended practices 1976–77.[a]

Region	Crops	No. of Cases	Value of cash inputs (Rs)	Working capital (Rs)	Total cost (Rs)	Outputs (kg)	Gross value (Rs)	Net profit based on Working capital (Rs)	Net profit based on Total cost (Rs)
Arid									
Nagaur	Pearl millet	25	343	714	794	1014	1176	461	382
	Sorghum	10	527	994	1112	1081	2118	1124	1005
	Sesame	1	106	338	392	148	519	181	127
Jodhpur	Pearl millet	21	301	872	938	1154	1374	502	436
	Green gram	13	98	613	660	667	1424	811	764
Narnaul	Pearl millet	13	756	1121	1410	1924	1893	772	482
	Cluster bean	3	211	556	825	1070	1342	787	517
Anantapur	Setaria	8	262	412	459	69	119	−293	−340
	Sorghum	4	308	492	541	46	93	−399	−448
	Pearl millet	10	294	482	526	65	102	−380	−424
Semi-Arid									
Hyderabad	Castor	16	317	679	920	518	1265	586	345
	Sorghum	10	393	755	1032	1107	1538	783	506
	Sorghum + red gram	6	347	729	946	1075 + 219	1691	963	745
	Pearl millet + red gram	13	251	616	833	1286 + 189	1536	920	703
Sholapur	Red gram	3	203	403	549	370	872	469	323
	Rabi sorghum	14	191	496	663	950	1594	1097	930
Bangalore	Ragi	13	759	1437	1520	1804	2195	758	675
Rahuri	Rabi sorghum	24	191	535	672	554	906	370	233

a. Based on data from demonstrations conducted in farmers' fields with plot sizes of 0.4 hectare or more. All cash inputs comprising seeds, fertilizers, and plant protection chemicals are fully subsidized, while farmers provide land and human and bullock power. All crop proceeds are retained by farmers.

Rs 175/ha for castor and pearl millet. The additional yield obtained ranged between 700 and 900 kg for sorghum and was 330 kg for castor. With the recommended practices, the yield of pearl millet increased by 1000 kg/ha. An additional investment of Rs 400 in ragi at Bangalore enabled the harvest of additional outputs ranging from 1200 to 1300 kg. Both at Rahuri and Sholapur, an additional investment of over Rs 170/ha was required for *rabi* sorghum; this resulted in additional yields ranging between 400 and 600 kg.

Thus, the cost of cultivation with recommended practices was high but the relative net profits were still higher. The net profit ranged between Rs 450 and Rs 1100 per hectare for the recommended practices in most cases, leading to additional net profits ranging from Rs 200/ha to about Rs 1000 over and above the existing levels.

One has to be aware of the inadequacy of the data presented. They pertain to only 1 year, but the year was about normal at most places and several soil and climatic regions were sampled. It may still provide an overview of the current level of technology in use by most farmers and the new dryfarming technology recently developed at research centers. The recommended technology is viable and feasible. It is also said to be neutral to scale. But it is still to gain popularity with farmers in the arid and semiarid regions of the country. It remains to be further diagnosed whether it is the low-resource base, socioeconomic inertia, or risk aversion that is responsible for the slowness with which the technology is moving.

Summary and Conclusions

The land-utilization pattern in these eight regions suggests that though the area under cultivation has been extended to marginal and submarginal lands, the intensity of cropping remains low, ranging between 84 and 125% at various locations. Double cropping is limited to areas with irrigation during the postmonsoon seasons (October-February). In rainfed areas, cropping patterns have been essentially developed within the constraints of low and erratic rainfall for a relatively short growing period ranging from 75 to 130 days. Considering the different categories of farms and locations together, it is observed that the principal food-grain crop depends on the rainfall and the length of the growing season. For example, pearl millet is important in Jodhpur, Nagaur, and Narnaul; sorghum is important in the Hyderabad, Rahuri, and Sholapur regions while setaria at Anantapur and ragi at Bangalore are important.

The farmers in these arid and semi-arid areas are still tradition-bound as regards the farming practices they follow. They are operating at a very low level of technology.

Summer plowing is not practiced except in some cases at Rahuri and Sholapur. In many regions preparatory tillage is casual and inadequate. For example, in areas like Anantapur, plowing is done once in 3 to 5 years, depending upon the soil depth, crop to be grown, and the bullock power available. The use of improved seeds, fertilizers, and plant protection measures is negligible. Even the farmyard manure available is spread thinly and the farmers prefer to use it only for cash crops. Tractors and threshers are becoming popular in the regions of Jodhpur and Nagaur. Investment in cash inputs per hectare does not bear any relationship to the size of the farm.

The high-value crops of the region attract significant investment per hectare in cash inputs compared to other crops of the region. Thus, within the constraints of low investment in terms of practices followed and inputs used, the yields of crops in all locations are low and it is doubtful that such low yields generate a margin of profit sufficient to sustain a farmer and his family.

Recent research advances are capable of remedying the malady of low crop yields and low profits in rainfed farming areas but at a relatively higher investment. Undoubtedly, profits will be higher. However, despite the fact that the new technology seems viable and feasible, farmers are reluctant to undertake investments required to adopt the technology. Perhaps their low resource base and risk aversion are the two principal reasons responsible for the low adoption of the technology. However, the real constraints to the adoption of the technology are yet to be ascertained.

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Discussant's Comments

H. Ruthenberg*

Farming systems work may have different objectives. Since this is an ICRISAT workshop, I assume that farming systems work seeks to enhance the relevance of biological science research work. I will discuss the various papers with this objective in mind.

Drs. Abalu and D'Silva submitted a paper that deals with a relevant subject in our context. They provide evidence from northern Nigeria that:

1. Mixed cropping produces higher gross and net returns than sole cropping.
2. Actual cropping patterns are rather close to those that should prevail if the minimization of income variability is the objective.
3. Actual cropping patterns are consistent with the objective of providing sufficient calories and protein for the families.

The authors conclude that there is rationality in what smallholders do. There is no doubt that they submit strong evidence to support their conclusions. It should be considered, however, that more information would be needed to really verify the hypothesis of an "income variability minimization" strategy. We would have to compare actual farm plans with optimal farm plans under several strategies.

Also it might be questioned whether the underlying assumptions of the linear programming models that they employ remain acceptable under the condition of rapid economic and cultural change. In particular, I would question the idea of a labor constraint in these farming systems where less field work is done per family than in most other African farming systems. For more than a decade I have been among those who emphasized that labor problems are crucial in tropical smallholdings and this is generally accepted. The history of science indicates, however, that there is reason to be cautious about lines of thought that are generally accepted. The word "constraint" originates from technical sciences and has recently been introduced into economics. Its precise meaning is rather stringent. My experience indicates that on African small farms we rarely face labor constraints but rather elastic and often kinked labor supply curves. A result based on constraints should therefore not be accepted unless there is much additional evidence than the results of normative linear programming exercises.

Drs. Abalu and D'Silva not only present their findings but also give directives for research on the basis of these findings. The adoption of innovations in northern Nigeria has been slow. Most recommendations are based on experiments with sole crops. They point to the rationality of mixed cropping and argue that research should work for improved mixed cropping systems.

I fully agree with the criticism of the authors. Past agricultural research in the tropics ignored the rationality of mixed cropping. But I cannot follow their argument that the presence of mixed cropping and its rationality in the existing setting is sufficient reason to invest research resources in it. It is a fallacy to assume that information about the existing systems provides conclusive evidence about the direction plant science research work should take:

1. The fact that a certain crop predominates in a given area is insufficient for research resource allocation. Dr. Sanders, for instance, argues convincingly in his paper for this Workshop about the Brazilian Sertao that sorghum should be substituted for the existing maize.
2. Mixed cropping may be the best in the traditional setting. With new varieties sole cropping may be better.
3. The fact that there is a food shortage in a given area is not sufficient reason to invest

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The editors regret to note the untimely death of Professor Ruthenberg in July 1980. He made substantial contributions to the understanding of traditional farming systems.

in food crop research. It may be that promotion of cash crops produces more welfare for the people concerned.

Certainly, no major research program in agriculture should be started without a fair understanding of the existing farming systems. Farming systems work as submitted by Drs. Abalu and D'Silva is indispensable. But if we only look at what exists we may overlook the much better chances that perhaps are offered by something entirely new.

It is useful in this context to distinguish between two basic strategies in the allocation of research resources:

1. The *improvement approach* aims at the betterment of existing systems. Relevant are such types of agricultural research which produce innovations that can be adopted by farmers without major additional changes.
2. The *transformation approach* concerns a completely new set of production patterns. The existing is discarded as inefficient and not worth improving, given the new possibilities. The replacement of Zebu cattle by exotic cattle for dairying in Kenya, and the development of high-yielding varieties are successful examples of the transformation approach.

Clearly, both strategies have to be considered. The important point in the context of our workshop is that farming systems analysis provides information which is indispensable for the design of research strategies. However, the knowledge of the biological science research workers about possible "breakthroughs" in their field is also indispensable. Information about both aspects has to go into the decision-making process.

Let me turn to the next paper, submitted by Dr. Jodha. It provides essential information about Indian cropping systems in areas with monsoon fallowing and about watersheds. The important conclusions are that monsoon fallowing is there for definite reasons, that mixed cropping predominates on rainfed land, particularly on small farms; that farmers concentrate limited water resources on high water-consuming crops; and that watershed development requires group action. The research implications are well stated: innovations have to be produced that would allow monsoon cropping on Vertisols, and the competitiveness of upland cropping has to be improved in order to make the reallocation of water resources a profitable proposition.

Dr. Jodha's presentation indirectly implies that farming systems research in the context of a research station has to proceed through two stages:

1. Baseline surveys to inform about the present situation before innovations from the research program are introduced. This information is needed for the initial research strategies.
2. The analysis of farming systems that undergo changes. This is the innovation-testing stage with a well organized feedback to adjust ongoing biological-science work.

The latter type farming systems research is rather different from farming system research work for other purposes:

1. It has to be much more specific. Total farms are too large a unit. Dr. Jodha already points to the need for plot-histories, which provide information on each plot.
2. It has to be geared to hypothesis testing and hypothesis finding at the same time. It is certainly not enough to describe the farming system with no specific objective in mind. Precise hypotheses have to be stated and tested. At the same time researchers have to look for new and better hypotheses.
3. Farming systems work of this kind requires meaningful classification schemes. The village is certainly too heterogeneous for the purpose. Farms that produce under almost identical conditions should be grouped together in particular as to soils, i.e. they should produce with almost the same physical production functions.
4. Such work requires permanency. It is better to follow a few farms over a longer period than to produce a one-shot analysis of a great number.

The next paper submitted by Mr. Rastogi discusses the existing cropping patterns in selected Indian dryland farming regions, the husbandry practices that prevail, the technologies that can be introduced and the costs and returns of existing and improved practices in monetary terms. Mr. Rastogi points to the wide discrepancy between the actual farming performance and the much higher returns that are obtained with more intensive practices experimented on large plots in farmers fields. There is thus a wide gap between present practice and what should be economically optimal from the farmer's point of view. The information provided by Mr. Rastogi is well organized and most valuable. Perhaps the value of future work along these lines could be enhanced by specifying classification that does not occur on a regional or village basis, but is designed on a farming systems basis. Also a break-down of a farm into separate fields and the collection of plot histories might increase the value of such work.

Of crucial importance is the explanation of the "gap" that Mr. Rastogi found. Plots husbanded by personnel from research stations normally yield much higher gross and net returns than farmers' fields. If, in the area analyzed by Mr. Rastogi, the index figure 100 is given to the gross return of the plots husbanded by research personnel, then the farmer would harvest 66 with the same inputs and his own management. He would harvest 33 with traditional inputs and his own management (private communication from Mr. Rastogi). These findings lead to a plea that future farming systems research should not only describe, but also try to explain, why things are as they are. India, meanwhile, has a great number of farming systems studies, which inform about what now exists but which would greatly gain in value if more effort would be directed to explaining why low-output and low-productivity farming systems prevail in spite of the fact that most farmers know about innovations that could improve their situation.

However, research institutes such as ICRISAT should remain "economic" as to socio-economic research that aims for explanation and understanding. Such research will be time consuming. The situation is complex, and human behavior may change rapidly over time. We don't command an operational theory of man, and some of the research may result in conflicts between controversial schools of thought in social sciences.

The emphasis in farming systems research should therefore be put into a well organized trial-and-error process. The initial step clearly is a basleline survey. A number of cooperating farmers have to be found; there usually is a sufficient number who are interested and prepared to cooperate, provided they obtain support. The idea is to test innovations as early as possible with these cooperating farmers, who should be well aware that they are dealing with something immature. Cropping and farming systems researchers face the problem that there is a rapidly growing number of seemingly interesting combinations of innovations. It is impossible to handle these numbers in experimental work. Crop and husbandry combinations chosen in experimental work at research stations are more or less shots in the dark. The involvement of the farming community in this process of trial and error allows the testing of a much larger number of innovations. It includes the experiences and intelligence of a great number of farmers who have a material interest in what they do. They rarely adopt bundles of innovations as recommended; they experiment on their own, and this is likely to generate ideas that would improve the relevance of research work provided there is a well organized feedback from the farming community to the biological science research workers.

This process of trial and error is not necessarily tied to an understanding of the farming systems and the human element involved. The farm household systems may be considered as "black boxes." We need not necessarily understand why farmers do what they do; but if the results are positive in terms of objectives in research then we may conclude that the innovations are useful. If this is not so we may continue the process with modified or entirely different innovations.

Chairman's Summary

W. H. M. Morris*

As a basis for discussion we have the comprehensive comments presented by Ruthenberg.

Abalu presented results that indicate (1) mixed cropping produces higher gross and net returns than sole cropping, and (2) actual cropping patterns are rather close to those that result from minimization of income variability and are consistent with the objective of providing sufficient calories and protein when the farm is large enough.

The hypothesis of income variability minimization is not really verified by the methodology used. Professor Ruthenberg pointed out that the term "constraint," borrowed from the technical sciences, may be abused by economists. We rarely meet labor constraints on African small farms, but rather elastic and often kinked labor supply curves. More evidence is needed before we can accept existance of a real labor constraint.

Abalu points out that the rationality of mixed cropping has been ignored by agricultural scientists in the tropics, but the presence of mixed cropping alone may not be adequate justification for investing research resources in it.

A fair understanding of the existing farming system is a necessary precursor for any major program in agricultural research. However, although the kind of work reported by Abalu is indispensable, it should not cause us to overlook the much better chances that perhaps, are offered by something entirely new.

Ruthenberg pointed out that there were two basic strategies in the allocation of research resources: (1) the improvement approach to better existing systems and (2) the transformation approach, which concerns a completely new production pattern. Farming systems analysis provides information that is indispensable for the design of research strategies, but the knowledge of the biological scientists on possible breakthroughs is just as important.

Jodha presented essential information on cropping systems and watersheds in areas with monsoon fallowing in India. His presentation implies that farming systems research at an experiment station needs to have two stages: (1) baseline surveys to understand the present situation, and (2) analysis of the changing farming system in testing the innovation. In the latter stage feedback should be used to adjust ongoing biological research. This type of research differs from the baseline studies in the following respects: it has to be more specific and include individual plot histories, and it has to be geared simultaneously to both hypothesis testing and formation; that is, description of the farming system needs to be complemented by testing of stated hypotheses and by the formulation of new and better hypotheses. This type of study requires detailed classification. The village is too heterogeneous a unit and farms or fields must be compared which have almost the same physical production functions. Such a study also requires continuity. It is better to follow a few farms over a longer period than do a single entry study of a large number of farms.

Rastogi discussed cropping patterns in the Indian SAT, as well as the husbandry practices, changes that can be observed, and the costs and returns of present and potential technologies. There is a wide gap between farmers' results and those from research in large plots on farmers' fields. A more detailed classification of the units studied, down to plots, should decrease this variability and explain this important discrepancy. This type of research needs to be directed towards explaining the "gap" as well as to pointing out its extent.

The large number of farming systems studies in India would be more valuable if a greater effort were made to explain why low output/low productivity farming systems prevail, in spite of

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the fact that most farmers know about the innovations that could improve their situation. However, institutions such as ICRISAT should be economic in their socioeconomic research program, seeking only explanation and understanding because of the time-consuming nature of this work and the problems of studying human behavior over time. The emphasis in farming systems research should therefore be put into a well-organized trial-and-error process. The initial phase is clearly baseline studies. There are usually a sufficient number of farmers who *are* interested and prepared to cooperate — given adequate support — in testing innovations at an early stage. The farmers may not accept a whole range of technological packages but rather experiment on their own, and they are likely to generate ideas that improve the relevance of research, provided there is a well-organized feedback to the biological scientists.

The study of this process of trial-and-error does not necessarily require an understanding of the farming and human elements of the systems. If the results from the farmers' efforts are positive in terms of objectives of research, the innovations will be useful. If their efforts are not positive then the process has to be modified or entirely different innovations tested.

In the light of the four criteria in the program, Dillon stressed the need for adding a macrolevel appraisal of the socioeconomic-political environment to the microlevel socioeconomic analysis. This type of appraisal could be used to help assess or decide on the allocation of research resources among countries by international agricultural research centers, on the basis that there is likely to be little benefit from expending resources on farming systems research where the sociopolitical situation is unfavorable to the target group.

Chapter 2

Socioeconomics of Prospective Technologies in SAT Regions

Socioeconomic Aspects Involved in Introducing New Technology into the Senegalese Rural Milieu

Moussa Fall*

Abstract

This paper discusses physical constraints and human factors relating to the introduction of new technology in the rural areas of Senegal, particularly in the Sahel, where investigations have been in progress for 3 years. Although the profitability of certain techniques has been demonstrated, the farmer still needs to be motivated towards change. This motivation is presently based mainly on increase in monetary income and production surplus. Production systems should be intensified; the marketing system should be better organized; the working of cooperatives should be improved; credit should be made more flexible. Literacy remains a crucial problem in efforts at modernization.

Agricultural production represents about one-third of the gross domestic product in Senegal, but approximately 70%of the active population is employed in this sector. In development plans, priority has been given to the modernization of agriculture and to the increase of farmers' incomes through large investments, introduction of technical innovations, and intensification of farming systems.

In this paper, we shall discuss some aspects of the introduction of new technology in the rural areas of Senegal, particularly the north central zone (Sahel), where investigations have been carried out for the last 3 years. In selecting one zone, we are aware that only partial results can be obtained. However, these can be compared with results of similar studies undertaken in other countries and can be verified for other regions of Senegal.

First, we shall briefly discuss problems related to the interaction between production techniques and the enviornment and then proceed to the economic evaluation of some innovations.

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NOTE: This paper is an edited translation of the original French text, which appears in Appendix 1.

Agricultural Production Techniques and Their Integration into the Physical and Human Environment

Production Techniques and the Physical Environment

One of the main characteristics of agriculture is the important influence of the physical environment on the production process. There is ample evidence of this influence in Senegal's rural areas, where the capacity of a given land area to absorb capital and labor largely depends on a number of soil-related limiting factors. This may be obvious; but it seems useful to repeat it as errors are frequently committed on this point and several failures are still attributable to inadequate adaptation of techniques to local physical conditions.

Production Techniques and the Human Environment

There is an obvious relationship between production techniques and the human environment, but this aspect is often overlooked. For a long time it was believed that in order to promote new techniques and equipment it was sufficient to show how effective and easy to use they were to future users. However, such measures are now known to be inadequate. Promotion of innovations is slow and transformation of farming techniques is difficult. There is need for a new approach involving the farmer, his traditions, and his social environment. This approach has to be based on two assumptions:

1. In order to understand a system, changes should be introduced that will help to perceive its functioning and the motivations and needs of those who make up the system, and
2. Modernization of family landhoidings is a long-term process because it not only involves the adoption of innovations but also requires a change in the mentality and behavior pattern.

Interdependence of Techniques

In the traditional agricultural system in Senegal, the interdependence of techniques is not clearly seen because of the inadequate use of factors of production and their poor combination. However, the system is a complex of exchanges (equipment, manpower, land use, etc.), and the modification of any one of these can lead to disruption.

The introduction of certain innovations and agricultural intensification has revealed the relationship between techniques:

- Effective fertilization requires crop maintenance and application of certain methods, such as thinning for millet.
- Introduction of animal traction requires better food for animals and increased water and fodder resources.
- The use of the planter has helped to expand cropped area, modify cropping plans, and increase labor productivity.

Thus it appears that innovations should be promoted through coherent and feasible technology packages that are integrated into the existing production system.

Problems of Transfer of Technology in Rural Areas of Senegal

Physical and Human Environment

The area involved is north-central zone which is entirely situated in the Sahelian belt. The dry season extends over 8 to 9 months of the year and average annual rainfall is about 500 mm. Soils are mainly Dior (poor in clay). There Is a large rural population with frequent migration, especially among the young people.

The *carre,* which is the production unit, may include a certain number of independent households that make up sub-land holdings. The head of the *carre* owns most of the production facilities and generally has control over decision-making.

The main crops are millet and groundnut; fallow is starting to disappear. The expansion of areas devoted to new crops (diversification) is quite slow.

Proposed Innovations

The main objective of the proposed innovations is to increase yields and labor productivity. They concern varieties, cropping techniques, equipment, diversification of activities, and the production system and are as follows:

1. Improved and suitable varieties are recommended.
2. The main techniques that are promoted *are:*
   a. adequate tillage (preplanting plowing before a cereal crop);
   b. heavy mineral fertilization (150 kg/ha) and basic application of phosphate in an intensive farming system;
   c. timely planting;
   d. chemical weeding of groundnut and early thinning (three plants per hill) of millet;
   e. incorporation of organic matter, either in the form of manure or of residues of a millet crop.
3. The equipment recommended to the farmer enables him to increase his labor capacity and improve crop maintenance.
4. Diversification of activities enables the farmer to minimize risks and to add to his sources of income. It was therefore proposed to integrate livestock raising with agriculture through summer fattening of animals and increased diversification of crops.

Simple and economically viable models are being studied.

Conditions for Promoting Innovations

An autonomous body SODEVA (*Societe de Developpement et de Vulgarisation*

Agricole — Society for Agricultural Development and Extension Services), along with other agricultural services, is responsible for the mobilization of farmers and promotion of techniques. This organization is increasingly involved in the distribution of production factors as well as their use by the farmers. However, the adoption of recommended techniques is not without difficulties, and a detailed analysis of the situation has revealed major constraints.

Technical Constraints

These constraints are found at all levels:

- The formulation of technical recommendations made through research is not always perfect and the technoeconomic references are sometimes inadequate.
- The development organization becomes a dead weight, impeding movement of technical information from the top to lower levels. Links with research are limited to certain aspects with little follow-up except for specific projects.
- The work and technical skill required of the farmers often exceeds their capabilities and extends beyond their short cropping calendar (early thinning, postharvest tillage, production of manure, etc.).

Human Constraints

Within the framework of the promotion methods adopted in the region, the social organization of the family landholding impedes adequate investment or stabilization of manpower — a rare resource at certain critical periods. However, this constraint is not insurmountable.

Farmers do not always have well-defined objectives and these are often contrary to the recommendations made.

Economic Constraints

Agriculture in Senegal is being rapidly transformed into a money economy with a relatively satisfactory market channel for groundnut. This has encouraged farmers to practice extensive agriculture in the absence of substantial technical progress.

The area cultivated per worker is a predominant factor in determining labor returns. As the second factor, the returns per surface unit may be practically considered as constant. So population growth, resulting in a decrease in the area cropped per worker, has led to a decrease in labor returns. Land availability is decreasing and rights of individual tenure do not permit the merging of landholdings. Owners of large landholdings who have the highest incomes more easily adopt techniques such as herbicides, tillage, hired labor etc. There is a gap between the big farmer and the small farmer, who is usually in debt and accepts with difficulty the costly innovations or those that do not bring in immediate returns.

The system of providing factors of production and market channels for certain products does not always function without difficulties. Cooperatives are often blocked by debts while farmers wait for the equipment they have ordered.

In all cases, the success of promotion efforts, even after proper study, still depends on proper organization of the economic enviornment of the producers.

Evaluation of the Impact of Promoted Techniques

Because of the economic constraints, research efforts are being directed towards study of the actual production systems and evaluation of the effect of new techniques in rural areas. The idea is not to "measure" technical progress of the landholdings but to evaluate their internal dynamics as well as their capacity to implement the recommended innovations.

Method of Approach

Two types of approaches may be considered for the area: studies of selected landholdings and more generalized and flexible promotion efforts. In the first case, investigations are planned to determine the extent to which techniques are assimilated; in the second case, differences between categories of landholdings are measured according to the degree of intensification.

Investigations

Three types of investigations can be distinguished:

1. investigations of population, farm equipment, and cultivated areas,
2. agricultural investigations,
3. socioeconomic investigations.

Analytical Methods

It is possible to characterize landholdings by processing data obtained from the first type of investigations. The other two types of investigations help to evaluate the extent to which the techniques are assimilated and their efficiency. For this purpose, we use comparative analysis, principal component analysis, regressions, and landholding counts.[1]

Comparative Analysis Matrix

This analysis provides four types of output with various combinations of variables and their statistical characteristics. With this analysis it was also possible to judge the importance of social status in the adoption of techniques (1976) in three pilot villages of the zone.

Groundnut is cultivated by all those who work on the landholding — head of the *carre,* household head, *sourga* (family labor), *navetanes* (seasonal labor), and women.

The head of the *carre* only cultivates 38% of the land on an average of two plots. The plots cultivated by women are much smaller than those of other members of the landholdings — an average of 0.39 ha, or one-quarter the size of the plots cultivated by the head of the *carre.*

Yields in the womens' plots are lower than those in plots cultivated by the head of the *carre;* as standard deviations are high, the differences are not significant, but they are the same in the three villages and tally with other observations (Table 1).

On the whole, it was observed that techniques do not differ greatly according to social status. The largest variations were recorded in women's plots and to a lesser extent for *the sourgas* (Table 2).

The study reveals the characteristics of the plots according to social status and the preeminence of the head of the carre in relation to other members of the landholding; they have the largest number of plots with heavy fertilization (Table 3).

The variables of this study were selected according to the objectives of the analysis:

- to determine the effect of the main criteria on landholding economy.
- to determine the effect of variations in size.
- to determine the levels of intensification of the selected landholdings.

Variance of all variables was explained by four independent factors — size (physical and economic), use of factors of production, soil productivity, and labor productivity.

The analysis brought out the following facts:

1. The farming system is purely "extensive;" size is a very important factor in income formation.
2. It is mainly the larger landholdings that are underequipped. The better equipped farmers make the best use of other inputs.
3. Soil productivity is not very important as

1. Due to space limitations, details of these methodologies are not presented here but can be found in the papers contained in the list of references at the end of the paper.

Table 1. Distribution according to status (1976 village-level studies in the Thies-Diourbel region).

Status of cultivator	No. of plots	Average plot area (ha)	Total area under groundnut (ha)	Total area under groundnut (%)	Yield (kg/ha)	Fertilizer (kg/ha)
Head of *carre*	50	1.54	77.07	37.9	1309	60
Household head	17	1.27	21.58	10.6	1273	39
Sourga	78	0.74	57.91	28.5	1005	15
Navetane	15	0.89	13.37	6.6	1103	50
Woman	86	0.39	33.47	16.4	847	19
Total	246	0.83	203.40	100	1077	31

Table 2. Cropping techniques according to statue.

Status of cultivator	No. of plots	Percent plots sown on first rain (%)	Plots hoed two or more times (%)	Average no. of hoeings	Average no. of weedings	Fertilized plots (%)
Head of *carre*	50	72	78	2.34	1.80	52
Household head	17	82	76	2.59	1.41	41
Sourga	78	63	94	2.46	1.78	15
Navetane	15	100	66	2.07	1.67	53
Woman	86	31	58	1.91	1.86	21
Total	246	57	75	2.23	1.78	29

optimum use is not made of inputs. So, remuneration for work is reduced.

Multiple Regression Analyses

This method is used along with principal component analysis. As expected, the explanatory variables are mainly cultivated area per agricultural worker and groundnut production. At present, in a large part of the zone, extensification presents a definite advantage over intensification. However, these two notions are not opposed to each other and, in cases of shortage of land, intensification is necessary.

Although millet and groundnut production are accounted for in the same manner, millet production has little effect on income formation, as yields were low in the year of investigation.

Annual Budgets

The main objective of this evaluation method was to study income formation. It does not include problems of marketing and interaction with extra-agricultural activities.

Cereal crops — millet and sorghum — were included in the calculations because production activities are closely linked within the landholding and because they are involved in transactions between villages.

Quantitative parameters (prices, expenses, units, workers, etc.) were used in all cases to obtain results for comparison and to avoid considering specific cases found in the area.

Two aspects were considered — calculated budgets and monetary budgets. The first method is often used for analyzing the performance of production systems and the second is used to study the accumulation capacity for explaining the more or less rapid progress of the system. In order to compare production systems, especially their productivity, *margins* (gross or net) or *added values* (gross or net) were used. Results obtained in 1975 and 1976 have confirmed the observations made above: on small holdings, despite higher groundnut yields and larger use of fertilizers, the gross product remains low.

An examination of the classes of landholdings in the sample shows that the *carres* vary from 3 ha to 27 ha in size. (The sample is not representative of the entire zone if we consider the fields of the *marabouts.)*

The net margin/worker is largest in the 27-ha *carre* size group whereas the net margin/ha is largest in the 15- to 18-ha *carre.* The results for farms using bullock power have shown that although bullock power helps to expand land

Table 3. Use of fertilizer according to status.

Status	Fertilized plots (%)	Average quantity of fertilizer per unit of all land (kg/ha)	Quantity of fertilizer used on fertilized plots (kg/ha)
Head of carre	52	60	116
Household head	41	39	95
Sourga	15	15	94
Navetane	53	50	94
Woman	21	19	89

area, it should, in order to obtain better returns, be integrated in a system where all the factors of production are used rationally.

Results of Farm-Level Studies by Extension Services (SODEVA)

As part of agricultural program evaluation, SODEVA has studied 162 landholdings of the zone (1977-78 agricultural program investigations, Diourbel region). The criteria for landholding selection were: landholdings that have already been studied, possibility of access in any season, and agreement of farmers.

The study has helped to assess the differences between categories of landholdings: TL - easily applicable or traditional techniques; TB — bullock power; TBFF - bullock power, heavy fertilization.

Two important facts may be emphasized:

1. The superiority of the TBFF (during the year of study —1977)[2] for millet production because of the increased use of hoes and intensive fertilization. Use of these techniques explains the increase in yield by 90 kg/ha on the TBFF.

2. Regression analysis helped to calculate the advantage of extensification.

In the conditions that were studied, it would be useful for the average farmer to increase his land area/worker up to 2.2 ha for millet (average now 1 ha) and up to 3.5 ha for groundnut (average now 1.5 ha). In this case millet production would increase by half and the gross margin for groundnut would increase to a total of 36 000 Frs.

Overall Comparison of the Economic Results of Landholdings (TL-TB-TBFF)

A comparison between the three types of landholdings shows a clear difference in the net margin per worker. Using TL as the reference level, the following indices of net margin can be obtained.

TL	=	100
TB	=	108
TBFF	=	128

The difference between TBFF and TL is due to millet and groundnut yields, cropping pattern, and farm equipment.

A breakdown of the net margin/worker gives the following TBFF/TL ratios:

Groundnut gross margin/worker	1.61
Millet gross margin/worker	1.09
Total gross margin/worker	1.29
Redemption/worker	1.38
Net margin/worker	1.28

Conclusion

We have discussed an important aspect of agricultural development — the introduction of new technology — in order to present the problem of its evaluation and its impact in rural areas. This analysis, though partial, has revealed the importance of the economic environment of the farmer in the farm modernization process.

In Senegal, although the profitability of certain techniques has been demonstrated, the farmer still needs to be motivated toward change. This motivation is mainly based on increased monetary income and production surplus.

For this purpose, marketing needs to be well organized; cooperatives should be allowed to play their true role; and the credit system should be made more flexible. Literacy remains a crucial problem for the increasing rural population.

Land shortage is beginning to be felt. The analysis revealed the following:

1. The farming system is purely extensive and income is determined by size.
2. Farms are relatively underequipped.
3. Soil productivity is low because production factors are underused.

Production systems need to be modified and economic conditions created for profitable intensification.

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Assessment of Prospective Soil-, Water-, and Crop-Management Technologies for the Semi-Arid Tropics of Peninsular India

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Abstract

This paper summarizes the economic analyses of experiments conducted by ICRISAT's Farming Systems Research Program from 1975 to 1978 to develop improved methods of soil, water, and crop management. On the deep Vertisols at ICRISAT Center the broadbed-and-furrow system of soil and water management was highly profitable. This could not be shown for the medium-deep Vertisols. On the Alfisols steps-in-technology experiments, profits from broadbeds and furrows were about 60% less than on Vertisols but were still attractive. However, in the larger scale Alfisols watershed experiments, broadbeds and furrows were less profitable than flat cultivation. The complete technology package of improved variety, fertilization, and soil management on both Vertisols and Alfisols at ICRISAT Center generated maximum profits per hectare with risks that seemed well within the revealed risk-aversion preferences of Indian SAT farmers. On ICRISAT Center Vertisol watersheds, the maizelpigeonpea intercrop system generated substantially higher profits, with less variability, than did the maize-plus-chickpea sequential system, especially on the medium deep Vertisols. The likelihood that a water-harvesting and supplementary irrigation technology will prove viable is much higher on ICRISAT Center Alfisols than Vertisols, due to the greater runoff-generating potential and scope for profitable crop yield responses to irrigation on Alfisols. It is unlikely that this technology will be viable on Sholapur Vertisols. Optimum watershed sizes would seem to be between 8 and 16 ha.

Scientists in the Farming Systems Research Program (FSRP) at ICRISAT have been undertaking research for the past several years that focuses on the development of improved methods of soil, water, and crop management that can help increase and stabilize crop production in the semi-arid tropics (SAT). From the outset, much of the research has been conducted on plots that have generated input-output data suitable for economic analysis. The authors have been working with their colleagues in the FSRP on the analysis of these data in order to identify economic strengths and weaknesses in the evolving technology and thus enhance the process of development of viable technologies.

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This paper attempts to summarize the results of this work over the 3 crop years 1975-76 to 1977-78. In the first section, we discuss the data generated and the experiments on which the ensuing analyses are based. In the second section, we discuss the results from the steps-in-improved-technology (SIIT) experiments conducted on Vertisols and Alfisols at ICRISAT Center at Patancheru near Hyderabad. We then proceed to discuss the larger scale watershed experiments at ICRISAT Center on both soil types. Next we describe simulation exercises performed to evaluate the economic potential for water harvesting and supplementary irrigation in three different agroclimatic situations. We conclude with a summary of the major findings of the work.

Data

The input-output data for the economic

analyses of the steps-in-improved-technology experiments were generated collaboratively by staff of the FSRP and the Economics Program (EP) of ICRISAT. The objective of these experiments, which began in 1975-76, was to measure the individual and complementary effects of the various components of prospective agricultural technology for the SAT. They were designed with plot sizes ranging from 0.07 to0.1 ha. These plot sizes were to enable the soil- and crop-management treatments to express themselves. This is not possible with the much smaller plot sizes generally used in agricultural experiments.

The four basic treatments in the SIIT experiments (Table 1) were (1) variety, (2) fertilization, (3) soil and crop management, and (4) water management. Each of these four basic treatments were examined at two levels in a factorial experimental design. One was aimed at simulating local practice (L) and the other the improved technology (I). The experiments were conducted on both the Alfisols and Vertisols at ICRISAT Center. More detailed explanation of the technical aspects of these experiments can be found in the reports by the Farming Systems staff (various years). Details of the economic analyses, including methodology, inputs, outputs, and price data, can be found in Ryan and Sarin (1977, 1978).

The operational watershed experiments on a field scale at ICRISAT Center aim to test the soil- and water-management aspects of prospective technology on a scale that simulates farm conditions. Small agricultural watersheds ranging in size from 0.3 to 11 ha on the Vertisols, and 0.3 to 5 ha on the Alfisols, have been the conceptual focus of this phase of the research of the FSRP. Input-output data on these large plots were monitored by field supervisors who recorded them daily in field pocket notebooks designed for the purpose. These were checked by staff of FSRPand the EP on a daily basis. Care was taken to ensure that pure "research-related inputs," such as moisture probes and the labor for their installation, were not included for purposes of economic analysis. Crop yields were derived from randomized sample cuts in each watershed treatment as described by the Farming Systems staff (various years).

The major comparisons of economic interest in these watershed experiments were (1) relative performance of the graded broadbed-and-furrow method of cultivation compared with the traditional flat techniques across the slope and/or on the contour; (2) effects of different

Table 1. Description of treatments used in the steps-in-improved-technology experiments (SIIT) at ICRISAT Center.

	Technology steps *treatments*			
Level	Varieties	Fertilizers	Soil and crop management	Water management
Local (L)	Traditional local	Farmyard manure only	Local animal-drawn implements; flat cultivation; delayed land preparation after harvest; one handweeding; minimum insect control	No supplementary irrigation
Improved (I)	High-yielding varieties	Optimum doses of N,P, as appropriate to crop and soil	Improved animal-drawn implements; cultivation on broadbeds and furrows on graded contour;post-harvest land preparation; improved plant protection	Supplementary irrigation applied if crops are stressed, plus added fertilizers if required.

graded slopes of the broadbeds and furrows; (3) effects of different types of bunds — contour, graded contour, field; (4) effects of water harvesting and supplementary irrigation.

Data from the rainfall-runoff experiments conducted since 1973-74 at ICRISAT Center, near Hyderabad, and from 1951-52 at the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) Station, Sholapur, have been used to develop empirical models for prediction of runoff. The descriptions of data and methodology are reported elsewhere (Ryan and Pereira 1978). In the present paper, we utilize historical daily rainfall data from Hyderabad and Sholapur weather stations for 70 and 29 years, respectively, to simulate daily runoff using the models derived.

Steps-in-Improved-Technology Analyses

It is important to measure the contribution of the various elements that constitute what is commonly termed the "package of practices." In this way, those elements that contribute most to the profitability of the new technologies can be identified, as well as their complementarities with other elements. Because of constraints of capital, labor, or other resources, many farmers may not be in a position to immediately adopt the full package of practices that might generate maximum profits per hectare; therefore, delineating the separate contributions of each element can assist in providing "ranges of technological options" from which farmers can choose according to their particular constraints (Ryan and Subramanyam 1975).

In deciding upon the approach taken in analyzing these experiments we have drawn liberally on the excellent paper by Perrin et al. (1976). Because risk is a major factor in the SAT, we have combined the SIIT results over 2 years in the case of the Vertisol experiments and 3 years for the Alfisols in order to enable a first approximation of the variability (risk) of profits of each treatment to be made, in addition to average profitability. The basic results of this exercise are shown in the appendices to the unabridged paper presented at the workshop.

Vertisols

On the basis of both profits per hectare and profits per rupee of variable cost, treatment in the Vertisols involving improved varieties, fertilizers, soil and crop management, along with supplementary irrigation (IIII), was the most profitable over the 2 years 1976-77 and 1977-78. The average net benefit per hectare was in excess of Rs 3600 and every rupee spent returned Rs 1.89 in *net* benefit, a rate of return of 189% (Fig. 1). The next best treatment was the same as the first except that it was without supplementary irrigation (III). The extra variable cost of irrigation was around Rs 300/ha plus about Rs 50 in added fertilizer, which together generated an additional Rs 740 in net benefits, or Rs 2.13 per rupee of expenditure. However, not all the irrigation treatments involved the use of water from runoff storage on the same catchment; in some case it was pumped from wells and in others from nearby drains. The cost of obtaining water from these sources has not been included, so it is not an appropriate evaluation of the payoffs from water harvesting and supplementary irrigation.

It is evident from Figure 1 that expenditure of amounts beyond about Rs 1500/ha is extremely profitable. For example, shifting from LII (local varieties, improved fertilizers and improved soil and crop management) to III (improved varieties, improved fertilizers and improved soil and crop management) involving only an additional Rs 100 can generate an additional Rs 1700 in net benefits. Figure 2 shows that such a shift may not only increase profits but also reduce risk, as measured here by the standard deviation of net benefits per ha over the 2 years analyzed. In this figure are shown the three steps that dominate all the rest, in that there are no steps more profitable and less risky than these.[1] Hence one would choose only among LLI, III, and IIII when generating farmer recommendations. The change from local to improved varieties under local fertilizer and local soil and crop management (LLL to ILL) increases net benefits from around Rs 70 to nearly Rs 900 with only a few rupees additional cost.

In general, Figure 2 shows that for these Vertisols during these two years, additional profits were earned at the expense of additional risk, as measured by standard deviation. However, Figure 3 shows that if we take the

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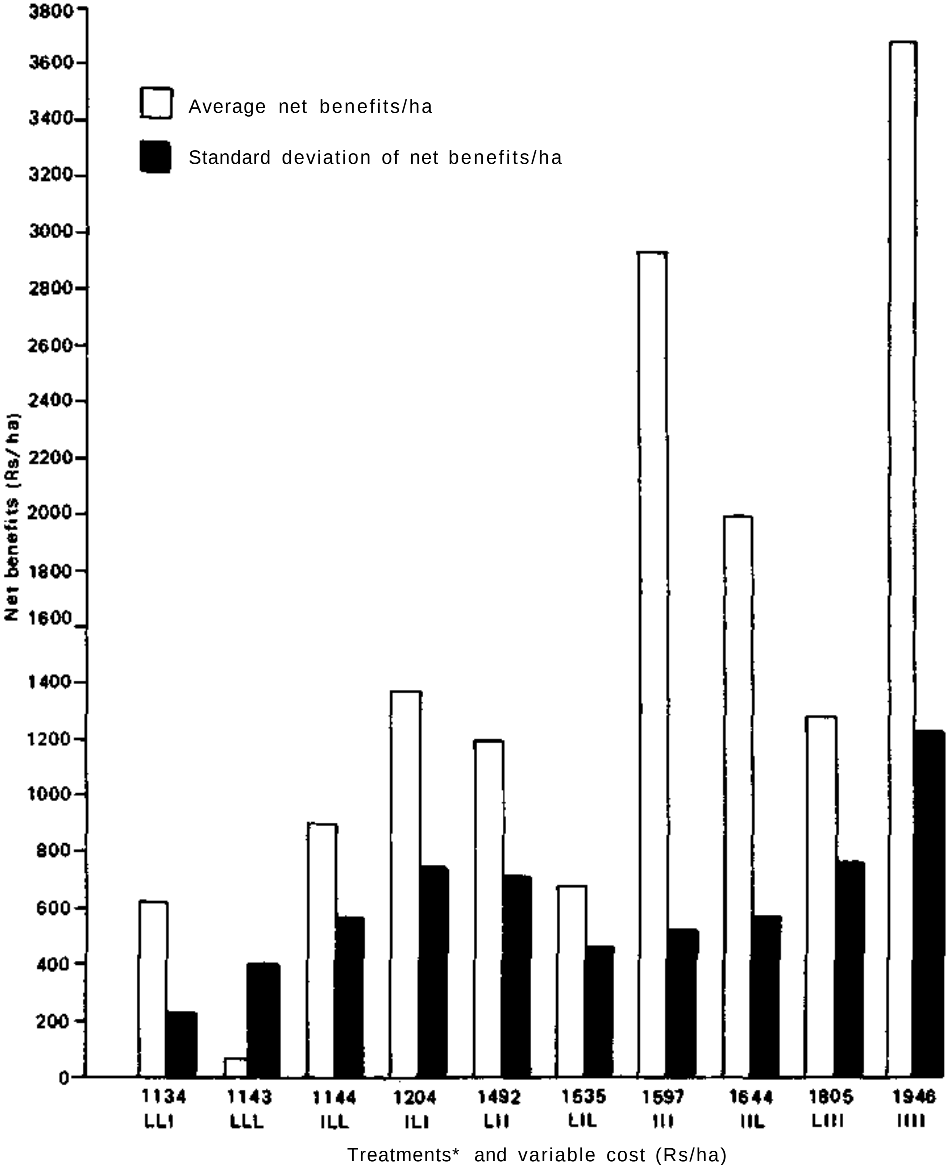

(*Refer to Table 1 for details of treatments)

Figure 1. Average net benefits and variable costs per ha in steps-in-improved-technology experiments on Vertisols at ICRISAT Center, 1976-77 and 1977-78.

coefficient of variation (CV) of net benefits as our risk criterion, and map it against cost requirements of each treatment, then only steps III and LLI are cost/risk efficient. By investing the Rs 1130 and Rs 1600/ha required to implement these steps, we can achieve the lowest CVs of 37 and 20%, respectively. No other steps can offer lower CVs without increasing the cost. it is interesting to note in both Figures 2 and 3 that the supplementary irrigation treatments always involve more risk than the nonirrigated treatments.

The additional net benefits from the improved soil- and crop-management treatments implemented under either local varieties and fertilizers, local varieties and improved fertilizers, or improved varieties and local fertilizers is around Rs 500/ha (Fig. 1). The estimated capital

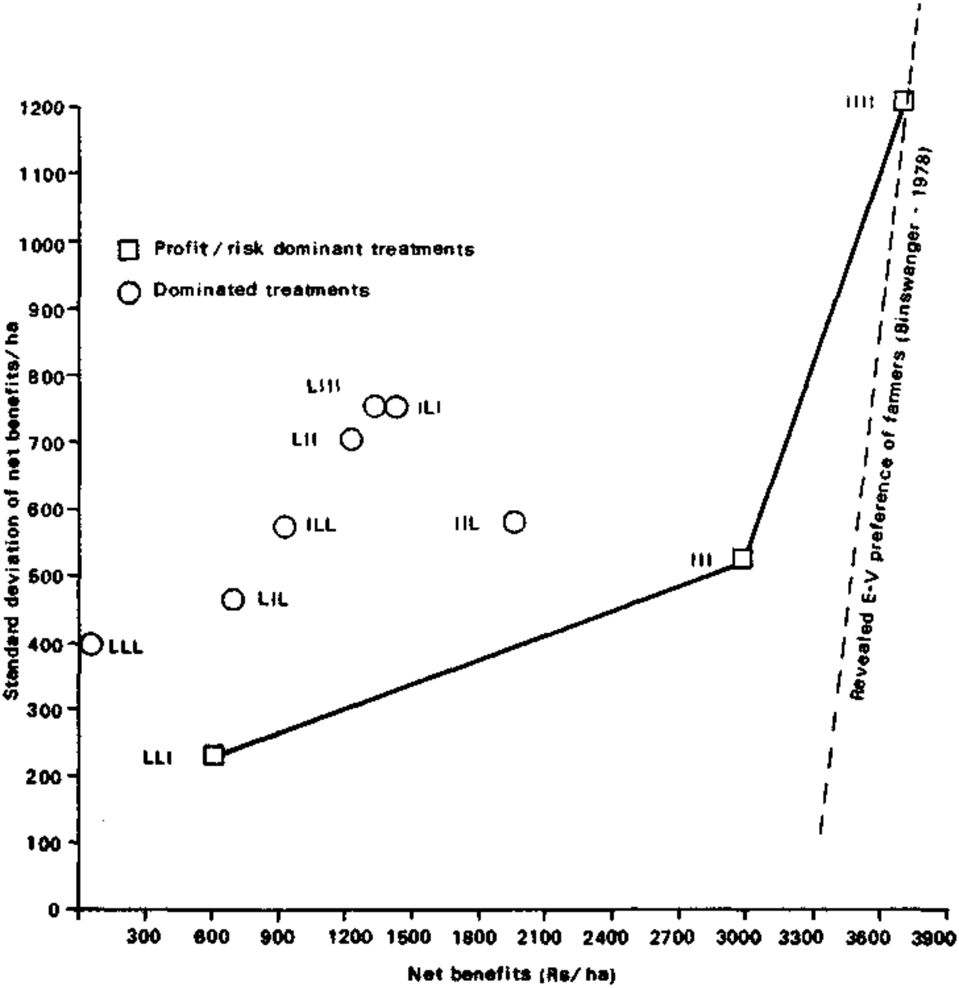

Figure 2. Net benefitlrisk profile of steps-in-improved technology on Vertisols at ICRISAT Center, 1976-77 and 1977-78.

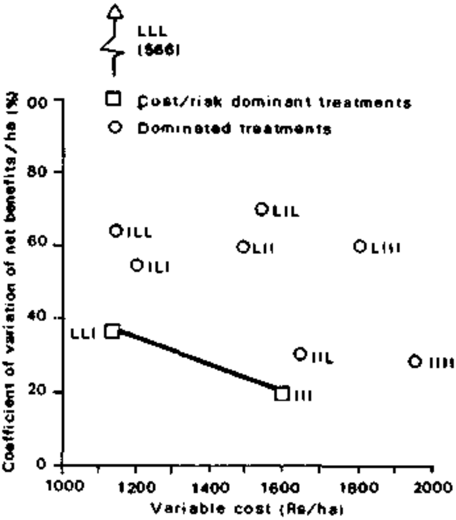

Figure 3. Variable cost/coefficient of variation of net benefit profile of steps-in-improved technology on Vertisols at ICRISAT Center, 1976-77 and 1977-78.

cost of the bullock-drawn wheeled tool carrier used in the improved broadbed-and-furrow system, which is a major component of this step, is around Rs 6500.[2] If this implement were only used for cultivation activities on 13 ha per year, it could more than pay for itself in 1 year under these conditions.[3] Under improved varieties and fertilizer levels, the improved soil- and crop-management steps can increase net benefits per hectare by more than Rs 1000, allowing the wheeled tool carrier to be paid for in 1 year from its operation on only 7 ha.

The additional net benefits from the change from local to improved fertilizer levels under local varieties, with either improved or local soil and crop management, amounted to around Rs 600/ha, from an added expenditure of nearly Rs 400/ha. In both cases, however, this involved an increase in the standard deviation of net benefits. When improved fertilizers were substituted for local fertilizers with improved varieties and local soil and crop management, the added net benefits were nearly Rs 1000/ha from an additional expenditure of Rs 500, with no change in standard deviation. When this change was effected on improved varieties with improved soil and crop management, the added net benefits were more than Rs 1500/ha from an extra expenditure of Rs 400, representing a phenomenal 375% rate of return. This additional return also comes with a smaller standard deviation than the local fertilizer step.

Alfisols

The treatment involving improved varieties, fertilizers, and soil and crop management without supplementary irrigation (III) generated the highest average net benefits on the Alfisol SIIT experiments conducted over the 3 years 1975-76 to 1977-78 (Fig. 4). Contrary to what we will show later for the watersheds, supplementary irrigation on the Alfisols SIIT experiments was not profitable.[4] It also increased risk, as reflected in the standard deviation of net benefits.

The differences in the steps involving local varieties and those with improved varieties, holding other steps constant, were not nearly as great as found in the Vertisol SIIT experiments. However, with one exception, those treatments involving improved varieties were better than their local variety counterparts. On an average over all the treatments, the Vertisols gave about 60% higher net benefits per hectare than the Alfisols and a standard deviation that was 20% less.[5]

2. Personal communication G. E. Thierstein, Principal Agricultural Engineer, ICRISAT. Prorated overhead costs of this implement have been included in our cost estimates.
3. Of course, it is also designed for other activities such as carting, which would further enhance its value.
4. This is largely because low-priced and low-yielding sorghum was the crop in the SIIT experiments, whereas in the Alfisol watersheds tomatoes, maize, sorghum, millet, and other crops have been profitably irrigated. High-valued tomato has been one of the most responsive crops in the watersheds and illustrates the importance of crop choice in determining the value of supplemental irrigation.
5. As the Alfisol SIIT data relate to 3 years whereas the Vertisols only relate to 2, we should not infer too much from this.

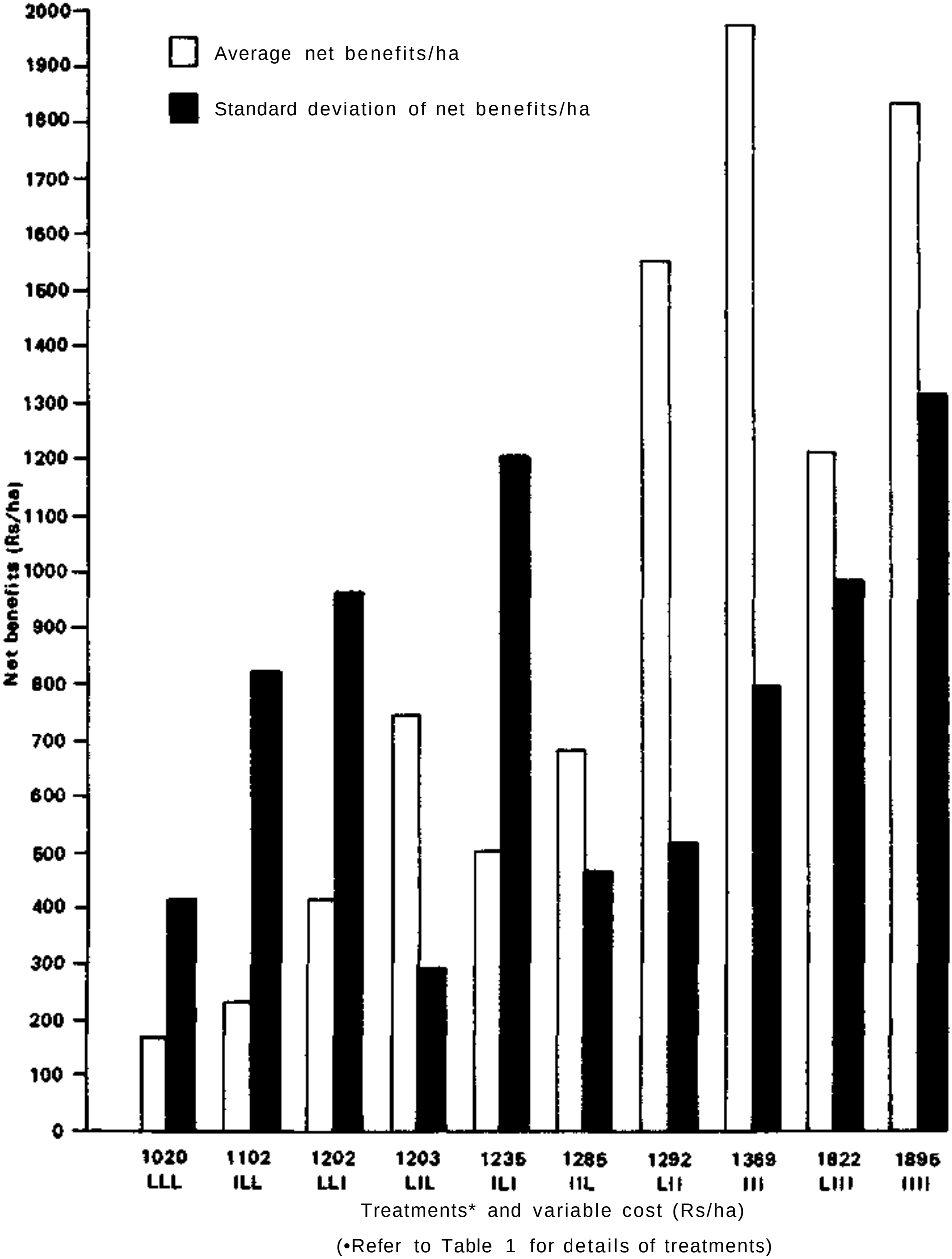

Figure 4. Average net benefits and variable costs per ha in steps-in-improved-technology experiments on Alfisols at ICRISAT Center, 1976-77 to 1977-78.

Figure 5 shows that the profit/risk dominant treatments are III, LlI and LIL on Alfisols in these 3 years, when standard deviation of profits is used as the measure of risk. No other treatments can give more net benefits with less risk. The line joining these three points in the figure represents the E-V efficiency frontier from among which a choice of recommendations can be made to farmers, depending upon their relative preferences for profits vis-a-vis risk. Added profits can only be earned by incurring more risk at the frontier, as was the case on the Vertisols.

The general slope of the E-V curves between the extremeties in Figures 5 and 2 is about the same at around 0.4.[6] Hence it seems the profit/risk tradeoffs on these two soil types may be similar. The steepest segment in Figure 5 between LlI and III has a slope (cotangent) of about 0.75. In Figure 2 the the steepest slope is about

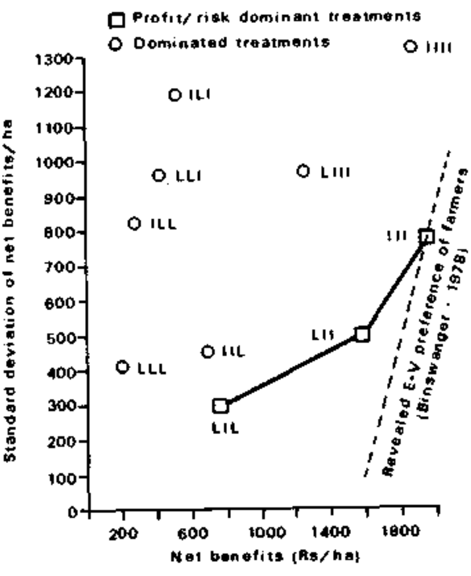

Figure 5. Net benefit risk profile of steps-in-improved technology on Alfisols at ICRISAT Center, 1975-76 to 1977-78.

6. We have measured this as $\Delta\bar{\pi}/\Delta\sigma$, where $\bar{\pi}$ is net benefit and σ its standard deviation.

0.9 between III and IIII. Binswanger(1978), in his innovative study of risk attitudes of farmers in six SAT villages of Maharashtra and Andhra Pradesh, found that the vast majority of them had moderate to intermediate levels of risk aversion. This implied a slope of their E-V indifference curves of between 2 and 3. It seems then that the profit/risk efficient technologies identified in these SIIT experiments may involve added risks per unit of added profits that are well within the risk aversion preferences of the bulk of SAT farmers. This means that from both a risk and profit point of view it is reasonable to recommend the III technology in the case of the Alfisols, and the IIII technology in the case of Vertisols.[7]

Figure 6 shows that the cost/risk efficient points using the CV of net benefits as the risk criterion, are LIL and LlI, III is marginally less efficient than LlI. For farmers unable to gain access to the Rs 1400/ha required for III, the analysis shows that both LIL and LlI would be attractive alternatives, the latter probably more so than the former.

When the improved soil- and crop-management step was implemented on these Alfisols under local fertilizers with either local or improved varieties, the added net benefits were less than Rs 300/ha from an extra expenditure of around Rs 150/ha. When the same step was implemented under an improved fertilizer and local variety regime, it resulted in an added net benefit in excess of Rs 800/ha from an expenditure less than Rs 100. The largest increment of all came from the improved soil- and crop-management step introduced on improved varieties grown with improved fertilizers. Net benefits per hectare increased more than Rs 1200 from the expenditure of less than Rs 100. These latter two steps, however, both came at the expense of additional variability in net benefits.

The effect on net benefits of adding improved fertilizers on the Alfisols when local varieties and local soil and crop management were employed was about the same as for the Vertisols, around Rs 600/ha. The effect of adding fertilizers when local varieties were grown, but with improved soil and crop management, was much higher on the Alfisols than the

7. The caution noted earlier about the underestimation of the costs of irrigation in the case of IIII in the Vertisols must be repeated here.

Vertisols — around Rs 1100 compared with Rs 600. The reverse was true of adding fertilizers under a situation of improved varieties but with local soil and crop management. On the Alfisols, this step earned just over Rs 400 additional net benefits per hectare whereas on Vertisols the figure was about Rs 1000. Adding fertilizers to improved varieties grown under improved soil and crop management generated about the same added net benefits of near Rs 1500/ha on both Alfisols and Vertisols.

It was significant that on the Alfisols the improved fertilizer step always reduced the variability of net returns at the same time it increased the average net returns. This was true regardless of the other four treatments on which it was introduced on Alfisols. This was only true for *one* of the four cases on the

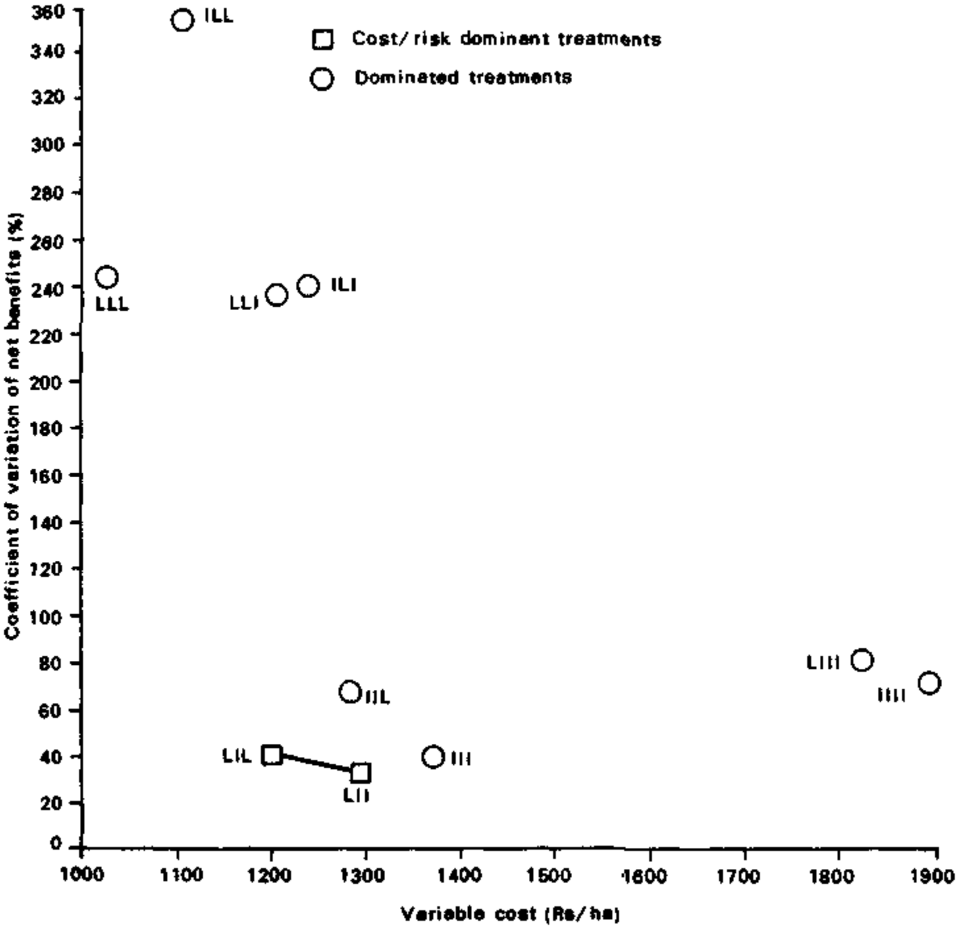

***Figure 6.** Variable cost/coefficient of variation of net benefit profile of steps-in-improved technology on Alfisols at ICRISAT Center, 1975-76 to 1977-78.*

Vertisols: the application of fertilizers under improved varieties and soil and crop management.

Watershed Experiments

The Vertisol watersheds on which maize was intercropped with pigeonpea in 1976-77 and 1977-78 were, on the average, 73% more profitable than the maize plus sequential chickpea cropping pattern (Table 2). The intercrop system also was 34% more stable than the sequential crop system. The intercrop profit advantage over the sequential was much greater on the medium-deep Vertisol watersheds than on the deep Vertisols (151% better vs 52%). However, the reduction in variability from the intercrop system compared with the sequential on the deep Vertisols (39%) was greater than the reduction on the medium-deep Vertisols (29%).[8] These results would support the generally accepted view that intercropping offers advantages over sequential (sole) cropping, not only in terms of profitability but also in terms of risk.

8. It is realized that we have combined both time and cross-sectional variabilities here in order to obtain an assessment of relative riskiness without the appropriate separation of variance components. With such a limited data set this seems the best approximation we can make at this stage.

The deep Vertisols seem much more profitable than the medium-deep Vertisols but are equally unstable. This is particularly true in the case of the maize plus sequential chickpea cropping system where the profits per hectare were more than 120% higher on the deep Vertisols. With the intercrop system, the superiority of the deep Vertisols was only 40%.

It seems from the experience of these 2 years that on the deep Vertisols the broadbed-and-furrow soil- and crop-management system is about 20%/ha more profitable under an intercrop situation than the flat method of cultivation implemented with the same HYVs and fertilizer levels.[9] It seems about one-third more variable than the flat system (Table 3). With sequential cropping the broadbed-and-furrow system was only 10% more profitable than the flat system but was 17% less variable.

9. The difference between the broadbed and furrow and the flat system of cultivation relate to the soil management, where the former has broadbeds with furrows formed 150 cms apart, compared with no beds in the case of the flat system (fertilizers and varieties are kept the same in both). Analyses of variance of pooled gross returns from the cropping treatments, using replication variability as the measure of error, showed that on deep Vertisols beds and furrows had a highly significant superiority over the flat method. On medium-deep Vertisols there was no significant difference (B. A. Krantz, personal communication).

Table 2. Comparison of profitability and variability of two cropping systems on Vertisol watersheds at ICRISAT Center. 1976-77 and 1977-78.

	Maize plus sequential chickpea		Maize/pigeonpea intercrop	
Watersheds	Weighted average gross profits per NCH[a] (Rs/ha)	Standard deviation of gross profits per NCH[b] (Rs/ha)	Weighted average gross profits per NCH (Rs/ha)	Standard deviation of gross profits per NCH (Rs/ha)
Deep Vertisols	2167	1510	3302	921
Medium-deep Vertisols	948	1310	2383	927
All Vertisols	1712	1499	2958	984

a. NCH = net cropped hectare. Gross profits are defined as the total gross revenue from sale of grain and fodder less the costs of seed, fertilizer, pesticides, insecticides, human labor (charged at ICRISAT wage rates of Rs 4.5 per day), bullock labor at actual cost, and pro-rated overhead costs of animal-drawn implements. For these crop comparisons no account is taken of land lost due to defferentials in areas of bunds, waterways etc.

b. Standard deviations are calculated from unweighted per ha gross profits for each of the 2 years taken separately across all watersheds In the comparison. There are 12 observations on the deep Vertisols and 10 on the medium-deep Vertisols.

On the medium-deep Vertlsol watersheds (Table 3) the broadbed-and-furrow soil- and crop-management system was slightly inferior to the flat-cultivation soil- and crop-management system. This was true for both the intercrop and the sequential crop system; there was not much difference in the variability of the two. It thus seems the improved broadbed-and-furrow technology does best only on the deep Verstisols. On the basis of these comparisons of net profit it cannot be recommended for the medium-deep and shallow Vertisols. If there are sufficient advantages from reduction of soil erosion under the broadbed-and-furrow system this, of course, could compensate for its lower profitability in these soils. However, the evidence for reduced soil erosion under the system is mixed.

The broadbed-and-furrow system implemented on a 0.4% graded contour on the deep Vertisois generated 20% higher profits than those watersheds where the system was implemented on a 0.6% grade (Fig. 7).[10] Those additional profits came at the expense of added variability, particularly in the intercrop system.

The deep Vertisol watershed on which the broadbed system was implemented within the existing field border bunds was slightly more profitable than when implemented with graded bunds (Fig. 8). The same was true under the flat system of cultivation. To the extent this is true generally, it suggests that achievement of the potential benefits of the broadbed-and-furrow technology may not require that traditional field border bunds be removed and graded bunds put in their place. It seems that the broadbeds can perform equally well within the farmers' own field borders. This may mean that it may not be necessary to convince contiguous groups of farmers on a watershed to agree to ignore their traditional land boundaries in order to effectively implement this essential ingre-

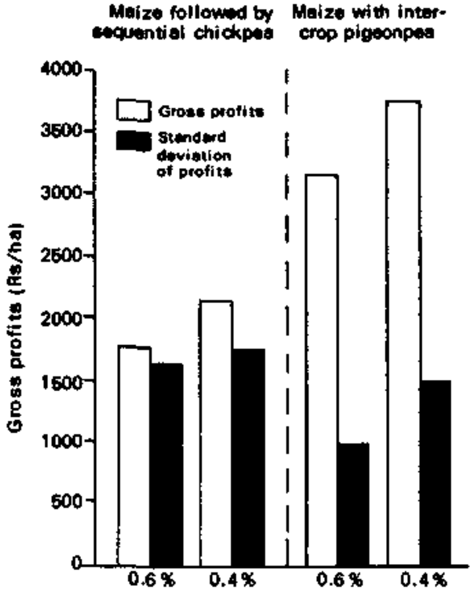

Figure 7. Comparison of profitability ( ) and variability ( ) of two graded slopes (0.6% and 0.4%) of broadbed-and-furrow soil and crop management systems under two cropping systems on deep Vertisols at ICRISAT Center, 1976-77 and 1977-78.

client of the prospective SAT technology. However, more research on this issue is required before a firm conclusion can be reached. It is hoped that the watershed research currently under way in ICRISAT's Village-Level Studies Phase II in Maharashtra and Andhra Pradesh will throw more light on this question.

Less research has been conducted on the Alfisol watersheds at ICRISAT in the past than on the Vertisols; 1977-78 was the first year in which we have been able to undertake some comparisons of the broadbed-and-furrow systems with the flat-cultivation system.

In 1977-78, the flat-cultivation watersheds earned on the average almost Rs 2100 (in gross profits) per ha compared to Rs 1900 in the water sheds with broadbeds and furrows. The crop grown was sorghum followed by sequential safflower, with adequate fertilizers in both cases.

10. As is true of all the comparisons discussed in this section, one cannot attribute all of the differences observed between the various watersheds constituting a given system to the system per se. This is because other things also differ between the systems, such as soil depth, drainage, etc., which may confound the comparisons. The FSRP is currently developing plans for replicated experiments to make more critical and reliable evaluations of these treatments.

Table 3. Comparison of profitability and variability of two cropping systems under two soil- and crop-management systems on Vertisol watersheds at ICRISAT Center, 1976-77 and 1977-78.[a]

Soil- and crop-management sytem	Cropping system			
	Maize plus sequential chickpea		Maize/pigeonpea intercrop	
	Net benefits per ha[b]		Net benefits per ha[b]	
	Weighted average (Rs/ha)	Standard deviation (Rs/ha)	Weighted average (Rs/ha)	Standard deviation (Rs/ha)
Deep Vertisols				
Broadbeds and furrows	2204	1484	3395	983
Flat cultivation	2038	1790	2770	729
Medium-deep Vertisols				
Broadbeds and furrows	887	1451	2316	952
Rat cultivation	1077	1303	2522	1027

a. Calculations are on a net cropped hectare basis.
b. Nat benefits are calculated by subtracting overhead land development costs from gross profits.

In the case of the pearl millet/pigeonpea intercrop system, followed by tomatoes and safflower in the postrainy season (because pigeonpea failed due to caterpillar attack), the gross profits were about the same for the broadbed-and-furrow and the flat-cultivation systems, at around Rs 1000 per ha.

A key element in the prospective technology for the SAT is the concept of water harvesting and supplementary irrigation in order to increase and stabilize crop production (reports of the Farming Systems staff, various years). Several of the watersheds at ICRISAT Center have tanks (water storage reservoirs) built on them to collect excess runoff from the rainfall for use in supplementary irrigation. We now have 3 years' data available on the performance of this component, from 1974-75 to 1976-77 (Table 4). The analysis shows that the response to supplementary irrigation in these 3 years has been more profitable on the Alfisol than on the Vertisol watersheds. Additional net benefits of almost Rs 400/ha have been achieved on the former while losses of around Rs 150/ha have occurred on the latter. The returns have been most spectacular on the tomatoes grown on the Alfisols, where with two irrigations the added profits exceeded Rs 4800/ha. Irrigated rainy season maize and sorghum on Alfisols were the next most profitable.

Profitable responses to supplementary irrigation on the Alfisol watersheds have occurred about 50% of the time, whereas on the Vertisols this has been true 30% of the time over these 3 years. These data suggest that the potential for water harvesting and supplementary irrigation technology may be higher on the Alfisols than on the Vertisols. This is also supported by the work of von Oppen and Binswanger (1977), who find that traditional paddy irrigation tanks in India are more densely concentrated where granitic substrata exist. These substrata are mostly restricted to the Alfisol regions of peninsular India. In another unpublished study, von Oppen shows that these traditional tanks are also more profitable on the Alfisols than on the Vertisols.

To adequately measure the long-run potential for a water-harvesting and supplementary irrigation technology aimed at supporting upland crops — as opposed to the traditional tank systems used for irrigation of lowland paddy — it is necessary to assess the probabilities of being able to have sufficient excess runoff stored and available in small tanks on the uplands at the time when crops can profitably

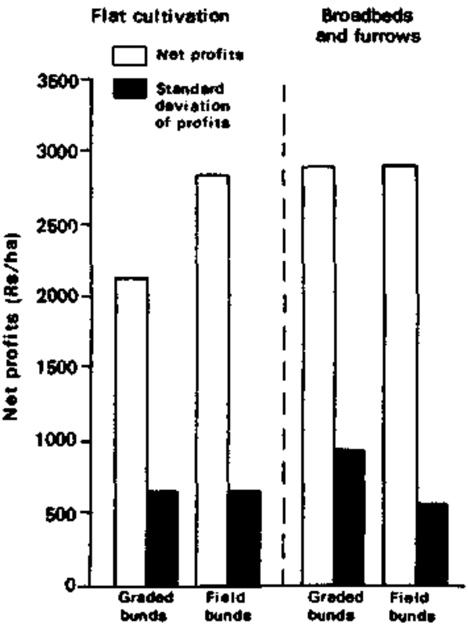

Figure 8. Comparison of profitability (π) and variability (σ_π) of two types of bunding under two soil and crop management systems on deep Vertisols with maize|pigeonpea intercrop at ICRISAT Center, 1976-77 and 1977-78.

respond to irrigation. The work that has been under way at ICRISAT on this is discussed in the next section.

Evaluation of Water Harvesting and Supplementary Irrigation Using Simulation

The extensive rainfall-runoff data available at ICRISAT Center and the AICRPDA Station at Sholapur have been used by Ryan and Pereira (1978) to derive empirical models for the prediction of runoff in these two areas. As the details of the data, methodology, and selected models are provided in that paper, we will not attempt to duplicate them here. The range of variables employed in the regression equations selected to predict runoff by Ryan and Pereira were:

(1) Daily runoff = f (daily rainfall, vegetative cover, area of watershed|plot, ridge and furrow dummies, flat cultivation dummy, types of bunding dummies, antecedent rainfall, vegetative cover index, rainfall intensity, soil type, soil depth, age of watershed).

The derived empirical prediction equations have been incorporated into simulation models that use historical daily rainfall distributions and generate daily runoff estimates for specified levels of the deterministic variables such as soil type, area of catchment, size of tank, type of cultivation and vegetative cover. Evaporation losses from the tank surface are determined by using monthly open-pan averages converted to a daily basis, with separate values for rainy and nonrainy days. The tank design has been assumed to be basically cylindrical in order to calculate surface evaporation losses in storage. For these studies, a tank of 20 ha/cm has been assumed and catchment sizes of 3, 8, 12; 16, and 20 ha simulated, using 70 years of daily rainfall data from the Hyderabad weather station since 1901 and 29 years from the Sholapur station since 1945.

We have chosen to present the results of the simulations for week 43; that is, the end of October. This is because, particularly for the Vertisols with their better moisture-holding capacities, it is possible that most of the payoff from water harvesting may derive from increasing the chances and yields of sequential postrainy season crops. We are in the process of constructing a model that will enable evaluation of the relative benefits of utilizing the harvested runoff water on rainy season crop versus saving it for postrainy season crop irrigation. However, as it is not yet completed, we thought it useful to restrict ourselves for the present to the postrainy season option.

Table 5 shows that under cropped conditions on the broadbed-and-furrow system at ICRISAT Center, the Alfisols have about double the runoff potential of the Vertisols. Under cropped flat conditions the Alfisols have only about 25% more potential. The Hyderabad Alfisols have almost three times the runoff potential of the Sholapur Vertisols under a cropped ridge-and-

Table 4. Additional net benefits from supplementary irrigation from runoff storage tanks at ICRISAT Center, 1974-75 to 1976-77.

Crops irrigated	Weighted average *additional* net benefits from irrigation[a] (Rs/ha)	
	Vertisols[b]	Alfisols
Rainy-season maize	-447	2781
Rainy-season sorghum	50	2455
Postrainy-season sorghum	50	117
Ratoon sorghum		-76
Tomatoes (ridges and furrows)		
- one irrigation		3053
- two irrigation		4861
Tomatoes (flat)		
- one irrigation		1240
- two irrigation		2375
Pearl millet		1054
Safflower		-294
sunflower	-725	70
Chikpea	80	< 0
Setaria		< 0
Overall average net benefit/ha	- 154	380[d]
Overall standard deviation of net benefitlha	660	1180[d]

a. Weighted by the area irrigated.
b. About 85% of the Vertisols were deep where the irrigation was applied; the others were medium deep.
c. Comparisons are on the basis of increased yields over and above zero irrigation.
d. Using single irrigation for tomatoes only.

furrow system. Under a flat-cropped system, they can generate about 50% more runoff than the Sholapur Vertisols.

The simulations clearly show that the coefficients of variation of net cumulative runoff at the end of October are inversely related to the mean levels of cumulative runoff at that time. This is true whether stored runoff changes due to changes in vegetative cover or catchment size. This suggests that in situations such as the Sholapur Vertisols, which have limited potential for runoff, there will be a much greater variability in the availability of runoff for irrigation — and hence more risk to the use of this system—than in situations where runoff potential is high, such as on the Hyderabad Alfisols. The CVs reach as high as 130% in the Sholapur Vertisols on a 3 ha catchment with cropped ridges and furrows, whereas on a similarly treated and sized Hyderabad Alfisol catchment the CV can be as low as 28%.

The effect of increased catchment size on runoff generation is not proportional, due to the negative signs on the area variables in the prediction equations (Ryan and Pereira 1977, pp 17, 22, 27).[11] For example, increasing the catchment sizes from 3 to 8 ha (170%) increased net cumulative runoff by around 70% on the Hyderabad and Sholapur Vertisols and by only 40% on Hyderabad Alfisols under cropped

11. The Sholapur runoff plots used to derive the equations were extremely small (0.002 to 0.007 ha) compared with the small watersheds used at Hyderabad (0.33 to 11 ha). Hence, to adjust the Sholapur equations to enable prediction for catchments up to 20 ha, the maximum plot size for Sholapur was Inserted into that equation and the coefficient on area from the Hyderabad Vertisol equation was also incorporated.

ridges and furrows (Table 5). In addition, evaporation losses increase with larger catchments as they more often have runoff in storage tanks than do smaller catchments.

The amounts of excess runoff which the 20 ha/cm storage tank could not capture are positively related to the mean net cumulative runoff totals at the end of October. Hence, the more runoff that is harvested on average, the more one could harvest if the runoff was profitable to use. This is where we now turn in our analysis.

What is the value of the stored runoff at the end of October? To determine this, we have adopted the approach of calculating the break-even crop yield increments required to recoup the costs of construction and operation of the tank, pump and pipes required for the water harvesting and supplementary irrigation system.

The basic equation for calculating the break-even yield assuming all costs will be borne by a single group of watershed farmers was derived as:

(2) $\bar{Y}_j = (88 + 10470/\bar{R})/P_j$

where $\bar{Y}_j$ = weighted average break-even yield over i years (i = 1, 2, 3 (N

P_j = price of crop j (net of harvesting, threshing and marketing costs)

$\bar{R}$ = averagenet cumulative runoff at week 43 over i years

If we assume that one pump and a set of pipes can be successfully shared by farmers from three catchments instead of the one assumed in equation (1) we obtain:

(2a) $Y_j = (88 + 7500/\bar{R})/P_j$

Both (2) and (2a) generate estimates of the average break-even yields which must be achieved in every one of i years. However, there will undoubtedly be years when R_i will be zero. Thus a more useful measure of the economic viability of the technology is obtained by deriving the break-even yields in years when only non-zero runoff is available at week 43. This is calculated as:

(3) $$\bar{Y}_j = \frac{N}{P_j\,(N-Q)}\,(88 + 10470/R)$$

in the case of (2) and:

(3a) $$Y_j = \frac{N}{P_j(N - Q)}\,(88 + 7500/R)$$

in the case of (2a), where

Q = number of years when R_i = 0

We have derived these break-even yield estimates for three agroclimatic situations with a range of catchment sizes, vegetative covers, and types of cultivation (Tables 6, 7, 8). All have been calculated assuming a crop priced at Rs 90 per 100 kg and use of irrigation. They show that the economic potential for water harvesting and supplementary irrigation in the postrainy season is best on Alfisols at ICRISAT Center, followed by Vertisols at the same location, and then on Vertisols at Sholapur. The superiority of the Hyderabad Vertisols and Alfisols over the Sholapur Vertisols increases as we move from a flat cultivation to a ridge-and-furrow system. For example, the break-even yields required in non-zero runoff years on Vertisols at Hyderabad under a flat-cropped situation are 28 to 66% less than on Sholapur Vertisols, depending on catchment size, whereas under a ridge-and-furrow cropped system, they are 50 to 63%. For Alfisols at Hyderabad, the comparable figures are 43 to 60% and 77 to 80%, respectively.

It would seem that, unless there are good reasons for believing that crop responses to the same amounts of irrigation are going to be vastly superior in the Sholapur Vertisols, it will be more profitable to concentrate on situations such as one has on the Hyderabad Alfisols and Vertisols than on Sholapur Vertisols. Whether water-harvesting and supplementary irrigation technology is going to be profitable depends on the ability of crops to generate yield increments in excess of the break-even figures derived in Tables 6, 7, and 8.

The likelihood that water-harvesting and supplementary irrigation technology based on postrainy season crop irrigation is going to be economically feasible if implemented on Hyderabad Vertisols under a cropped ridge-and-furrow regime is doubtful according to our analysis. Under the optimistic assumption that the costs of a pump and pipes can be shared by three groups of watershed farmers, yields of SAT cereal foodgrain crops such as sorghum and maize would have to increase by more than 1800 kg/ha in the years when runoff is available (77% of the time) on a catchment size of 3 ha (Table 6). Yield increases on a 16-ha catchment would have to exceed 800 kg/ha in the 97% of years when runoff would be available at the end of October for supplementary irrigation. If it proves infeasible to share the pump and pipes with any but a single group of watershed

Table 5. Cumulative runoff net of evaporation losses in a 20 ha-cm storage tank at end of October using derived empirical rainfall-runoff models in simulation exercises.

	3-ha catchment			8-ha catchment		
Soil, location, crop and land management	Mean net cumulative runoff Oct 31[a] (ha-cm)	CV of net cumulative runoff Oct 31 (%)	Mean excess runoff to Dec 31 (ha-cm)	Mean net cumulative runoff Oct 31 (ha-cm)	CV of net cumulative runoff Oct 31 (%	Mean excess runoff to Dec 31 (ha-cm)
Vertisols Hyderabad						
Fallow; flat cultivation	11.2	62	7.5	16.4	29	34.4
Cropped[b]; flat cultivation	10.4	68	6.7	15.8	34	30.5
Fallow; 0.4% ridges and furrows	7.2	102	4.1	11.3	66	20.6
Cropped; 0.4% ridges and furrows	6.5	111	3.6	10.7	70	18.7
Vertisols Sholapur						
Fallow; flat cultivation	9.9	72	3.1	13.6	53	19.2
Cropped; flat cultivation	8.4	89	2.6	11.9	67	16.0
Fallow; ridges and furrows	5.8	120	0.3	8.7	99	6.9
Cropped; ridges and furrows	4.8	130	0.1	8.1	106	5.1
Alfisols Hyderabad[c]						
Cropped; flat cultivation	12.8	45	5.2	18.4	13	34.3
Cropped; 0.4% ridges and furrows	12.7	48	5.1	18.0	19	36.2
Cropped; 0.6% ridges and furrows	16.6	28	17.3	18.5	13	80.0

a. Net of evaporation losses in storage but assuming seepage losses of zero.
b. The crop was assumed to be of 100-day duration and sown early June.
c. Virtually all experimental plots were cropped in the monsoon so there is no prediction for Alfisol fallows.

Table 6. Break-wen crop yields required to cover coats of water harvesting and supplementary irrigation system on Vertisols at ICRISAT Center.[a]

			Additional break-even yield required in N years[b] on		% of years with zero runoff at end Oct (100Q/N) (%)	Additional break-even yield required in (N-Q) years[b] on	
Catchment size (ha)	Type of vegetative cover	Type of cultivation	1 Watershed $(\bar{Y}_i)$ (kg/ha)	3 Watersheds $(\bar{Y}'_j)$ (kg/ha)		1 Watershed $(\bar{Y}_i)$ (kg/ha)	3 Watersheds $(\bar{Y}'_j)$ (kg/ha)
3	Fallow	Flat	1140	850	4	1190	880
8			810	610	4	850	630
12			760	570	0	760	570
16			770	580	0	770	580
20			770	580	0	770	580
3	Cropped	Flat	1220	1000	6	1290	950
8			830	620	0	830	620
12			790	590	0	790	590
16			780	590	0	780	590
20			790	590	0	790	590
3	Fallow	Ridges and	1710	1260	26	2310	1690
8		furrows	1130	840	6	1200	890
12		0.4%	1000	740	9	1090	810
16		grade	970	720	3	1000	740
20			960	710	3	990	740
3	Cropped	Ridges and	1880	1380	23	2440	1790
8		furrows	1180	880	6	1260	930
12		0.4%	1040	770	6	1110	820
16		grade	1020	760	3	1050	780
20			1040	770	9	1140	850

a. A crop valued at a P_j Rs 90 per 100 kg is assumed here such as sorghum, maize or pearl millet. If a crop valued at Rs 240 is assumed, such as pigeonpeas or chickpeas, then all the break-even yields here would decrease by about two-thirds.

b. N = total number of years used in the simulation; Q = number of the N years when net cumulative run off at week 43 is zero.

farmers, the break-even yields on a 3-ha catchment would increase to *more* than 2400 kg/ha and those on a 16-ha catchment to almost 1100 kg/ha. These break-even figures do not decrease greatly even if a fallow is maintained instead of a crop.

For the Sholapur Vertisol situation, it would not seem that water harvesting and supplementary irrigation based on postrainy season crop irrigation could be profitable, except perhaps under a flat fallow system. On a 3-ha cropped ridge and-furrow watershed, yield increments in excess of 3600 kg/ha would be required to pay the costs of the technology, assuming three groups are sharing pump and pipe costs (Table 7). On a similar 16-ha catchment more than 2200 kg/ha would still be required. On a flat fallow catchment of 3 ha, the comparable break-even yields are about 1200 and 900 kg/ha, respectively.

Achievement of any of the above yield increments may be quite difficult in the Vertisols, which have a much higher moisture-holding capacity than the Alfisols. In years of good rainfall (and hence runoff) soil moisture profiles will be relatively full and crop response to irrigation may be small. Also, even though the probabilities of a further "wet" week after week 43 in Hyderabad are less than 32% and in Sholapur less than 43% (Virmani et al. 1978; p 12), there will be some occasions when rain falls after the application of irrigation, thus negating the ef-

Table 7. Break-even crop yields required to cover coats of water harvesting and supplementary irrigation system with pump and pipes shared between farmers on Vertisols at AICRPDA station, Sholapur.[a]

Catchment size (ha)	Type of vegetative cover	Type of cultivation	Additional break-even yield required in N years[b] on: 1 watershed $(\bar{Y}_i)$ (kg/ha)	Additional break-even yield required in N years[b] on: 3 watersheds $(\bar{Y}'_i)$ (kg/ha)	% of years with zero runoff at end Oct (100 Q/N) (%)	Additional break-even yield required in (N-Q)[b] years on: 1 watershed $(\bar{Y}_j)$ (kg/ha)	Additional break-even yield required in (N-Q)[b] years on: 3 watersheds $(\bar{Y}'_j)$ (kg/ha)
3	Fallow	Flat	1280	940	17	1540	1140
8			950	710	14	1100	820
12			980	730	17	1190	880
16			1020	760	17	1230	910
20			1090	790	24	1430	1050
3	Cropped	Flat	1490	1100	17	1800	1320
8			1070	800	14	1240	920
12			1110	820	24	1460	1080
16			1150	860	31	1670	1240
20			1220	900	31	1780	1310
3	Fallow	Ridges and Furrows	2100	1530	41	3600	2610
8			1430	1050	34	2180	1610
12			1430	1060	41	2450	1800
16			1460	1070	44	2640	1940
20			1540	1080	48	2980	2080
3	Cropped	Ridges and Furrows	2550	1850	48	4920	3580
8			1540	1130	45	2780	2040
12			1520	1120	48	2940	2160
16			1540	1130	48	2970	2180
20			1600	1180	48	3100	2270

a. A crop valued at a P_j of Rs 90 per 100 kg is assumed here such as sorghum, maize or pearl millet. If a crop valued at Rs 240 is assumed, such es pigeonpeas or chickpeas then all the break-even yields here would decrease by about two-thrids.

b. N = total number of years used in the simulation; Q = number of the N years when net cumulative runoff at week 43 is zero.

feet of irrigation and probably not producing compensatory runoff. All these factors act to suggest that these break-even yield estimates are absolute minimum levels required to justify investment in the system.

The Hyderabad Alfisol situation seems quite different. Yield increments of less than 1000 kg/ha are required to justify investment in water harvesting and supplementary irrigation of postrainy season crops. It can be as low as 600 kg on catchments exceeding 8 ha (Table 8). With the experience we have had at ICRISAT with yield increments on Alfisols with irrigation, it seems these figures should be achievable.

As mentioned earlier, the present analysis has assumed all runoff is saved for irrigation of postrainy season crops and not used for irrigation of rainy season crops when they become stressed. To the extent the latter is a more profitable use of stored runoff, then the break-even yields reported here may be overestimates. To adequately answer this requires more extensive simulation of alternative irrigation decision rules employing crop yield-irrigation response functions. Work is presently under way on this. However, based on experience to date and on a priori grounds, it is unlikely that rainy-season supplementary irrigation on Vertisols will be profitable. B. A. Krantz (personal communication) suggests that the mere availability of stored runoff in the rainy season can act as an insurance for the farmer,

Table 8. **Break-even crop yields required to cover costs of water harvesting and supplementary irrigation system of Alfisols at ICRISAT Center.[a]**

Catchment size (ha)	Type of vegetative cover	Type of cultivation	Additional break-even yield required in N years[c] on: 1 Watershed ($\bar{Y}_i$) (kg/ha)	3 Watersheds ($\bar{Y}'_i$) (kg/ha)	% of years with zero runoff at end Oct (100 Q/N) (%)	Additional break-even yield required in (N-Q) years[b] on: 1 Watershed ($\bar{Y}_i$) (kg/ha)	3 Watersheds ($\bar{Y}'_j$) (kg/ha)
3	Cropped	Flat	1010	750	1	1020	760
8			730	550	0	730	550
12			720	540	0	720	540
16			720	550	0	720	550
20			730	550	0	730	550
3	Cropped	Ridges and	1020	760	3	1050	780
8		Furrows	750	560	0	750	560
12		0.4%	730	550	0	730	550
16		Grade	730	550	0	730	550
20			730	550	0	730	550
3	Cropped	Ridges and	800	600	3	820	620
8		Furrows	730	550	0	730	550
12		0.4%	720	550	0	720	550
16		Grade	720	540	0	720	540
20			720	540	0	720	540

a. A crop valued at a P_j of Rs 90 per 100 kg Is assumed here such as sorghum, maize or pearl millet. If a crop valued at Rs 240 Is assumed, such as pigeonpeas or chickpeas then all the break-even yields here would decrease by about two-thirds.

b. As there were no fallow treatments in the runoff data it was not possible to derive runoff or break-even yield estimates for fallow situations. In these low moisture-holding capacity soils post-rainy season cropping after fallows is probably not worthwhile anyway.

c. N = total number of years used in the simulation; Q = number of the N years when net cumulative runoff at week 43 is zero.

leading him to invest more in HYVs, fertilizers, plant protection, and other inputs than he would without a tank. However, any such insurance effect can only operate over the potentially irrigable parts of the catchment. With a cropped-and-ridged catchment of 8 ha for example on Hyderabad Vertisols, only 25% of the catchment can be irrigated on average. On Hyderabad Alfisols the figure is 44% and on Sholapur Vertisols 20%. The fact also remains that the insurance value must be real; when there is a dry spell in the rainy season there must be viable amounts of stored runoff in the tank to save the crops. In the dry years when the insurance is most needed, the probability that there will be insufficient runoff will also increase. The answer to this requires simulation of the historical data as we are currently doing.

It seems that a minimum catchment size might be about 8 ha. Break-even yields rise substantially for catchments less than this. It also seems that once catchments exceed about 16 ha the break-even yields begin to rise due to the negative effects of area and evaporation *on* runoff.

If instead of a crop worth Rs SO per 100 kg, higher-valued crops of say Rs 240 are irrigated, then the break-even yields in Tables 6-8 would all fall by a factor of two-thirds.

Conclusions

In the Vertisol steps-in-improved-technology experiments at ICRISAT Center, the complete package of technology generated the highest profits of Rs 3600/ha, which represented a 190% rate of return on variable costs of Rs 1900/ha. The two most profit/risk efficient treatments were local or improved varieties with improved fertilizers along with improved soil and crop management. Irrigation applied to either of these increased profits but also substantially increased variability of profits.

On Vertisols, the implementation of improved broadbed-and-furrow systems under local fertilizers with or without HYVs, or under local varieties with improved levels of fertilizer generated Rs 500 additional profits per hectare. If implemented under HYVs and improved fertilizers, this rose to Rs 1000. If these small field results are replicable on larger watersheds, added profits could pay for the extra Rs 6500 capital costs of a bullock-drawn wheeled tool carrier in about 1 year if it is used on 7 ha.

For an added investment of about Rs 400 per ha on both the Vertisols and the Alfisols, the increase in profits from the addition of fertilizers ranged between Rs 600 and Rs 1500, depending on the varieties and soil- and crop-management treatments employed.

In the Alfisol steps-in-improved-technology experiments, profits of Rs 2000/ha from the full package were 60% less than those generated on the Vertisols. Variability, however, was 20% less.

The local variety, improved fertilizers and improved soil- and crop-management treatment, along with the local variety, improved fertilizer, and local soil- and crop-management treatment, were the most profit/risk superior of all treatments on the Alfisols. The levels of the profit/risk tradeoff implied by these two treatments, as well as the two efficient ones on the Vertisols, are well within the risk aversion limits revealed by the sample of farmers in the Indian SAT studied by Binswanger (1978). Hence, one would be confident in recommending these to farmers.

The implementation of improved broadbed-and-furrow systems on Alfisols with local fertilizers and local varieties or HYVs increased profits by about Rs 300 ha. With local varieties and improved fertilizers, this increased to Rs 900, while with HYVs and improved fertilizer the increased profits amounted to Rs 1200/ha.

In the larger-scale watershed experiments on Vertisols at ICRISAT Center, the maize/pigeonpea intercrop system, on the average over 2 years, generated 73% higher profits than the maize-plus-chickpea sequential crop system. The intercrop system also had 34% less variable profits. This intercrop advantage was greater on the medium-deep Vertisols than on the deep Vertisols.

Deep Vertisol watersheds in general were 40 to 120% more profitable than those on medium-deep Vertisols. Broadbed-and-furrow systems with intercrop maize/pigeonpeas on the deep Vertisol watersheds were about 20% more profitable than the flat system of intercropping. This advantage is much less than shown in the steps-in-improved technology experiments and adds a caution on making inferences from small-field experiments to watersheds that can be more than ten times the size of experimental fields, particularly where soil-management systems are being used. Under sequential maize and chickpea the advantage of the broadbed-and-furrow system on deep Vertisols was reduced to 10%. Broadbed-and-furrow systems were less profitable than flat systems on medium-deep Vertisols.

The next step in this work is to incorporate the various steps in technology into activity analysis models that include both profit and risk considerations. Programming optimal technology choices under various constraint situations can determine the place of this new technology vis-a-vis traditional technology.

The profits from broadbed-and-furrow systems implemented within traditional farm field bunds on deep Vertisols were comparable to those implemented on a complete watershed with graded "guide" bunds. If this result is replicable, it suggests that the broadbed-and-furrow system may not require implementation on a full watershed, with all the potential problems of group action this may entail, to have its advantages expressed. It may be possible to achieve the benefits on an individual holding basis.

On the Alfisol watersheds *preliminary* indications are that the flat methods are more profitable than the broadbeds and furrows. The average profitability of supplementary irrigation from excess runoff harvested on the watersheds has proved to be much greater on the Alfisols at around Rs 400/ha. It has been up to Rs 5000/ha in the case of irrigated tomatoes. On the Vertisols, losses from irrigation have averaged Rs 150/ha.

Simulation models, using derived rainfall-runoff relationships to evaluate the economic potential of postrainy season supplementary irrigation from harvested runoff water, showed that ICRISAT Center Alfisols have double the runoff-producing potential of the Vertisols under cropped ridges and furrows. The ICRISAT Center Alfisols have three times the runoff potential of the Sholapur Vertisols.

The coefficients of variation of annual net cumulative runoff available at the end of October using historical rainfall distributions were inversely related to the mean level of annual net cumulative runoff. Hence those areas where runoff generation potential is least will also be the ones where runoff availability will be most variable.

It is doubtful that water-harvesting and supplementary-irrigation technology for postrainy-season crops can be profitable on Hyderabad Vertisols under a cropped ridge-and-furrow system; it is more likely under a flat-fallow system where more runoff is produced. It seems more or less certain that this technology will not be economically viable on the Sholapur Vertisols. The Alfisols offer much better possibilities for this type of technology. More research is required to determine the relative merits of utilizing stored runoff for irrigation of rainy season versus postrainy season crops. Only the latter alternative has been examined here.

The optimum economic size of catchment in these three areas would seem to be between 8 and 16 ha.

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New Agricultural Technology in the Brazilian Sertao

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Abstract

This paper describes the relevant characteristics of the Brazilian Sertao with regard to new agricultural technology. It then reviews the research effort on one new technology — the introduction of sorghum — drawing some useful lessons. In the given region, labor is not merely a seasonally limiting factor of production; laborers also suffer from chronic nutritional problems. Thus, the effects of new technology on the distribution of income of producers have efficiency as well as equity considerations. The potential for increasing yields of basic foods depends on fertilizer response and soil conditions, both of which tend to be poor at present. It is necessary to first identify plants with drought-tolerance potential and then select varieties and undertake basic agronomic research. As the agronomy results studied show that sorghum outyielded corn, and the modeling and farm trials show that the introduction of sorghum fits into the farmer's other activities and is profitable, policy intervention in favor of grain sorghum seems called for. Several steps are suggested for such intervention.

The Brazilian Northeast has the largest concentration of poverty in Latin America with a per capita income of approximately $200 in 1970. Fifty-two percent of the land and 41% of the population (11.5 million) are in the semi-arid region, the Sertao (Table 1). Out-migration from the rural areas has been occurring at a staggering rate. Nearly 2 million left the rural areas of the Northeast in the 1958 drought (Ward and Sanders, 1978). Meanwhile, population growth is continuing at a 2.5% rate, further aggravating the present inadequacies of nutrition, public health, and human capital formation in a region with inadequate, irregular rainfall.

What can new agricultural technology do in this environment? What are the appropriate types of agricultural technology? How does this relate to ICRISAT? This paper will attempt to at least provide some background to respond to these questions. In the first section some relevant characteristics of the region will be briefly described. Then some proposed and potential technologies will be considered. Some more specific results of modeling and field testing of the introduction of sorghum into the region will be analyzed. A final section will attempt to generalize the process of ex ante technology evaluation.

Crops, Drought, and Constraints in the Target Area

Cattle raising was the principal reason for settling the Sertao as land utilized for sugarcane and subsistence crops in the Zona da Mata (humid/coastal strip) became too valuable to produce cattle in the late eighteenth century. Settlement increased along the rivers, and later dams, as the *vaqueiros* (cowboys) acquired their own cattle and became independent. In the nineteenth century the world demand for cotton substantially increased, especially during the U.S. Civil War. This hastened the development of the northern Sertao northwest of the Zona da Mata, i.e. in the states of Piaui, Ceara, and Rio Grande do Norte, with the diversification into tree cotton production combined with the livestock activity. Sertao land distribution evolved

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Table 1. The population and area of the different ecologic subregions of the Brazilian Northeast?

Subregions	Population (1970) No. (million)	Population (1970) %	Area %
Humid coastal strip ("Zona da Mata")	7.7	27.3	7.2
Transition zone ("Agreste")	4.1	14.5	10.8
Drought Polygon ("Sertao")	11.5	41.0	52.4
Transition to Amazon	3.4	12.o	22.4
Humid valleys and highlands	1.3	4.5	2.4
Transition to central plateau ("Cerrados")	0.2	0.7	4.8
Total northeast	28.1	100.0	100.0

a. Source: Unpublished data from SUDENE.

into two principal types: large cattle estates, often with tree cotton tended by sharecroppers, and small subsistence units. Over time high population growth and the need for all Sertao farms to be located near a water source resulted in these small farms acquiring their present long, narrow, rectangiriar shapes, with one end of the rectangle on the river.

As in most cattle zones, land distribution in the Northeast became extremely concentrated. In 1970, 68% of the farms in the Northeast were less than 10 ha but only occupied 5.6% of the land area. Ninety-four percent of the farms were less than 100 ha, occupying only 30% of the area (Censo Agropecuario Brasil, 1970). The Northeast had the largest number of farm properties of all the Brazilian regions with 2.2 million in 1970. There were 873 000 farms less than 10 ha — the largest concentration of small holdings in Brazil (almost 59% of the total in the country). At the same time, there were 3572 properties with more than 10 000 ha in the Northeast. These 3572 properties had a larger land area (3.6 million ha) than that of the entire small holding group (2.7 million ha).[1] The land distribution problem is further complicated by the lack of fertile areas except for isolated regions of high fertility generally on the coast and in some valleys and highlands

1. Data from the Preliminary 1970 Census cited in Paiva et al. (1973, pp 372-3).

The predominant crop activities of the northern "Sertao" are tree cotton-corn-cowpeas in association (or mixtures). In the first year of the five-year economic cycle of the tree cotton, corn and cowpeas are planted between the cotton rows by the sharecroppers and the small farmers. After the first year the small farmer generally prunes the tree cotton back and plants corn and cowpeas again whereas the sharecropper goes on to another area of the same or another farm to repeat the cycle of obtaining his subsistence crops while establishing the landlord's investment crops, cotton and pasture.[2] In the Sertao south of Paraiba tree cotton becomes less important; instead there is a greater concentration on cattle and supporting activities such as "palma," a spineless opuntia cactus with a high water content which is often combined with cottonseed meal as cattle feed. Field beans, cassava, castor beans, upland rice, sisal, and tobacco are also important in particular regions. Livestock is a method of capital formation for small and medium farmers and is the principal activity of most larger farmers. The tree cotton leaves serve as an emergency pasture reserve in inadequate rainfall years.

The farmer's approach to drought is to plant long-term crops with good drought resistance such as tree cotton, castor beans, and cassava. His food crops — cowpeas and corn — are

2. For further detail see Johnson (1971).

planted in the 3- to 5-month rainy season. Pasture, fruits, sweet potatoes, and rice are cultivated on the small areas of the farm with water. Unfortunately, rainfall availability for the basic food crops (corn and cowpeas) is very erratic during the growing season.

Most of the Sertao receives from 500 to 800 mm of rainfall concentrated in a 4-month period. Approximate probabilities of insufficient rainfall within the growing season are:[3]

- Full-scale drought (i.e., no rain during most of growing season) — 12% (last one in 1970).
- Mini-drought (i.e., no rain for 2 to 6 weeks in growing season) — 30% (last one in 1976).

Cultural practices also revolve around this rainfall irregularity. In Irece, a large-farmer bean area in the Sertao of Bahia state, two to three plantings are often necessary. In small-farmer regions, farmers plant a mixture of varieties of the basic food crops and plant at several times to minimize risk. Fertilizer use is generally zero, because of little response with present varieties and irregular rainfall conditions.[4] The most obvious pressing constraint is the lack of water; thus drought tolerance and better methods to take advantage of available moisture are the most important new technologies.

After water-saving technologies, there is some sketchy evidence that labor is more constraining than land. Land prices have been increasing slower than labor prices have been in Brazil and in the Northeast (de Albuquerque Lima and Sanders 1978 p 101). Moreover, intensity of land utilization decreased dramatically as farm size increased slightly (Table 2|. Slightly larger small farmers cultivated less than 20% of their area, whereas farmers having 10 ha or less cultivated almost 60%. With the lack of chemical fertilizer inputs and the low initial fertility of most of the soils in the Sertao, long rotation periods are practiced to give a slight fertility boost to the low yields of the basic crops.

If farmers take the risks inherent in semi-arid agriculture, there is additional land available in spite of the high concentration. Sharecroppers move between farms, and seasonal labor shortages — especially for the necessary weeding after the intense rains — are important in determining cotton yields and area cultivated.[5] By overcoming these constraints of seasonal labor availability a reasonable internal rate of return of 35% is attained with the purchase of an animal cultivator (de Albuquerque Lima and Sanders 1978, pp 107-110). This inexpensive implement, useful for both cultivation and land preparation on lighter soils and manufactured

3. These subjective estimates were obtained from researchers in the agricultural school of the Federal University of Ceara. Substantial rainfall data are available. See Hargreaves (1973).
4. For a review of fertilizer studies on traditional Northeastern crops see the references cited in Sanders and de Hollanda, (1979, p 119).
5. See A. W. Johnson, (1971) for more detail on sharecroppers and Albuquerque Lima and Sanders, (1978, pp 110-112) for more information on seasonal labor problems.

Table 2. Land use intensity for crops in a sample of small farmers in Caninde Ceara, 1973.

Indicators	Available land area (ha)							
	Up to 10	10-20	20-30	30-40	40-50	50-60	60-70	70-80
Mean area cultivated (ha)	3.8	5.7	8.5	8.8	9.4	12.2	10.3	11.1
Land use intensity[a]	0.59	0.49	0.36	0.27	0.24	0.24	0.17	0.18
Number of observations	10	16	9	7	8	4	7	5

a. Measured as ($A_c/A_t - A_{NA}$), where
A_c: cultivated area in crops
A_t: total area
A_{NA}: area not appropriate for agriculture according to the farmer.
Source: de Albuquerque Lima and Sanders (1978, p 103).

in Sao Paulo, is presently being adopted by small farmers in the Northeast.

Labor is not only a seasonally limiting factor of production, but is also affected by chronic nutritional problems. In a sample of Ceara small farmers and sharecroppers, 46% of the families had inadequate caloric levels. Protein deficits were less because of the cowpeas and small-scale livestock production. Surprisingly, the nutritional situation of the low income urban inhabitant was even worse (Ward and Sanders 1978, pp. 8, 17). An inadequate investment in nutritional and related human needs of low-income rural inhabitants implies that they probably will not be very successful as migrants to the city. If the rural migrants are unable to move out of their low income position in the urban area, their nutritional situation becomes worse. Thus, the effects of new agricultural technology on the distribution of income of producers has efficiency as well as equity considerations, given the present human capital deterioration in the Sertao.

Agricultural Technology Alternatives in the Sertao and Public Policy

Since the Sertao was developed as a cattle region and most of the area is concentrated in large holdings, it is not surprising that most regional effort in research as well as agricultural credit has been for cattle. One theory of Sertao development has been to foster out-migration so the *minifundia* could be consolidated into larger units more efficiently producing higher price and income elasticity products such as cattle. In the late 1950s the central government began promoting industrialization in the urban Northeast through income tax credits and other direct subsidies. Since 1960 the urban population of the Northeast has been increasing at a 4.6% annual rate compared with only 1.2% for the rural population (Ward and Sanders, 1978, pp 17-18).[6]

In addition to rural-urban migration, rural-rural migration has been encouraged through colonization projects. Two weeks after personally witnessing some effects of the drought of 1970 President Medici implemented the PIN (Programa de integragao Nacional) program of national highway construction to penetrate unsettled areas in the Amazon and northern Mato Grosso (Sanders 1973). The Transamazon highway was regarded as a method of transferring a rural population from a region of excessive density to one of inadequate density. Unfortunately, the road construction was inadequately supported by agricultural research, and little migration actually took place.[7]

In the early 1970s, the central government also implemented a program concerned with agricultural productivity and income distribution within the Northeast, the PROTERRA *(Programa de Redistribuicao de Terras e de Estimulo a Agro-lndustria de Norte e Nordeste)* program. (Venezian 1972, p. 33). The productivity of the basic food crops of the Northeast had been falling, with total production being maintained by area expansion (Table 3). For example, corn acreage in the Northeast increased more than 2.5 times from 1950 to 1975, whereas yields slightly decreased. (Johnson 1977, p. 6).

In various international centers there has been research on the basic food crops of the Northeast: corn, field beans, cowpeas, cassava, and rice. However, only a small proportion of this research has been on drought tolerance. Within the Northeast some traditional agronomic research has been done, such as fertilization, spacing, and variety testing. Some breeding improvements have been made, as in field beans, and new seeds of improved selections have been distributed.

In general, the potential for increasing yields of these basic food crops does not appear very promising. Why? First, yields at present are extremely low. Second, developing cultivars with good fertilizer response under irregular

6. For further detail see Moura (1971).

7. The target in the organized colonization was 100 000 families or approximately one-half million people over the period 1971-1974. By 1974 INCRA (the Brazilian land reform and colonization agency) reported that only 5717 families had been settled. There was also spontaneous settlement but much of this settlement was temporary and few data are available. In 1974 and 1975 the central government changed its strategy for the Amazon to promoting growth poles and large enterprises. See Wood and Schmink (1978, pp 8, 19, 20).

Table 3. Trends in corn and bean production in the Brazilian Northeast.[a]

Crop Year	Corn Production ('000 t)	Corn Area ('000 ha)	Corn Yields (kg/ha)	Beans[b] Production ('000 t)	Beans[b] Area ('000 ha)	Beans[b] Yields (kg/ha)
1967/68	1703	2128	800	870	1517	573
1968/69	1597	2062	774	818	1507	543
1969/70	871	1700	512	448	1199	374
1970/71	1695	2159	785	961	1593	603
1971/72	1535	2192	700	861	1640	525
1972/73	1512	2199	687	868	1681	517
1973/74	1418	2186	678	601	1499	401
1974/75	1580	2450	645	794	1705	466

a. Source: Unpublished data from SUPLAN, Ministerio da Agriculture, Brasilia, 1976.

b. Includes field beans and cowpeas. In Bahia approximately 95% of the beans are field beans and in Pernambuco 50%. The proportion of field beans is lower for most of the rest of the Northeast, being only 5% in Ceara.

rainfall conditions appears unlikely given the experience with present and improved varieties in the poor soil conditions of the Northeast. Hence, it appears to be necessary first to identify plants with drought-tolerance potential and then select varieties and undertake basic agronomic research.

Subsistence cropping has always been a supplementary activity for *vaqueiros, parceiros* (sharecroppers), and small farmers; hence, few inputs have been utilized, little research has been done, and absolute yields have remained low. There is a further complication: the average annual rainfall in the Sertao is not extremely low compared to other semi-arid regions of the world, but it is extremely irregular, and the probability of inadequate rainfall in the growing season is high. Corn is notoriously sensitive to lack of rainfall during the critical stages of growth. "Corn yields are reduced by 50% or more if there is water stress during the critical periods regardless of the level of rainfall for the rest of the growth cycle."[B] Perhaps corn is an inappropriate crop for the region, and a new crop with drought tolerance is necessary.

Although there are an estimated 50 million ha sown to sorghum in the world, placing it fourth in grain production behind wheat, rice, and corn, very little grain sorghum is planted in the Brazilian Northeast.[9] In addition to its drought tolerance, sorghum can tolerate light sandy soils, salinity, and low fertility (Purseglove 1972, pp. 270, 286). It seems to be the perfect crop for the irregular rainfall, low fertility conditions of the Sertao. Given the physical production

8. Cited from Goodwin et al. (1980, p 7.) See also Denmead and Shaw (1960) and Robins and Domingo (1953).

9. It appears that grain sorghum was introduced from Africa into Brazil in the early slave trade. However, the slaves principally stayed in the Zona da Mata where adequate rainfall makes corn superior. Only in the last century with greater population pressure in the Sertao have subsistence crops become important there. Grain sorghum thus has no tradition of production or human consumption except in the Acu Valley of Rio Grande do Norte, where a type of cornbread ("cuzcuz") is traditionally made from sorghum. On the introduction of sorghum see 0. Johnson, 1978, pp 5, 6).
In semi-arid East Africa where sorghum probably originated and where it is an important food crop, the exact opposite substitution is occurring. Maize is generally preferred for food, hence has a higher market price, requires less labor, does not have bird problems, and is less attacked by storage insects than sorghum. Moreover, new earlier varieties of maize are being introduced. With this substitution, the potential for disaster increases when rainfall is irregular. See Purseglove, (1972, pp 259, 262).

characteristics of corn and sorghum, corn seems to be a historical accident; it does poorly under both drought and the adverse soil conditions cited.

The only available estimate of grain sorghum availability in the Northeast is 4274 tonnes in 1973, of which 3000 tonnes were produced there, 1000 were imported from the Brazilian south and the rest from outside the country. The major use was for chicken feed (Nobre and Kasprzykowsky 1975, pp 46).

How does sorghum yield in the Northeast? Across regions from 1973-1975, under experimental conditions, sorghum consistently outyielded corn and gave reasonable absolute yields of 3 to 4 t/ha (Table 4). Rainfall conditions were normal to above average during this period. The real advantage of sorghum was illustrated in a mini-drought year when the corn harvest practically failed but selected sorghum varieties still yielded around 2 t/ha with fertilizer and 1.6 t/ha without fertilizer (Table 5).

How does the sorghum do in farm trials and what are the other constraints to its introduction? The next section attempts to answer these questions.

Table 4. Yields of regional trials of IPA sorghum lines and corn, 1973—1975.

Identification number of IPA cultivar	Mean of 2 regional trials 1973 (kg/ha)	Mean of 6 regional trials 1974 (kg/ha)	Mean of 12 regional trials 1975 (kg/ha)
7300201	3330	3113	4368
7300206	2674	3184	3929
7300958	Not planted	3438	3861
7301154	3402	3574	4192
7301183	3107	3074	4003
Corn	2188	2476	3353
Rainfall range during the crop cycle (mm)	250-361	295-748	508-941

IPA stands for the Instituto de Pesquisas Agronomicas of Recife, Pernambuco, Brazil.
Fertilization levels of 90 kg of N, 90 of P_2O_5 and GO of K_2O were utilized.
Aztec variety (Corn) was utilized in 1973 and was replaced by Centralmex in 1974-1976.
a. Source: Faris and de Lira (1977, p 7).

Table 5. Results of sorghum regional trials in Paraiba and Pernambuco with and without fertilization In a mini-drought year, 1976.[a]

IPA-identification number	With fertilizer[b] (Mean yields over 7 regional trials) (kg/ha)	Without fertilizer (kg/ha)
7300201	2507	1790
7300206	2169	1750
7300958	1748	1724
7301154	1865	1546
7301183	2359	1584
Corn	740	627

Source: Faris and de Lira (1977, p 7.).
a. The rainfall during the crop season ranged from 147 to 322 mm.
6. 90 kg of N, 90 kg of P_2O_5, and 60 kg of K_2O.

New Technology in the Sertao: Modeling, Farm Trials, and Marketing

A new crop combination of tree cotton and sorghum more than doubled farm income in a MOTAD (Minimization of Total Absolute Deviations) risk activity analysis for one region of the Sertao. Farmers were shown to be strong risk avoiders but highly efficient in their choice of crop systems (Sanders and de Hollanda, 1979, pp 109-115). These model results were tested on farms in Rio Grande de Norte in 1976. There, sorghum yielded 1154 kg/ha without fertilizer and 1785 kg/ha with a low fertilizer application.[10] The corn crop was almost a complete failure, with a 70 to 80% yield reduction in this mini-drought year. As in the sorghum yield data of Table 5, there was a physical response to fertilization in the farm trials in spite of the rainfall deficit and it was profitable to use fertilizer.[11] With a better rainfall distribution the returns to fertilizer on sorghum are expected to be even higher. This provides some supporting evidence for the hypothesis that drought tolerance must first be obtained before attacking the fertility problem. Sorghum has now performed very well in the Northeast in comparison with other alternatives, not only in agronomic trials but also in the profitability-risk and farm constraint evaluation context. Moreover, the model results were confirmed in farm trials.

Further refinements of the model and data indicated that even with the extremely high risk avoidance preference characteristics of Sertao farmers incorporated, the introduction of sorghum resulted in a 25% increase in farm income (the "net margin"). The sorghum activity entered principally because of the substantial reduction in the standard deviation of the optimum farm plan. With this risk reduction from the availability of sorghum technology, there was an expansion of the area cultivated (Goodwin et al. 1980, p 17). At present risk-aversion levels, unfertilized sorghum was preferred. With lower risk-avoidance coefficients, higher levels of chemical fertilizer were utilized in model solutions. This appears to indicate the importance of field estimation of farmers' risk coefficients as an input into research design. In spite of the large emphasis in Brazil on subsidized credit this instrument had no effect upon the introduction of new technology in the modeling results because, at these high levels of risk avoidance, farmers use few purchased inputs. The model results indicated that a farmer, knowing about the grain sorghum activity but exaggerating the riskiness of this new activity and even having a high coefficient of risk aversion, will adopt sorghum on a small area of his farm.[12] After observing field results of this innovation, the accuracy of the farmer's perception of its riskiness will increase. Moreover, increased earnings will in time reduce farmer's risk aversion and encourage him to use higher levels of purchased inputs, especially fertilizer.[13] Once the farmer is prepared to use more purchased inputs, the credit instrument becomes potentially more effective. In summary, farm-level testing is expected to be a much more efficient instrument than credit subsidies in the early stages of technology introduction.

Extending the data series and introducing more fertilizer technologies into the model, especially *for* sorghum and other *crops on* the small area with *Vazante* (water), the preferred crop choice was to continue the typical *consorcio* (cotton-corn-cowpeas) for the subsistence requirement but also introduce sorghum in a monoculture without fertilization. If the farmer is prepared to take more risk, he can earn a higher income. With these crop plans, sorghum forces the traditional *consorcio* into the poorer soil areas until it disappears from the product mix on small farms.[14] With the introduction of

10. Twenty kg/ha of N and 60 kg/ha of P_2O_5 were utilized. Birds were not a serious problem in these farm trials nor was the sorghum midge. Barbosa et al. (1976, p 16).
11. Profits were almost doubled by fertilization in spite of the inadequate rainfall.
12. A farmer is expected to exaggerate the riskiness of new technology until he has gradually acquired his own empirical knowledge of the crop on his farm or in his region.
13. Increased income over time should lead to greater wealth. At higher wealth levels individuals can take more risks because they can survive bad years.
14. Mean farm yields of sorghum over a 12-year period were estimated to be 1290 kg/ha without fertilizer and 1958 kg/ha with fertilizer of 80 kg/ha of N (Barbosa, 1977).

sorghum, farm income can be doubled as in the earlier results. With medium size farms, the high prices for corn and cowpeas, and the increased labor requirements for sorghum enable the cotton-corn-cowpea activity with improved technology to force out sorghum at the highest risk levels. Thus, the model results appear to show a comparative advantage for smaller farms in the production of sorghum. Fertilizer subsidies had no effect upon the farm plans chosen, except at the highest income-risk position.[15] By shifting the income-risk curve upward, agricultural insurance plans resulted in new technology being introduced much sooner at lower risk levels. The risk insurance also stimulated a more intensive land use.[16]

The agronomic results show that sorghum outyielded corn, and the modeling and farm trials show that the introduction of sorghum fits into the farmer's other activities and is profitable. Now who will buy the sorghum?

There are many potential uses of sorghum. In the short run it is unlikely that it will be used for human consumption in spite of the sorghum "cuzcuz" eaten in the Vale do Acu. Human food habits in the absence of extreme pressures — as from a natural calamity — appear to be fairly inflexible in the short run. However, even on small farms in the Sertao animals are important, and the sorghum can be easily substituted for corn. Very preliminary estimates indicate that up to one half of the corn utilized on small farms in the Sertao is for animal feed. There is an increasing demand for poultry in the Northeast with the rapid introduction of poultry technology and the resulting reduced costs of production. Ration-mixers in the Northeast import the concentrate and, when rainfall is adequate, mix it with locally purchased corn. When rainfall is inadequate, corn must be imported from the south. Sorghum would increase the probability of local availability of a cheaper feed source by being less likely to fail and it would eliminate the high transportation cost of importing corn from southern Brazil.

Utilizing linear programming of chicken rations and the projection of the total demand for corn in the Northeast at different relative prices of sorghum and corn, potential demand curves for sorghum and corn were constructed by Campos et al. (1978, p 113). By 1980, 400 000 to 514 000 tons of sorghum could be utilized in chicken rations.[17]

The risk here for the small farmer is the shift from home consumption of com and cowpeas to sale of sorghum to an oligopoly of feed factories. Governmental intervention or the creation of cooperatives could overcome this risk. Policy intervention in marketing seems much more feasible than the search for corn varieties with sufficient drought resistance to be competitive with sorghum. There are many other potential uses of sorghum, such as a partial substitute for wheat in bread, but these may require even more governmental intervention.

Given the large population in the Sertao, the failure of various types of policies to eliminate this high density of small farmers and sharecroppers, the efficiency loss to society from allowing human capital deterioration of this group, and the lack of interest of most large farmers in the Sertao in other activities besides cattle, Brazilian policy makers may well maximize the social benefits of new sorghum technology by designing it specifically for small farmers. There are a series of policy options to do this:

1. Concentrate research on grain sorghum only, *not* forages.
2. Develop varieties, *not* hybrids. Small farmers will not be interested in purchasing new seed each year and private companies selling hybrids are generally more interested in large farmers.
3. Give *no* subsidies for mechanical harvesters. With the large labor requirements of bird control, sorghum harvesting, and increased labor for weeding, small farmers may have a comparative advantage in

15. The 40% fertilizer price subsidy available in Brazil prior to 1977 was utilized in the model.
16. This agricultural insurance was not the official program, PROAGRO, which operates only through credit and had no effect according to model results. Rather two programs were considered guaranteeing 60% and 75% of the income of the *basic consorcio* with improved technology.
17. In 1974, there were 25 factories producing balanced rations in the Northeast with an installed capacity to produce 276 740 tons. Ninetyfive percent of this ration produced was for chickens with 3% and 2% for swine and cattle, respectively. See Nobre and Kasprzykowsky, (1975, p 75).

sorghum production *unless* the government offsets this advantage through subsidies for machinery purchase.

4. Use governmental intervention if necessary to enforce advance contracts between feed mixers and farmer cooperatives.
5. Finance regional farm trials of sorghum so that region-specific problems can be identified and farmers can become familiar with sorghum technology.

There are many technologies which could be developed for the Northeast. It appears that the most viable for rapid introduction now is sorghum. With regional testing on farms and governmental intervention to facilitate marketing, the introduction of sorghum could progress rapidly in the Sertao. Corn acreage has been increasing over the past 25 years in many regions not appropriate for corn. The research appears to be available now for a government initiative to substitute sorghum for corn in the Sertao and thereby concentrate corn in zones with higher rainfall where yields can be increased with higher levels of inputs.

Ex ante Economic Analysis and Technology Design

This paper has attempted to describe the relevant characteristics of the target region and new technology and then to document the research effort on one new technology, the introduction of sorghum. Suggested stages of economic support of the research design process are outlined in the five steps below.

1. Identification of the crop. The benefits of crop research depend upon:

a. the potential area of the crop in the region;
b. the ability of researchers to correctly identify the principal restrictions to increased yields;
c. the potential of the scientists to find a technical solution to the (se) restriction(s);
d. the economic conditions required to implement the technical recommendations and market the product.

In international centers the crop is designated by external funding agencies or previous commitments so that concern can be focused on items b and d above. National centers will have to make the difficult allocative decision between crops.

Here sorghum was chosen over corn because of its greater tolerance of drought and low fertility. The marketing problems appeared to be superable, with some governmental intervention.

2. Identification of the clientele. Researchers often claim that their technology is scale neutral but assume that their client farmers will use high input levels and have sufficient water available at critical times of crop growth. These are critical assumptions because there is frequently a trade-off between varieties with maximum yields with adequate water and high fertilization and varieties with drought tolerance and some response to lower fertility conditions.[18] Maximizing the yield under optimistic projections about water availability and fertilizer use could then lead to the rejection of varieties with good performance under more adverse conditions. Many regions will not be affected by irrigation or innovations in water-saving technology. Moreover, small farmers without water control are not expected to use high levels of inputs because of strong risk-avoidance characteristics. If the technology is to be oriented towards small farmers, it may be necessary to make the more pessimistic assumptions.

For various reasons discussed previously, small farmers are expected to be the principal clientele of the new sorghum technology. The new varieties, which are not as impressive on the experiment station, may have much more potential for diffusion. Subjective projections about potential diffusion of various types of material may be as important as the biologists' estimation of the potential yield increases resulting from various breeding strategies.

3. Ex ante modeling of the farm level effect of new technology. Using all available data and synthesizing data when there were gaps, the farm level potential effects of new technology introduction were evaluated. Sorghum was an excellent potential activity according to these results. Farm testing confirmed the model results.

4. Feedback. In 1976 IPA began doing research on unfertilized sorghum (reported in Table 5).[19] Physical data gaps on the yields of sorghum with different states of nature — i.e.,

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18. J. Ryan called this trade-off to my attention.
19. The first sorghum ex ante modeling activities were presented in 1975.

climate and pests — and information requirements about farmer's risk attitudes were identified as necessary information for future research.

5. Results. In 1976 the State agricultural planning agency (CEPA) of Rio Grande do Norte, with World Bank financing, began extending credit for animal-powered mechanization and undertaking farm-level testing of sorghum in "consorcio," with and without fertilizer, in the Rural Norte Project.

Postscript:
Unfortunately, no direct Brazilian central government intervention to facilitate grain sorghum marketing has as yet occurred. Moreover, much of the research focus on sorghum in the Northeast has been shifting to forage sorghum as a result of strong pressures from the cattle producers.

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Discussant's Comments

R. J. H. Chambers*

Fall's succinct paper discusses physical constraints and human factors relating to the introduction of new technology in the rural areas of Senegal generally and the Sahel in particular. He presents some findings from a study of actual production systems and the effect of new techniques in rural areas. Many questions might be asked about the methodology of the study and about the findings. Of particular interest is the finding that women and *sourga* (family labor) have the smallest plots, the lowest rates of fertilizer application, and the lowest groundnut yields. It is difficult to interpret the significance of this without more information.

The author stresses the value of individual case studies of farmers; these might provide insight into farmers' constraints and rationality. However, one wonders whether there are not dangers of a certain *dirigisme* when, for example, he writes: "In Senegal, although the profitability of certain techniques has been demonstrated, the farmer still needs to be motivated toward change." There may be nuances here that are lost or added in translation from the French. But it may be asked whether it is not often more important for researchers to learn more about farmers' situations and views rather than for farmers to be motivated. There is, indeed, a hint of this point of view when the author says, "The foundation of technical recommendations made through research is not always perfect." The key question, not addressed in this paper, is not how to motivate farmers, but how to improve the research and development (R & D) process.

The paper by Ryan, Sarin, and Pereira summarizes the economic analyses that have been made of the experiments conducted by ICRISAT's Farming Systems Research Program from 1975 to 1978. These have been designed to develop improved methods of soil, water, and crop management that can help increase and stabilize crop production in the semi-arid tropics.

There can be no doubt about the value of this sort of economic analysis. The "steps-in-improved-technology" (SIIT) approach compares the costs, benefits, and risks of various combinations of four innovations concerning variety, fertilizer application, soil and crop management, and supplementary irrigation, on two types of soil. This provides a tool for screening out lines of research that are unlikely to be useful to farmers. It is possible that the detail of the analysis represents an overkill, when decisions about research priorities will be based on comparative orders of magnitude. But on the other hand, detail and rigor are often necessary in order not merely to be right, but to be seen to be right.

A point of interest in the paper is the suggestion (attributed to Krantz) that the mere availability of stored runoff will act as assurance to a farmer, encouraging him to invest more in HYVs, fertilizers, plant protection and other inputs, even if in a given year he does not use the water.

In the various combinations of treatments on the Vertisols and Alfisols, it is surprising to note the relative significance for profitability of improved fertilizers compared with supplementary water. One wonders whether, in the real world of small farming, the relative importance of these two factors might not be different for the following reasons:

1. Access and the real price of fertilizer. The actual price of fertilizer to farmers is often higher than the list price because of the incentive payments that have to be made to officials. There is also evidence that smaller, less influential farmers have to pay more than larger, more influential farmers, not only in cash terms but in the time they have to devote to negotiations. The risks of not being able to obtain fertilizer may also be greater for smaller and less influential farmers. As official prices were used in the calculations there may be some over-

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estimation of profits from fertilizers, though probably not sufficient to alter the basic conclusions.

2. The cost of water. The experiments have been structured by the scale of watershed chosen for the tanks, the size of tank, the pumping technology (diesel), and the size of pump (5 HP). A conclusion is drawn that:

> A minimum catchment size might be about 8 ha. Break-even yields rise substantially for catchments less than this. It also seems that once catchments exceed about 16 ha the break-even yields begin to rise due to the negative effects of area and evaporation on runoff.

There are two lines of argument here, leading in opposite directions:

First, with these techniques and this scale, it might be that for the smaller farmers (those who were less influential) and those higher up on the catchment, the stored water would be less profitable than in the calculations. The larger and more influential farmers would be likely to get water first, in a more timely manner and in larger quantities, and those lower down in the catchment could argue that their water cost less because it required less diesel to pump, so that those higher up should pay more.

Second, and on the other hand, if the tank and pumping technology had a smaller scale and were cheaper, then the profitability of water for the smaller, less influential farmers and those higher up the catchment could be greater. Obviously there are many considerations here, and ICRISAT has canvassed many ideas about alternative systems. But in real village situations, it might be that the combinations of technology developed on the research station would have been screened out as impracticable at a very early stage, and the R & D process might have followed a quite different course leading to micro-storage of water on individual farmers' fields and animal or human power for water lift for high-priced crops.

The thrust of these points about relative access to and costs of improved fertilizer and of supplementary irrigation is that the value of economic analysis is limited by the location and built-in rigidities of the research itself. It is much better to have economic analysis than not to have it, as this meticulous and thorough paper demonstrates. But it is better still if right from the start of research, farmers and social scientists are involved and if the balance of location for research of this sort is shifted to villages. This would eliminate lines of development that farmers would not accept, shortcut some of the needs for sophisticated analysis, and identify at an early stage what is so much more difficult to gauge from a research station: who is likely to benefit and who to lose from a new bundle of techniques in the real world of the village.

The paper by Sanders describes the relevant characteristics of the Brazilian Sertao with regard to new agricultural technology and reviews the research effort concerning one such technology: introduction of sorghum, a new crop in the region.

There are many points of interest and insight in the paper. These include the relationship between nutrition and efficiency (although the phrase "human capital deterioration" is perhaps unnecessarily clinical); the irrelevance of fertilizer and credit when farmers have high risk-avoidance; the value of field evaluation of farmers' risk coefficients as an input into research design; the observation that farmers carry out small-scale trials on their own fields, and the idea that R & D can be designed specifically for small farmers to give them a comparative advantage, as with sorghum with its high labor requirements.

Although it does not overstress them, the paper raises crucial issues about government policy and political economy. These issues have general application but are all too often not discussed. The question here is whether measures will be taken that will benefit the smaller and less influential farmers. This question applies at three levels of decision and action:

1. Pricing policy and policy for mechanical technology. Sanders writes:

> With the large labor requirements of bird control, sorghum harvesting, and increased labor for weeding, small farmers may have a comparative advantage in sorghum production *unless* the government offsets this advantage through subsidies for machinery purchase.

This issue may be taken even further through a policy for technology as India has dona by prohibiting the import or manufacture of combine harvesters. But this can only be done with a resolute political will to offset the powerful interests that benefit from such technologies to the detriment of the poorer people.

2. Marketing. The author writes, "Unfortunately, no direct Brazilian central government

intervention to facilitate grain sorghum marketing has as yet occurred." One may speculate that such marketing organization would serve the major interests — the large cattle farmers — of the region.

3. Research priorities. The interests of the smaller farmers do not appear to have been reflected in research priorities. Only a small proportion of past research was on drought tolerance; and much of the research focus on sorghum in the Northeast has been shifting to forage sorghum due to strong pressures from cattle producers. This is the point at which the paper ends, and another subject starts. The determination of research priorities, whether by design or default, is political since it determines who will benefit. If these priorities are influenced by large-farmer interests then countervailing research is needed to offset them. It is here that ICRISAT, through its choice of crops and priorities, has a major role to play.

The Socioeconomics of Prospective Technologies: People and Priorities

R. J. H. Chambers*

Abstract

This paper is concerned with the decisions and processes that generate mechanical, biological, and chemical technologies that have an impact on life in the semi-arid tropics (SAT). The author makes these assumptions: that such technologies, separately or combined, influence social relations and the distribution of benefits within societies; that in much of the SAT, rural populations are increasing and will continue to do so for decades to come; and that there is room for maneuver in setting research and development priorities and in decisions taken during the research and development (R & D) process. The central issue is how to optimize decisions and action that affect and are part of R & D. It is contended that modes of thought, values, and criteria need to be re-examined. In much of the literature of agricultural development, including agricultural economics, people are treated as resources rather than users of resources — as means rather than ends. And thinking about research priorities often starts with a crop or a farm system or a mechanical technology rather than with the poorer people in a rural environment and their interests and future. The author suggests that decision-making and research might be improved through expanding environment-specific research, conducting more of it in collaboration with rural people, developing cost-effective methods for rural appraisal, changing professional reward systems, enabling professionals to become individually more multidisciplinary, and learning from the true multidisciplinarians, the rural people themselves.

> "If everybody minded their own business," said the Duchess in a hoarse growl, "the world would go round a deal faster than it does." Lewis Carroll, Alice in Wonderland.
>
> "When the rockets go up, who cares where they come down? That's not my department..." Tom Lehrer song.

In this paper "socioeconomics" is taken to include the concerns of the social sciences generally, and not just sociology and economics. It would be artificial, restrictive, and unhelpful to make the scope narrower. "Prospective technologies" are similarly interpreted widely to include technologies that are "in prospect" in the sense of being actively developed, and also others that are not being developed but might be developed if accorded priority. "Technologies" include mechanical, biological, and chemical technologies. The Ft & D discussed is the formal R & D of organizations and not the informal R & D of rural people, important though the latter is.

Analysis of the socioeconomics of prospective technologies can focus on the receiving environments or on the processes that generate the technologies, or on both. Though considering both, this paper is primarily concerned with the decisions and processes that generate technologies, since this is where many important choices lie. It is not concerned with the diffusion of technologies that already exist. The central issue is how to optimize decisions and action that affect and are part of R & D processes.

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EDITORS' NOTE: In preparing for the workshop, Dr. Chambers wrote this thoughtful paper on the subject of the session. Although he also was asked to open discussion it was felt this paper merited Inclusion as a separate contribution to follow his comments on the papers formally presented.

In approaching this issue, three assumptions are made.

First, in the semi-arid tropics (SAT), mechanical, biological, and chemical technologies, separately or combined, influence social relations and the distribution of benefits within societies. Prospective technologies can be expected to continue to exert such influences. Decisions about research priorities and decisions within the R & D process are therefore political and value-laden in their implications, however technical they may appear. In receiving environments, the "talents effect" as Andrew Pearse(1977) has called it after the biblical parable, is widely prevalent, so that those who have more get more and those who have less may lose even the little that they have. But technologies vary widely in the ease or difficulty with which they can be captured and used by different categories of people, and they can be designed with target groups in mind, including poorer people. Whether deliberately or by default, a social policy is built into new technology.

Second, in much of the SAT, proportions as between population, land and water are changing and will continue to change. In almost all areas, rural populations are increasing and can be expected to continue to increase. Short of some demographic disaster, and in spite of high levels projected for rural-urban migration, rural populations in most countries will continue to grow rapidly for decades. Table 1 indicates orders of magnitude: rural populations in most

Table 1. Rural and urban population projections for some countries wholly or partly In the semi-arid tropics.[a]

	1975 (millions)		2000 (millions)		% increases 1975-2000	
	rural	urban	rural	urban	rural	urban
Angola	5.2	1.2	8.1	4.4	55	278
Bolivia	3.4	2.0	4.8	5.4	43	169
Botswana	0.6	0.1	1.0	0.4	65	459
Chad	3.5	0.6	4.9	2.0	42	254
Ethiopia	24.8	3.1	42.2	11.4	70	265
India	481.5	131.8	717.3	342.0	49	160
Kenya	11.8	1.5	24.6	6.4	109	328
Mali	4.9	0.8	8.7	2.6	76	237
Mexico	21.8	37.4	28.7	103.6	32	177
Mozambique	8.7	0.6	15.3	2.3	77	300
Niger	4.2	0.4	7.9	1.6	90	283
Nigeria	51.5	11.4	94.0	40.9	82	259
Pakistan	51.6	19.0	84.6	62.3	64	228
Paraguay	1.7	1.0	2.6	2.6	59	167
Rhodesia	5.0	1.2	10.1	5.0	100	309
Senegal	3.2	1.3	4.7	3.5	48	179
Sudan	15.9	2.4	30.0	8.9	89	271
Tanzania	14.4	1.0	29.8	4.25	107	307
Thailand	35.1	7.0	62.2	23.4	77	236
Upper Volta	5.5	0.5	9.2	17	67	244
Zambia	3.2	1.8	4.6	7.0	44	280

a. Source: FAO, based on data a few years old. More recent figures would probably generally show slightly lower percentage Increases, but without affecting orders of magnitude. Percentages are based on the original figures which were in thousands, and which have here been rounded to millions to one decimal place. Brazil has not been Included because much less than half Its area is in the SAT. Its percentage increases for the country as a whole are, however, estimated at only 13% rural (44.5 million to 90.3) and 149% urban (65.3 million to 162.2).

of the SAT countries are projected by the FAO to increase in average of about 58% between 1975 and 2000. Percentage rates of increase of rural populations in the SAT are estimated to be generally lowest in Central and South America (Mexico 32%, Bolivia 43%), with Asia higher (India 49%, Pakistan 64%, Thailand 77%), and West and East Africa highest (Nigeria 82%, Ethiopia 70%, Tanzania 107%, Kenya 109%). Since these are national averages, some local and regional increases will be higher. Locally, too, resources will be augmented (as through irrigation, forestry, imported inputs such as chemical fertilizer) or diminished (as through depletion of groundwater, removal of forests, declining soil fertility, and soil erosion). There may be a widespread phenomenon of poorer people, as in parts of Kenya (Mbithi and Barnes 1975; Johnston 1979), migrating into lower rainfall and fragile environments, which they then degrade irreversibly with the possibility of a later backwash of refugees returning to densely populated higher potential areas.

The third assumption is that there is room for maneuver in setting R & D priorities and in decisions taken during the R & D process, and that more room could be made. This is a controversial point. On the one hand, we have the experience of market and institutional forces combining to give priority and resources to research that benefits the better-off and that has often concentrated on commodities for export. We have examples of pressures from commercial producers for research that favors their interests but may not favor the smaller farmers (e.g. Sanders 1979). We have the theory of induced innovation that sees innovation as a response, albeit sometimes lagged, to factor proportions and prices (Ruttan 1977). But on the other hand, research institutions in the public sector are to varying degrees insulated from political pressures. The international research institutes, more than most, have discretion or mandate to give priority to the interests of those rural people who are without voice and who are unable to make demands upon research. They are also well-placed, through their prestige and their training programs, to strengthen new professional values and to influence the incentives arid rewards in national research systems that induce priorities and affect behavior among other scientists. Further, in the "post-green revolution" period, there is now heightened awareness of the social and economic implications of research decisions. This should extend the room for maneuver in using R & D as a means for conscious social engineering.

These three assumptions bear on the question of how to optimize decisions and action in R & D . Questions can be asked about three clusters of points:

- modes of thought, values and criteria
- future orientation
- professionalism and priorities.

Modes of Thought, Values, and Criteria

Introspection is a first step. How have we been programmed to think about research? What points of departure and modes of thought are dominant? The words used in discussion reflect implicit priorities and direct attention in some directions rather than others. For example, what meanings are likely to be attributed to the word "development" when it is set in the phrase "socioeconomic constraints to development of semi-arid tropical agriculture?" Is it rural development as defined in the World Bank Sector Paper on Rural Development?

> Rural development is a strategy designed to improve the economic and social life of a specific group of people — the rural poor. It involves extending the benefits of development to the *poorest* among those who seek a livelihood in the rural areas. The group indudes small-scale farmers, tenants and the landless. (World Bank 1975 : my emphasis)

Or is it increasing agricultural production? Or does it mean different things to different people, or different things to the same people at different times, in different contexts?

Much of the literature, especially in agricultural economics, tends to equate development with agricultural production. People are treated as resources rather than users of resources, as constraints rather than purposes, as means rather than ends. Discussing poverty we then talk clinically about the low productivity of human resources, underutilization of labor resources in rural areas (Ruttan 1977, pp213, 215), and even the efficiency loss to society of human capital deterioration (Sanders 1979, p 16). People are quantified as labor, as faceless figures in factor proportions. All this has its uses; without careful numerate analysis good decisions would be harder. But the dangers are also great. Those most in need-the poorest-may be treated as a residual rather than as a primary focus, and technical euphemisms such as "underutilized labor resources" and "human capital deterioration" may hide acutely deprived people.

If people are the starting point, then they should come first in lists of criteria for ex-ante appraisal of prospective technologies. There is, of course, much scope for argument here about direct and indirect benefits to the poorer people. The issues are not simple. But in terms of the World Bank definition, there is a case for ex-ante analysis that starts with all the people in a given environment, including and especially the poorest and the landless. It can be misleading to suggest that "the farmers with tiny landholdings" are "the poorest of the poor."[1] They may be; but often they are not.

Starting with people, a key priority is the creation of adequate livelihoods. Where these are not already adequate, a criterion becomes the net livelihood-intensity of prospective technology in a receiving environment. Livelihood-intensity here is the extent to which a technology would generate or sustain livelihoods at or above an acceptable level. It is not the same as labor-intensity. The livelihood-intensity of a technology is not constant; it is specific to an environment and is sensitive to seasonalities. For example, a technology that provided food or income flows for poor people during lean periods of the year so as to push them above a minimum for the whole year would, in the environment concerned, have a high livelihood-intensity. The *net* livelihood-intensity is specified because a new technology usually displaces an old one that was already generating and sustaining livelihoods.

In practice, however, where does thinking about research priorities start? How often, and in what circumstances, does it start with the poorer people in a rural environment and their interests and their futures? Does such thinking in practice start from other points and ask other questions, starting with a crop, or a farm system, or a mechanical technology, or a problem (a pest, a water deficit, salinity, a "constraint"), and proceed through the avenues of technical analysis, or technical plus economic analysis? Does it approach actual people only through the analysis of factor proportions and prices and the underutilization and low productivity of human resources? Do such formulations run the risk of making things worse for some of the poorer people? Are opportunities missed to improve the lots of poorer people?

Future Orientation

In the theory of induced innovation, research responds to changing factor proportions. There is a process of dynamic adjustment to changing relative factor prices (Ruttan 1977). In this adjustment there may be time lags, sometimes of decades. Thus factor proportions and prices change first, and priorities follow later. Koppel, however, has argued that assessment of technology should be future-oriented (1978, pp 6-7). By this he means that it should anticipate the consequences of prospective decisions, rather than be an exercise in forecasting. This may not go far enough.

Forecasting has been discredited to the point that the word "futurology" is used with disdain. Perhaps this is in part because the arrogance of futurologists has been matched so often by the enormity of their errors. It has, however, been practiced mainly in fields of complex and rapid change and of high uncertainty, and mainly in the rich countries; in Third World countries it has concentrated on urban and industrial development, again areas of relatively high uncertainty. But are changes in population, in relative factor proportions, and in technology in rural

1. Quotation from statement prepared by Dr. Sterling Wortman, Vice-President, Rockefeller Foundation for two Subcommittees of the US House of Representatives, 23 September 1975, quoted in Sprague 1976. The full relevant part of the quotation in Sprague is: "The bulk of the basic food supplies of the agrarian nations are produced by the many farmers with tiny landholdings, often in remote and isolated areas, plus those people in coastal areas who depend upon near-shore fisheries and aquaculture for a livelihood. For the most part, the gains in productivity and income of these rural people-the poorest of the poor-will require the development for and use by many farmers of new high-yielding, science-based crop and animal production systems tailored to the unique combination of soil, climate, biological, and economic conditions of every locality in every nation."

areas in the SATs as uncertain? Might a guess at the rural population in a SAT region in the year 2000, say, inspire more confidence than a guess at the anti-anti... missile-missile technology of the same year? And might it be made with much less expensive research? If so, it may not be too difficult to be ahead of the game. Environment by environment, future endowments and proportions could be estimated and, at the very least, directions of change identified. Research priorities might then be reviewed, bearing in mind probable gestation periods for setting up institutions, recruiting staff, conducting R & D, and then enabling and allowing diffusion. Instead of waiting for factor proportions to change, the approach would be to anticipate their change, and thereby to help generate adequate future livelihoods.

Professionalism and Priorities

It is easy to add research objectives to lists of criteria. Technical scientists cannot be uniformly pleased with their social science colleagues for having made decisions more complicated. Suggesting that adequate livelihoods should be placed at the center of research objectives for many environments, and that priorities should follow from environment-specific and future-oriented analysis, may appear to be the last straws. Agricultural scientists and engineers may sometimes despair at the failure of some social scientists to understand the nature of their work. Social scientists, it may seem, have compulsions to multiply criteria; no sooner is one set met than another is added, so that the technical scientists can never win. In suggesting any new criteria, there is an obligation to see if, at the same time, decision-making and research can be made more manageable. Four complementary suggestions follow. All would bring scientists closer, in thinking and understanding, to rural people and rural environments.

First, research might generally move physically closer to and into rural environments and be carried out in closer collaboration with rural people. Some activities are best carried out under controlled conditions on research stations; others are most efficiently carried out with farmers as collaborators and evaluators (Hildebrand 1977, pp 14-15). Biological research can be viewed along a spectrum from very basic research in supportive sciences, such as genetics, to very applied operational research on farmers' fields (Binswanger and Ryan 1977, p 221). There are institutional, professional, and personal reasons of convenience that tend to concentrate personnel and resources at the basic research and research station end of the spectrum. The high returns to agricultural research suggest that resources devoted to it should be expanded. Much recent experience suggests that that expansion should coincide with and reinforce more decentralization of research, moving a higher proportion of scientists closer to the rural environments to which their research should relate, and in which much of it should be conducted.

Second, cost-effective rural appraisal might be developed much more systematically as a subject. Rapid appraisal of rural situations is widely practiced but not much written about.[2] Authors are coy about describing the way they find out about rural situations when time is short. Yet rapid rural appraisal is very widely undertaken and its methods are continuously being improved by practitioners; but they lack the respectability of elephantine surveys or profound participant observation. They are described apologetically as "quick and dirty" when in practice much conventional rural research is inefficient — "long and dirty" — and much rapid work is "quick and clean." Ladejinsky, for example, identified the adverse distributional effects of the "green revolution" on brief field visits in India (Ladejinsky 1969a, 1969b, cited in Clay 1978), years before expensive, extensive surveys came up with the same findings to two (spurious) decimal points. There is much potential here for new methods of learning from rural people, for example through repertory grid techniques (Richards 1979) and appropriate methods of quantification (Barket 1979). Armed with cost-effective "quick and clean" methods of learning from rural people

2. See, however, the papers of the Workshop on Rapid Rural Appraisal, Institute of Development Studies, University of Sussex, November 1978. See also the work of Belshaw (1976), Biggs (1978), Collinson (CIMMYT 1977, 1978) and Hildebrand (1978), and forthcoming from CIMMYT, "Planning Technologies Appropriate to Farmers' Circumstances: A Manual of Procedures."

and about rural situations, technical and social scientists engaged in R & D should be able to short-circuit long channels of noncommunication and should be able to experience and learn for themselves much more directly.

Third, changes might be made in professional reward systems for researchers, relating these to desired behavior. Some of the most serious socioeconomic constraints to development are in ourselves, the elite professionals who write papers and conduct research. What are the things we do not see, understand or do because of our conditioning, motives, and lifestyles? It is easier to ask this question than to answer it; and the writer makes no pretense to any virtue on this score. But perhaps more could be done through rewards to those scientists who pioneer new methods that truly serve the poorer people, who work on subjects of low prestige, and who work in creative partnership with rural people.

Finally, there is the question of who does what. If war is too important to be left to the generals, as Clemenceau believed, social scientists have also been right in arguing that agricultural and mechanical R & D is too important to be left to technical scientists. The most common, and desirable, response has been to add social scientists to the staffs of research institutes and stations, and sometimes they are involved in research decisions. But the social and economic implications of prospective technologies seem too important to be left just to the social scientists. Multidisciplinary collaboration has its uses and its place. It is especially vital in determining research priorities and the allocation of research resources. But it also has its well-known difficulties and costs. The Duchess in Alice in Wonderland might have been speaking for many who feel that the involvement of many disciplines slows up decisions and action. At the same time, the social and economic implications of new technology are so great that technical scientists cannot wash their hands of them: it is the irresponsibility, in part, to see "where the rockets come down." Perhaps solutions can be sought in all professionals becoming more truly multidisciplinary, in social scientists learning to think more like technical scientists, in technical scientists learning to think more like social scientists, and in all alike working with and learning from those true multidisciplinarians, the rural people themselves.

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Chairman's Summary

J. L. Dillon*

Three papers were presented in the session. The paper by Fall pertaining to Senegal emphasized that while some new techniques were available, their acceptance by farmers was low. Lack of adequate marketing and credit facilities were identified as critical constraints. Ryan et al. presented an analysis of improved soil and water management and watershed technologies being researched at the ICRISAT Center. Analysis of steps-in-improved technology, runoff simulations, and watershed-based supplementary irrigation systems yielded some useful guidelines about research strategies and also the cost-effectiveness of new techniques. The paper by Sanders examined the rationale, possibilities of adoption, potential economic impact, likely constraints in adoption, and consequent policy needs of improved sorghum technology in Northeast Brazil.

The discussion covered four broad areas. First, several *methodological* issues were raised. For example, it was pointed out that economic evaluation of prospective technologies should be based on a range of possible input-output prices and not on current or single-valued prices only. The importance of conducting sensitivity analysis was emphasized. Similarly, since risk is such an important characteristic of the SAT environment, economic evaluation should incorporate this fact. The usefulness of activity analysis and programming techniques in ex ante evaluation was also pointed out.

The other point repeatedly emphasized was the crucial importance of testing on farmers' fields and village-level trials. While .there was no difference of opinion regarding this need, some participants expressed the fear that unless professional biases were overcome and the reward and incentive systems for scientists underwent a drastic change, the real purpose of such "testing" on farmers' fields would not be served.

The importance of incorporating needed policy and institutional changes in economic evaluation of prospective technologies was also strongly emphasized. It was felt that even though these often involve political considerations, it would be useful to spell out constraints in this area. Price policies for output and inputs, as well as marketing and credit institutions, were repeatedly mentioned as important in this context.

The need to analyze likely effects of technological change on income distribution was stressed by several participants. The difficulties in such analyses were pointed out but the group felt that, to the extent possible, this should be attempted.

It was also pointed out that the evaluation work should also include the realities of "differential access" to factor markets of farmers in different size categories. The importance of offering a range of improved technological options rather than a single "package" was considered relevant in this context.

The main conclusions were as follows:

1. *Technology design.* It was felt that there is a need to learn from, and take advantage of, elements of farmers' present practices. This should be used as the starting point for any research. Greater stress is needed on the ex ante economic evaluation of prospective technology.

2. *Agricultural policy.* Economic evaluation of prospective technology should include discussion of the constraints imposed by existing policies being pursued by governments and also by the existing rural institutional infrastructure. Inter alia, it must indicate needed changes in these directions.

3. *Future socioeconomic research in national programs.* Large-scale field trials on farmers' fields were identified as a major need.

4. *Future socioeconomic research at ICRISAT.* Using ICRISAT's own prospective contributions to technology as case examples, ICRISAT should aim to develop methodologies oriented to the ex ante design and evaluation of new technologies so that these methodologies may be available to national programs.

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Chapter 3

Socioeconomic Field Assessment of Prospective Technologies

Socioeconomic Field Assessment of Dry Farming Technology in the Indo-UK Project, Indore (India)

Ashok K. Chaudhari*

Abstract

This paper describes the effects of the introduction of improved soil-, water-, crop-, and livestock-management technology on Vertisols in the Indo-UK Project at Indore, Madhya Pradesh, India. Since 1974, when the project began, farmers on the 2000 ha area have markedly increased their adoption of HYVs of sorghum, wheat, and chickpea and have begun growing soybeans and maize as new crops. The area under kharif (rainy season) crops has risen substantially during the past 4 years from 32% of the gross cropped area to 54% in addition to a tenfold increase in the area double cropped. Along with increased use of fertilizers and irrigation, these changes have increased crop yields by 30 to 500% and net returns per hectare by an average of more than 170%. The technology has been labor and bullock intensive and this has favored small farmers who have much higher man|land and bullock|land ratios than large farmers.

The Malwa region, in which Indore District fails, is characterized by an annual average rainfall of 980 mm and heavy Vertisols (black soils). It has not responded very enthusiastically to the adoption of new dryfarming technology. Still in vogue is single cropping, mostly in the *rabi* (postrainy) season on limited stored moisture and very little use of fertilizer, coupled with traditional farm practices and continuance of outdated implements. This is mainly because of the farmer's fear of greater risk in the adoption of *kharif* (rainy season) cropping and the cost of modern inputs such as fertilizers, high quality seed, and plant protection chemicals. His fear has been reinforced by unsatisfactory soil- and water-management practices previously recommended.

The average size holding in the Indore area is about 6.9 ha, but scattered holdings with low production have posed management and investment problems. The investment on inputs such as fertilizer is low because of the very small proportion (9%) of net cultivated area receiving assured irrigation.

Research work conducted by the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) main center at Indore since the *rabi* of 1970-71 has resulted in development of a dryland technology which, if applied to farmers' fields, will completely change the condition *of barani* (dry) farming. However, there is a large gap between the average yields of experimental plots and farmers' fields.

This project was started during late 1974 on a net cultivated area of some 2000 ha. Its objective is to bring about development of farming on a catchment basis after utilizing all available resources. The project seeks to increase land productivity by adoption of advanced technology in land improvement, soil and water conservation, crop husbandry, animal husbandry, exploitation of underground water, etc.

There are four facets of the actions through which the project seeks to transfer the technology suited to this dry farming area:

1. land husbandry, including a soil and water management program,
2. cropping program,
3. livestock management program, and
4. farm machinery program.

The main task of the farm economics discipline is to monitor agroeconomic data emerging from the various implemented programs and estimate the periodic changes in investment and returns of individual farms. Socioeconomic assessment has been made of:

1. benefit to and participation of small farmers,

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2. adoption among farmers,
3. changes in cropping patterns,
4. changes in irrigated areas,
5. overall indications of project-induced changes.

Before we proceed to socioeconomic assessment, it is imperative to focus on what has been done through various programs to improve the productivity of agriculture and livestock. Though no estimation has been made of monetary gains to each program, they all have contributed significantly to better returns from crop and dairy enterprises.

Soil and Water Management

Various activities have been undertaken in soil and water management, mostly on community land, but also on individual plots where a group of farmers have agreed to the program.

About 6 km of storm drains were constructed to protect 390 ha of land from erosion. Grassed waterways of 10 km were constructed to drain water from 736 ha. In waterway bed stabilization and gully reclamation 15 gabion structures were constructed on waterways and have worked successfully during the rainy season.

These measures have improved overall drainage and minimized soil erosion over some areas and helped eliminate water stagnation along some bunds.

Cropping Program

Several measures have been adopted under this program to improve the productivity of farmers' land — namely, a change in varieties of popular crops, introduction of more remunerative crops and replacement of *kharif* fallow by crops. It has been the policy of the project to give special consideration to small and medium-sized farms. Some examples of these measures are:

- Change in varieties of already popular crops. Sorghum hybrid CSH-5 was planted on 300 ha during 1978-79. In *rabi,* high-yielding and improved varieties of wheat (Kalyan sona, RR 21, Narmada-4, and Narmada-112) on 364 ha and chickpea (Ujjain-24) on 365 ha were planted during the crop year 1977-78 on the advice of project scientists.
- Introduction of new crop varieties. Soybean (T49, JS 2, and Ankoor) on 224 ha and maize (Chandan 3 and Ganga 5) on 89 ha were planted during *kharif* 1978-79. These crop varieties are new to this area and are quite remunerative.
- Replacement of *kharif* fallow by crops. On 1800 ha of cultivated land, the area under *kharif* crops has increased from 32% of gross cropped area in 1973-74 to 54% during 1977-78.
- Double cropping. Farmers practiced double cropping on 244 ha in 1975-76, on 420 ha in 1976-77, and on 744 ha in 1977-78. Before 1975-76, the double cropped area was only 72 ha.
- Increased use of fertilizers. The quality of fertilizer nutrients applied by farmers has increased progressively (Table 1).

Table 1. Use of nutrients in Indo-UK Dry Farming Project area.

	Nutrients used (kg)		
Year	N	P_2O_5	K_2O
1974-75	4 260	3 326	712
1975-76	15931	10 630	648
1976-77	14714	10 832	1090
1977-78	16 630	10 845	840

These measures on the part of the cropping program have increased the land productivity considerably, mainly through crop-variety substitution, fertilizer application, and stability in area coverage (Table 2).

Fodder crop yields also have been increased. Vidisha 60-1 and J-69 varieties of sorghum fodder, berseem, oats, and a new fodder crop — feosinte *(Euahlaena mexicana)* — have been introduced in the project area to improve livestock management. All have higher yield potential (Table 3). Thus the crop husbandry scientists have helped farmers to raise better crops and double production — especially in the *kharif,* — maintain better livestock, and realize higher returns through enhanced land productivity.

Table 2. Crop yields before and after the Project.

Crop	Before Project (1973-74)		After Project(1977-78)		
	Variety	Average yield (kg/ha)	Variety	Range (kg/ha)	Average yield (kg/ha)
Sorghum	Local	430	CSH-5	1200-4300	2020
Maize	Satna	550	Chandan-3	1000-2400	1500
Soybean	Kalitur (black)	550	T-49	650-1150	750
			JS-2	800-1350	820
Wheat (rainfed + irrigated	Local + Mexican	500	Narmada-4 Malawraj	N.A.[a]	630
Chickpea	Local	450	Ujjain-24	N.A.[a]	630

a. Not available.

Table 3. Improved fodder crop yields in Indo-UK Dry Farming Project area.

Fodder Crop	Average yield green fodder (metric tonne/ha)
Sorghum Vidisha 60-1 + Cowpea	41.5
Sorghum j-69	51.8
Berseem + Oats	124.3
Lucerne + Oats	81.2

Livestock Management Program

The project's effort has been to improve livestock to actively complement productivity of the land by applying more organic matter in the soil, raising better young stock to augment farm power, and improving milk animals. The following three main activities were undertaken:

1. Feeding greens to yield more milk. Based on observations of 27 cows and 56 buffaloes, an average increase of 400 ml in daily milk production per cow (ranging from 1.3 to 1.5 liters) and of 650 ml per buffalo (ranging from 3.2 to 3.8 liters) were noted as a result of feeding greens.
2. Breeding. In all, there were 92 local cows inseminated with Jersey semen and 21 she buffaloes with murrah bull semen, besides natural service of 79 she buffaloes.
3. Health coverage. Animals of the area were protected against seasonal contagious diseases through vaccinations in addition to treatment for minor ailments.

The idea behind operating the livestock program was to minimize the risk of failure of the single-crop enterprise and to provide farmers with a stable source of income.

Farm Machinery Program

The contribution of this discipline to project farmers has not been very significant. Only one survey — the field activity survey — was conducted to assess the use of time by human labor for various field operations. The study revealed that in most of the field operations, after every 45 to 60 minutes of work farmers take 10 to 15 minutes rest, reflecting the hard labor involved. This reduced the actual working hours to only 6 or 61/2 in an 8- to 10-hour working day. Besides drudgery, work is constrained by weather and soil conditions. "Dufan" and "Phadak" implements allow fairly rapid sowing but need two or three laborers to operate them. Availability of tractor power is only about 0.1 hp/ha in the farm-size groups above 4 ha, demanding use of alternative tractor power sources.

Approach to Execution of Programs

The project approach, especially in land husbandry, was to work with the approval of farmers. When the farmer objected, we did not undertake the work; nor did we attempt to use force (through the state law on land improvement). With any new practice related to soil and water management, cropping program, or livestock management, farmers were first shown the usefulness of the new practices and then convinced of their suitability.

Input subsidies in various forms were given to participating farmers. Particular care was taken to include small farmers to the extent possible. Subsidies in the beginning on items such as hybrid/improved seed, fertiliser, and plant protection chemicals were withdrawn gradually so that farmers were able to build their economy through their own efforts. Until the 1978-79 *kharif,* small farmers (< 2 ha) were provided free seed whereas for others it was on an exchange basis. This measure has developed a sense of self-reliance among the majority of farmers.

Benefit to and Participation of Small Farmers

This project, unlike many other developmental projects, has especially benefited small farmers owning up to 2 ha, and the number of such participants is quite high. In the beginning, land productivity was low for small farmers, even though they used more human labor per hectare than large farmers. The obvious reason was their very limited investment capacity.

An attempt was made to estimate the intergroup variations in the yield level of important crops for the year 1976-77. About 35% of the total farm holdings were taken into consideration (Table 4). Average yield levels have an inverse relationship to the size of holding. In general, small farmers (up to 2 ha) obtained the highest yields of crops and also raised two sequential crops on most of their holdings. This was because small farmers have more human labor (6.8 family members per ha) and bullock power (1 pair of bullocks for 1.8 ha of land) compared with large farmers (>12 ha) who have 0.6 family members per ha and 1 pair of bullocks for each 10.1 ha of land (Table 5). The dryland technology's requirement of more tabor thus is better suited to small and medium-sized farmers.

The figures in Table 6 show the number and percentage of participating small farmers in the crop program during 1978-79.

Adoption of Improved Practices by Farmers

This was a common program agreed to by the Indo-UK Dry Farming Project and the coordinating cell of the AICRPDA in Hyderabad. The prime aim of this study was to ascertain to what extent farmers adopt feasible and viable recommendations and their motivation for doing so, thus determining pre-requisites necessary to bring needed changes in agriculture. In all, 72 farm families (20% of the population) were studied during 1975-76 and 137 farm families (38% of the population) during 1976-77. Size groups of holdings were made in accordance with instructions from the Coordinating Cell of AICRPDA as follows: below 1.0 ha, 1.1-2.0 ha, 2.1-4.0 ha, 4.1-8.0 ha, and in excess of 8.0 ha. Six crops — maize, soybean, sorghum, wheat, chickpea, and sugarcane — were included in the study to estimate the extent of adoption during 1975-76 and all but sugarcane during 1976-77.

Adoption during 1975-76

Sampled farmers had 434 ha under crops. Of this, only about 43% was planted to high-yielding improved local varieties.

The maximum use of fertilizer was observed among farmers in group 1.1 to 2.0 ha (15.6 kg/ha N and 11.2 kg/ha P_2O_5) followed by the largest size group (14.7 kg/ha N and 10.4 kg/ha P_2O_5). Soils of this area are not deficient in potash; therefore, farmers seldom apply any quantity of this nutrient.

The analysis of the level of fertilizer use indicated that farmers are still applying imbalanced doses of fertilizer nutrients, and they need to be educated on this aspect. Farmers with holdings of more than 4.0 ha in many cases applied between 50 and 100% of the recommended doses of nutrients, whereas smaller farmers generally applied less than 50% of the recommended doses, reflecting their financial inability to invest.

Most farmers adopted only two practices: improved high-yielding seed and fertilizer. Significant adoption occurred in maize, chickpea.

Table 4. Variation in the average yield levels across farm size groups (1976-77).

Size-group (ha)	*Phaseolus* (Urd) No. of obs.	Area (ha)	Average yield (kg/ha)	Hybrid sorghum No. of obs.	Area (ha)	Average yield (kg/ha)	Local sorghum No. of obs.	Area (ha)	Average yield (kg/ha)
Below 2.0	4	4.35	210	2	0.90	1780	11	11.44	420
2.1-40	3	3.00	30	3	3.55	1660	10	9.85	380
4.1-8.0	12	13.50	190	-	-	-	25	35.47	490
8.1-12.0	3	4.75	70	1	0.50	1400	6	12.75	250
12.1 and above	13	39.25	130	4	4.30	1460	25	92.95	260
All Groups	35	64.85	140	10	9.25	164	77	162.46	330

Size-group (ha)	Maize No. of obs.	Area (ha)	Average yield (kg/ha)	Black soybean No. of obs.	Area (ha)	Average yield (kg/ha)	Groundnut No. of obs.	Area (ha)	Average yield (kg/ha)
Below 2.0	10	4.04	1110	2	1.00	850	1	0.60	80
2.1-4.0	9	4.60	450	4	4.60	840	2	1.05	2810
4.1-8.0	15	9.15	360	7	11.25	640	3	0.85	1800
8.1-12.0	6	2.19	880	2	0.75	670	-		-
12.1 and above	15	12.35	460	8	10.90	520	6	3.55	450
All Groups	55	32.33	540	23	28.50	630	12	6.05	1010

Size-group (ha)	Wheat (irrigated) No. of obs.	Area (ha)	Average yield (kg/ha)	Wheat (unirrigated) No. of obs.	Area (ha)	Average yield (kg/ha)	Chickpea No. of obs.	Area (ha)	Average yield (kg/ha)
	11	10.50	2110	14	9.82	790	13	11.60	430
Below 2.0	13	15.90	1710	8	8.15	730	14	12.81	500
2.1-4.0	17	31.80	1380	23	51.85	660	34	71.45	210
4.1-8.0	4	8.25	1760	8	15.75	530	9	24.30	150
8.1-12.0	15	49.90	1860	28	159.40	590	28	133.35	190
12.1 and above	60	116.35	1720	81	244.97	610	98	253.51	220

and wheat. In maize, 10% of the farmers adopted high-yielding seed, covering 10 to 40% of their area; about 11% fertilized their area. In chickpea, about 13% planted improved seed and 17% fertilized their crop. Wheat was the most popular crop in terms of adoption, with 30% of the farmers planting the recommended seed variety in 10 to 40% of their cropped area. More than 54% applied fertilizer on 40 to 50% of their wheat area.

Reasons for nonadoption were given as: the costly nature of seed and fertilizer input, capital shortage, risk of possible losses, nonavailability of suitable seeds, poor cooking quality of the produce, and unawareness of the methods of hybrid seed cultivation, fertilizer application, and plant protection.

Five farmers under 25 years of age, 28 farmers of the 25 to 50-year age group, and 18 above 50 all cited lack of capital as a major constraint to adoption. Four farmers were not at all convinced about the new technology.

Ten illiterate, 1 literate, and 29 farmers with primary school education cited lack of capital as

Table 5. Availability of bullock power (1976-77) in Indo-UK Project area.

Size-group (ha)	Total No. of farms	Total operated area (ha)	Average size of holding (ha)	Total No. of bullock pairs	Operated area covered by a pair of bullocks (ha)	Bullock pairs/ha of land (5/3)	Bullock pairs/farm (5/2)
Below 2.0	31	30.89	1.00	17	1.8	0.55	0.55
2.1-4.0	26	81.36	3.13	21	3.9	0.26	0.81
4.1-8.0	46	277.88	6.04	48	5.8	0.17	1.04
8.1-12.0	16	153.16	9.57	21	7.3	0.14	1.31
12.1 and above	28	564.33	20.15	56	10.1	0.10	2.00
Village	147	1107.62	7.53	163	6.8	0.15	1.11

Table 6. Participation by small farmers in crop program.

	Small farmers[a]		Other farmers	
	(no.)	(%)	(no.)	(%)
Sorghum CSH 5	40	14	252	86
Maize Chandan 3	13	41	19	59
Ganga 5	7	13	46	87
Soybean T 49	15	13	101	87
JS 72-44	6	30	14	70

a. Percentage of small farmers to total farmers is about 16.

the main reason for nonadoption, whereas 3 literate and 3 primary school-educated farmers were not satisfied about the superiority of the technology. Four primary school educated farmers said difficulty in marketing their produce was the reason for nonadoption.

Adoption during 1976—77

Sample farms covered 729 ha of the net cultivated area. Double cropping was done on 197 ha, indicating a cropping intensity of 127%.

Seed. Of the five crops included in the study, chickpea and wheat alone covered two-thirds of the area under recommended seed varieties. Chickpea covered the largest cropped area (17.6%), followed by wheat (13.9%) (Table 7). Among the five size-groups, the highest percentage adoption was in the 1.1 to 2.0-ha group; adoption declined with increased size of holding.

Fertilizer. Of the 927 ha cropped area, only 350 ha (37.8%) was fertilized. The percentage share of various crops in the fertilized area was: wheat, HYV/improved, 40.1; wheat, local, 13.0; sorghum HYV 10.3; soybean, 9.6; chickpea, 8.7; and maize, HYV 7.2. The rest of the 11.1% fertilized area was in local sorghum and other crops not included in the study (Table 8).

Highest adoption of fertilizer was observed in the case of the smallest size-group (48.2% cropped area fertilized) followed by size-group 5 (44.7%), size-group 3 (38.4%) and size-group 2 (32.1%). Percentage of fertilized area was highest in the smallest size-group because they have much less area to cultivate and fertilize (Table 9). This confirms our earlier contention that smaller farmers are adopting dry farming technology in increasing numbers.

Consumption of N per hectare was found highest (18 kg) in size-groups 1 and 3, followed by 14.7 kg in size-group 4 (Table 9). Application of P_2O_5 was highest in size-group 1 (12.1 kg), followed by size-group 3 (10.0 kg).

Among the six crops, nitrogen application was highest on sugarcane (81.0 kg/ha), followed by vegetables (70.8 kg/ha), wheat HYV (50.8 kg/ha), and sorghum HYV (33.5 kg/ha).[1] P_2O_5 application was highest on sorghum HYV (50.1 kg/ha), followed by improved chickpea (26.8 kg/ha). Almost every farmer indicated lack of capital as the main constraint to use of fertilizer. About one-third expressed their lack of awareness of suitable crop varieties. A few farmers

1. Gross cropped area.

Table 7. Adoption of recommended teed, 1976-77.[a]

Crop	Size-group (ha) Below 1.0 1	1.1-2.0 2	2.1-4.0 3	4.1-8.0 4	8.1 and above 5	All Groups
Sorghum	1.33	1.85	4.33	6.95	26.01	40.47
	(7.9)[a]	(3.5)	(4.0)	(3.3)	(4.8)	(4.4)
Maize	1.27	1.17	2.43	3.35	7.07	15.29
	(7.5)	(2.2)	(2.2)	(1.6)	(1.3)	(1.6)
Soybean	0.18	5.39	11.22	24.97	33.00	74.76
	(1.1)	(10.1)	(10.3)	(11.9)	(6.1)	(8.1)
Wheat	2.75	10.18	26.48	37.17	52.50	129.08
	(16.3)	(19.1)	(24.3)	(17.6)	(9.8)	(13.9)
Chickpea	2.82	12.89	13.12	36.87	97.20	162.90
	(16.7)	(24.2)	(12.1)	(17.5)	18.1)	(17.6)
Total	8.35	31.48	57.58	109.31	215.78	422.50
	(49.5)	(59.1)	(52.9)	(51.9)	(40.1)	(45.6)

a. Figures in parentheses indicate percentage to total cropped area.

expressed their doubts about the superiority of some improved HYVs.

One significant fact observed in the case of fertilizer consumption was that quantity of nutrients applied per hectare has increased over the year 1975-76. This led to better crop yields in 1976-77.

Change in Cropping Pattern

It has been the main emphasis of the soil- and water-management program to provide maximum soil cover through *kharif* cropping to minimize soil erosion and save the upper fertile stratum of the soil. Through project innovations, the percentage *of kharif-cropped area* has increased from 30.8% of total cropped area in 1974-75 to 49.4% in 1977-78. The increase in rainy season crop hectarage that this represents is over 200% (Table 10). More *kharif* cropping has increased not only the average net earnings of farmers, but also helped in building a more fertile upper soil stratum. Some of the increased (nonirrigated) *kharif* crop area has been at the expense of a reduction in the area of (nonirrigated) *rabi* crop area, which fell by 18%.

Table 8. Adoption of fertilizer, 1976-77.

Crop	Area sown <ha)	Area fertilized (ha)	Percentage cropped area fertilized (%)
Sorghum HYV	40	36	89
Sorghum local	131	16	12
Maize HYV	15	13	88
Maize local	28	18	63
Soybean	75	34	45
Wheat HYV/IMP	129	121	93
Wheat local	203	46	23
Chickpea	231	30	13
Total	852	314	37

Change in Irrigated Area

Various activities in soil and water management to improve the drainage conditions and in the cropping program to grow better crop varieties suitable for rainfed conditions have tempted farmers to invest in constructing open wells and lift equipment to provide at least one or two light irrigations *for rabi* crops such as wheat and vegetables, for which moisture supply is considered to be very critical. The number of such wells has increased from 130 in 1973-74 to 186 during 1977-78, increasing the area under assured irrigation from 172 ha to over 254 ha. This is an increase of about 48%. Of the increased irrigated hectarage, more than 80% has gone

Table 9. Adoption of fertilizer, 1976–77 (Total consumption in kilograms).

Crop	Size-Group (ha) Below 1.0 N	P	1.1–2.0 N	P	2.1–4.0 N	P	4.1–8.0 N	P	K	8.1 and above N	P	K	Per hectare actual consumption N	P	K
Kharif															
Sorghum local	–	–	–	–	65	42	59	129	–	51	65	–	10.9	14.7	–
Sorghum HYV	23	–	55	60	89	195	273	321	–	766	1226	–	33.5	50.1	–
Maize local	3	3	–	–	23	–	79	191	–	140	14	–	13.9	11.8	–
Maize HYV	106	35	18	46	101	23	55	23	–	318	124	–	44.5	18.7	–
Soybean	–	–	104	35	112	136	227	281	–	227	186	–	19.8	18.9	–
Other kharif	–	–	–	–	–	–	5	12	–	–	–	–	2.0	4.8	–
Total Kharif	132	38	177	141	390	396	698	957	–	1502	1615	–	24.3	26.3	–
Rabi															
Wheat local	16	33	–	–	84	49	328	166	–	650	413	–	23.6	14.5	–
Wheat HYV / Wheat Improved (irrigated)	142	100	64	185	1435	615	1873	463	–	2609	1283	60	50.8	21.9	0.5
Gram Improved	13	32	36	74	28	28	99	197	–	189	483	–	12.0	26.8	–
Sugarcane	–	–	35	–	23	–	46	–	–	69	92	–	81.0	15.0	–
Vegetables	–	–	–	–	–	–	46	–	75	–	–	–	70.8	–	115.4
Total Rabi	171	165	135	259	1570	692	2392	826	75	3517	2271	60	37.8	20.5	0.6
Per Hectare[a]	19.2	5.5	6.4	677	7.5	7.6	8.3	11.4	–	8.2	8.8	–	–	–	–
Ave. Nutrient[b]	17.2	16.5	4.2	8.1	27.6	12.1	18.9	6.5	0.6	9.9	6.4	0.2	–	–	–
Consumption[c]	18.0	12.1	5.9	7.5	18.0	10.0	14.7	8.5	0.4	9.3	7.2	0.1	–	–	–

a. Kharif; *b.* Rabi; *c.* Total.

into wheat alone, and the rest into vegetables and other *rabi* crops.

Farm Business Analysis

As revealed by Table 11, significant changes have occurred in operational charges, gross income, and net income. The level of investment and return declined during 1974-75 because of adverse climatic conditions and a poor harvest. The changes in input and operational costs per hectare may not appear substantial since the cropped area has increased considerably and the total quantum of investment would therefore be far more than the 1973-74 level.

For want of an appropriate price index for the area, deflation of cost and return data could not be determined. However, if we allow for 5% annual inflation, the net return per hectare for the years 1974-75 to 1976-77 would be Rs. 163, Rs. 386, and Rs. 445, respectively (Table 11). These figures represent an increase of 137% in 1975-76 and 173% in 1976-77 over the net return per hectare of 1973-74. We may not find

Table 10. Cropping pattern In the Project area.

Crop	1974-75	1975-76	1976-77	1977-78
			ha	
Sorghum	161	173	169	320
Sorghum mixtures	189	210	238	260
Maize	21	64	80	115
Soybean	132	85	127	414
Other kharif[a] (irrigated)	16 (2.4)	25 (3.2)	40 (4.5)	24 (1.8)
Other kharif (nonirrigated)	151	199	222	215
Total kharif[a] (nonirrigated)	654 (97.6)	730 (96.8)	836 (95.4)	1324 (98.2)
Total Kharif[b]	670 (30.8)	755 (34.2)	875 (36.6)	1348 (49.4)
Wheat (irrigated)	115	126	174	197
Wheat (nonirrigated)	582	546	543	508
Chickpea (irrigated)	10	16	29	21
Chickpea (nonirrigated)	583	628	670	570
Other rabi (irrigated)	35	44	37	51
Other rabi (nonirrigated)	183	89	61	32
Total rabi[c] (irrigated)	160	186	240	270
Total rabi (nonirrigated)	1348 (89.4)	1263 (87.2)	1274 (84.2)	1109 (80.4)
Total rabi[b]	1508 (69.4)	1449 (65.8)	1513 (63.3)	1378 (50.6)
Total Area Cropped	2178	2204	2389	2726
Net Area Cropped	1946	1960	1969	1981

Note: Figures in parentheses indicate percentage area—
a. to kharif cropped area,
b. to total cropped area,
c. to rabi cropped ares.

Table 11. Farm business analysis of sample farmer.[a]

Particulars	Year			
	1973-74	1974-75	1975-76	1976-77
No. of farmers	107	171	137	146
Net cultivated area (ha)	607	1006	823	996
Gross cultivated area (ha)	625	1088	942	1309
Intensity of cropping (%)	103	108	114	131
Input costs (Rs/ha)	233	196	269	257
	(100)	(84)	(116)	(110)
Operational costs (Rs/ha)	231	169	168	313
	(100)	(73)	(116)	(136)
Interest on working capital, land revenue and taxes (Rs/ha)	29	26	39	34
Total expenditure (Rs/ha)	493	388	576	608
	(100)	(79)	(117)	(123)
Gross income (Rs/ha)	656	560	1005	1127
	(100)	(85)	(153)	(172)
Net income (Rs/ha)	163	172	429	523
	(100)	(106)	(263)	(321)

a. Figures in parentheses denote percentage change, with the bate year 1973-74 taken as 100.

any actual change in net return of 1974-75, as the project did not undertake a major soil- and water- management and cropping program that year.

Final analysis of the farm-survey data for 1977-78 has not been completed. However, case studies of four individual farmers reveal that cropping intensity on these farms has increased by one-third and in some cases is double that of 1973-74. Net farm income has increased threefold to fivefold and net income per hectare from twofold to fourfold when compared with 1973-74.

Overall Assessment

As previously stated, the project's main thrust was on farmers' participation in the program to win their confidence and achieve success. Farmers of the area now understand the philosophy of the dry-farming technology. The demonstrations with new and improved high-yielding crop varieties on farmers' fields have revealed their yield potential under rainfed conditions. The project's main emphasis on increased *kharif* cropping to fully utilize the abundant moisture available in the monsoon in these heavy black soils and to provide an efficient soil cover to prevent erosion has been realized. Farmers now grow more recommended *kharif* crops (also *rabi* crops wherever possible), apply fertilizer, take proper care of their milk cattle and thus realize better yields. They are now becoming prosperous, which is evidenced by their better standard of living. More than half of their overdue institutional loans have been repaid.

Evaluation studies have succeeded in identifying socioeconomic constraints to adoption of scientific crop and livestock management. Imbalances in fertilizer application and other related problems and profitability of traditional and recommended cropping patterns have been revealed. These observations have been conveyed to concerned scientists so that they can make appropriate adjustments while formulating plans for the future.

Human Nature and the Design of Agricultural Technology

Victor S. Doherty*

Abstract

Application of research results from the cross cultural study of human group size and function suggests organizational strategies suitable for promoting widespread improvement of land management and for development of supplementary irrigation. Improvement of land management may be most rapid if the necessary implements can be owned individually by even the smallest farmers, and by small-scale entrepreneurs. Development of supplementary irrigation may be most rapid if irrigation sources are owned by individuals or are large enough to justify government administrative assistance in their operation and upkeep. Further cross cultural study and field experiments are suggested to test these hypotheses.

This paper comprises a resume of some anthropological and sociological studies on the sizes and functions of human groups and an application of conclusions from these studies to the improvement of land- and water-resource management in semi-arid tropical agricultural regions. In particular there are discussions of alternative possibilities for the ownership and use of multipurpose, bullock-drawn wheeled tool carriers and for supplementary and life-saving irrigation of rainfed crops. The technologies and farming systems discussed have been studied over the last several years at ICRISAT. They have recently been brought to the stage of experimentation in village contexts. Thus the present paper also includes a consideration of ways to obtain meaningful social organizational data and analyses from such field experiments. It should be noted that the particular agronomic techniques discussed were first designed in an Indian context and are being tested at present under Indian conditions. Thus adaptation is clearly needed before their application in other contexts. At the same time, the principles involved, including improved land management and supplementary irrigation, are themselves widely applicable.

The primary anthropological questions here deal with how much cooperation is to be expected from different sizes of groups of farmers under different conditions. The answers to these questions will help to determine whether group ownership and control can be considered in a particular case or whether individual ownership and control is necessary. The anthropological analysis is put forward on the basis of hypotheses about human nature and is not limited to any particular cultural context.

Anthropological Analysis of Group Size and Function

In order to contribute to a general understanding of the conditions under which one can expect cooperation by farmers, an exploratory review of literature and of a limited number of cases was carried out recently by Doherty and Jodha (1977). On the basis of the study several hypotheses were formulated. One of these was that small groups of people form effective task groups for short-term cooperation but do not cooperate successfully over the long term. Another was that successful long-term cooperative groups are likely to be of large size. In the cases of both large and small groups, it is

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NOTE: This is a revised version of the paper presented at the Workshop and incorporates findings from research conducted since then.

assumed that cooperation is to be enforced primarily by the group itself or that outside administrative help will be minimal. As we will see below, if structural, administrative aid from outside the group itself is available then the situation changes somewhat.

The above hypotheses are supported by work carried out in two related sciences, anthropology and sociology, seeking to explain the basic dynamics of human groups. On the sociological side the research referred to is that on small groups, so-called. Useful summaries of these studies are available in a series of review articles (Deutsch 1968; Hare 1968; Homans 1968; Raven 1968; Sherif and Sherif 1968). Much of this research was initially formulated to answer questions about efficiency and function in different sorts of group. The research referred to in anthropology includes the important work of Birdsell (1968, 1973) on sizes and functions of groups in hunter-gatherer societies. On the axiomatic basis of the unity of the human species, it is hypothesized that the cross cultural comparison of simple societies, such as those of hunter-gatherers, will be instructive regarding the possible existence of basic tendencies and structural units, which arise in human nature and which must be taken into account even in more complex societies. Among the specific studies to be discussed below, social organizational and cognitive studies in stratified but still relatively simple societies (Goodenough 1965) and in much more complex, stratified societies (Mahar 1959; Hiebert 1971: 58-66) confirm that basic organizational principles suggested by the work of Birdsell and the small group sociologists on the one hand and by social psychological studies on the other (Miller 1956)[1] have a basic constancy across social types.

Some of the basic reasons for a seeming difference in the ability of different sized groups to perform different functions lie in the fact that there can be no society without individuals or individual domestic groups. Each domestic group, for example, will have continually different needs vis-a-vis neighboring households as its members move through different stages of life and as continually varying economic changes affect each of these differing combinations of individuals in different ways. Such development is inevitable in human life, even in egalitarian band societies. The inequalities of modern and peasant societies exacerbate the situation. In the cases of both large and small groups, smoothness of operation and continuity of the group itself depend upon how well individual or individual household needs can be dealt with. Sahlins (1972) shows how the essential individualism of nuclear groups is maintained in even the most egalitarian and well integrated society and in societies supposed to be ruled by the communal ethics of extended lineage ties. Similar insights regarding the importance of individual benefits in assuring group continuity are contained in the work of Mancur Olson (1971). One need not be a social atomist to maintain such a position. Many societies are indeed cooperative, peaceful, and value unagressive behavior. Yet logically it would seem that these characteristics are possible exactly because potential causes of conflict among individuals are minimized by the structure of the society and by its culture.

Since societies are made up largely of individuals and individual households, and since individual differences are inevitable, small groups can be expected to be less stable than large groups; this is because differences acquire relatively more importance the fewer the number of individuals in a group. Large groups, similarly, will have a better chance of balancing out such differences, putting down factions as they arise, and enforcing general rules. On the basis of such reasoning we can propose appropriate functions for different sizes of group: short-term tasks for small groups, and long-term administrative tasks for larger ones. Where small groups do have long-term coherence we can expect that it is because some additional, outside structure supports them, preventing or compensating for the rise of individual differences, which would disrupt such a group left on its own. Very high profits to cooperation might also bind small groups.

Supporting the view that small groups are task groups, there is some cross cultural evidence that people order their environment physically and mentally into small sets for day-to-day operational purposes. A hunting-gathering local band is likely to contain about 25 persons. On a basis of five persons per family or hearth, it will contain about five discrete interest

1. Quoted in Goodenough (1965).

units based on common economic alliances, including marriage. Both psychologists and anthropologists have data to indicate that seven, plus or minus two, is the maximum number of discriminations easily made by the unaided human mind on the basis of any single continum (Goodenough 1965: 17-18; Miller 1956; Mahar 1959). The work by Mahar, on caste ranking in an Indian village, revealed that her informants lumped together some ritually relevant actions out of a list of 13 such actions; the result was to distinguish seven potentially operational status ranks. When 21 village castes were ranked on the basis of whether or not key actions from the ritually relevant set were allowed with members of certain castes, the result indicated that the same informants used these potential ranks to classify their fellow villagers into an average of 5.4 functional status groups. In a study with similar results, Hiebert 1971, pp 58-66) analyzed the responses of 42 adult male informants to a series of questions about relative caste rank among 30 castes and about relative individual rank among 18 men known to all the respondents. He found that, as a whole, his informants distinguished nine caste status groups and four individual status groups of statistical significance.

Taken together, these findings suggest that as task groups, groups of small size (7 plus or minus 2 members) would be suitable from a sociological and social psychological standpoint, while they would also command advantages of scale by combining the efforts of several persons. If long-term coordination is needed, and if this coordination is to be locally generated rather than administered, then it seems that much larger groups would be needed to overcome the tendencies to factionalism that are unavoidable in small groups combining several individuals or domestic units whose interests will inevitably diverge over all but the short term. Optimum sizes of large groups are much less clear theoretically than are optimum small group sizes (see Birdsell 1973). Birdsell's modal number is 500 population, or about 100 families for linguistically unified groups among hunter-gatherers. Progressively larger sizes may be necessary as society and technology become more complex.

If hypotheses of the kind formulated here can be substantiated, they can be quite valuable in assessing the merits in different social situations of different agricultural technologies. The limited generalizations made here on the optimum size and the generally appropriate functions of small groups do seem to be well supported by both anthropological and sociological research. These generalizations are applied below to the solution of particular problems. The generalization that impersonal rules are best established and enforced in the contexts of groups much larger than the optimum task group size of about seven persons also seems to be well-founded and is applied below. More information is needed on both small and large groups and their potential roles in promoting agricultural development. Research in this area should be carried out focusing particularly on the possible effects of different cultural, social, and economic contexts.

Prospects for Improved Land Management in the Semi-Arid Tropics

The bullock-drawn wheeled tool carrier already mentioned provides our first example. The implements—especially plows, cultivating blades, and simple seeders — most commonly used by smallholder farmers of the central Indian semi-arid tropics today have advantages of being cheap as well as being easily manufactured and repaired in villages by minimally skilled workmen. At the same time, these implements are difficult to use for deep plowing; for relatively sophisticated land-management techniques aimed at reducing erosion, maximizing rainfall infiltration, and eventually improving soil quality; and for precise handling of high-potential seeds with greater-than-minimum doses of fertilizer. For these reasons an improved machinery system has been sought by scientists working on these problems; one choice has been a bullock-drawn implement known by its tradename of *Tropicultor.*

Experiments using this basic multipurpose unit and its attached implements have been carried out at ICRISAT with a broadbed-and-furrow system to improve water storage in the soil profile and to reduce erosion and waterlogging. The furrows are placed at a gradient (0.4% to 0.5% slope, or 40 to 50 cm drop per hundred meters distance) sufficiently steep to assure good drainage while leading the water off the land slowly. This allows for good infiltration of rainwater and minimizes erosion. The width from furrow to furrow is 150 cm with the furrow being several centimeters deep. The furrows can also be used to apply water if supplementary irrigation is planned with runoff water collected from the catchment. Grassed waterways are required to dispose off surplus water from the graded furrows. Reorganized field boundaries may be desirable to make it easier to site the grassed waterways in the most appropriate location. This is also likely to improve the field layout and make it more efficient for tool carrier operations. The raised beds are a semipermanent structure and remain in place from season to season. The beds themselves require a minimum of tillage; this provides further protection against erosion. The improved implement used provides additional benefits of faster plowing, which helps to conserve the fleeting soil moisture. It provides more exact seed and fertilizer placement, important when high-potential seeds and more-than-minimum fertilizer doses are used. Where individually owned plots are relatively large — on the order of 10 to 20 ha — or where group action among farmers is possible, grading and readjustment of field borders and the installation of grassed waterways can be carried out on a unified watershed basis (Krantz et al. 1978). There are indications from economic analysis, however, that profits to the improved system of tillage within existing field boundaries are comparable to those on comprehensively developed small catchments (Ryan et al. 1979); so the job of improving land management may be easier than originally thought.

It has been calculated roughly that at 1979 prices a wheeled tool carrier of this type — with a minimum set of implements of medium price, and manufactured in India — might cost approximately Rs 7500 (about U.S. $930) or more. Analysis of experiments on the ICRISAT research station indicates that it is possible to reach a high degree of profitability in SAT India, given such costs (Ryan et al. 1979; Binswanger et al. 1979); however, further research, in on-farm situations, is still needed.[2] Much depends of course on the availability of fertilizer and care-responsive, high-yielding cultivars of high value rainfed crops with a good local market.

In considering how to put the wheeled tool carrier into wide use by all classes of farmers in the countryside, one immediately encounters organizational questions. The report by Binswanger et al. assumes that the implement will be used for agricultural purposes on approximately 15 ha of land, an area that presently represents the limit of the machine's coverage. (Some reduction in range might be experienced on some soils and in some climatic situations.) This specification concerning range, as well as the cost projections already presented, seem to argue against the wide use of the implement by small farmers in India. Many of these smallholders use almost no purchased inputs on their rainfed holdings, whatever may be the case on their irrigated plots (Bapna et al. 1979). Their holdings in India are much below the 15-ha range noted above. Their overall financial situation in one representative area (Table 1) is not good. Their existing agricultural implements are of the simplest and cheapest kind, while the greatest part of their existing assets is represented by their land.

Although their financial situation makes it difficult to envisage how such an expensive implement could be introduced on a wide scale among such farmers, there are several reasons why an implement such as the Tropicultor is to be preferred to some simpler implement. As a simple, minimum-tillage arrangement, broadbed-and-furrow systems or other ridging systems can be formed by so-called ridging plows; this system is common in parts of West Africa. However, in the semi-arid tropics as elsewhere cropping patterns vary greatly from season to season and year to year, and the beds formed by ridging plows are too narrow to be flexible in planting a number of crops in a variety of patterns from year to year with the wheeled tool carrier. Furthermore, planting quickly at an exact depth while still arranging for exact seed and fertilizer placement can be difficult without a tool carrier of some kind, and

2. The wheeled tool carrier can also be used as the base for a bullock cart, which would seem to have some advantage over many traditional carts since It would have pneumatic tyres and an increased load carrying capacity. Sufficient levels of nonagricultural use would reduce the hectare coverage necessary to make the wheeled tool carrier pay. More research on the returns to all these variations, particularly in on-farm situations, is needed.

Table 1. **Average financial condition of small farmers* in selected areas of semi-arid tropical peninsular India, 1976-77 crop season.**

Village	Land operated (ha)	Value of owned land (Rs)[b]	Value of year's gross agricultural output (Rs)	Value of owned implements (Rs)	No. of pairs of bullocks owned[c]
Aurepalle (Andhra Pradesh) (10 farmers)	1.4	2593	517	165	0.3
Shirapur (Maharashtra) (9 farmers)	1.4	8236	1341	416"	0.1
Kanzara (Maharashtra) (9 farmers)	1.3	4256	696	83	0.1

a. Data collected in the Village-Level Studies of ICRISAT's Economics Program. Small farmers are defined for each village as the ten farmers having the smallest operational landholdings out of a random sample of thirty farmers In each village. Further details are in Jodha et al. (1977).

b. Rs 8.00 = US $1.00 in 1979.

c. The cost of a pair of working bullocks ranges from Rs 800 to Rs 4000 or more, at 1979 prices.

d. The relatively much higher average value of owned implements in Shirapur is due to the fact that one farmer in the sample for that village owns an electrically powered pump. The average value of owned implements for the other 8 small farmers in Shirapur is Rs 56.

agronomists see these as elements that are at least as important as the tillage system alone. The strategy for intensive rainfed cropping in semi-arid tropical areas is to cover large areas of land quickly and exactly with optimum amounts of seed and fertilizer during optimum planting periods of fleeting duration, so that the soil will be protected by a crop and later rainfall penetration will be maximized.

Under these circumstances how is one to introduce on a wide scale an improved implement that most farmers cannot afford, and whose cost would take years to be amortized by an impoverished, individual smallholder? The problem is compounded even further by the fact that, for the long-term ecological health of such semi-arid tropical farming regions, uniform coverage is needed on a watershed basis with this kind of improved implementation rather than piecemeal coverage of individual farms. Ryan et al. (1979) reported that in some cases the improved tillage system gave similar returns both within preexisting field boundaries and within reorganized field boundaries. Still, in order to minimize dangers from erosion and localized flooding for any single farmer it may be better for all farmers to sow in the improved way. Such uniform coverage would be desirable both from a community standpoint and from a long-term individual standpoint as it would conserve soil, improve soil conditions on the watershed as a whole, and improve local water tables. Nevertheless, while watersheds chosen for development feasibility studies in three villages typical of the three main agroclimatic zones of semi-arid tropical peninsular India involve contiguous areas of only about 18, 17, and 20 ha, respectively, they include the land of 5, 14, and 12 individuals (Table 2). Moreover, the farmers on these watersheds represent a range of social and economic classes and castes in their respective villages, and the prospects for cooperation among them are not increased by these basic socioeconomic disparities.

Faced with this kind of situation, one might argue that if the maximum amount of land is to be covered by improved tillage it makes sense to start with large farmers. It could be argued that this would also have the fastest effect in raising overall yield levels. However, such a strategy is unacceptable from the viewpoint of equity. If all farmers of alt sizes are to benefit from improved land management, then means for cooperation among them or for the supply of

Table 2. Data[a] on selected watersheds in three central peninsular Indian locations (1978-79 crop season).

Village		Area of watershed plot (ha)	Total area operated per farmer (ha)[b]	Watershed plot as % of total operated area	No. of oil and/or electric pumps owned	Pairs of draft bullocks owned	No. of family members	No. of family workers
Aurepalle	Range	0.5-8.0	1.6-9.7[c]	29-52[c]	0-1[c]	1-4[c]	4-6[c]	2-4[c]
(5 farmers)	Mean	3.5	5.7	40	0.8	2.3	4.8	3
(Watershed 18 ha)								
Shirapur	Range	0.5-3.9	0-16.9	0-100	0-1	0-4	4-10	1-4
(14 farmers)	Mean	1.4	7.1	25	0.3	1.4	7	2.5
(Watershed 17 ha)								
Kanzara	Range	0.4-5.5[c]	0-38.4[c]	0-100[c]	0-1[c]	0-10[c]	1-14[c]	1-8[c]
(12 farmers)	Mean	1.4	8.5	33	0.2	2.2	7.6	3.5
(Watershed 20 ha)								

a. The data given here are based on verbal interviews; in some cases also they are incomplete. Although they can be taken as indicative of the general situation for the farmers to whom they refer, they certainly would be revised by more thorough investigations. Such full investigations of resources and of farming systems followed by participating watershed farmers are planned. Also note that due both to organizational and resource constraints the actual land and water developments finally carried out in 1978-79 dealt only with portions of these watersheds. The experience of this and subsequent seasons will be reported in subsequent publications.

b. Where total operated area is zero all land owned by a farmer is leased out including plots on the selected watershed.

c. Data not available for one or more farmers.

low-cost improved implements to individual small farmers would seem to be necessary. Having identified the innovation and its purpose, one is faced in the case of the wheeled tool carrier with a problem of human organization to ensure its best use for human well-being.

Group Size Studies to Solve Organizational Problems in Improved Land Management

For improved land management using the wheeled tool carrier, a number of means to introduce the implement system are possible. They include individual ownership of one or more implements and the addition of rental of wheeled tool carriers to the already existing services of multipurpose farmers' cooperatives. We need to know, however, how such alternatives rate in terms of human organizational efficiency. We need to take account of human nature in the same way we measure agronomic and economic suitability.

If our reading of the implications of research on group size is correct, the alternative of cooperative ownership for the machine can be rejected. This is because the economics of scale do not seem to indicate that a group large enough to be stable could be formed around the machine.[3] Optimum planting days are limited in the semi-arid tropical environment and, as already noted, the area that the implement can cover efficiently is likely to be 15 ha or less, depending upon variables such as field layout, climate and soil condition, bullock power available, and the task involved. Given the data in Tables 1 and 2 we would expect to need roughly from 5 to 15 small farmers to reach a combined holding size equal to the range of the implement. It seems to be too much to expect groups of this size to take on the complicated long-term ownership and managerial duties required by

3. The returns from Tropicultor use calculated In Binswanger et al. (1979) do not seem to be large enough to hold together a small group without considerable administrative help.

common possession and use of a farm implement. Large farmers and those with upper middle size holdings seem to present no problems, as individual ownership could be appropriate for them economically. Cooperation on the part of groups of small farmers does seem unlikely, judging from the analysis of group size and function presented above.

Although anthropologically a large group would seem to be more likely to be able to enforce stability, the economics of the situation seems to preclude dependence on such a group. The buying power of a hundred or more farmers could purchase tractors as easily as it could purchase wheeled tool carriers. Whatever the social benefits or costs outside the cooperative group (Binswanger 1978), such an organization would be likely to find tractors more remunerative than bullock-drawn tool carriers. Thus the alternative of wheeled tool carrier ownership by a multipurpose cooperative is rejected according to economic reasoning.

Having applied criteria of group size and economy, we are left with the alternatives of individual ownership by farmers or by entrepreneurs. Either arrangement is anthropologically acceptable according to our reasoning here. The choice depends upon the scope for reducing the cost of the implement or for increasing the area that one machine can cover during the optimum planting season. Extreme low cost would be the key to making the implement available to individual small farmers.[4] On the other hand, assured coverage of a relatively large area — or perhaps enhanced performance of nonagricultural work — might be necessary to make the implement pay, even for a very small-scale entrepreneur. Plans to develop either option would be likely to benefit from a survey that examined existing patterns of investment and use of implements, particularly expensive items such as pumps, which, like the improved tool carrier, are relatively large capital investments.

4. Work is presently in progress at ICRISAT on such a low-cost model, based on a small wooden bullock cart; the cart itself cost Rs 550 (about US $70) In a rural market town in central peninsular India in 1978. The cost of the added toolbar and attachments is as yet unknown but could not be less than Rs 600 ($75) with 1979 prices.

Potential for Development of Irrigation Based on Runoff Water

The question of rainfall runoff conservation is particularly complex (see, for example, Kampen et al. 1974; Krantz et al. 1978; Ryan et al. 1979). Climatology, soils, cropping patterns, and other physical and biological variables, along with economics, all play a part in determining the minimum size and the proper height-to-depth ratio for a tank that will assure efficient and profitable storage without too much loss from evaporation and seepage. Analysis of some of these criteria are in the three reports just noted and in von Oppen (1974, 1978). In a full analysis of the problem, we must also ask whether group size and function have human organizational consequences that should be considered in determining the sort of farmer for whom supplemental irrigation from tanks might be appropriate and what sort of farmer might benefit particularly from the results of different research strategies.

Runoff collection reservoirs, or tanks, built on experimental watersheds at ICRISAT Center near Hyderabad are relatively small and are designed to trap and hold water for the protective and supplementary irrigation of dryland crops, by gravity or pumping (Kampen et al. 1974). Similar traditionally used tanks in the Hyderabad area are often operated with the water distributed in a more or less unregulated flow, and almost always for rice rather than for crops that need less water. The traditionally overwhelming importance of rice in this context deserves special notice. There is a great deal to be said for rice as a crop, particularly because of its agronomic qualities under prevailing conditions in the rainfed area around Hyderabad. Masefield (1977, pp 21-22) points out that:

> There are rice fields in Asia which have probably been continuously under the crop for centuries without any conscious input of plant nutrients by the cultivators, but which can still be relied upon, provided that water is available, to produce a steady half tonne of paddy per acre (1250 kg/ha). No other cereal can emulate this feat.

Nevertheless, Masefield (1977, p 22) adds that "a good rotational program" with the right inputs might actually be a more efficient user of resources. Thus development of new technology, including new varieties of high-value dryland crops, and the development of institutions to support supplementary irrigation instead of intensive irrigation do seem to hold promise for increased food production over wide areas. The development of supplementary irrigation might also lead, in the right institutional context, to the concentration of crop production effort on areas of the greatest potential for intensive dryland cropping, thus allowing for reduction of pressure on marginal areas of shallow soil.

Recent analysis of runoff potential for small catchments in two semi-arid tropical regions of central India indicates that on Alfisols (red soils) of medium depth, even under improved tillage and cropping patterns, catchment areas of between 8 and 16 ha could generate enough runoff to make supplementary irrigation of dryland grains and legumes economically feasible for at least part of the catchment when used to support a postrainy-season second crop (Ryan et al. 1979; Ryan and Pereira 1978). Such irrigation would also be planned to protect the catchment farmers against occasional droughts during the rainy season; however, the economics of this portion of the technology remains to be assessed. The crops envisioned include, but are not limited to, dryland cereals such as sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum americanum*) and dryland legumes such as groundnuts (*Arachis hypogaea*), chickpea (*Cicer arietinum*) and pigeonpea (*Cajanus cajan*).

Application of Group Size Studies to Problems of Runoff Water Harvesting and Use

In designing the experimental tanks for supplemental irrigation of crops consuming small amounts of water, it was originally thought that several farmers could cooperate to use this water. In considering such a possibility, however, one immediately runs into problems of group size. On Alfisol experimental watersheds at ICRISAT Center, analysis showed profits with supplementary irrigation from small tanks on watersheds 8 to 16 ha in catchment size.[5] Table 2 suggests that under central peninsular Indian conditions about 5 to 15 farmers would be involved in a catchment of such a size. Significantly, such a group of farmers would be faced with very difficult management problems if they were to cooperate on their own. The analysis of returns from supplementary irrigation in the postrainy season indicates that even in a profitable situation there would be enough runoff on average to provide water for only about 44% of an 8-ha catchment (Ryan et al. 1979, pp 30-31). The potential management difficulties for a cooperating group are made more difficult by the fact that runoff varies according to rainfall from year to year so that the members of a group could not depend upon a constant resource. The potential cooperators would also find it hard to achieve individual equity for an irrigation resource to be used by different individuals on crops with different water requirements at different times.

Our analysis of the relative durability of large and of small groups leads us to hypothesize that small groups of from 5 to 15 farmers could not cooperate easily to maintain such irrigation tanks and to distribute the water from them. Such cooperation might be possible given outside administrative monitoring by government; it might also be fostered by a very high profitability from supplementary irrigation. It would seem, however, that this would need to accrue at the same rate to each farmer, and to be realizable in no other way (Doherty and Jodha 1977). Outside administrative control of the degree needed to counteract fissiparous tendencies in such small groups around such a variable resource would probably be quite expensive to apply widely, given the large population and intensive agricultural exploitation of the Indian countryside. One might also propose that a large group, such as a village, unite to control the administration of many small tanks.

5. Economic returns from supplementary irrigation with collected runoff water are much less certain on Vertisols (black cotton soils) than on Alfisols. This is because the Vertisols retain moisture in the soil profile rather well, so that particularly in the deeper Vertisols moisture is available in the crop root zone even when the surface is dry. There may be potential for supplementary irrigation on Vertisols; wells prove quite profitable in some of these areas, for example, and there are often significant amounts of runoff. However, these subjects need further study.

Since the resource in question under such a scheme — the tanks — would be divided, this plan as well would seem to invite difficulties and appropriation of the tanks by individuals (see Doherty and Jodha 1977; Olson 1971).[6]

If unaided cooperation among small groups of farmers is not likely to be successful for the distribution of supplemental irrigation water, alternative strategies to improve the use of runoff water are needed. Either tank size or irrigation technology (pumps, sprinklers, drip systems), or both, might be investigated. The same subjects could be studied to see how larger, potentially more stable groups could be accommodated for purposes of supplementary irrigation. Indian agricultural and governmental groups are now in fact experimenting with ID, or "irrigated dry," cropping management of tank command areas. Such groups might not have to be large enough for self-regulation if enough farmers or enough land area were included to reduce the costs of government administrative aid; this seems to be the strategy with the Indian experiments. One would still be advised to be on guard against sources of factionalism. If irrigated dry cropping strategies seem appropriate, much could be learned about how to support them by study of successful and unsuccessful management strategies followed by those administering traditional rice-irrigation tanks. One cannot neglect the possibility also that under tank irrigation, rice-growing was or is the best strategy, given limits placed by such factors as rainfall, geology and soils, evaporation, and potential for response to irrigation by different crop species. Even if they are to continue primarily to support rice, traditional tanks should be studied to see what management techniques have been successful and how they could be improved, so that they may make their optimum potential contribution in the context of semi-arid tropical farming systems. The question of wells and of sale of water by well owners also seems to be important. And we should also note that tanks often raise or make possible the yield of economic amounts of water from wells downstream; percolation tanks have been built in India, specifically for such effects, in some areas not especially suited for tank-based gravity flow irrigation.

Formulating and Field Testing Behavioral Hypotheses

Neither technology nor an organizational judgment can be considered proven until it has been tested and found acceptable under natural conditions—that is, in farmers' fields and in social organizational contexts typical of the agricultural areas for which it was made. For this reason we require field tests of specific hypotheses derived from analyses such as those above.

Field experiments designed to test anthropological hypotheses cannot be carried out with as many replications, and with the same kind of control over variables, as can biological experiments on research stations. However, field tests and experimental control of variables are possible. As in any test, it is useful to proceed on the basis of specific hypotheses. We may hypothesize first what would happen if it were shown that supplementary irrigation of some dryland crops is profitable in particular agronomic contexts. *Our hypothesis is that farmers would prefer that small-sized sources for supplementary irrigation be privately owned.* If the hypothesis is correct and if the optimum size of catchment for a small tank used for postrainy-season irrigation is 8 to 16 ha (Ryan et al. 1979), we can expect that only those relatively few farmers who happen to own a large piece of land of the appropriate sort would show interest in small tanks. The rest would be expected to show more interest in wells; or in supplementary or intensive irrigation from publicly-supported tanks and from canal systems; or in chances to purchase water from well owners where the latter might have surplus available to sell.

6. The possibility of joint ownership and operation by an extended family or by a lineage group also presents itself. In this case the authority of the family substitutes for what would otherwise be necessary: the authority of the society as a whole. Such cases do exist in India for the common ownership of wells, and tenurial rights seem to be adjustable by such means as one party buying out another, when in its normal cycle of development the extended family becomes too attenuated. Such a possibility might be worth investigating with respect to tanks. This possibility too, however, would face the problems of equity among users and of profitability relative to other possible sources of water, particularly wells.

With respect to the wheeled tool carrier, *our second hypothesis is that both large and small farmers generally will prefer individual ownership of such small and medium-scale cultivation implements.* If such is the case, we should expect cooperative groups to form about these tool carriers only if enforced and supported organizationally from outside. Such groups might also be promoted by a combination of exceptionally high returns and relatively high capital costs for the implement. Overall however, if the implements were to spread widely, we would expect that it would be as a result of reducing capital costs to the individual farmer or of systematically placing it in the hands of many entrepreneurs, or of both these conditions.

Testing such hypotheses requires working directly with farmers, in contrasting social and cultural environments. The aim is to separate the influences of human nature on the one hand — the supposed basis of the hypotheses we have advanced above — from the influences of particular social, cultural, and economic contexts on the other. For this reason, and in order to reduce the volume of sheer descriptive work necessary as background, it is desirable to choose societies — and where possible, particular communities — that are already well known economically and ethnographically. Even where such choices are possible, it must be recognized that social, cultural, and economic variables can only be held constant or varied in the most approximate way in the real world. In order to reduce the possibility of error, therefore, it is necessary to supplement field tests with comparative studies of a large number of related cases drawn from the ethnographic and economic literature. Thus comparison is important both in the initial formulation of hypotheses and in their testing.

An experiment to test the technology discussed in this paper is under way on representative watersheds in three villages of peninsular India in which sample farm families participate in studies by ICRISAT scientists. Data regarding the watershed farmers and their holdings on the watersheds were detailed in Table 2. In these three villages a wide range of economic data (Binswanger and Jodha 1978) has been collected every 3 to 4 weeks since June 1975 on the same 40 farm households in each village, and they thus provide a particularly favorable environment for an experiment of this kind. The three villages are also desirable for such an experiment as they are in somewhat contrasting cultural and social areas within India and in contrasting natural agricultural environments.

The exact plans for development of each watershed were laid out in March and Aprill 1979 by ICRISAT staff of the Farming Systems and the Economics Programs, staff of member institutions of the Indian Council of Agricultural Research, and the farmers in the villages. The final agronomic and organizational shape of the experiment has depended upon the advice of a committee of these scientists on the one hand and and the decisions of the watershed farmers on the other. The decisions to be made concern such matters as whether and how to provide for supplementary irrigation; how to organize the use of a limited number of wheeled tool carriers among a relatively large number of farmers; which cropping patterns to concentrate on; whether to reorganize existing field boundaries in order to make land management easier and to improve drainage; and other similar questions. Basic items of technology to be tested are the use of supplementary irrigation on a dryland cropping system, and improved land management with the use of a wheeled tool carrier. Supplementary irrigation is part of the experiment on at least one watershed (in Aurepalle in an Alfisol region); depending on further analysis, it may or may not be provided on Vertisols. It is planned that the first, financially-aided phase of the experiment will run for 2 years. At the end of 2 years, financial aid will be withdrawn. Monitoring the actions of the farmers — both on the study watersheds and in the rest of the village — as they decide what further use if any to make of the technologies and systems presented will constitute the next phase of the experiment.

It is apparent that during the 2 years of financial aid to farmers participating in the experiment, not even an approximately complete field test will be possible for the hypotheses advanced above. Whereas we hypothesized that private ownership of small-scale supplementary irrigation resources would be most sought after, in the one village where such irrigation is planned so far it will be made available from a single source, and the agreements for its use among the several watershed farmers will be supported by the efforts of

ICRISAT staff. Similarly, we hypothesized that private ownership of the wheeled tool carrier would be preferred; yet cooperative use is to be enforced and managerially aided for these 2 years. This period is, however, both experiment and demonstration as regards the farmers' participation. Although much can be learned on a social organizational level from their reactions during this time, the main purpose must be to familiarize a relatively large number of farmers with the technology so that they will be able to make valid judgments about it in relation to their own situations. The real test, both economically and organizationally, will come at the end of the 2 years, when technical advice will be provided but financial subsidy will be withdrawn. If the various components of the packages have proved themselves and are adopted for their own use by the farmers, it should be possible at that stage to learn a great deal about the social organizational arrangements that are locally preferred and feasible to support the use of the new technology. By that time also comparative studies of similar cases should be completed and will provide considerable insight as the further progress of the experiment is measured. In all, such a testing program might require 4 to 5 years. As more is learned about how to carry out such tests, and as major areas of interest requiring such tests are identified, the scope will increase for such multipurpose field studies and for field studies paralleling laboratory and research station experiments.

Conclusion

In many areas of the semi-arid tropics, and particularly in SAT India, it seems clear that the evolution of agricultural systems today must be towards more intensive use of natural agricultural resources and towards the simultaneous protection and improvement of these. The task is complex since new technologies that are devised must take account of human potential as well as of agronomic and economic potential. Applications of the comparative method in anthropology, such as that made here with respect to human group size and function, seem to have potential for important practical results if combined with agronomic and economic insights. What is needed now is an expansion and diversification of such applied studies. Field tests of hypotheses formed on the basis of such studies are also necessary and should be carried out in a series of contrasting environments that are well known socially, economically, and agronomically, in order to come as close as possible to a situation in which variables are controlled. Such field tests should be accompanied by special, more widely comparative studies of particular institutions and technological questions which prior analysis has suggested will be important so that the results of field tests can be applied operationally as soon as possible.

In this paper insights gained from comparative analysis have been applied to problems in the use and ownership of an improved implement—a bullock-drawn wheeled tool carrier — for improved land management; and to problems in the collection and use of water for supplementary irrigation of dryland crops. Areas likely to be of particular importance in devising eventual solutions were identified. These areas include work to make the tool carrier inexpensive enough for individual smallholders with very small financial means and research to make the implement attractive to individual, small-scale entrepreneurs who would rent it out or use it to do custom work. As one step in the testing of anthropological hypotheses, a survey of existing investment and use patterns with such relatively large capital items as pumpsets was also suggested. Areas of importance for special investigation with respect to the organization of supplementary irrigation include the funding, management, and administration of existing tanks designed for gravity irrigation or for groundwater recharge; they also include study of the ownership and management of wells. Research on all these items is under way or planned. Field experiments are also under way to introduce farmers to the concepts and technologies involved and to encourage them to make their own adaptations. These experiments are being carried out in villages where stratified random samples of farm households have been studied with regard to economics, social organization, and farming practices for 3 years prior to the initiation of the field agronomic experiments described here and where the same samples of households continue to be studied. It is hoped that this combination of field research and special topic investigation will prove efficient in devising ways to spread improved land and water management more quickly and effectively in semi-arid tropical agricultural regions.

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Farmer Participation and Accounting for the Needs of the Most Disadvantaged Groups: Some Ideas on Participation at the Outset of a Research Program

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Abstract

This paper presents some ideas on farmer participation in agricultural development programs, based on a research program conducted in the Experimental Units of Sine-Saloum in Senegal during 1974-76. The author finds that any project concerning large rural populations has to be based on an analysis of social structures and stratification. He finds also that the most favored groups and categories develop strategies whereby any changes introduced in the system invariably maintain or strengthen their position in the hierarchy. He argues that the research or development worker cannot be neutral or indifferent to the fact that innovations are always rejected or distorted by a group or social category to the disadvantage of others. Often, it has to be remembered that the poorest strata are poor not because they are backward, but because they are involved in a series of unequal relationships. It is hoped that this microlevel study can be extended to a national or international scale.

We take this opportunity offered by this ICRISAT workshop to present some ideas about farmer participation in agricultural development programs. This text is not final and at present is based only on a research program conducted in the Experimental Units of Sine-Saloum' in Senegal from February 1974 to July 1976.[2] We expect to gradually extend this research to other programs within and outside the Experimental Unit project. This explains why the text is not properly structured as well as why it is summary in nature. The examples are given to illustrate rather than demonstrate the research that has been conducted.

The research program on which this paper is based is entitled Land-Tenure Systems Program. The objectives of the program are:

- to study traditional land-tenure laws, especially the changes following the legislation on land-tenure systems passed in 1964 in Senegal but not implemented, especially in the Experimental Unit villages and those neighboring them.
- to define and experiment with a methodology for developing and consolidating village lands through inexpensive techniques and methods that can be used by farmers and require wide farmer participation.
- to propose practical ways of implementing land-tenure laws, taking into account the effects of new technologies and of the traditional land-tenure laws on the land-tenure system.

This involves *research-action* or *research-development* interaction. The study was not limited to the land-tenure system of a given

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NOTE: This is an edited translation of the original French text, which appears in Appendix 1.

1. The papers for this workshop by Moussa Fall and M. Benoit-Cattin are also on the experimental unit project.
2. Madicke Niang, geographer, and various scientists from the Senegal Institute for Agricultural Research (ISRA) participated in this program. For an overall report of the research program see Faye and Niang (1977).

farming community but, with the consent and participation of most of the villages in the Unit, we introduced radical changes in their ways of using land and soil.[3]

The research-action character of the Land-tenure Systems Program arises mainly from technical considerations, and it can be summarized as follows:

During experiments with new techniques and cropping operations, agronomists identified the division and distribution of cultivated plots and the unreliable character of land-tenure rights of a large number of farmers, among other constraints to the adoption of new cropping practices. The shape of these plots was unsuitable for animal-draft cultivation.

During the development of the research program for studying and alleviating these constraints, the essentially technical approach was widened and also became a land-tenure system approach.

Farmer Participation in the Research *Program*

The program involves the problem of farmer participation in two ways:

- explicitly: because one of the main objectives was a return to simple and inexpensive land development and consolidation techniques that would enable participation by farmers and would possibly be implemented by them. Similarly, in the proposals for implementing land-tenure laws, the mode and structures for land management had to be entrusted to the farmers.
- implicitly: because such an important intervention cannot in any way leave the farmers indifferent.

Their involvement may undoubtedly range from open hostility with actions or violent reactions to collaboration. Noninvolvement and indifference on the part of the farmers, for whatever reason, was not permitted.

The etymological meaning of the word "to participate" is "take part in something" and "Le Robert" dictionary defines the word "participation" as "adherence, collaboration, contribution."

We can also hold that the attitude of the farmer who remains indifferent to technical proposals made to him is not neutral, and that this attitude is in itself another way of participating.

In the first stage at least we prefer to adopt the above definition and we should try to examine, in the light of the Land-tenure Systems Program, what the other conditions are that enable farmer participation in an appropriate research program.

Conditions for Participation

Taking into Account the Needs and Priorities of Farmers

Today this condition is unanimously accepted. Projects and research programs developed recently go even further, as they aim at "meeting the needs of the poorest farmers."

At the outset of the program, a negative attitude could be expected from farmers whose opposition to the land-tenure laws was general. The law on national territory in force for 10 years (1964-1974) was only applied occasionally.[4]

The rural people have retained the following ideas regarding the legislative laws:

> The State holds the lands and recognizes the right of cultivation of those who actually cultivate the land; the lands that their former masters could not cultivate may be taken and given to other cultivators. Thus, the State not only deprived landowners of their land but also forbade land loans, transferred former loans to the beneficiaries, who were for the most part "foreigners" brought in and settled by the landowners; finally, the State wanted to redistribute their land, preventing them from transferring it to their descendants.

However, these aspects of the law only concerned a few farmers of this region, only a few

3. In three villages land was developed and consolidated: one in the first year and two in the second year; a total of 3000 ha involving 250 "masters of land."

4. The farmers applied—and continue to apply—the traditional law, only in the case of serious conflict or when the conflicting parties decide to appeal to the administrative authorities is the existing law used to settle the conflict.

big *maltres de terres* (masters of land), and some groups *of peulh* livestock raisers.[5] On the other hand, this law, which also envisaged consolidation of lands, carried positive aspects for most of the people.

The first phase of research work was to present the aims of our program to the farmers to enlist their support. During our meetings with farmers, organized in every quarter, we found that their attitudes were mainly hostile to the program and ranged from blind distrust to open hostility. One of the meetings even ended in insults. Farmers seemed to be unanimous in their rejection of the law and therefore refused any research aiming at its implementation. On the basis of these reactions, we tried to analyze and understand the motivation and concerns of the people.

Fortunately for this analysis, we were able to use the studies conducted during the past 2 years by an anthropologist, L. B. Venema, on social structures and stratification of the rural population. We also benefited from the detailed information that the extension workers had obtained in the quarters where they worked. Collective and individual discussions were systematically carried out to identify farmers' attitudes and to relate them to the categories and social groups in Venema's study.

Rather than immediately formulate and present to farmers proposals for developing and consolidating their lands, we put forward the following contractual agreement:

- The research would be divided into several phases, each being preceded by collective meetings organized in every quarter. The research team would present the work done by them and this would be discussed subsequently. The action planned in the next phase would be presented and discussed. After each phase the team would undertake to continue with the program only if the farmers approved of the work done in the earlier phase and gave their consent for the next one.
- In the first phase, in addition to studies on the land-tenure laws, land surveys would also be carried out. The farmers had to guide us over the area and settle litigations according to the land-tenure law or the traditional law.

During the first phase, we progressively took into account the concerns and interests manifested by the different groups and developed proposals for development and consolidation of the land. The proposals were presented to the farmers individually and in small groups to study their reactions. Once the distrust towards the research team disappeared, we were successful in relying on a number of influential farmers who were leaders of their groups for relaying proposals or for making counter proposals to us.

After establishing the land survey, we were able to present and obtain the consent of most farmers from all quarters, except the *peulh* quarter, for a set of coherent proposals for development and consolidation of their lands. The farmers undertook to participate in actually applying these proposals.

The tentative conclusion of this part of the Land-tenure Systems Program is that in a project concerning the entire rural population, it is indispensable to start with an analysis of the structures and social stratification of the concerned rural population. The needs and priorities that are identified should be related to the social categories and groups that make up the rural population. It is only on the basis of this analysis that a program can be built and objectives determined that will aim to meet the needs of the poorest categories.

Once this analysis has been carried out and we have identified the poorest categories that generally make up the majority of the farming community in the Third World (these categories being viewed in their relation to the other social categories with which they have dependence and domination relationships), we can build a program and determine the objectives for meeting their needs. This condition appears to be a necessary one if farmers are to participate in the project and not be passive towards it. Participation is not an abstract notion, it is the adherence, the collaboration of groups whose needs the project aims to satisfy.

Helping the Poorest Farmers to Meet Their Requirements

In a community, any modification of the land-

S. The *paulhs* are a race whose main occupation is livestock raising. This law under which lands would also be consolidated had positive aspects for most of the farmers.

tenure system concerns all the people: those who do not cultivate any longer because they wish to transfer their land to their descendants; those who cultivate; those who are not cultivating as yet because they are the future users of this land.

To the extent that the program aims to assist the most disadvantaged categories, it modifies the relationship between the different groups and the social categories. It should be expected that the most favored groups and categories will develop strategies whereby these changes maintain or strengthen their position in the family or social hierarchy or, alternatively refuse these changes.

Through relationships of authority, clientele, domination, and dependence, certain people are better placed to defend their interests or use the project to their benefit. These are men in relation to women; adults in relation to the younger people; rich farmers (farmer-traders, farmer-transporters) in relation to poor farmers; families long settled in the area in relation to newly settled families.

A few examples illustrate this phenomenon:

- Information on conflicts within certain *carres* (compounds) proves that heads of landholdings or of *carres* have tried with the consolidation of land to oust the women or young people to poor-quality plots or to reduce the size of their plots; others have tried to take the fields managed and cultivated by them, but belonging to nephews or younger people who are still their dependents. On the other hand, certain young people have tried to take advantage by forcing the adults who managed their lands to divide the family lands into equal parts, which is against the traditional law that gives certain privileges to adults.
- During the official land surveys *the maltres de terres* have tried to recover the lands that they had loaned to families who had come and settled in the village sometimes more than 5 years ago, and which over time would certainly become gifts of land.
- The people living in quarters neighboring those of *the peulhs,* although opposed to any idea of land reallocation affecting them, constantly asked us to reallocate the fields that the *peulhs* possessed but did not cultivate.
- In both the Experimental Unit villages we came up against the category of rich farmers.[6] Without being openly opposed to proposals for land development and consolidation, they systematically refused to exchange fields, arguing that their lands were already of a good size or more fertile. On at least three occasions they involved clientele, family, and lineage solidarities to raise the farmers against us, and obliged us to stop operations of dividing fields and to initiate discussions with the community.[7]

Although the research or development worker does not put himself in the place of groups or social categories whose requirements the project aims to satisfy, it is not possible to be indifferent to this aspect and to confine the program to the proposal of innovations. These innovations can always be rejected or distorted by one group or social category to the disadvantage of others. Therefore, one of the tasks is to help the groups whose living conditions the project aims to improve by putting them in a situation where they develop their own strategies to modify their social status.

We approached this problem in the following ways:

- first, by participating in the life of the village — long stays, participation in their ceremonies, visits to *carr6s,* discussions in the village, meals with farmers, and various small services. Thus we deliberately created a situation for a dialogue with the farmers so that they could express their opinions spontaneously.
- by considering the problems raised by the groups and their proposals in order to clarify them and to relay them to other groups for their opinions.

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6. Farmers call them *borom barke* (literally "those who have the baraka"). Generally, they possess large areas of land; their oxen manure the land, which is sown to cereals and loaned at usurious rates to poor farmers between cropping seasons. Their activities are usually nonagricultural — mostly trade and transport — and control of farming cooperatives.
7. However, one of them succeeded in postponing allocations in the Thysse Kayemore village for 1 year.

- by organizing assemblies in the quarters through informal discussions with leaders and different members of the groups. Experience has shown us that without these preliminary discussions the groups and categories situated at the bottom of the social hierarchy are rarely able to express their interests because of the order of speakers, relationship of authority, order of birth, age, sex, etc.
- by assisting the farmers in clarifying and translating their requirements into proposals for action in this sensitization work, the research team had to be careful not so much to remain neutral but to avoid being the tool of any group. This is all the more difficult as the poor farmers have a tendency to adopt a passive attitude and to let the project team oppose the other farmers the moment a proposal conflicts with their interests. At first it may be surprising to see farmers urge us to appeal to the administrative authorities or to compel one of their people to accept a land exchange or modification of the boundaries of his fields, whereas they themselves refuse to publicly take any position or exert pressure on him. In one case, for example, where a rich head of a *carr6* refused to modify the boundaries of his fields under the pretext that it was harmful to his interests, it required 2 hours of heated discussions with the villagers to make them agree to appoint a committee to verify the merits of his arguments. Without the intervention of the young people present, we would not have been successful. In fact, in this case, he was one of the usurers of the village.

Conclusion

Our experience shows that two conditions are required for farmer participation:

- The first is to know whom the project aims to help — which categories of people (the men and/or women and/or the young people), which farmers (the poor, and/or middle-class, and/or rich farmers), in order to determine if the objectives of the program correspond to the needs of the people concerned. For this purpose, as we have mentioned earlier, it is necessary to start from an analysis of the structure of the rural population in order to identify the different groups and the relationships between them.
- The second is that it is not sufficient that the program be based on such an analysis if the decision is to help the poorest strata of the rural population. It must be kept in mind that these people are not poor because they are technically backward, but because they are also involved in a series of unequal relationships that prevent them from adopting the proposed innovations or, when they do adopt them, to benefit from these innovations.

If research-action aims to obtain the adherence and collaboration of the most disadvantaged strata of society, it should help them to work on the unequal relationships in order to change them. Studies of these relationships at the village-level in developing countries are rare and should be increased. These should not be restricted to internal village structural relationships but relationship also between villages themselves and the national and international systems of which they are a part.

Reference

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Socioeconomic Field Assessment of Prospective Technologies in the SAT of Mali: A Case Study in an OACV Zone

B. Traore*

Abstract

This paper presents a model of the peasant household economy, taking the area under an OACV+ in Mafias a case and condensing its basic features into a linear programming algorithm. This model is then used to simulate the impact on small holders of various government rural development strategies. Based on the findings of the study, the following policy implications are derived: (1) although the intermediate modern technology being introduced is considered to be cheap, it is still too costly for the subsistence farmer and an even cheaper technology is needed; (2) increased farm credit and output price incentives would be the most effective tools for adoption of new technology by farmers in the area; (3) extension institutions which play an important role should be well organized and made truly operational; (4) all possible effects must be considered and the measures recommended must be within an all-embracing, cohesive agricultural development plan. The paper also lists the limitations under which its findings must be viewed and makes suggestions for further research.

Fully recognizing the Importance of rising agricultural productivity in the growth and development of the economy (the rural sector contributed approximately 64% to Mali's 1971-72 GDP), the Malian Government embarked upon a vast scheme of agricultural development in its 1974-78 plan. The central thrust of this scheme was:

1. to develop a set of crops most adequate for the ecology and the socioeconomic characteristics of each zone;
2. to develop the production set (livestock, fishery, handicrafts, etc.) that will associate most effectively with agriculture;
3. to develop activities or aspects of social life other than only economic potentialities, particularly the management skill of the farmers.

To foster these policies, the Government operated through extension institutions called OPERATIONS. These schemes, in collaboration with research institutions, have developed packages of new technology that are being introduced to farmers. The problem is, however, that very little is known about the socioeconomic organization and decision parameters of the farmers who are expected to adopt this new technological package. Hence, interventions into the peasants' farming systems are being effected with only rudimentary knowledge about the constraints faced by farmers and the likely impact of these interventions on rural households.

As Low's (1974) study in Ghana indicated, peasant farmers tend to behave in ways that optimize their objectives, given the constraints within which they operate, and it is only by understanding why and how they come to their production decisions that it would be possible to pursue policy objectives consistent with farmers' aims. Thus, for effective planning and policy formulation, situational economic and technical farm data are required. We need

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+ "Operation Arachide et Cultures Vivrieres" (OACV) is an extension scheme for the development of groundnut and cereals in a specific zone, sponsored by the Government of Mali, the World Bank and the French FAC.

reasonable information on the physical resources, farm income levels, net revenue of different enterprises, and the potential increase in income and production that can result from the optimal utilization of the existing and potential farm resources.

Following the compilation of such information, what is necessary to answer questions involved with interventions in the rural sector is a structural-form representation of the peasant household economy. The basic features of such a representation can be condensed into a linear programming algorithm, which can then be used to simulate the impacts of various government rural development strategies on small-holders. This is the conceptual procedure followed in this study using an OACV area in Mali as an example.

Objectives of the Study

The objectives of this study were:

1. To formulate a simulation model of small-holding farmers in the area under study, using a linear programming algorithm.
2. To use this simulation model to test the impact of government rural development policies on the OACV area.

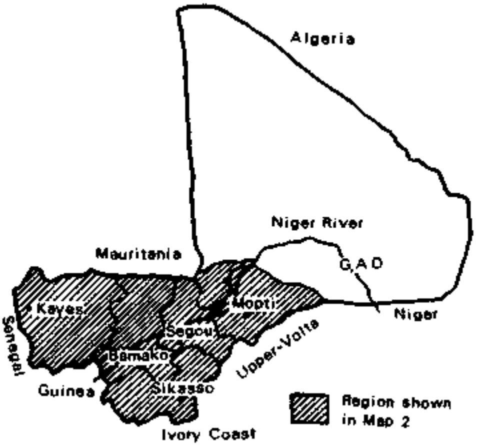
The aim was to identify the production potential and determine the expansion path consistent with increased producer prices, increased resource levels, and improved technology.

The Study Area

OACV covers an area of 138 000 km^2, encompassing three administrative regions — Kayes, Bamako, and Segou (see Maps 1 and 2). Fifteen percent of the total area is located in the Guinean climatic zone, where annual rainfall is more than 1000 mm. The remainder is located in the Sudanian and Sudano-Sahelian climatic zones, where the rainfall ranges between 450 and 1000 mm. The OACV zone is completely included in the area defined as semi-arid tropical by ICRISAT. Both climatic zones noted above are characterized by a long dry season (7 to 8 months) and a short rainy season (4 to 5 months). The first useful rains occur at the end of May and early June. July, August, and September are the wettest months.

Map 1. Republic of Mali.

Scale 1/1.000.000



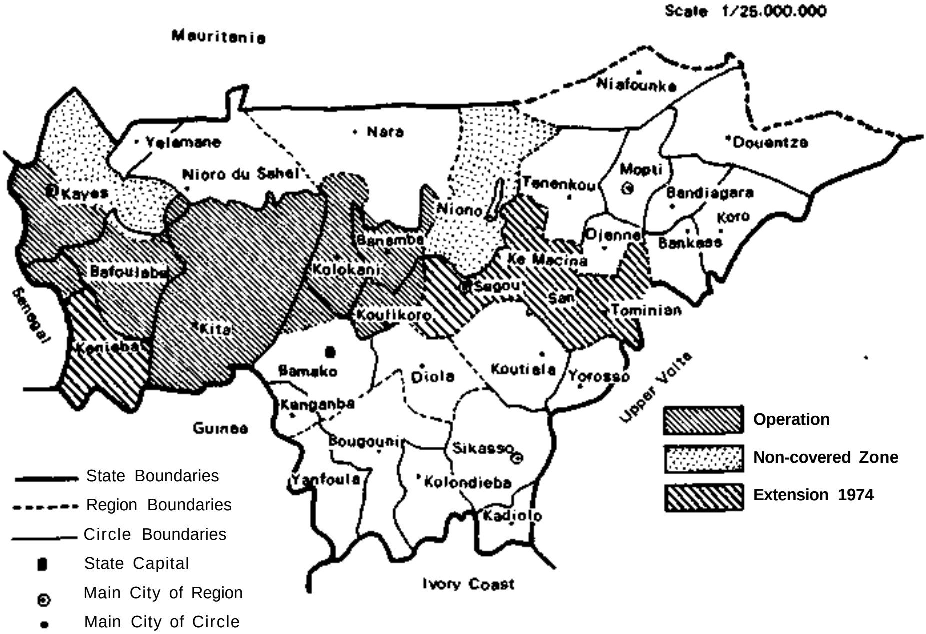
The total population of the area was estimated in 1976 at 1.1 million inhabitants, corresponding to a density of 8 inhabitants per km^2 (for the entire country the density is 4 inhabitants per km^2). Ninety percent of the active population is employed in agriculture. Bambaras and Malinkes are the most important ethnic groups in the area, and they are known to be hard-working farmers, receptive to innovations (n'Daiye 1970).

The OACV is divided into ten operational sectors. This study is based on data collected in eight villages of the subsector of Sirakorola, one of the three subsectors of the Koulikoro sector (see Map 3). The most important crops grown in the area are sorghum, groundnut, millet, suna, fonio, cowpea, and bambara nut. Some farmers use ox-plows, but most of the farmers still use only hand tools.

Empirical Approach

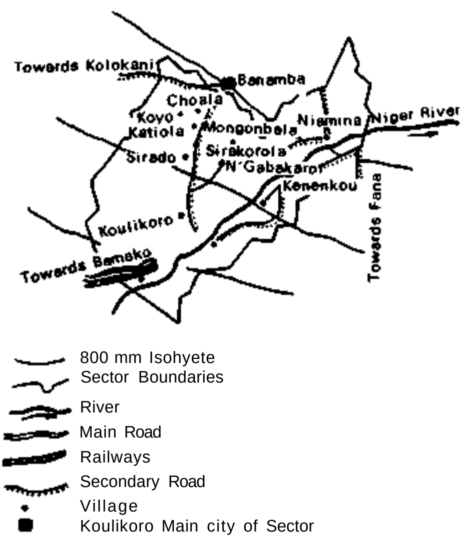
The analytical technique consisted of tables and charts and a linear programming model. First, an "average" farm was computed for two categories of farmers: the wealthier, relatively well-equipped farmers, and the poorer, nonequipped smallholder. Second, a programming analysis of the average farms was

Map 2. OACV Zone in Mali.



Map 3. OACV Sector of Koulikoro.

Scale 1:1.500.000



carried out to determine the optimal cropping program, given the existing technical relationships, average yields, simulated expected yields, prices, resource base, and other limitations specified by the households' planning environment. Third, solutions were obtained: first, with varying levels of resources, keeping the technological coefficients and output prices constant; second, with varying output prices keeping the levels of resources and technological coefficients constant; and third, with improved technology, increased levels of resources and output prices. Finally, static normative supply curves were derived from the programming results of varying output prices.

Programming Models for the Study Area

Restrictions in the Models

Two kinds of restrictions were considered in the models: resource restrictions and subjective restraints. Land, labor and capital were the most important resource restrictions while subjective restraints included consumption habits, family living expenditures, etc. Farm sizes, farm labor, labor devoted to nonfarm activities, non-durable capital available for production, were all restricted to their average amounts observed during the survey.

Activities in the Models

Five groups of activities were defined in the study:

1. farm production and off-farm actvities.
2. cash holding and family living costs activities.
3. capital borrowing, labor hiring, and social labor-using activities.
4. food inventory and consumption activities.
5. buying and selling activities.

Technology and Technical Coefficients of Production

As stated, we considered two groups of farmers: the nonequipped farmers whose practices are more traditional (Group I), and equipped farmers who are more involved with modern practices (Group II). The improved practices, which are not yet generally adopted exactly as advocated by research and extension institutions, were simulated and included in the basic models for investigation.

The improved practices being introduced include better land preparation, early seeding, seeding density, improved seed varieties, use of fungicides and fertilizers, and ox-drawn plowing practices. Information on improved technology was drawn from a report of the Institute of Rural Economy (1973). Results from experimentation in research stations were corrected for normal farm conditions to information concerning three crops grown under improved technology (IT): groundnut, sorghum and millet.

Technical coefficients of production were obtained by computing the average of the farming units in each group.

Analytical Model

In terms of our problem, the linear programming objective of the basic model was to maximize a revenue function, which was expressed as follows:

$$\text{Max } Z = \sum_{j=1}^{K} C_j X_j + \sum_{j=k+1}^{l} C_j^* X_j^* + \sum_{j=l+1}^{n} C_j^{**} X_j^{**} + \sum_{j=n+1}^{n} C_j' X_{j}' + S + \alpha U - E - \sum_{p=1}^{q} D_p Y_p - \sum_{p=1}^{t} H_p G_p$$

Subject to: $A(X+X^*+X^{**}) + A'X' \leqslant B$

$$\begin{aligned} S &= R_1 \\ U &\leqslant R_2 \\ E &= R_3 \\ Y_p &\leqslant B_p\ (p = 1, 2, \ldots\ldots., q) \\ G_p &\leqslant B_s\ (s = 1, 2, \ldots\ldots., t) \end{aligned}$$

and: $X_j;\ X_j^*;\ X_j^{**};\ X_j';\ S;\ U;\ E;\ Y_p;\ Gs \leqslant 0$

The problem was conceptualized in the entire household framework, comprising pure farming activities and other activities as described below. There are r farming activities comprising k sole crop activities, l-k two-crop mixture activities, and n-l three-crop mixture activities cultivated under existing practices; and r-n sole crop activities being produced with improved technology.

- Z = the return to be maximized (household total income minus farm production variable costs, and total living costs)
- X_i = the jth activity which is cultivated sole under existing practices
- X_j^* = the jth activity comprising two crop mixture under existing practices
- X_j^{**} = the jth activity comprising three crop mixture under existing practices
- X_j' = the jth sole crop activity under improved technology
- S = savings (cash holding) activity
- U = off-farm activity
- E = family living expenses paying activity
- Y_p = the p^{th} food inventory using activity
- G_p = the s^{th} food buying activity
- C_j = net price of the j^{th} sole crop activity under existing practices
- C_j^* = net price of the j^{th} two crop mixture activity under existing practices
- C_j^{**} = net price of the j^{th} three crop mixture activity under existing practices

C'_j = net price of the j^{th} sole crop activity under improved technology
D_p = net price of the p^{th} inventory using activity
H_p = net price of the s^{th} food buying activity
α = net price of off-farm activity.

Assuming there are m available resources, A is m by n matrix of input-output coefficients, and B is m by 1 vector of available resources.
R_1 = the level at which savings using activity is constrained
R_2 = the level at which off-farm activity is constrained
R_3 = the level at which family living cost paying activity is restrained
B_p = the level at which the p^{th} inventory using activity is constrained
B_s = the level at which the s^{th} food buying activity is constrained

As stated earlier, improved technology options were simulated and introduced in the basic model for investigation.

Sources of Data

The data collection process and the way in which the data were used in the model are fully discussed in the main study. Some of the data collected are presented in Tables 1 to 9 at the end of this paper.

The analysis is based on data obtained from three sources:

Farm Survey

The author carried out a farm survey over a 6-month period (August 1977 through February 1978) in the study area. Twenty-four households were chosen to represent the farming systems in the area (22 were retained for the analysis) and input-output data were collected from them. Twice-weekly visits were paid to each of them by enumerators throughout the survey period. In combination with the cost route method, we used the direct measurement technique and the group farm interview. A structured interview schedule was used. All 161 farm plots of the sample were carefully measured with field compasses and tapes. Production and daily household food consumption were, as far as possible, directly measured. Market prices of agricultural products were also collected throughout the survey period.

Personal Interviews

Personal interviews took place with the staff of the Evaluation Unit of the Institute of Rural Economy, OACV field demonstrators and other staff members, and the local administrative authorities of Sirakorola.

Reports and Documents

Relevant government reports and documents were consulted.

Table 1. Evolution of total, rural, and agricultural populations of Mali from 1969 to 1973.

Years	Total population ('000)	Rural population Total ('000)	Rural population %	Agri. population Total ('000)	Agri. population %
1969	4929	4537	92	4171	85
1970	4980	4646	93	4198	84
1971	5142	4775	93	4224	82
1972	5257	4871	93	4299	82
1973	5376	4969	92	4337	81
Average growth rates %	2.19	2.29		0.97	

Source: Service de la Statistique Generale de la Compatabilite Nationale et de la Mecanographie (1976).

Table 2. Progress of innovations application in OACV (1967/68–1974/75).

Factors		1967–68		1968–69		1969–70		1970–71		1971–72		1972–73		1973–74		1974–75	
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Improved seeds	G[a]	1 329	3[b]	4 927	10	8 319	12	15 394	15	14 965	16[b]	15 059	16	16 808	19	52 297	49
	C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fungicides	G	6 982	15	10 491	22	11 229	16	18 556	18	22 491	24	20 732	22	33 482	37	36 054	34
Insecticides	C	2 633	7	11 381	23	13 087	18	11 205	11	20 135	22	17 416	18	14 989	17	37 347	35
Fertilizer	G	1 824	4	4 925	10	5 704	8	19 107	19	23 403	25	30 438	32	40 346	45	36 260	34
	C	–	–	–	–	–	–	–	–	–		–	–	–	–	23	0.01

Source: *OACV (1970).*

a. G = groundnut, C = cereals (millet, sorghum).

b. The percentages represent the proportion of cultivated areas on which the respective technologies were applied.

Table 3. Introduction of equipment In the OACV.

Equipment	Before 1974	Increase 1974-75	Total
Multifunction plows	2425	905	3330
Seeders	1941	887	2828
Carts	1353	180	1533

Source: OACV (1976).

Table 4. Credit situation in OACV (1967/68-1974/75) (million M.F.).

Kind of credit	Amount lent	Amount repaid	Balance to be paid
Seeds	568	413	156
Fertilizer	546	415	131
Equipment	212	90	122
Total	1326	918	409

Source: OACV (1976).

Table 5. Characteristics of holdings in the study area (1977/78).

	Group 1	Group II
Average farm size (ha)	5.34	14.19
Average number of plots	5.55	8.10
Average size of plots (ha)	0.91	1.63
Average number of collective plots	3.33	4.85
Average size of collective plots (ha)	1.27	2.29
Average number of individual plots	3.33	5.25
Average size of individual plots (ha)	0.58	1.07

Source: Derived from survey data.

Table 6. Composition and average size of households in the survey villages, September 1977

	Group I	Group II
Male adults	2.9	5.3
Female adults	3.4	6.8
Children (8-14)	2.0	3.4
Total	8.3	15.5

Source: Derived from survey data.

Table 7. Average number of tools and equipment per household (1977/78).

Tools and equipment	Group 1	Group II
Hand tools	6.22	10.31
Plows	-	1.69
Seeders	-	0.85
Carts	-	1.08
Plowing-oxen	-	3.23
Pulling-donkeys	-	1.15

Source: Derived from survey data.

Table 8. Average yields observed for different crop enterprises in the study villages 1977/78 (kg/ha).

Crop	Group 1	Group II
Groundnut	218	295
Sorghum	518	580
Millet	269	527
Suna	1038	910
Fonio	916	691
Cowpea	-	0
Bambara nut	184	245
Sweet potato	9300	-
SO/CP Sorghum	674	355
Cowpea	29	54
GN/BN Groundnut	140	96
Bambara nut	45	31
GN/SO Groundnut	416	-
Sorghum	92	-
MI/CP Millet	-	321
Cowpea	-	328
SU/SO Suna	804	-
Sorghum	408	-
M/C/B Millet	-	807
Cowpea	-	5
Bambara nut	-	16

Source: Derived from survey date.

Summary of Findings

Table 10 shows some results of the model with improved technology and varying resources levels. Columns B2 through B6 are results from hypothetical increases in resources levels. The overall results of the study can be summarized in words as follows:

1. The analysis of production factors in the study area shows that for future development of agricultural production in the area, introduction of appropriate improved technology should continue for increased productivity and farm size.

2. The analysis shows also that mixed cropping is relatively unimportant in the study area; it occupied only about 12% of the average farm land for group I (nonequipped farmers), and 6% for group II (equipped farmers).

3. Three types of labor were observed during the study: family labor, social labor including communal and exchange labor, and hired labor. Group I farmers spent about 46% of total family labor on off-farm activities, and group II farmers spent about 33%. These activities generated approximately 55% of the total income of households.

4. It was discovered that, in terms of total quantity of rainfall, the survey year was among the worst seasons experienced in the area.

5. It has been demonstrated that, in abnormal conditions, the use of expected — rather than actual — crop yields was more appropriate in the study of farmer decision-making.

6. Optimum farm income is very low and there is very little scope for improvement, given the existing level of resources, technology, and farm prices. However, this optimum is 40% higher than the actual farm income observed in the area.

7. With existing practices, the relative profitability of groundnut decreases as resource level is increased.

8. Groundnut was produced under improved technology only at high resource levels.

9. Introduction of new technology resulted in higher gross income and higher gross returns relative to resources, and it engendered larger farm size.

10. Adoption of new technology would increase with higher resources levels.

11. For the adoption of new technology, capital is the most limiting factor for group I farmers, and the September-October labor shortage is the most limiting for group II farmers.

12. Labor productivity increased with the introduction of new technology.

13. Supply responses to groundnut and sorghum prices are higher when improved technology is introduced in the model.

Table 9. Average income in the study villages, M.F. per household (1977/78).

	At official prices		At market prices	
	Group 1	Group II	Group I	Group II
Gross farm income	99 948	233 732	208 750	488 626
Variable costs	11 317	28 706	11 317	28 706
Gross margin	88 631	205 026	197 433	459 920
Fixed costs	3 317	44 609	3 317	44 609
Net farm income	85 314	160417	194 116	415311

Source: Derived from survey data.

Policy Implications

1. Although the intermediate modern technology reckoned to be cheap is the type being introduced, it is still too costly for the subsistence farmers. Therefore, research institutions should continue searching for cheaper technology.

2. Cereals are actually harvested manually; an improvement in this area by research institutions could contribute to relaxation of the labor constraint.

3. Increased farm credit would be the most effective policy for technology adoption in the study area; this would enable farmers to acquire improved farm inputs and to hire casual labor at peak farming periods. It shoud, however, be supplemented by an output price incentive for increased farm income that would enable farmers to pay the credit back.

4. Extension institutions have a very important role to play in the process; these institutions bring government decisions to farmers, train them for improved skills, and help them to take full advantage of such decisions. Therefore, these institutions should be well organized and operational.

However, in planning agricultural development schemes aimed at farmers, it is always necessary to consider both direct and indirect effects of the policies involved. For example: a farm output expansion policy should be accompanied by adequate arrangements for storage and marketing of the increasing quantities of products to avoid a cost-price squeeze; an increased groundnut price could reduce the competitive position of groundnut on the international market and cut down exports; rising cereal prices could lead to a price-wage spiral; etc. Therefore, whatever policy is chosen has to be within an all-embracing cohesive agricultural development plan.

Limitations and Suggestions for Further Studies

1. The major limitation of this study is that it determined the most profitable path of adjustment and supply responses to improved technology, credit and price policies, but not necessarily the most probable ones. For many reasons — mostly social, technical and weather constraints — it generally takes a long time for farmers to follow the lines suggested in the results. Intensive research, education, and extension activities could go a long way to reduce the lag in adjustment.

2. The analysis was not extended to derive elasticities that would indicate the magnitudes by which suggested policy variables should be manipulated; this could be part of further studies.

3. Other issues such as integration of livestock enterprises, or influence of weather uncertainty on farming decisions, were not included in this study and would be desirable fields for further research work.

4. More study and empirical work, covering other agricultural products and other parts of

Table 10. Summary of optimum farm plans and shadow prices (M.F.) under a combination of improved technology and existing practices of group I and variable resource levels.

Activities	Constraint levels											
	B_1		B_2		B_3		B_4		B_5		B_6	
	Act. level	Shadow prices	Act. level	Shadow prices	Act. level	Shadow prices	Act. level	Shadow prices	Act. level	Shadow prices	Act. level	Shadow prices
1	2	3	4	5	6	7	8	9	10	11	12	13
Existing practices (ha)												
Groundnut	1.04		1.04			5 498		9 823		10 405		13 592
Sorghum		2 241	5.32			7 337		8 847		21 720		24 339
Millet	0.33			18 864		32 768		33 464		55 432		47 200
Suna	0.23			237 066		8 071		4 266		39 741		19 986
Fonio	0.13	–	0.13	–	0.13	–	0.13	–	0.13	–	0.13	–
Bambaranut	1.47	–	2.36	–	6.93	–	8.36	–	9.67	–	42.60	–
Sorghum/cowpea	0.30	–	0.30	–	2.77	–	1.60	–	0.72	–	0.30	–
Groundnut/bambaranut	–	12 739	–	349 785	–	10 799	–	13 617	–	4 759	–	17 142
Groundnut/sorghum	–	32 512	–	410 545	–	35 473	–	38 479	–	50 142	–	40 890
Suna/sorghum	–	16 468	0.30	–	0.30	–	0.30	–	0.34	–	0.52	–
Improved technology (ha)												
Groundnut	–	28 380	–	366 013	0.83	–	0.83	–	0.83	–	0.83	–
Sorghum	1.84	–	0.58	–	0.43	–	1.04	–	1.48	–	1.63	–
Millet	–	–	0.79	–	0.78	–	0.79	–	0.79	–	0.20	–
Buying: (% of cons.)												
Millet	47.21	–	–	25	0.00	–	–	4	–	24	47.21	–
Suna	42.85	–	42.85	–	42.85	–	42.85	–	34.44	–	–	4
Sonio	15.38	–	15.38	–	15.38	–	15.38	–	15.38	–	15.38	–
Cowpea	16.66	–	16.66	–	16.66	–	–	–	–	–	16.66	–
Bambaranut	–	–	–	–	–	–	–	–	–	–	–	–
Selling: (% of production)												
Groundnut (kg)	1000	–	1000	–	1000	–	1000	–	1000	–	1000	–

Continued

Table 10 *continued.*

Sorghum	13.66	–	56.85	–	13.72	–	13.69	–	13.69	–	13.65	–
Millet	–	89	–	12	–	37	–	33	–	13	–	43
Suna	–	108	–	40	–	97	–	99	–	37	–	33
Sonio	–	416	–	1 008	–	317	–	310	–	76	–	78
Cowpea	–	49	–	414	89	–	72	–	38	–	–	349
Bambaranut	95	–	97	–	99	–	99	–	99	–	100	–
Total labor used (m.d.)	309	–	557	–	599	–	582	–	605	–	1713	–
% of available labor used	41	–	75	–	67	–	55	–	50	–	–	–
% of April family labor used	12	–	24	–	48	–	29	–	15	–	10	–
May "	15	–	79	–	10	–	13	–	15	–	15	–
June "	64	–	69	–	100	296	99	–	98	–	85	–
July "	59	–	100	133	100	2 057	100	2 057	100	3 126	100	440
August "	39	–	95	–	100	2 057	100	2 057	100	1 961	100	440
September "	59	–	83	–	100	2 057	100	2 057	100	1 160	100	440
October "	100	2 663	100	897	100	1 706	100	1 688	100	200	100	440
Nov. Dec. Jan. Feb. "	50	–	94	–	80	–	76	–	75	–	100	240
% of Sept. social labour used	–	200	–	200	100	1 857	100	1 857	100	960	100	240
October "	100	2 463	100	697	100	1 506	100	1 488	98	–	100	240
Nov. Dec. Jan. Feb. "	–	200	–	200	–	200	–	200	–	200	100	240
April hired labor used (m.d.)	–	–	–	–	–	2 057	–	2 057	–	1 961	–	440
May "	–	–	–	–	–	2 057	–	2 057	–	1 961	–	440
June "	–	–	–	–	–	1 761	–	2 057	–	1 961	–	440
July "	–	–	–	–	0.11	–	16.02	–	30.00	1 164	291	–
August "	–	–	–	–	2.56	–	14.83	–	27.59	–	420	–
September "	–	–	–	–	1.86	–	0.31	–	–	801	273	–
October "	–	–	–	–	–	351	–	369	–	1 761	25	–
Nov. Dec. Jan. Feb. "	–	400	–	400	–	2 057	–	2 057	–	1 961	104	–
Capital used (M.F.)	9793	–	11317	61	22634	4	33951	4	45268	4	499796	–
% of total capital used	86.53	–	100	–	100	–	100	–	100	–	–	–
Inventory: % used												
millet	100	93	100	16	100	41	100	37	100	17	100	47
sonio	100	449	100	1 041	100	350	100	343	100	108	100	111
cowpea	100	74	100	439	100	25	100	25	100	25	100	374
bambaranut	100	20	100	20	100	20	100	20	100	20	100	20

Continued

Table 10 *continued*

Gross revenue (M.F.)	127 817	297 014	503 852	570 687	634 199	2 165 498
Total land cultivated (ha)	5.34	10.82	12.17	13.05	13.96	46.21
gross return/hectare	23 749	27 450	41 401	43 731	45 430	46 862
gross return/man day	410	533	841	980	1 048	1 264
gross return/capital	12.95	26.24	22.26	16.80	14.00	4.33
% of crop mixtures	5.62	5.54	25.22	14.56	7.59	1.77
% of sole crops	94.38	94.46	74.78	85.44	92.41	98.23
% of sole groundnut	19.47	9.61	6.82	6.36	5.94	1.79
% of improved crops	34.45	12.86	16.76	20.38	22.20	5.75
Total capital borrowed (M.F.)	–	–	11 317	22 634	33 951	488 479
Total labor used/hectare (m.d.)	57.92	51.47	49.22	44.62	43.36	37.06

Source: Derived from analytical model.

the country, remains to be carried out to give a complete picture of the problems encountered by the farmers, their possible solutions, and the consequences of these solutions. If this kind of study, or a variant of it, is conducted in other parts of the country, it could be of particular interest for the formulation of agricultural development policies, the orientation and implementation of research and extension institutions.

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Socioeconomic Research on Operational Landholdings

M. Benoit-Cattin*

Abstract

This paper explores the methodology of on-farm research. The method is based on a rational choice of specific situations. It concentrates on the farm as a place where decisions on agricultural production are taken. The author holds these decisions are a result of the dialectic relationship between economic and social systems and ecosystems and a given historical context. Topics covered include selection of investigation locations, village-level studies, the residential unit as a unit of investigation, identification and analysis of the farm, the cultivated plot as an observational unit, study of livestock raising, method for analyzing observations, interdisciplinary work, and the integration of analysis and action.

This paper puts forward several proposals concerning the methodology of on-farm research conducted within an agricultural research program. These proposals are based mainly on the author's experience in Senegal within the Experimental Units project and earlier in the Ivory Coast (interdisciplinary study in a forest region).

The general objective of this research is to understand the dynamics of farms in order to explain their present status and to gain a better idea of their future potential. This is neither a review of a development project nor is it a statistical study. Farm dynamics are related to technical innovations or proposals developed through agricultural research. It is therefore a useful link between research and development; it is also useful for technical research in terms of identification, selection, and designing methodology to study problems (feedback).

The method is based on a rational choice of specific situations. A limited number of situations are selected to enable a better understanding. It focuses on the farm as a decision-making center for agricultural production. These decisions are a result of the dialectic relationship between economic and social systems and ecosystems and a given historical context.

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NOTE: This is an edited translation of the original French text, which appears in Appendix 1.

Primary Concern of the Investigator

The investigator should first draw up a general bibliography. Using theses and other literature he should collect information on the settlement process and important events in agriculture — wars, colonization, market economy, etc. From development projects and their reviews, he can gain information on past, present, and future development efforts.

Selection of Investigation Locations

The place for investigations will be the village. In practice, investigations can be conducted in three or four villages with one or two investigators per village. Beyond that, it will be difficult to handle information, especially in the beginning.

Generally, the village is a definite administrative unit but, in practice, the study can be conducted in a village made up of several possibly widespread quarters or in several villages having certain relationships within the same cooperative or area. These quarters or villages may correspond to different lineages, ethnic groups, *or* castes.

The selection of these villages is very important and should be made in consultation with all the people who know the region —

administrators, researchers, development officials, etc. (collaboration with development officials will avoid the possibility of disputes over the "representativeness" of the results). The selection criteria should be related to the ecosystem (rainfall, soil, vegetation, etc.) and the economic and social system — time and density of settlement (land saturation), different ethnic groups, proximity to a town, etc.

Village-Level Studies

A few preliminary investigations will enable a better verification and characterization of the villages selected and will provide a basis for further investigation.

The investigator should study:

- the history of the village and its quarters.
- the land-tenure system and land use including livestock raising.
- the collective equipment.
- the cooperative.
- the relations with outside areas (neighboring villages, migrations, exchange of produce, transfer of income, etc.).
- the cropped areas and other structures in relation to development projects.

The information can be collected through discussions with certain people (village heads, leading citizens, development officials, etc.). An exhaustive demographic census may be carried out after the census of residential units. This will provide more accurate data on family structures, migrations, extra-agricultural activities, and income, etc.

The Residential Unit as a Unit of Investigation

Without forming any preconceived ideas on whether the farm (economic unit) corresponds to the compound *or* physical residential unit, the latter will be retained as the primary investigation unit because it is easily identified, socially recognized and organized, relatively stable, etc. In Senegal the residential unit is the *carre* ("compound" in English[1]) although subsequent investigations may reveal that a *carre* may include several farms or economic (production) units.

An identification method is established and used on all schedules —year, village, quarter, residential unit, household.

A rational choice can be made for detailed investigations based on village-level studies, the residential units, and different situations (ethnic group, caste, lineage, land availability, time of settlement, farming systems, system of livestock raising, internal complexity, etc.). Each investigator should be able to study about ten residential units.

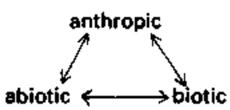
The Farm: Its Identification and Analysis

Analyses should be based on the farm since it is, by definition, the place where economic and social systems interact with the ecosystem through agricultural practices.

The farm is a system. The study of this system and how it functions requires the identification of its factors and the analysis of the relationship between these factors in relation to the objectives of the system.

The agricultural system has several objectives in a transitional agricultural economy (from subsistence to market economy). When, as for any other system, its primary objective is its perpetuation, it seeks to be self-sufficient in food and to maintain the land-tenure system. Most of the other objectives (these vary with individuals, their status, etc.), increasingly generate monetary requirements.

The factors of the system may be classified into: anthropic, biotic, and abiotic having reciprocal relationships:



The *relationships* between these three categories of factors are identified and analyzed *within* and *between* the residential units.

Types of relationships include:

- relationships between anthropic factors: family structures, households, social status and hierarchy, organization of work, monetary exchanges, debts, etc.,

1. Also called "keur" in Wolof and "m'bind" in Serere.

- relationship between biotic factors: crop rotations, cropping patterns, composition of herds, livestock-raising systems,
- relationship between abiotic factors: sets of farm equipment.
- relationship between anthropic and biotic factors: distribution of crops and animals according to individuals and their status, consumption of agricultural produce.
- relationship between anthropic and abiotic factors: distribution of land, of implements, etc. according to individuals, their status, and mode of acquisition.
- relationship between biotic and abiotic factors: yield factors, animal traction.

These relationships occur mainly within the organization of agricultural work (in a broad sense): who does what, with whom, on whose plot, etc. It is this complex interdependence within the organization of agricultural work that enables the identification of the farm.

The Cultivated Plot as an Observation Unit

It is in the cultivated plot that these factors, mainly their relationships, can be observed: ownership of the plot, organization of work, use of draft animals and equipment, cultural practices, etc.

To complement these observations, studies are required of the residential unit and farms once they have been identified: population, migrations, extra-agricultural activities and income, inventory of sets of farm equipment (draft animals and implements), monetary expenditure (debts, etc.), consumption of agricultural produce, etc.

Study of Livestock Systems

This study follows the same general approach. The animals constitute the biotic factors to be related to the anthropic factors (owners, managers) and abiotic factors (pastures, harvest by-products, organic manure for plots). This applies to relationships within the residential unit or village, and possibly between villages (transbumance or nomadism).

It is important to identify the interactions between livestock and agricultural systems. These systems supplement and/or compete with each other and these relationships have a determining influence on their future.

Method for Analyzing Observations

The quantification of observations is not an end in itself but a means of providing a better identification of the relationships between the factors. Thus a study of operation schedules is of little use in itself; moreover, it is tedious and often disappointing. On the other hand, having obtained information on the organization of work, it would be useful to specify the nature of certain exchanges (reciprocation, imbalance) by evaluating their importance. An estimation of half days of work is generally sufficient for this purpose. The same observations can be made for budget investigations.

For recollection, the methods for statistical analysis are — factorial, correspondence, regression etc. These are the means available to investigators and should be used to study certain problems, not vice versa — data should not be collected to apply existing methods.

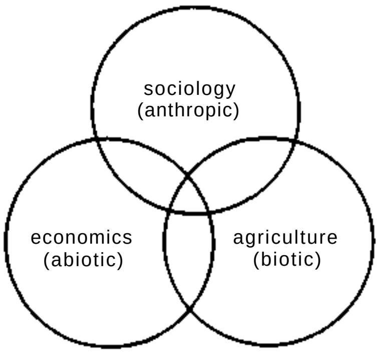
The relationships between factors (whether quantified or not) can be presented in a very practical way by using a *matrix* and this can be done at all stages of the investigation (primary analysis to the final presentation). Using a double-entry matrix of this type, it is possible to quantify, aggregate, classify, and check (cross-checking, blank squares) data.

Mathematical farm models are a simplified way of representing certain types of farms and are generally used for computerized simulation. But it should be noted that this model is only possible, and in any case relevant, if proper information is available on the mechanism of the farm — that is, if these analyses are sufficiently advanced and include innovations made within the production systems. A model requires the use of normative data compiled by using a specific methodology.

Remarks on Interdisciplinary Work

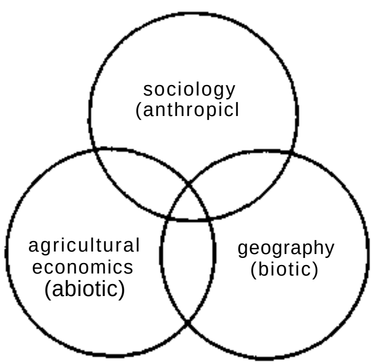
The type of factors within the farm system and their relationships belong to several scientific disciplines. However, all these analyses can be carried out by an investigator with training in agriculture with some knowledge of socio-economics. There is, however, a risk that he may concentrate on the biotic and abiotic factors.

On the other hand, a useful collaboration may be set up between two or three scientists specializing in sociology, agronomy, and economics.



The areas where the circles of each discipline overlap shows interaction between the approaches.

As the same scientist often knows agronomy and economics, the area of study is widened by including a specialist in geography who would have a better spatial perception of the phenomenon and expert knowledge of mapping techniques.



In these two cases of interdisciplinary work *the common problem* may be extended to the dynamics of the rural society. The *common ground* between the two will be the selected villages as shown earlier.

Such truly interdisciplinary work seems difficult when more than three scientists are involved because it requires that they work together at the location (and in the office) and that they should have certain affinities and a certain common philosophy.

Research and Action

The originality and fruitfulness of the work carried out for more than 10 years in the Experimental Units project in Senegal is due to the integration of analysis and action. The analysis of the situations and their changes provides guidelines for action, and the results of action enrich the dynamic analyses.

Initially, the primary objective was to promote as quickly as possible in the rural areas technical innovations developed through agricultural research. This required a certain number of corollary activities concerning livestock raising, cooperation, marketing of produce, extension activities, land-tenure system, farm management, etc. Analysis and action were combined for all these aspects.

For farm management, much work was done and its analysis has provided the main methodological proposals given in this paper. Work on farms has been progressively organized and structured so that it has been possible to develop a method of recommendations on farm management. This method has improved with increasing information on farm dynamics.

At present, the recommendations on long-term management focus on promotion of techniques (for agriculture and livestock) and provide basic material for analyses on farm dynamics.

Research on farm dynamics becomes more relevant as it is conducted over a long eventful period: a single still does not make a movie.

Discussant's Comments

Victor F. Amann*

The five papers presented in this session cover many subjects — from the well-documented field assessment presented by Dr. Chaudhari to the theoretical discussion of proposed research by Benoit-Cattin. Unfortunately, I was asked only one hour ago to discuss these papers because the discussant was unable to attend.

Dr. Chaudhari discusses the adoption of dryland farming technology in the Malwa region of Madhya Pradesh. His findings show the gap between farm and experimental results. This is mainly due *to* low investment in seed and fertilizer, which is not an unusual result. He found, however, that the project results showed significant yield increases through adoption of new varieties, which is quite significant in a 5-year period. It seems to demonstrate that farmers are willing to adopt new ideas that increase income if labor requirements do not change significantly.

Mention was made of improved animal husbandry and of a machinery program. However, no data was presented on the use and distribution of draft power. These two factors are important in improving farm output in Africa and I wonder if the same problems are important in India.

The analysis shows that small farmers with less than 2 ha of land were the major beneficiaries of the scheme, although the author later discusses a general imbalance in the use of fertilizer. It would be of interest to know how the small group received greater benefits. For example, was it better weeding or increased labor use? The paper suggests that intensification of labor use has high marginal returns on small units.

The last point, on the improvement in farmer response to farm business analysis after they were fed back some data, is similar to experience in other countries. It seems logical that when farmers see the results of the research after the endless questions they are asked and the cooperation requested of them by field researchers, they are more responsive. There seems to be a lesson here for researchers to have a system of information feedback to their respondents.

The second paper, by Dr. Doherty, discusses the sociological problems of introduction of two separate technologies. The introduction of the wheeled toolbar does seem to create some special problems in human relationships, especially, as the paper suggests, when the cost of the machine is beyond the purchasing capability of a single farmer. Group action for purchase of such an implement would undoubtedly cause *human* relations problems because timely plowing is so important for ensuring a crop. The paper suggests that despite the technological possibilities of the machine in improving output, reducing power needs, and increasing the speed of plowing, it must be made available at a lower price if adoption is to be expected. The idea of group action in the purchase and use of a machine as costly as the wheeled tool carrier seems remote. I would like to know how the Tropicultor in West Africa received such widespread usage. Perhaps something can be learned from that experience for use in both India and southern Africa.

The second innovation discussed is the watershed technology for supplemental irrigation. This seems to be an old practice in parts of India, but more widespread use is suggested. The problem raised for discussion by the author relates to management of the organization and the question of the optimum size of a group to make this innovation workable. This same question is now under discussion in Botswana where dams are built at the instigation of groups for watering cattle. The control of livestock numbers for ecological and range preservation reasons is part of the package, but in arable agriculture water use may be more difficult to control.

Field tests designed to show possible

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socially-related preferences for different options in the application of new technology, such as the studies under way at ICRISAT and described in Doherty's paper, are quite important. These should be carried out in a variety of social environments, as well as in a variety of agroclimatic environments as at present. In India, it seems necessary to identify relatively egalitarian SAT farming societies for this purpose, which might reveal contrasting socially-based preferences regarding such new technology, as compared with the highly stratified societies of the three villages in which such research is presently under way.

ICRISAT scientists, and trainees and scientists who visit ICRISAT, need to know much more about different types of social organization of agriculture in SAT areas. These different organizations need to be assessed for their effects on productivity, investment, conservation, and welfare. The results of such assessment need to be taken into account from the beginning in the design of new agricultural technology. It is suggested that there is an urgent need to add to our knowledge of the comparative social organization, especially for land use, land tenure, water use, water tenure, labor, and related topics.

I shall discuss the papers by Messrs. Faye and Benoit-Cattin together as they both deal with theoretical approaches to landholding research. The paper by Mr. Faye discussed the relationships between the wealthier and the disadvantaged groups in society. His thesis is that changes usually do not have any appreciable effect on the relative positions of groups within a village or society. The poorest strata usually get these by chance and remain poor due to a series of unfortunate circumstances. Research is required at the microlevel to see if these circumstances can be understood and if unequal relationships can be changed either by internal or external forces. The author did not suggest that differential aversion to risk may be the chief determinant of the relative position of people in the socioeconomic hierarchy.

Mr. Benoit-Cattin presented a theoretical paper on the methodology of research on operational landholdings in the West African context. His basic concern is the farm unit or family. He points out that a family in a compound or village is affected by other interrelationships that are not family-related. The relationships between sociology, economics, agronomy and geography are all important in operational landholding research.

One point he raised that was given very little attention at this workshop was the interaction between livestock and cropping. Understanding the competitive and complementary relationships is important in determining a more satisfactory landholding situation and can effect interpersonal relationships within a village, group, or family. This will require some microlevel research.

Both papers concluded that land tenure must involve every family in the village of compound and that social structures and land tenure relationships require closer examination. The paper by Faye was mostly concerned with land tenure and its effects on the various economic strata in the society and how they are affected by land tenure and social change. It seems that a fuller understanding of the land tenure/social justice relationships would be useful for policy makers.

The last paper I want to discuss was presented by Mr. Traore of Mali, who presented a very well-organized analysis. Methodologies were clearly identified which aimed at testing farmer acceptance of the package of new technologies within a linear programming framework. The results showed that larger farmers were the earlier and more frequent adopters, which is different from what Chaudhari found in his research in India. The paper points out that adoption of a relatively simple intermediate technology is slow because its cost often seems to be too high for early acceptance. If price and credit were closely tied these factors could lead to larger output, provided farmers were assured of adequate credit at reasonable terms and product prices were consistently high. Unfortunately the author should have emphasized that in the real world, these conditions cannot usually be met, especially for export crops. Even though the paper shows results subject to the constraints in the model, it did not produce any surprising new discoveries. The methodology used is very clear-cut and could be a very useful tool of analysis if adequate data are available.

Chairman's Summary

B. A. Krantz*

Five papers were presented on socioeconomic field assessment of prospective technology. The papers by Chaudhari, Faye, and Traore were based on actual experience with research-cum-extension or extension schemes to spread specific technologies in areas of India, Senegal and Mali respectively. The other two papers, by Doherty and Benoit-Cattin, dealt with the approaches and methodological aspects in conducting studies for socioeconomic field assessment of prospective technology.

Chaudhari's paper records the extent of adoption of improved farming practices by farmers in the Indo-UK Project on Dry Farming at Indore (India). From 1974-75 to 1977-78 farmers have been able to adopt a number of new practices that increased cropping intensity, income, and employment. In particular, cropping of the traditionally *kharif* (rainy season) fallow lands has increased from 34% of net sown area in 1974-75 to 68% in 1977-78. Some farmers reported lack of capital, supplies, and risk as the main constraints.

Traore presented results using linear programming as a method of analysis. The results showed that larger farmers were earlier and more frequent adopters of new technology. Capital was found to be a major constraint faced by slow adopters of technology.

Faye presented some ideas emerging from a research-cum-action program conducted in the Experimental Units of Sine-Saloum (Senegal). He concluded that proper identification of target groups based on full understanding of social structure is essential if the prospective technologies are to reach the small and poor farmers.

Benoit-Cattin also used the Unites Experimentales Project in Senegal as his reference while presenting a methodological framework for conducting research for socioeconomic field assessment of prospective technology.

Doherty's main concern was human organization, to facilitate adoption of technology which is technically *or* financially indivisible and therefore beyond the capacity of individual farmers to adopt it. Adoption of the watershed as a unit of resource management and of an animal-drawn Tropicultor which facilitated conservation and efficient use of moisture were two items in the context of which the need for group action was emphasized.

Dr. Amann initiated the discussion after briefly summarizing the contents of papers presented. Except for a few questions seeking clarification on specific aspects of the research-cum-action programs, most of the discussion centered on the issues of methodology and research approach discussed by Doherty and Benoit-Cattin in their papers.

In particular, the participants questioned the validity of ideas involving specification of desired numbers of people in a group to ensure durability and viability of group action for adoption of watershed based technology, as discussed by Dr. Doherty. Also questioned was the relevance of the framework of hunter and gatherer societies for the study of an integrated community of Indian farmers to learn about conditions required for viable group action among farmers. The need for recognition of 'profitability' or 'utility' as a key factor in inducing group action was also emphasized. Mr. Benoit-Cattin's suggestions about the unit of investigation (i.e., residential unit or operational holding) were also debated; it was concluded that flexibility in the approach was required and it depended on the purpose of the study.

In terms of policy conclusions the following was the feeling of the group:

1. Since the term prospective technology may mean different things (e.g., innovation at its early stage or the technology yet inside the fences of experimental stations), the methodology for its socioeconomic field assessment will differ accordingly. The questions relating to the area, time span, and sample sizes for such

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studies can also be decided only on the basis of the characteristics of the technology.

2. It would be desirable that field assessment studies involve the local agencies responsible for development programs in the area. It may facilitate execution of the study as well as the subsequent follow-up.
3. If quantitative models are developed for the purpose of socio-economic field assessment of prospective technology their validity should be fully established on the basis of the extent to which they approximate the real-world situation.
4. The time lag between conduct of studies and reporting of results should be as short as possible to facilitate quick feedback to research stations so that timely amendments in the technology can be made.

Chapter 4

Issues in Foodgrain Marketing

Reforming Grain Marketing Systems in West Africa: A Case Study of Mali

Elliot Berg*

Abstract

This paper examines the foodgrain-marketing problems of the West African republic of Mali and analyzes why numerous proposals for reform have proven infeasible or too difficult to implement Among the principal findings are: (1) the Mali government is severely limited by physical, financial, and organizational factors in what it can implement; (2) the present mixed system of marketing (government and private sector) cannot be easily improved as recommended in some studies; (3) uncertainty over prices and general market disorganization divert farmer effort to cash crops and may reduce farmer willingness to undertake greater efforts or new ventures in grain production; (4) since existing cooperative organizations are instruments of government used mainly for grain requisition purposes, farmers are reluctant to set up true cooperatives that could better defend their interests; (5) external assistance including food aid and a line of credit in the Operations Account in Paris has diluted the impact of grain-marketing policies and allowed the Mali government to maintain policies without having to fully absorb the consequences; (6) until very recently, the government had not been presented with well thought through proposals. The author concludes that in any successful reform the State grain agency will have to play a major role — even under a "minimalist" assumption about the State's role in grain marketing — and that major improvements will result from indirect measures such as improvement and extension of feeder-road networks, better information on crops and marketing and better dissemination of such information, closer attention to relaxation of production constraints on food grains, and improved policy analysis within government Such indirect changes will widen the options for reform and increase the probability of their adoption.

The West African republic of Mali may hold a record in the world of foodgrain marketing, price policy, and storage: in the past 5 years, no fewer than 11 missions have studied Mali's problems in this area and have written reports thereon. And this is not an accident. Mali's difficulties have been and remain deep-rooted, and finding a way out is not simple. One happy result of all this attention is that Mali's grain-marketing system and price policies are unusually well documented. Since marketing and price issues are important in the country's rural development, Mali provides a highly pertinent case study. The nature of the problems — the deficiencies of existing structures and policies — *are* clearly observable, as *are* the obstacles to reform; and in many respects, the Mali situation has close parallels throughout West Africa. In this paper I will focus on the question: why has reform proven so difficult?

Deficiencies in Marketing Performance and Policy

There is little disagreement in most of the reports, and in the understanding of concerned Malians, about the kinds of inadequacies that characterize grain marketing performance and policies in Mali. These diagnoses have been described in detail in CILSS/Club du Sahel (1977, Vol 1, and Mali in Vol 2). Here we will only summarize some of the main problems.

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Policy Objectives Not Met

First, the present marketing policies are failures when judged by their own objectives. The main objectives of the present marketing policy, as these are conceived by Malian representatives and written in relevant documents, are (1) to control the grain market *(maitriser)* so that producers can be guaranteed a remunerative minimum price; (2) to guarantee grain supplies for deficit regions, including urban areas; (3) to stabilize prices to both consumers and producers. Related objectives are the protection of peasants against possible exploitation by traders and the development of "orderly" trading arrangements.

It is not uncharitable to observe that none of these objectives has been achieved. As can be seen in Table 1, one-half to three-fourths of the total volume of marketed millet/sorghum passes through the "traditional" sector — i.e., private traders. In addition, the state grain trading agency, the Office des Products Agricoles du Mali (OPAM) has not been able to maintain a floor or ceiling price on grain purchases and sales, nor has it been able to stabilize consumer or producer prices seasonally or interannually. Table 2 is indicative.[1] Moreover, OPAM does not even supply most of the grain to deficit regions; it was estimated in the mid-70s that private traders handled 60% of the grain supply in the remote and particularly food-scarce Sixth Region.

The reasons for these failures to attain stated objectives are well known. OPAM's shortages of financing, storage capacity, trucks, and personnel played a part. Inflows of food aid and the demands of the 1972-74 drought led OPAM to play a major role in channeling imported grain, to the neglect of its internal marketing role. A price policy imposed on it by government (low consumer prices for millet and sorghum) reduced its liquidity, and a policy of purchases and sales at uniform national prices led to further operating deficits and a reduction in liquidity. At least up to 1976, the slowness with which the grain quotas were set and delays in release of crop-financing funds by the banking

Table 1. Estimated total marketings of millet/sorghum and amounts marketed through "official" channels, 1960–1978.

(000 tons)

	1960/61	1961/62	1962/63	1963/64	1964/65	1965/66	1966/67	1967/68	1968/69
Total marketings[a]	125	124	130	129	98	108	111	125	84
Official purchases[b]	20	21	29	16	17	26	57	60	8

	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Total marketings[a]	90	107	107	94	99	128	130	120	119
Official purchases[b]	26	12	29	11	9	40	71	n.a.	n.a.

Sources: CILSS/Club du Sahel, (1977, Vol 1, p 41); FAO (1978).
a. 15% of estimated production.
b. After 1965, OPAM purchases.

1. For additional data on divergence between official and actual market prices for foodgrains, see OLSS/Club du Sahel) (1977 vol 1, p 54).

Table 2. Official and actual market prices for foodgrains (February 1978).

	Official price		Actual market price	
	Producer	Consumer	Producer	Consumer
	Malian Francs/kg			
Millet/sorghum/maize	36	56.5	30.5	150
Rice (Paddy blanch)	45	–	–	–
Rice		137	–	300

Source: FAO (1978).

system meant that ORAM was never even present in the market until January, after the peak postharvest marketing period was over.

Thus, OPAM and the existence of a legal monopoly has not protected the producer against presumed "exploitation," as it was designed to do. Nor has the hope that state grain marketing would impose a more orderly and efficient organization *on* the grain trade been borne out by experience. There is considerable uncertainty over marketing responsibility, not only between public and private sectors but within the public sector as well. For example, ambiguity over marketing jurisdiction has recently arisen between the cooperatives, OPAM and Operation Mils-Mopti, which has taken over responsibility for grain marketing in the area of its activity.[2]

OPAM Operating Deficits and Inefficiency

In recent years the Mali economy has been characterized by severe budgetary and balance of payments disequilibrium. Budget deficits from 1972 to 1976 were between one-fifth and one-third of total expenditures and close to one-third of recurrent revenues. During the same period the overall balance of payments showed large and growing deficits, amounting to between 20 and 50% of recorded imports.

The accumulation of debt by OPAM (and other public enterprises) was a major factor in the economic deterioration of the 1970-76 period. During these years OPAM accumulated a debt of 38 billion Malian francs (about U.S. $80 million), 12 billion of it in 1974 alone; this was equal to 40% of total budgeted government expenditures during that year.

Some of this debt arose during the 1972-74 drought, when Mali imported large amounts of grain to stave off famine. These imports were sold at heavily subsidized prices and were financed by bank credits to OPAM. But much of it arose from the meager margins between OPAM's buying and selling prices for grain, which make it impossible for the agency to *cover* its marketing costs.

A significant proportion of OPAM's deficit also derives from management inefficiency, particularly with respect to transport and storage operations. Transport deficiencies commonly delay movements of grain stacked outdoors under tarpaulins, exposing it to the first rains. The IDET/CEGOS (1976) Report is only one of the many that refer to substantial losses because of poor storage management. The burden of these losses is passed on to producers and their cooperatives, removing any direct incentive for OPAM to improve its per-

2. A recent evaluation report by Berthe and Meyer-Ruhle (1977, p III-10) comments: "After the beginning of the 1976-1977 campaign the government suddenly decided that in the Bankass and Djenne *cercles* the existing cooperatives would take over the grain collection and deliver directly to OPAM. It is, however, expected that this was only a temporary measure (the reason of which Is not officially known) and that in the coming season *Operation Mills* will again be charged with commercialization in Its whole intervention area."

formance.[3] In other cases, grain stored indoors suffers heavy losses because of insufficient or improper fumigation, infested sacks and failure to rotate grain properly.

Poor Marketing Services to Farmers

The private grain trading system is undeveloped. The number of individuals working exclusively as traders is very small. More important, there is extremely little specialization in foodgrains, just as there appear to be very few traders who are full-time traders and nothing else, so there are few traders who work at the grain trade alone.[4] Most buy and sell consumer goods and other crops. All this means that the distinction between producers and traders is frequently obscure, as is the distinction between traders and consumers. The person who acts as millet assembler also trades in consumer goods, in rice, in groundnuts.

In addition to small scale and lack of specialization, the grain marketing system is characterized by poorly developed rural credit arrangements. Private traders do provide some credit, but it is unclear how much. Although it is widely believed that a substantial proportion of producer millet sales are made to pay off preharvest debts, such evidence as exists suggests that this is a relatively minor factor. The IDET/CEGOS study found that in only 15% of the villages they surveyed did traders appear before the harvest. They report that most of the sales in the villages come from reduction of stocks as the new harvest approaches. The 1973 FAO (Panhuys) Report estimated — very roughly — that perhaps 5000 tonnes of millet/sorghum were sold to traders in debt repayments at harvest time. This would have been less than 5% of marketed output.

Similarly, very limited amounts of grain are stored by traders. It is rare to find private traders with a storage capacity of as much as 50 tons. Most storage, like most trading activity, is mixed — i.e., grain and other commodities, frequently including consumer staples such as sugar, will be stored in the same place, generally a room or two in a rather rudimentary building.

The private sector marketing facilities provided to sellers of foodgrains are thus very rudimentary. In comparison with what is available for export crop producers, they are markedly deficient; the public grain trading agencies do not provide much more. Neither public agencies nor private traders maintain an effective presence in the villages. For first echelon storage (at *cercle chefs-lieux)* in the state marketing circuit, the farmer himself, or the village authorities acting in the name of the village cooperative, must arrange for transport of grain from the farm to the *cercle.* But the cooperatives are paid too little by OPAM: costs of transport from village to the district *(arrondissement)* level are not fully covered. Sometimes the local cooperatives are not paid at all. Moreover, they (that is, the farmers) must bear the costs if inadequate storage and transport delays cause losses of stored grain.[5]

Illustrative of the differences in public marketing services provided for cash crops and those for food crops is the fact that the Operations will send trucks to bring groundnuts to main storage points whenever a village or group of villages can assemble 80 sacks — and this at no cost to the producers (CRED 1976, pp 119-120).

It is much the same with other services normally provided by a marketing system: credit, trader-provided storage capacity, off-farm inputs. Credit is available via the export crop

3. If not stored properly, grain delivered to OPAM deteriorates rapidly. Each year important quantities (thousands of tons) cannot be carried away before the onset of the rainy season and are thus rendered unfit for consumption. The loss is absorbed by the producers, if OPAM has not already paid them and by the cooperatives, if OPAM's funds were distributed, since OPAM demands repayments (IDET/CEGOS 1976.)

4. The IDET/CEGOS Report states categorically: 'There are no private traders in Mali who deal in millet alone: millet purchases at the farmer level and wholesale are considered by the main agents only as a supplement to marketing of other products (especially sheanuts and groundnuts)."

5. In its village survey, the IDET/CEGOS team noted that in almost 40% of the villages, peasants "spontaneously" declared that their costs of transport of grain to the *arrondissement chef-lieux* were not paid for. The cooperatives (Federations de Groupements Ruraux) take the rebate that OPAM gives for this purpose, to meet their own expenses (IDET/CEGOS 1976, vol 3, p 41).

promotion agencies, as are fertilizers and other inputs. However, with a few exceptions (e.g., the Operation Mils-Mopti), food growers must rely on "traditional" sources of credit, little of which appears to be provided by traders. And few input-provision schemes are available, except for export crops.

Negative Production Effects

It is not possible to know the extent to which inadequacies of marketing arrangements and policies have affected grain production. Table 3 shows existing estimates of output trends for major crops during the past 20 years. It is clear that until 1974 foodgrain production was stagnant or declining; the same is true for groundnuts, though not for cotton. But it is impossible to separate the effects of marketing policy, price policy, general economic policy, and weather variations.[6] One must nontheless strongly suspect — as so many observors have — that the uncertain, thinly structured, and relatively poorly-functioning marketing system has had negative effects on grain output and on producer willingness to sell.

Negative Equity Effects

The marketing system has many inequitable features. There is, first of all, the quota or requisition system, by which decisions are made on the amounts of grain that villages must deliver to OPAM at official prices. In a year of poor harvests, this system requires the delivery of grain at below market prices. Those whose grain is requisitioned may have to buy for their own consumption later in the year, at free market prices.

Similarly, until very recently, OPAM has had almost no motor pool of its own. It had to rely on truckers, public and private, who were paid according to an officially fixed tariff structure that was generally too low to make OPAM assignments profitable. As a result, OPAM (with local administrators) regularly "requisitioned" private trucks — i.e., forced them to carry grain at the unprofitable, edicted rates. One consequence was that many transporters took their trucks into neighboring countries when the buying season began.[7]

A third form of inequity arises from OPAM's normally limited capacity to meet demands in urban areas and deficit regions. A dual market is created, since a favored group is provided with OPAM's stocks at official prices while others buy in the free market at a much higher price. Some idea of the magnitude of the differences is given in Table3 above; grain purchased in the free market in early 1978 cost two or three times, as much as OPAM-provided grain. The FAO (1978) describes the consequences as follows:

> When (OPAM) has insufficient stocks it reduces the quota which consumer cooperatives receive for delivery to households. These households then must buy on the free market, often at twice the prices. As for the public sector, and civil servants, the quota is generally maintained, which makes these consumers a privileged group. But they are only 2 percent of the labor force...

Obstacles to Reform

If it is true that most technicians would agree with the main elements of the preceding diagnosis, then the question arises: why has it proved so difficult to make appropriate changes? After all, as we noted at the outset, Mali's grain marketing and price policy arrangements have not gone unstudied, nor is there any lack of proposals for change.

Politics

One part of the explanation must be found in the political environment. The political factor is indeed obvious and always mentioned. The Malian political authorities have persistently hesitated to raise official foodgrain prices to urban consumers, presumably because of unwillingness to risk severe political reaction. Their perception in this matter may be right; examples of disturbances and political upheav-

6. Given the data uncertainties, it is often not even clear what has to be explained.

7. Tementao 1977, p 54. However, tariffs have been revised upward since 1977, and OPAM has been endowed with a considerable vehicle pool of its own (some 40 trucks). So the problem of transport requisition may be less substantial now. But it can be counted on to reappear as soon as prices change and/or OPAM's motor pool shrinks in size.

Table 3. Production, marketing and official producer prices of principal crops in Mali 1957–1978.

	57/58	58/59	59/60	60/61	61/62	62/63	63/64	64/65	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78
Millet & Sorghum																					
Production ('000 tons)				833	827	867	863	651	721	737	830	568	603	715	715	624	660	850	865	800	790[a]
Producer Price (MF/kg)		16	11.6	10	10	10	10	11	11	15	16	16	18	18	18	20	20	32	32	32	
Rice, Unhulled (Paddy)																					
Production ('000 tons)				160	145	200	189	192	162	162	172	134	161	137	157	116	130	250	260	257	200
Marketing					24	28	31	27	26	32	35	26	34	40	52	47	59	84	100		
Producer Price (Paddy blanch) (MF/kg)		12	12	14	8	11	11.6	12.6	12.6	16	18	18	25	25	25	25	25	40	40	40	
Cotton																					
Production ('000 tons)				9	10	18	24	31	22	32	39	50	51	59	74	72	55	71	100		
Marketing ('000 tons)				5	6	12	16	28	18	28	33	45	45	53	68	66	51	61	90		
Producer Price (1st Quality) (MF/kg)	34	34	34	34	34	34	34	34	34	34	40	40	45	50	50	50	50	75	75	75	
Groundnuts (Unshelled)																					
Production ('000 tons)				122	138	167	182	173	153	159	119	96	136	156	152	135	132	188	205		
Marketing ('000 tons)				54	63	67	74	50	27	40	29	33	57	74	60	50	43	70	87		
Producer Price (MF/kg)		14.8	15.8	14	14	14	14	13	13	16	24	24	30	30	30	30	30	40	40	45	

Source: CILSS/Club du Sahel, (1977, Vol 1, Statistical Appendix); FAO (1978, Annex 3).
a. Provisional estimate.

als have in fact frequently followed efforts to eliminate food subsidies enjoyed by urban populations — for example, in Egypt and Peru in recent years.

The political factor is clearly present and important. Two aspects of it are worth special comment. First, it is evident that reformers, particularly outsiders, tend to give less weight to the political risks of change than do the political authorities concerned. This is true even where the objective political realities are similarly perceived. But such similarity in perception is rare; reformers will naturally tend to see fewer risks than politicians.

Secondly, in Mali in particular, the political authorities appear to have been especially sensitive politically and hence resistant to risky policies. This is reflected in the economic policies and performance record on the past decade. Of all the Francophone West African countries, Mali has had the most persistent balance of payments deficits and the most persistent budget deficits.[8] These deficits have also been the largest, relative to the size of the economies in question. In Niger and Upper Volta, countries similar to Mali in many ways, and also under military rule in the last decade, public expenditures have risen 5 to 6% a year; in Mali the rise has been about 15%. The major source of the budget deficit is generally said to lie in the Malian government's policy of hiring secondary school and university graduates. But such a policy does not exist in neighboring states.

The employment policy is only one of several elements suggesting that the Malian government has tended to be more anxious than similarly placed governments to avoid imposing reductions in income and economic welfare on the bulk of its urbanized population. Its import policies in 1973 and 1974 are another indication. Mali's total tonnage of food imports (aid and purchases) was higher than any of the other drought afflicted countries of the region; in 1974, the Malian government paid out of its own resources for 55 000 tonnes of rice, at a time when lower-priced coarse grains were available. Similarly, Mali was the last of the Sahel states to raise official consumer prices for foodgrains closer to world prices; it held out until early 1975 while the other governments of the region let prices rise in the autumn of 1974. Similarly, Mali's wage policy response was somewhat faster and stronger than its neighbors (Table 4).

Mali's grain-marketing and price policies, then, are part of a larger pattern of economic policies that reflects not only an unwillingness to risk urban political unrest but a more general unwillingness to accept tough discipline in economic management. There are many reasons for this (Berg 1975). One of the most fundamental is the existence, in the French Treasury, of the line of credit known as the Operations Account. Mali has been able to incur large budget deficits — and balance-of-payments deficits — by drawing on this Operations Account. There are really two factors at work here relevant to grain marketing reform: the Malian government has been especially reluctant to impose hard choices in grain price policy, and it has been able to avoid these choices, as it has been able to avoid or soften similar unpleasant constraints in the budget and credit areas, by drawing on its line of credit at the Operations Account.

Different Donor/Recipient Perceptions

A second obstacle to reform or more generally to the introduction of economically efficient policies derives from the different interests and perceptions of the parties to aid transactions. What lenders might regard as economically efficient is not seen as such by the borrowing country.

The clearest and most relevant example is in the area of storage programs and policies. On the basis of strict cost-benefit accounting (risk questions aside) it may be possible to demonstrate persuasively that a foreign exchange-based food security policy, with a relatively small "first line of defense" emergency reserve, is the most cost-effective strategy for Mali. This would involve a public, centralized storage capacity of far less than the hundreds of thousands of tonnes now existing or envisaged. But from the Malian government's point of view things look different. There is first of all the fact that the Malian authorities will see greater likelihood of famine and will

8. Chad, in the midst of the Civil War, may have had budget deficits that were as large a share of total expenditures as in Mali.

Table 4. Wage changes by skill level, 1967-1975. (1967-1969 = 100)

	1970	1971	1972	1973	1974	1975°
Mali						
Unskilled rate	100	100	100	136	193	217
Middle-level manpower rate[b]	100	100	100	100	111	116
University graduate[c]	100	100	100	103	109	115
Niger						
Unskilled rate	100	100	100	100	140	160
Middle-level manpower rate	100	100	100	100	100	112
University graduate	100	100	100	100	100	104
Senegal						
Unskilled rate	100	100	100	106	145	212
Middle-level manpower rate	100	100	100	100	120	136
University graduate	100	100	100	100	109	121
Upper Volta						
Unskilled rate	99	99	100	109	134	150
Middle-level manpower rate[d]	n.a	n.a	100	100	108	175
Consumer Price Index, Capital City (1970 = 100)						
Mali[a]	100	121	130	168	194	-
Niger	100	105	115	128	137	-
Senegal	100	106	114	135	147	-
Upper Volta	100	102	99	107	116	-

Source: Berg, (1975, pp 118,122).
a. January
b. Typical rate, middle-level worker, Civil Service (except for Upper Volta, where It is private sector rate.)
c. Starting rate, University graduate (Licence), civil service.
d. Actual rate, one employer, private sector.
«. Foodstuffs only.

weight its impact more heavily. But aside from this, the Malians know that there are almost no opportunity costs to aid funds available to construct grain storage facilities. From the local point of view, only if discounted future local costs of silo maintenance and operation exceed discounted benefits will it be advisable to adopt an "objectively determined" cost-effective solution.

In these circumstances, it is not surprising that large increases in storage capacity have occurred or are under consideration not only in Mali but throughout the drought-prone Sahel. This is despite the generally weak analytic and technical support for the storage strategies implied. It is not hard to see why local perception and local interest tend to prevail in this area. Silo construction is relatively cheap; silos are attractive to donors because of their visibility and their apparent contribution to a politically attractive goal; they can conceivably bring dramatic benefits in time of catastrophe; and there are many competitive donors anxious to help in food security matters.

Underestimation of Present Defects

Many Malian officials and other observers are fully aware of the deficiencies of the marketing system as outlined earlier. The public position most *often* expressed by responsible local officials is to recognize these problems, and to suggest that the reasons for them lie not in the structure of the situation but are rather due to OPAM's lack of resources and experience. They point out that OPAM is, and has always been, short of credit for financing crop purchase, short of trained staff, without its own transport facilities, and with only limited storage capacities. They also point out that the extraordinary demands of the drought years made it impossible for OPAM to meet its marketing/

price policy objectives, and that indeed OPAM's operational life has been too short for any meaningful evaluation.

Because this general issue is so central to the understanding of marketing/price policy questions and to the problem of reform, it is important to address it directly and at some length. The defects of the marketing system are in fact structural in nature, not incidental or transient. The present system contains a number of basic contradictions, major flaws that cannot be eliminated except by transformation of its essential characteristics.[9]

Difficulties in Peaceful Public-Private Sector Coexistence

First, the peaceful coexistence of public and private sectors in the grain trade requires that prices be the same in both sectors. If not, grain sales will tend to flow to one or the other sector, depending on harvest size, as is presently the case. As things now work, if the official producer price is above the market-determined price, farmers will sell to OPAM, if they can. Thus, in years of bountiful harvest, OPAM can buy all the grain it wants, or for which it has financing and storage capacity. In lean years, it can buy little. This tendency can be clearly seen in OPAM's pattern of purchases. In recent years it has been able to buy insignificant quantities in a year of poor harvest and high market prices; such purchases are almost always made during bumper crop years.

This all-or-nothing tendency can be avoided only in one of two ways. One is for the Government to abandon any positive price. The Government's official producer price would be the same as, or close to, actual free market prices. This presents an obvious inconvenience: it means abandonment of a primary *raison d'etre* of the state trading system itself. The second solution is to make available the financial resources and storage capacity required to implement a true price stabilization effort. OPAM could then buy for a buffer stock in good years and sell in lean years. Similarly, OPAM would support grain prices throughout the year near their desired level by buying during the post-harvest period and selling during the *soudure* ("lean" or "hungry" season). The question is, to what extent is such stabilization feasible and desirable?

The question of stabilization will be taken up later, but here it can be noted that year-to-year price stabilization is certain to be very expensive in Malian conditions because of (1) wide variation in rainfall, output, and especially in marketed supply; (2) a possible tendency for farmers to subsitute public storage for some village-level private storage; (3) risks of heavy storage losses. Its desirability is also open to question on the grounds that, if successful, it could *destabilize* producer incomes from foodgrain sales, a result that may not be in line with public policy objectives. Most important, if price stability encourages production of foodgrains for the market, and/or if — as is likely — the stabilized price is higher than the average market-determined price,[10] then additional marketed supply might be called forth in volumes burdensome to the economy.

Just as price differentials create awkward conditions on the producer side, so do they create problems on the consumer side. Whenever prevailing market prices at the retail level are higher than official retail prices, farmers, traders, and some consumers have strong incentives to bypass the state structure and deal with each other directly.

The existence of a private trading sector imposes restraints also on another basic aspect of state grain price policy: the principle of uniform grain prices over the whole national territory. This *perequation* principle can be pursued by OPAM without involving losses (deficits) only if losses incurred by OPAM activities in areas where marketing costs exceed the average are balanced by profits from purchases and sales in markets of easy access and hence lower than average costs. But in a system of coexisting public and private trading sectors,

9. The present system has the following central features: partial, fictional state monopoly of the grain trade; purchase of part of the crop at fixed prices by imposition of quotas; sale of publicly purchased grain, mainly in cities and other deficit zones; use of price averages *(perequation)* such that official producer prices are uniform nationally and official consumer prices are similarly uniform.

10. Assuming that the price stabilization scheme is not a "pure" stabilization effort, but has price-raising intent.

the private traders occupy the profitable markets and leave the unprofitable ones to the state agency. The traders buy where and when producers offer grain for sale at relatively low prices — i.e., in the more productive regions, and those served by better roads, at harvest time. They sell, similarly, in the most attrative markets (especially Bamako and the other towns) where unit marketing costs are relatively low. OPAM is constrained to buy and sell everywhere, and at the uniform national prices. Under the circumstances, there is no way OPAM could avoid deficits; if its buying and selling prices were fixed at levels reflecting true average costs, the result would be to abandon the market to the private sector, or uniform national pricing would have to be abandoned.[11]

A related problem has to do with smuggling. So long as private traders are allowed to operate, and a policy of uniform national pricing continues, there will be a strong tendency for grain to move over frontiers. Only if government could effectively impose an export monopoly (or assure harmonized pricing policies around frontiers) could extensive smuggling be avoided. This, incidentally, provides additional incentive to seek alternative means of meeting the government's regional equity objectives, to the extent that such goals are of high and continuing priority.

Another fundamental problem in the mixed trading system has to do with price and quality differentiation. The state trading sector cannot effectively compete with the private traders unless it establishes a much more refined price structure than now exists. At present, extremely little differentiation exists. OPAM offers the same price for millet, sorghum, and maize. Prices are the same for different kinds of millets and sorghums (e.g., white millet and red millet). Buying and selling prices do not differ with respect to the quality of millets and sorghums.

The more egregious aspects of this homogeneity could presumably be dealt with relatively easily — i.e., different prices for millet, sorghum, and maize. But even here, delicate decisions might be required and wrong decisions could lead to serious distortions. What should be the relative prices of maize, sorghum, red millet and white millet? Demand conditions vary from region to region and year to year, as do supply conditions, due to rainfall variations. Unless it reproduces the private sector price structure, OPAM risks finding itself with unwanted surplus stocks of some grains and recurring shortages of others. Or, if OPAM enforces a price structure on the private sector it could give wrong signals to producers — as, for example, it is presently doing by paying "too much" for sorghums as compared with millet and making sorghums more profitable to produce even though they are less desired by consumers.

Quality differentiation poses even more problems. Under the present system, OPAM obtains the worst quality grains, since it pays the same price regardless of quality. For OPAM to try to reproduce the rich variety of quality and price differentials that typify even the most isolated rural market is almost unthinkable. It would require enormous manpower and surveillance and would involve so much bureaucratic discretion as to invite extensive abuse, particularly if used in conjunction with the quota system for requisitioning grain. In the long run, farmers would only sell to OPAM if the quality gradings and price differentials available there were as favorable as in the private market.

Difficulties in Primary Marketing

The organization of the state sector's crop purchase is extremely cumbersome. The system works as follows. Crop size is estimated in every village in July. These estimates are sent to the *Commandant de Cercle.* who — advised by a cereals committee — transmits these estimates to the Governor of the region. The Governor sends the estimates to the Ministry of Interior, which then determines the quota of grain that will be required of each district *(arrondissement).* This *arrondissement* estimate is taken as a quota that the administrative head of the *arrondissement* must deliver to OPAM at the *cercle* headquarters, whence it is stored or shipped to deficit regions.

At every step of the way, these arrangements give rise to grave problems and potential abuses:

11. Some other means might be sought to implement the Government's objective of favoring remote and uncongenial regions. Grain transport costs, or all transport costs, could be directly subsidized; civil servants (and other wage earners) could be given a salary supplement, etc.

a. In July the villagers have only a very rough idea of the size of the coming harvest. They have in any case every incentive to understate their estimate. The *arrondissement* head also tends to make minimal estimates, so as to reduce his risks of nonperformance. The *encadreurs,* however, have an interest in overestimating production.[12]

b. The primary marketing is traditionally the responsibility of the cooperative organizations, the groupements ruraux. But these are administrative units. Membership is obligatory. The executive committee of the cooperative is frequently the village council. The Federation des Groupements Ruraux (FGR) is chaired by the regional administrative head. In general then, there is no arms-length relationship between "the administration" and the "cooperatives." So the whole process of quota determination tends to set farmers against the Government. When the quotas cannot be met, force is used — "arguments of authority," as the IDET/CEGOS Report puts it.

c. The system of *previsions* is often not completed until December. But this is too late for ORAM to take account of the estimates in its financing request to the Malian Development Bank. So the credit allocation to OPAM is not only based on uncertain crop size estimates but is very late as well. This seems to be the main reason why, in most years, OPAM has been unable to enter the market immediately when sales are at their peak, at or near harvest time (September-November).

d. The cooperatives (i.e., the farmers themselves) are responsible for transporting their quotas from their fields to the *cercle,* where OPAM's responsibility begins.[13] At best, the payment made by OPAM for this service is (or has been) below costs; in fact, very often the FGR keeps the OPAM transport rebate *(frais de collecte)* "with or without the agreement of the producer." (IDET/CEGOS, 1976, Vol 2).

e. The FGR has to rely on private transport. Until 1978, the official tariff was too low to induce truckers to carry grain, given the lack of back-haul cargo, the long waiting times, the bad roads, etc. So the truckers have been frequently "requisitioned" — i.e., forced to carry grain. As noted earlier, this leads some transporters to take their trucks out of the country at harvest time, thereby accentuating the shortage of transport.

f. Organizing primary marketing and seeing to transport and storage involves senior administrative officials in the demanding and complex business of the grain trade. The radios and trucks of the prefects and *commandants de cercles* are mobilized in the annual effort to coordinate truck movements. The administrative officials can force truckers to take assignments. Many mistakes inevitably occur: in one area trucks may be sent for a delivery that is too small. Elsewhere, not enough transport is made available, so the grain stock cannot be picked up before the rains begin.

g. On the consumer side there are further anomalies, at least as of 1977.[14] The "cooperatives," in addition to purchasing and transporting the crop, are responsible for sales to rural consumers. In theory they buy millet and sorghum from OPAM's warehouse at the *cercle chef-lieu.* They sell it to their constituents with a legally prescribed mark-up — an amount generally insufficient to cover the costs of moving the grain by truck from *cercle* to *arrondissement* What is especially striking is that the cooperatives cannot keep grain themselves, for sale to their members, because of OPAM's legal monopoly. They must sell grain at OPAM's retail price. The farmers thus are given no incentive in the official marketing system to store grain through their cooperatives. Nor do they have any incentive to utilize the official marketing chain. They buy and sell on the

12. Hans Guggenheim (1977, p 12) points out the tendency for young *encadreurs* "to feel that their pride is involved in producing high yield figures and in commercializing as much as possible." Guggenheim also mentions one village where the quota one year was 40 tonnes, and the commandant asked for 400 tonnes the next year. The quota was finally fixed at 160 tonnes. Given the lack of knowledge of yields and output it is easy to see how such problems could arise.

13. The *groupement rural* (village) takes It to the district *(arrondissement)* headquarters, the *Federation des Groupements Ruraux* takes it from there to the *cercle.*

14. Recommendations for change have been made, but it's not known whether they have been adopted.

"traditional" (i.e., private) market.[5]

Distributional Inequities

These have already been described. It is the difficulty of avoiding them that is stressed here. So long as the state sector is responsible for only a portion of the crop, and a dual price structure persists, benefits and costs of the system will be unequally distributed. In bad crop years, losses will be suffered by those producers forced to sell to OPAM at the lower-than-market price. In good years, producer benefits will go to those who sell to OPAM at the higher-than-market price. Comparable inequities exist on the consumer side. Under the present arrangements, the benefits of low official retail prices go to the relatively well-off civil servants who tend to be fully provided by OPAM at the official price; others often have to pay two or three times as much as the free market. These perverse distributional effects could conceivably be reduced, and distribution of low-priced grain effected by such methods as "fair price shops" for low income people, but such finely tuned distributional efforts are extremely burdensome administratively. How the distributional problems on the producer side could be handled is not obvious. Using higher-than-market purchase prices as an instrument of income distribution policy would demand great administrative and organizational inputs, might have undesirable incentive effects, and might not be feasible anyway. It would certainly open up very substantial opportunities for administrative discretion and corruption.

The Worst of Both Worlds

As we have seen, the present trading system poorly provides the services producers seek in a trading system: protection against monopsony, access to credit, transport, storage, and market information. Competition among buyers, stimulated by free entry into trade, is not legally encouraged or even allowed, but no stable and effective state-provided alternatives exist. One of the main justifications for public intervention in marketing is the presumed inequality of bargaining power of the peasant vis-a-vis the trader, but the present arrangements do not balance the bargaining situation. A relatively small share of marketed output is bought at the official price by the grain agencies. The bulk of primary marketing is still in the hands of private traders. Given the risks and uncertainties of the legal situation, there are fewer traders than there would otherwise be, and the price demanded by traders for their services is probably higher than it would otherwise be.

From a longer-term and development point of view, the present arrangements do not encourage — perhaps do not even allow — the strengthening of private marketing skills. Their ambiguity discourages technical progress in trading practices and techniques, the growth of trading capital, and the emergence of more complex entrepreneurial skills.

Conflict Between Private Trader Efficiency and Doctrinal Factors

Because the mixed system has serious disadvantages while the preconditions for an acceptable coexistence between public and private trading sectors are so demanding, drastic modifications are called for if marketing deficiencies are to be effectively addressed. This is where the fundamental problem for reformers emerges. For there are only two ways to go: toward liberalization of the trading system — i.e., a greater role for private traders — or toward more thorough state control. And while the technical or economic advantages are overwhelmingly on the side of liberalization, doctrinal or ideological predispositions call for strengthening the state trading monopoly.

There can be little doubt about the substantial economic advantages of a private trading system compared with a state grain trading monopoly.

The private or "traditional" grain trade uses resources more efficiently than state trading agencies. The supply of traders' services is highly elastic at relatively low levels of remuneration. Private trade is, for many thousands of

15. The IDET/CEGOS Report (Vol 2) summarizes the situation this way: 'Thus producers pay for this service (the storage of millet) which Is performed by their own organization, and pay at a much higher price than it costs, and they pay to an organization which doesn't give the service (OPAM). The result is that when producers need millet they trade with other producers in traditional markets..."

Malians, a part-time activity. Farmers, urban workers, school children, women, all may do a little grain trading. They tend to do so in slack periods of the year. They also trade in connection with local market activities that have a social component. In such circumstances, the opportunity costs of engaging in trade are very low. It is the same with casual or informal traders — chauffeurs and others with command over empty cargo space. These traders' services are offered in relative abundance and at low cost.

Even full-time traders do not deal in grain alone. The volume of trading activity and the rate of return from grain trading seem too low to encourage specialization. Thus, costs of trading operations are shared by general trade — in cash crops and consumer goods, as well as foodgrains.

Since foodgrains are heavy in relation to their value, transport costs are critical; and it is in the transport area that the private trade has particularly large cost advantages. First, some considerable part of the privately-sold grain is brought directly to local periodic markets by the farmer or a member of his household. Secondly, some grain is moved between local and regional or national markets by the informal trader mentioned above. Most important, the specialized state grain trading agency normally faces fearsome cost problems because of lack of return cargo. Especially in the remote regions, there is little cargo brought by truckers carrying grain from local *chefs-lieux* or wherever the primary bulking point is located. The private trade is much more economical in its use of transport — for example, by searching for two-way cargo, mixture of cargo, etc. What is true of transport is true of other inputs. The traditional trade in general uses human and physical capital more efficiently than the public trading structure. The latter requires formally trained manpower — managers, accountants, clerks — whereas the traditional trade relies on human energy and skills developed informally in the market place. Because it tends to be of larger scale and more complex, the state structure requires physical facilities — offices, warehouses, trucks, cars, etc. — that are more modestly provided in the traditional trade. It also requires inputs that are scarcer than physical and human capital: coordination, organizational capacity, and information. A decentralized private trading system economizes on all these.

There are many well-known, general reasons why small organizations *or* private individuals tend to be more efficient than larger organizations, especially state organizations: speed and flexibility in making decisions; freedom to hire, dismiss and reward; detailed and specialized knowledge of the activity in question; the stronger urge for material incentives. Many aspects of the grain trade do not lend themselves easily to large-scale operations.[16] To illustrate, *one* need only consider the probable difference between public and private responses to a situation of deteriorating grain stocks in a warehouse. The private trader would surely be more likely than a public servant to prevent infestation or improper rotation. On the state side, incentives and capacities to prevent infestation are limited by personnel and budget constraints. The flow of information to managers is slow and uncertain. The capacity to respond to unforeseen local situations is limited by poor communications, lengthy administrative procedures and diffusion of responsibility.

But it is perhaps less the advantages of the free market solution than the disadvantages of the monopoly solution that provide the strongest arguments for liberalization:

Foodgrain market structures do not lend themselves to state monopolization. Grain is grown over much of the country. It is traded in thousands of villages and hundreds of rural periodic markets. As a result of tens of thousands of small transactions, the bulking function is performed: small traders put together marketed supply virtually bag by bag. The distinction between traders and farmers or consumers is generally unclear, and the informal or casual traders, who utilize transport capacity for small adventures into grain trading, play an important role. Moreover, Mali has thousands of kilometers of virtually open frontiers, with ready buyers *on* the other side. And for food crops there is an alternative not avail-

16. This is to say that marketing activities that benefit from significant economies of scale in the circumstances of semi-arid West Africa are substantially outweighed by activities characterized by the quick onset of scale diseconomies.

able for many export crops: increased storage or consumption.

Complications related to price policy arise in a monopoly situation. In a year of bad rains and short crops, cereal prices in intravillage transactions will tend to be higher than the state agency's price, as they will be in any permitted grain transactions. (Prices may also be higher in neighboring countries.) Farmers may, therefore, prefer: (1) to store more grain or (2) to sell only at higher than official prices (i.e., in a parallel market). It would presumably be necessary to extend the system of quotas, requiring delivery of all marketed grain to the state at official prices, with the implications of cost and coercion implicit in all such policies. Rigid controls over grain shipments would be required.

Imposition of an effective monopoly would require an agent of primary marketing to replace the traders who presently handle two-thirds of the marketed crop in most years. The prime candidates for primary marketing would be the cooperatives. But, as already stated, these are virtually nonexistent in Mali, as autonomous producer organizations in any event. They lack structure, money, trained staff warehouses, and transport. To give such embryonic organizations the task of primary marketing of food grains would overwhelm them.[17]

Because of the weakness of the cooperatives, proposals for fuller monopolization of the grain trade in Mali frequently recommend use of the *operations de developpement,* the regional development agencies that provide extension and other assistance to farmers on given crops in given regions of the country — the *Operation Arachides et Cultures Vivrieres* (OACV), for example, or the *Operation Mils-Mopti.*

The regional development organizations have the technical capacity and administrative structure that is frequently lacking among the cooperative organizations. They also have marketing experience, since many of them are responsible for marketing the cash crops that are their major focus. Frequently, they have a large number of buying points and substantial transport capacity. They are therefore possible candidates for taking on the task of primary marketing. Were they to do so, however, severe problems could be anticipated.

The development agencies have shown themselves capable of attracting considerable resources from aid donors, and this explains their relatively strong administrative and financial position. Their success in attracting assistance has also allowed them to operate with relative autonomy. It has allowed them to attract and hold capable staff, by payment of better remuneration (especially fringe benefits) than is available in the Civil Service. The access to technical assistance in some cases has also helped. Also, access to nonbudgetary funding has allowed these agencies financial flexibility beyond what is usual in the public sector.

Despite their strengths, then, the *operations* are vulnerable. It remains unclear how they will find internal sources of self-financing on a long-term basis. Their work of agricultural extension, combined with other activities that nowadays make up "integrated rural development" thus has a certain urgency. The hope must be that, whatever happens in the decades ahead, the efforts of the development agencies will bring about irreversible and self-sustaining changes in agricultural practices in the direction of modernization and improved productivity.

The basic task of these agencies is the stimulation of production, providing the rural population with trained cadres, introducing new methods, more and better education and equipment. The production task alone makes enormous demands on available resources in money and manpower. It might be imprudent to further burden these agencies with the marketing function. This is especially so since past experience attests to the existence of price-making priorities which strongly tend to favor low consumer prices. A policy of low consumer prices for foodgrains, combined with high costs of marketing, can be expected to put pressure on the primary marketing agents, who can find that marketing of foodgrains is costing them more than they are being paid by the other agents further along in the distribution chain.

17. A recent FAO paper (1976) comments as follows ... "cooperatives as forces for the encouragement of rural development, while offering such promise, tend to disappoint and too much must not be expected of them. Given good management and a clearly defined and limited role they can perform well... When they are allocated too many responsibilities they tend to sink beneath the burden."

This has been the experience in *Operation Mils-Mopti.* The OMM buys the grain from farmers and transports it to OPAM storage depots in *arrondissement-level chefs-lieux.* Berthe and Meyer-Ruhie (1977) indicate the kinds of diversions and problems that have arisen:

> OPAM is supposed to receive the cereals at the chef-lieux of the *arrondissements,* OMM being responsible for the transport from the collection points to the *chef-lieux.* However, since OPAM does not have available agents and storage facilities in most of those places sufficient (owned or contracted) transport capacity the rule is that OPAM receives the merchandise only in the capitals of the *cercles,* thus increasing the transport volume of OMM.
>
> There are major difficulties in handling the grain after delivery by the farmers:
> - insufficient transport facilities to meet the increased transport requirements,
> - no storage facilitles at the collection points,
> - delays in discharge and weighing at the OPAM reception points in the peak season (at the end of the campaign).
>
> These shortcomings are causing losses of grain because of open-air storage with serious damages when evaluation is delayed beyond the start of the rainy season. *Last year, OMM was involved in grain transport until the month of August which considerably affected their extension activities for the new season. However, since damages and losses are at the risk of OMM until the grain is handed over to OPAM, evacuation of the cereals constitutes a priority activity to the Operation.* (Italics mine.)
>
> OMM tries to recuperate sacks and money from farmers who have not delivered the envisaged quantities. Sometimes one or both of them cannot be recuperated. Figures of those losses were not available.

This suggests a final consideration: the impact on farmers. Grain marketing is full of uncertainties. Transfers of funds to finance crop purchases can be delayed or reduced. Transport, storage, advances of credit for purchase of inputs — all can create the kinds of pressures indicated in the OMM case. Good rains can create a large disposable surplus which cannot be marketed at announced official prices or transported and stored appropriately. Bad harvests will unloose producer pressures to sell on parallel markets for higher than official prices. Unless an effective price policy is introduced, these price problems will be inevitable.

The involvement of the development agencies in primary cereals marketing thus sets loose a whole array of potential conflict — or at least adversary relationships — between the development organization and its clients, the rural producers. There are high risks that resulting distrust could affect peasant attitudes toward the development agency, its personnel, and its efforts to increase production.

For all these reasons, it would seem highly undesirable to give the *Operations* full, or even major, responsibility for grain marketing. But other alternatives are either not feasible or scarcely more desirable. The absence of a suitable substitute for the private trader in primary marketing is a major constraint to state monopolization.

The present mixed arrangements, then, are disadvantageous from the point of view of both economic growth and social equity. They also have many elements of built-in instability. At the same time, introduction of more extensive state monopoly is inappropriate to the structure of grain marketing and certain to bring on heavy social, economic, and administrative dislocations. The conclusion would seem inescapable: private trade in grain should be legalized and private traders allowed, even encouraged, to perform marketing services. The trouble, of course, is that this simple yet compelling conclusion conflicts with deeply held ideological convictions

In Mali, as in so much of the world, there exists among urban people, civil servants and intellectuals, a widely shared vision or model of farmer behavior and rural market performance. The majority of farmers are believed to have intense demands for money income at harvest time to pay taxes and debts, meet the costs of marriage, and postharvest ceremonies and celebrations. They meet these demands by selling part of their grain crop. But they sell it in the immediate postharvest period when prices are at their lowest. They buy back grain later in the year when prices are at their peak. Farmers are believed to be widely indebted to traders, who demand repayment at harvest time, paying the farmer extremely low prices — i.e., exacting a very high real rate of interest.

All of this occurs, according to this view, in rural grain markets where the winds of competition are notably absent. Traders conspire to keep buying prices low. They easily and invariably exploit the peasant, who is seen in this view as isolated, lacking information, without alternatives and denuded of means to resist.

The belief that grain markets work this way is extremely widespread in Mali, as elsewhere.[18] However, there are very few empirical studies that confirm this belief. The number of careful studies of the structure and functioning of grain markets is extraordinarily small, even in places like India where these questions have been the subject of heated controversy for decades (Lele 1971, Spinks 1970). Ruttan's comment (1969, p 83) — referring to South Asia a decade ago — is still applicable generally:

> Much of what passes as analysis in the marketing literature represents little more than a repetition of the conventional wisdom regarding middlemen behavior with little or no empirical content...

This sparsity of empirical studies supporting the model of the trader-entrapped peasant and the monopsonized market is certainly true of Mali. To my knowledge, there are no studies that discuss more than casually the functioning of Malian grain markets. The CEGOS study, *on* unclear evidence, claimed that in 50% of the villages surveyed, *some part* of marketed cereals output was sold *sur pied* (on the stalk). But they also assert that most of the sales that took place in the villages came from stocks sold off as the harvest approached.[19]

It is no exaggeration to say that the "monopsonized market" model is at best unproved, at worst pure myth. Nor is it unfair to observe that it is a priori dubious, given the structural characteristics of grain markets in the country.

There exists an alternative model, a different way to see farmer behavior and market performance. The "average" peasant, in this view, reflects in his behavior hundreds of years of cultural experience and social adaptation. He plants as much grain as he will need to feed his household on the assumption of normal rains, with some safety margin. He maintains, at the village or household level, a storage capacity equal to at least 1 year's consumption, and perhaps 2 years, in order to protect himself against the bad rains he knows will come periodically. He knows very well that he will need cash income at the time of the harvest. He prepares for it during the dry season — by migrating or engaging in some local income-earning activity. He prepares for it also in his production decisions — by growing cash crops, for example. He is perfectly aware that grain prices will be lowest at harvest time and highest during the *soudure,* and tries to arrange his purchase, sale, and storage decisions accordingly.

According to this way of looking at things, similarly, the grain market is characterized by reasonably effective competition. Entry is easy. Anyone can become a petty trader; little is required in terms of capital or skill. Since incomes available in other rural occupations are relatively low, the elasticity of supply of traders' services is surely-very high. Even the most isolated farmer need not sell his grain at an unsatisfactory price; all he has to do is journey to the nearest periodic market to sell it there, either selling it himself or giving it to a small trader to be sold. In the rural markets, there are

18. The United Nations, Economic Commission for Asia and the Pacific (1975, p 2) reports "The stereotype of indigenous marketing systems for the small farmer is that it is exploitive, collusive, economically inefficient and operating with high profit margins for the trader. At the bottom is the small farmer, poor, often illiterate and unorganized, whose small volume of business is of poor quality, unstandardized, costly to handle and relatively unimportant to the trader. The general poverty of the small farmers and their chronic indebtedness to money lenders, who are often the traders who buy their produce, weaken the farmer's bargaining power, especially at harvest time. This weakness is aggravated by the farmers' lack of knowledge about prices and alternative marketing procedures... The inherent weakness of the small farmer means that he is an easy target for exploitation — underweighing or under-assessment of the produce, charging high interest rates, etc."

19. See IDET/CEGOS (1976, Vol 3). Panhuys mentions a Malian trading circuit of what he calls a "usurious" type,.on which debts are reimbursed in kind at harvest time. Typically, he notes, 1000 MF were borrowed, and 100 kg of millet were given as repayment at harvest time. (This refers to the early 1970s.) He estimated that perhaps 5000 tonnes entered the market this way — less than 5% of total market millet/sorghum.

always passers-by who act as casual traders — civil servants, bus drivers, teachers, others — who are anxious to fill empty cargo space with grain to sell in the larger towns and whose presence gives a strong presumption of competition on the buying side, a presumption that would exist anyway because of the large number of traders in the market.

This second model of a calculating peasant and a competitive market is, of course, congenial to the preconceptions of many economists. But it is more than that. It also seems to fit well with what has been discovered by a number of recent studies in countries with socioeconomic and ecological structures similar to Mali. But, in the present context, the point is not the truth or falsity of these ideas; it is rather that the "exploited peasant/collusive market" model is the way most policy-makers in Mali see the world, and it creates the unwillingness to move the marketing system more openly and more fully into reliance on private trade.

Suggested Reforms

The policy analyses done for and/or by the Malian Government contain numerous proposals for marketing reform. All of these, however, had serious ambiguities or flaws that have reduced their relevance and suitability. One set of proposals suffers from narrowness of focus; these can be called the "improvement" proposals. A second set of proposals for fuller state monopolization leaves unanswered many fundamental questions, which render it inapplicable. The most recent reform proposal, involving greater liberalization, is more fully developed than previous analyses, but also has questionable aspects.

"Improvements"

The so-called improvements aim at improving present arrangements without raising fundamental questions about the allocation of marketing responsibility between state and private sectors or the scope for price policy. An unfriendly critic might call these "band-aid" proposals. They focus on specific and immediate problem areas, not the system as a whole.

One example is the 1973 FAO Report (the Panhuys Report). Although this report is quite far-reaching in its discussion of the marketing system and its deficiencies, and generally perceptive in its diagnoses, the principal proposed change is that official grain prices be raised by a specific amount.

A more striking example is the 1975 report of the BDPA (Bureau de Developpement de la Production Agricole) done under the auspices of the French Ministry of Cooperation. This document analyzes the structure and functioning of OPAM and concentrates on internal administrative factors that contribute to its inefficiency. Although there is considerable discussion of OPAM's "relationship to its external environment," no questions are raised about the terms of coexistence of the private sector or about the nature and limits of price policies. The drafters of this report explicitly reject structural changes relating to OPAM's role (BDPA, 1975, P 68):

> It should be noted that some people we talked to urged that OPAM's role be more limited, more oriented toward imports, storage and the supply of towns and grain-deficit regions, leaving buying responsibility to the operations in millet, maize, rice, groundnuts and cotton and sales to other, better-adapted organizations;
> In addition to the fact that this proposal would lead to a considerable reduction in (OPAM's) monopoly status, it is not clear that overall efficiency would be improved by allocating (grain purchase transport/storage and sale)... to three different institutions.

Fuller State Monopolization

The second category of reform proposals recognizes the elements of basic instability now existing. The proposals address this problem directly, by suggesting a strengthening of the state monopoly. This was the principal recommendation of the IDET/CEGOS (1976) study, which was financed by the World Bank and which was intended to be a comprehensive if not definitive study of the problem.

The CEGOS Report provides much useful material on how the marketing system works and is unsparing in describing its deficiencies. The report makes recommendations on a broad front. It urges that producer prices be increased, that quality grading be introduced, that marketing margins be increased and the *baremes* be made more realistic, that peasants be allowed to repurchase grain from OPAM at a price closer to the producer price. A series of recommendations are also devoted to improvement of OPAM's administrative and financial situation: to suggestions that OPAM's debts be lightened, that it be given adequate working capital, that the banking system release credit for crop purchases earlier and more flexibly, that OPAM's grain storage capacity be increased, and that a drought reserve stock of 60 000 tonnes be established.

Most of these recommendations, and others not mentioned, were addressed to real problems and are generally acceptable. It is the major structural proposals that raise questions.

First of all, the report recommends exclusion of private traders from the primary marketing and the wholesaling of foodgrains; the traders would be restricted to retailing. No real justification is presented. In fact, the report gives limited attention to the question of market structure. It asserts in passing, that grain markets are monopsonized. Thus, in discussing farmer revenues from grain production, it states:[20]

> ... when crops are short, (farmer) incomes are cut due to the shrinkage of marketed volume...; the rise of prices on the parallel market does not re-establish the level of income from food crops because only a small part of the increased retail price is transmitted to farmers, because of agreements among traders.

The considerable problems implicit in this proposal are very summarily treated. The role of primary marketing is given to the FGRs (the "cooperatives"), whose nonoperational character the report elsewhere recognizes. The FGRs lack staff, structure, experience, resources, even autonomy from the administration. Yet the CEGOS report proposes they be given trucks and other equipment and a full monopoly over purchase of the grain crop. The private transport of grain from surplus to deficit regions would be prohibited by this proposal, but only a line or two is devoted to the administrative implications and none to the economic implications. Finally, even the restricted role left to the private sector is, it turns out, quite untenable. This extraordinary admission is worth citing in full:

> The control of the legalized retail trade would consist essentially of making sure that traders sell at official prices and that they sell "OPAM brand" grain. The system would only permit the escape outside the OPAM circuit of a little grain, and this only on local markets. The retail shops would buy their grain from OPAM. They would have no interest in selling below the official price. But they would have an interest in buying below OPAM's wholesale price (prix *de retrocession).* The possibility would be limited by putting a brand name on the commodities.
>
> This brand name matter raises delicate problems. It seems that the short-term solution would be "micro-packaging" *(micro-conditionnement),* for example, packaging in 5- or 10-kg bags. But the costs of this operation, which would have to be done all over the country in order to avoid raising transport costs by making grain shipments obligatory, is high, at the same time that results are uncertain because of the difficulties of control.
>
> We are forced to recognize that there's a problem here: it will only be overcome when innovative actions will make OPAM's services superior to those of traditional trade...

Other basic recommendations in the CEGOS Report have major inadequacies or inconsistencies, though perhaps none so fundamental as the one just described.

The report recommends a rise in producer prices for foodgrains, but the rationale for this increase is nowhere explained or defended. In fact the main thrust of argument is that a price rise is unnecessary (because marketed output is not price-responsive) and undesirable (since marketed output may come mainly from larger farms).

The *report* proposes the purchase at a fixed producer price of a given quota of grain, with the rest being bought at prices determined by harvest size. The incentive and equity effects of such a system are unclear, and are not much discussed in the report.

The *report* proposes *to* subsidize farm-level storage, while making access to FGR grain stores cheaper and easier.

The CEGOS proposals were adopted by the Mali Government, which created a commission

20. It should be noted that no reference to such price agreements is found elsewhere in this report, nor are any other studies cited as evidence.

to make recommendations on implementation. The report of this commission supports the basic CEGOS proposal to strengthen the OPAM grain-marketing monopoly (Republique du Mali 1976). It introduces a complex system of arrangements, however. In years of good harvests, private traders could act legally at the wholesale level. When harvests are moderate or short, they would be prohibited from doing so. Thus the commission report estimates that in 3 years out of 5, private traders would be restricted to retail sales; no private shipment of cereals of more than 1 tonne would be allowed beyond the *arrondissement* level.

The enforcement of this prohibition of grain shipment presents mind-boggling administrative difficulties in West African conditions. The IPGP commission proposal required control of all grain movements exceeding 1 tonne — i.e., 10 sacks. But thousands of vehicles carry such quantities of grain in Mali. Every cart, every private vehicle, every bus, would be a potential violator of grain shipment prohibitions. Unless OPAM were to use only its own trucks, every private transporter would have to be given appropriate papers, with specification of cargo and destination. Multiple check points would presumably be required. Some surveillance and control might be required at the local periodic markets, of which there are hundreds. Opportunities for administrative abuse and corruption would be abundant.

The economic disadvantages of systems of shipment control are well-known. To the extent that these controls are effective, they raise prices in deficit regions and reduce them in surplus regions. They discourage production and marketings in the more productive zones and encourage local self-sufficiency rather than regional specialization. They raise prices generally by substantially increasing transaction costs for illicit grain movements, to the extent that these continue.

Liberalization

These recommendations to enforce the state's legal monopoly have not been adopted by the Mali Government. And since 1976 a third set of proposals has come forward that recommend movement in the opposite direction: toward a greater role for private trade and a dilution of OPAM's monopoly status.

One of these proposals was not specific to Mali, but arose in the context of the Club du Sahel (CILSS/Club du Sahel 1976). The Grain Marketing, Price Policy and Storage Working Group of the Club commissioned a "diagnostic study" in 1976, which was done by the Center for Research on Economic Development (CRED) of the University of Michigan. An early draft of the report of that study argued that basic improvement in the grain marketing situation in Mali (as in Niger and Upper Volta) required that the private trade be legally recognized and private traders encouraged. This recommendation was hotly debated at a meeting of the Club Working Group in early 1977 and was resoundingly rejected by that group, which consisted of representatives of the Sahel governments (many of them officials of state grain marketing monopolies) and several donor agency spokesmen. The final report made no recommendations; it defined a set of options, including liberalization, and assessed advantages and costs.

The most recent proposals come from a multilateral mission composed of representatives of five bilateral donors under the sponsorship of FAO (1978). This mission report first stresses the gravity of the present situation in grain marketing and the urgency of the need for change. The "restructuring" of the cereals sector, it states, has become "imperative." Three reasons are given: the "excessive" annual budget deficits to which OPAM's "exorbitant indebtedness" makes a major contribution; the present system's failure to encourage production, "which stag nates despite a vast potential," and its parallel failure to supply consumers with moderately priced foodgrains; the big differential in grain prices between Mali and her neighbors, which encourages smuggling so that even in a normal year (1977-78), the country had to call on food aid and commercial imports amounting to some 60 000 tonnes (FAO 1978, pp 8-9).

The report rejects at the outset the possibility of an effective state monopoly, as suppression of private trade. Traders are said to perform "indispensable functions____they will always exist because they have a useful and Important function which cannot be otherwise performed." The monopoly option is "unrealistic" (FAO 1978, p 6).

Three "practical" options are set out. The first is to give OPAM greater resources, allowing it to raise producer prices and also raise its marketing margins, so as to reduce its deficits. Retail prices would rise appreciably. While this option is said to have numerous advantages (reduced OPAM deficits, reduced smuggling) it is rejected because it would require increased public expenditure, compensating wage increases and hence increased budget strains. It would also leave intact the double market system, which OPAM would be unable to dominate.

The second option is to turn the entire domestic grain market over to the private traders (who already have three-quarters of it anyway). OPAM would retain a monopoly of imports and exports and would manage food security stocks. The report lists many advantages for this option; it displays, in fact, a restrained lyricism about the results.

> The advantages of this option are first its simplicity and its economy. It costs the state little, since security stocks would continue to be externally-financed. OPAM's debts and structural losses would vanish. The right prices (*la verite des prix*) would prevail, and the role of private traders would be recognized. The double market would disappear. Smuggling would be discouraged in years of bad harvests, once local prices would rise. The supplying of towns and deficit zones in case of scarcity is assured by the state through its security stocks (FAO 1978, p 10).

But, says the report, the principal social objectives are not attained by this option: ". . . there is no guarantee that the cities will be properly supplied other than in periods of emergency, nor that retail prices will be affordable. Nor is there any guarantee that producers will receive remunerative prices in periods of abundance . . ."

For these reasons the mission proposes the adoption of a third option. Private trade will be legalized (traders will be licensed), and will compete in primary marketing with the *Operations,* and, to the extent possible, with the cooperatives. OPAM will control the market by buffer stock operations around a ceiling (retail) and a floor (producer) price. The floor and ceiling prices would be freed "in principle" for several years, but the report is vague on this point; it also calls for annual reconsideration of prices. The report also proposes that the floor and ceiling prices be regionalized — set higher in deficit regions, lower in surplus areas.

There is little doubt that this multilateral donor/FAO report addresses fundamental issues and puts forward more operational and more promising proposals than the earlier reports. The private sector is legalized and given a central role. The proposals for market control stress indirect measures — use of the market mechanism via purchases and sales from buffer stocks, rather than direct administrative measures. The report deals with broad strategy, not detail, and proposes a more deliberate, in-depth set of studies to guide implementation. The report comes with a stamp of approval, in some sense, of the five most concerned bilateral donors, so its impact and audience may be larger than is normally the case with such documents.

The proposals nonetheless present certain difficulties that threaten their viability. The major one is price policy — in particular the scheme for interannual price stabilization.

Certain elements in the physical and economic environment in Mali put constraints on any price policy that stimulates supply above "normal" or "market-determined" levels. This is the case with policies that attempt to set higher-than-market prices for foodgrains, as it is for policies that aim at stimulating production by providing stable prices to producers. First, grain production is highly variable from year to year because of wide annual variations in rainfall and the close dependence of harvest size on the volume and distribution of rainfall (IBRD 1976, p 25). Secondly, marketed grain output — the "disposable surplus" — varies by even more than total output. A good harvest increases the surplus available for sale by a multiple of the increase in total production.[21] Thirdly, the price elasticity of demand for foodgrains is probably relatively low — i.e., consumption does not increase by as much as

21. If production is 1 million tonnes, of which 150 000 are marketed, a rise in production to 1.1 million tonnes will increase the saleable surplus by as much as 67%. Of course, some of the increase in production will be consumed by the producers, either because they formerly produced too little to meet their own needs or because they want to consume more grain as part of the general increase in Income implied by the larger harvest. But It Is probable that most of the increase will be sold.

price falls, nor fall by as much as price rises. This means that changes in marketed output tend to lead to sharp inverse changes in grain prices. Finally, in normal years, domestic production almost entirely satisfies domestic demand — i.e., foodgrain imports are marginal. Opportunities for import substitution are small, since wheat is the only significant grain import and is imported in relatively small quantities.

Assuming that grain production, and especially marketed supply, is responsive to price, a positive price policy — one that sets producer prices higher than market-determined levels, or maintains a stability of prices that stimulates output — will generate "excess supply." The question of its disposal will have to be faced. There are four main possibilities: the grain can be sold to consumers at a subsidized price; it can be stored for stabilization or emergency reserve purposes; it can be used in new ways — as feed for cattle or poultry, for example; or it can be exported.

The first possible use of a price-induced "excess" cereals supply, sales on the domestic market, founders on the troublesome barrier of sluggish demand. Given the low price elasticity of demand for millet and sorghum — the basic grains — the consumer price would have to fall very low in order for consumers to absorb significant quantities of additional output. However, this implies subsidization if the "positive" producer price policy is to be maintained, and subsidization raises questions about equity, incentive effects, and macro-economic consequences for which there are no obvious answers in the present state of knowledge. The question of who benefits and who pays, for example, depends on the socioeconomic position of those who buy grain and those who sell. If it is true, as sometimes claimed, that the bulk of marketed millet output comes from a relatively small number of larger farmers, while pastoralists and deficit peasants in poor regions buy much of the marketed millet, then what is involved is a transfer of income from relatively poor to relatively better off groups.[22]

On the incentive side, the higher food grain price may lead not to an expansion of aggregate agricultural production but *to a* change in the crop mix, with millet and sorghum being substituted for cotton and/or groundnuts. The macro-economic effects of this change may not be positive — e.g., national income will probably be lower and the balance of payments less favorable as a result. There are also budgetary implications, with revenues declining and expenditures rising as a result of the grain price and subsidy policy.

If the "excess" grain that is purchased one year can be stored and then sold the following year when the harvest is poor, the problem will be reduced but not eliminated. If producer prices are set above the long-run average market-determined price, there remains the problem of what to do with the induced increase in grain supply in the face of highly inelastic demand. If price stability as such provides incentives to higher production, there will be more output than otherwise. Moreover, it is not possible to postulate a nicely oscillating cycle of good years and bad. It is highly likely that there will be a number of successive good years before a bad one. In the absence of export markets, the accumulation of grain stocks is the most likely consequence. The costs of this storage, including costs of losses through infestation, spoilage, and quality deterioration, are likely to be considerable.

Surplus foodgrains could conceivably find other uses, particularly given the relatively low prices at which they might be offered for non-food consumption. The most obvious and frequently mentioned possibility is in the area of feedgrain for poultry and cattle. This is certainly an interesting and important possibility, but is not clear that the potential feedgrain market is at present capable of absorbing more than a relatively small volume of grain.

There remains the export possibility, which is real. The recent West African Rice Study done by the Stanford Food Research Institute in conjunction with WARDA, indicates that Mali can export rice to the Ivory Coast at competitive and socially profitable prices, assuming world rice prices behave as now projected. The Senegalese rice market, dominated by imports of much cheaper Asian brokens, is more difficult to penetrate. On the other hand, Mali may be able to export millet/sorghum to

22. There exists no study of this question in Mali, nor indeed are there many studies of it elsewhere. The IDET/CEGOS Report suggests that better-off farmers are responsible for much of marketed output.

Senegal and other neighboring countries.[23]

While export potentials certainly exist, there remain many uncertainties, and in all cases many obstacles to be overcome, particularly in transport and in marketing. The export possibilities for millet and sorghum seem less promising than for rice mainly because export of surpluses would be avoidable mainly in good years, when external demand is low. It would be imprudent to base a general food-grains price policy on export potentials without knowing more about the nature and dimensions of these potentials.

We have thus far concentrated on price levels, not stabilization, which the FAO Report stresses. Many of the above considerations apply to the proposal to stabilize grain prices interannually. There are other reasons why interannual price stabilization is difficult, risky, and expensive.

First, as noted earlier, marketed supply is a small proportion of total production and is subject to especially large changes as total production changes. Thus interannual stabilization efforts will require considerable storage capacity relative to the total size and value of marketed output. An interannual stabilization effort is, in this sense, likely to be expensive.

Second, interannual grain stabilization has certain inherent contradictions. The presumed primary purpose of attempting to stabilize prices is to reduce the producer's uncertainty; fluctuations in price are believed to deter efforts to expand production. However, a price stabilization scheme that effectively reduces uncertainties could be sustained only at great cost, for it implies a support price that would be maintained over a period of years, regardless of harvest size. Such an inflexible support price would mean large storage costs should there be a succession of good harvests. Moreover, if the reduction of farmer uncertainty leads to increased grain production and marketings, this too would have to be bought up by the stabilization agency in order to maintain the support price. On the other hand, if the grain agency reduces its support price as annual harvests and market conditions change, it undermines its primary objective: reduction of producer uncertainty by reduction of price fluctuation.

Third, price stabilization schemes can be destabilizing if the stocks held by the stabilization agency are not large. If the harvest is bad, traders may recognize that sales from the buffer stock will be inadequate to maintain the official price ceiling. They will have nothing to lose by hoarding grain while they await the inevitable rise in price when the buffer stock is exhausted.

Finally, the presumed incentive effects of stable prices remain unproved. One can argue that what Malian farmers need and want is an assured market, better marketing services, reduced exposure to arbitrary action and the right to sell grain at market prices. These kinds of changes would have a greater effect in stimulating production and marketed supply than would any price stabilization scheme.

Given the high costs, high risks of failure, and limited benefits attached to interannual grain price stabilization schemes, it is unclear why such a scheme is proposed in the FAO Report. If the authors believed in the importance and efficacy of such arrangements, they do not demonstrate it in the report. An intra-annual price stabilization scheme would have been tactically preferable. Such schemes, while not without problems, are easier to implement, less risky and less costly. They might also have some genuine social benefits. If distress sales are common (peasants forced by indebtedness to sell at low prices immediately after the harvest), an effective intra-annual stabilization scheme could help. In general, intra-annual price stabilization is more finely targeted in terms of reducing possible exploitation of peasants by traders due to imperfect markets and unequal bargaining power.

Despite its dubious recommendation of interannual price stabilization, the FAO Report provides a workable basis for meaningful reform, unlike many other reform proposals that have been made in Mali in the past few years. If the proposed ceiling (retail) price can be kept high enough, and the floor (producer) price low enough, the proposed *fourchette* idea may prove an ingenious device for giving freer play to market prices. What remains highly problematic is whether in time of short harvests, the Mali government will allow official consumer prices to rise to the market-determined level,

23. According to Michallof's (1977, p 26) estimate, Malian sorghum can be delivered in the interior of Senegal, more cheaply than U.S. sorghum (1976 prices). The reason is that transport costs to Kaolack from Dakar are substantial.

and whether it will allow OPAM to pay producers the market-indicated prices.

External Support

Foreign assistance reduces the economic costs of maintaining the existing marketing arrangements, and in this sense impedes reform. Food aid, though of course necessary in time of crisis reduces the impact of inadequate policy. More specifically, inflows of aid in the form of grain that is sold by OPAM, facilitates the generation of working capital for OPAM and thereby reduces the stresses of financial deficits caused by price policies and marketing/storage inefficiencies. Also, the existence of the line of credit available to Mali in the Operations Account in Paris has generally diluted the negative impacts of grain marketing policy — as it has done with other economic policies — allowing the Mali Government to maintain ineffective policies without having to fully suffer the consequences.

Conclusions

I have tried in this paper to outline the main problems of grain marketing policy in Mali and to indicate the obstacles to improvements in that policy. Mali is the focus of discussion because it is well-documented and because it is analytically simpler to discuss one country than the region as a whole. Much of what has been said is applicable elsewhere in semi-arid tropical West Africa.

Of the many general conclusions that emerge from this analysis, six seem worth special emphasis.

1. It is clear that the West African environment imposes numerous and severe constraints on public policy options ingrain marketing. Total grain output is highly dependent on rainfall, hence it is variable. Marketed output is only a small share of the total and is potentially volatile in volume. The country is large in physical size; grain production is spread over vast areas; there are few specialized grain traders; traditional marketing is small in scale and dispersed in space. Frontiers are numerous and highly porous; traditional trade has always ignored them. The financial environment is similarly constraining. Budgets are in deficit. Expenditures are mainly on salaries, which moreover are under continual erosion in real terms. Little public money is available for materials, supplies, and maintenance. The budget process is at once rigid and uncertain. Intrapublic sector accounts are in frequent disarray. On top of this, there is the limited availability of trained people, scarcities of organizational inputs, and particular scarcities of coordination capacities. These physical, financial, and organizational factors put down clear limits on what the Mali government can effectively implement, either in terms of price policies *or* direct state trading operations.

2. The present mixed system of marketing cannot be easily improved. Stable coexistence between an OPAM operating along its present lines and the private marketing sector requires effective price stabilization or abandonment of significant price support objectives, introduction of a much more refined price structure, abandonment of uniform nationwide pricing, and harmonization of prices with neighboring countries. And even if all this were done, most of the flaws and inequities of the present system would still be present.

3. Grain-marketing policies have probably had significant negative impact on grain production and the attainment of the priority objective of food self-sufficiency. Uncertainty over prices and the availability of marketing services, and general market disorganization, have probably led to diversion of farmer effort into cash crops where this has been possible and may have reduced farmer willingness to undertake greater efforts, or new ventures, in the grain production area. These effects have not been of larger magnitude, or at least more apparent, because of the partial nature of OPAM's monopoly — i.e., the fact that government has not been able to fully implement its policies. The substantial availability of food aid during the last decade has also been significant in diluting the effects of policy, as has the availability of credit from the French Operations Account, which has indirectly financed OPAM's deficits by underwriting Mali's ongoing budget and balance of payments deficits.

4. The longer-term impact of the present marketing policies may be of greater significance than the impact on output in the short run. As things now stand, the development of true cooperatives is extremely difficult. The

existing cooperative organizations are instruments of government, used mainly for grain requisition purposes. So long as the requisition system endures, farmers will hesitate to set up organizations for defense of their interests (in the areas of storage, credit, and crop sales for example). So the democratic development of the countryside is impeded. Similarly, the development of trading competence, techniques and capital is severely obstructed, since traders presently operate with strong discouragement or at best, uncertainty. Finally, to the extent that marketing functions are transferred to the *operations de developpement,* the production-oriented activities of those organizations will be compromised. These *operations* are highly dependent on foreign financing, which cannot continue forever. They thus have a moment in history, so to speak, to help Malian farmers increase their productivity. Diversion from this effort, or weakening its effectiveness, could therefore have substantial effects on long-term development.

5. Of the many factors that have been responsible for the slow reform of the marketing system, two seem particularly critical. The first is the lack of firm knowledge, due to a lack of basic studies, about how the grain markets actually function in Mali. The sparsity of knowledge allows continued circulation of beliefs that may have little foundation in fact, such as belief in monopsonistic markets. In any case, it is difficult to frame suitable policies in the absence of better information and understanding about farmer decision-making, the pattern of grain selling and buying, the structure and functioning of grain markets, on-farm storage economics, and the behavior of grain prices.

The second factor has been poorly articulated reform proposals. Until very recently, the Mali government had not been presented with proposals that were well thought through and operational. Some have been highly management-oriented, indicating how OPAM could organize its work better. But these never addressed the basic problem of what OPAM's work could or should be. The most extensive reform proposals, those of the IDET/CEGOS Report, contained loose ends of a serious nature. They never showed how the full state monopoly that was proposed could be implemented. The Mali Government commission that took the CEGOS recommendations the next step put forward an extraordinarily complex proposal involving exclusion of traders from wholesale trade during "bad" crop years, and a draconian system of shipment control, to prevent movement of grain from surplus, low-price areas to deficit, high-price areas. Present proposals for reform are more viable, though there remain questions about the feasibility or desirability of key recommendations.

6. Certain policy implications should be clear from this discussion, although they have not been made explicit; it is not the purpose of this paper to propose policies but rather to make clear the nature of the problems and the obstacles to change. It is, first of all, evident that no marketing reform can hope to succeed without allowing the private trading sector a fuller role. It is equally evident that, as noted above, scarcities of manpower and other critical inputs severely constrain what the state sector can effectively do. But it should at the same time be stressed that a state grain agency has a major role to play, even under "minimalist" assumptions about the State's role in grain marketing. Such an agency would manage a grain security stock; manage grain imports, particularly crisis imports; provide market information; and perform market inspectorate functions. It might buy and sell in the open market for special purposes — e.g., localized production crises. It might operate a buffer stock for seasonal price stabilization. It could do grain storage extension work, especially for new grains such as maize. It could provide for the needs of collective consuming units, such as the army, prisons, etc.

It is also, equally obvious that major improvements in grain marketing can and will come from indirect measures; improvement and extension of feeder road networks; better information on crop size, prices, marketings, etc. and more effective spread of this information; closer attention to relaxing production constraints in foodgrains; improved policy analysis capacity within government; more basic studies about how grain markets actually work, about farmer behavior with respect to production decisions and crop disposal, about grain storage, about price behavior in markets at different echelons of the distribution chain. More and better knowledge and changes that indirectly improve market structure and performance will widen the options for reform and increase the probability of adoption.

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Foodgrain Marketing and Agricultural Development in India

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Abstract

This paper examines foodgrain marketing in India and its impact on agricultural development by presenting the approaches and results of four major areas of research in agricultural marketing presently under way at ICRISAT. Agricultural market channels in India are competitive and pricing efficiency in general is good. Consumer preferences (both evident attributes and cryptic characteristics) for sorghum and pearl millet have a measurable effect on market prices, and a quality preference index can be derived from such preference measures for selecting "good quality" grain. ICRISAT's foodgrains in India are primarily grown for home consumption. However, price elasticity of supply for groundnut and pigeonpea in Andhra Pradesh is positive and sizable. Though pricing efficiency of markets is generally high, it varies from market to market. Pricing efficiency was found to be determined by a number of factors from which it could be concluded that more markets with fewer traders per market, equipped with equally distributed telephones and supervised by a frequently changing market secretary, would be conducive to improved pricing efficiency. Investments in improvements of agricultural market exchange have measurable payoffs. The removal of interregional trade restrictions was found to cause aggregate foodgrain production to increase, through relatively minor shifts in cropping patterns.

Agricultural marketing in India is relatively well-developed. There are at present nearly 4000 regulated markets scattered across the country to which farmers can bring their produce and where auctioning ensures competitive prices. Market prices are reported nationwide on the basis of metric measures. Many traders are equipped with telephones so that individual markets are well-integrated into a wider network of interregional market channels; and since 1977 the policy of "food zoning," which used to severely inhibit private interregional trade of various foodgrains, has been abolished.

Thus markets are operating in India, and one might ask, how can research on foodgrain markets in this country contribute to development?

This paper presents in brief the approaches and results of four major areas of market research at ICRISAT that will demonstrate how this can be done. The areas reported are: (1) consumer preferences, (2) supply response, (3) market channels and pricing efficiency, and (4) foodgrain policies and agricultural productivity. We conclude that there is need for more market research that helps to quantify the impact of market channels on allocation of agricultural activities, including adoption of new technologies. Such quantitative evidence will help decision makers in India as well as in other semi-arid tropical (SAT) countries of the world to make decisions on investments in market improvement that will overcome market-related constraints to agricultural development.

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Preference Index of Foodgrains to Facilitate Selection for Consumer Acceptance

ICRISAT has been assigned the task of generating improved cultivars of four foodgrains —

sorghum, pearl millet, chickpeas, and pigeonpeas.[1] In order to be adopted rapidly, new cultivars — apart from producing high and stable yields — must also be acceptable to the tastes of consumers. The relatively low degree of commercialization of farmers who produce these crops restricts adoption of new varieties and therefore places a special premium on good quality. Adoption rates will depend largely not only upon yields but upon how well the new varieties are liked compared with the traditional types.

As will be shown below, "good quality" that ensures consumer acceptance is not conditioned by only one or two visible characteristics; it is based upon an optimal configuration of a complex of several qualities, many of them invisible. In order to incorporate this optimal quality mix into new cultivars, breeders may have to adopt a quality index for preferences that will facilitate selection for consumer acceptance. This index would be established on the basis of the degree to which a number of measurable well-defined and relevant characteristics are available in a particular variety or line, each of these qualities being weighted by a parameter derived from the analysis of consumer preferences for known varieties.

Information on Quality Preferences Generated by the Market

The answer to the question of how to determine and measure what is liked seems rather simple; a grain is of good quality if it consistently fetches a higher price in a competitive market.

A market where innumerable consumers choose among the different qualities of a particular crop and pay certain prices for the various qualities can be regarded as a large, continuous consumer panel. People express their preferences by paying higher prices for qualities they prefer, and vice versa (see Fig. 1). A competitive market forces traders to offer prices strictly according to the position of sup-

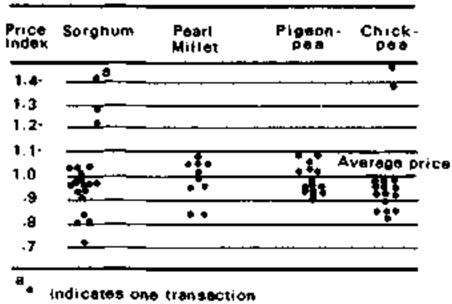

Figure 1. Variation of prices of individual lots of food grains transacted on a selected market day.

ply and consumers' demand. Our observations indicate that different lots of a particular foodgrain traded in any market day are very carefully assessed according to their appearance as well as origin (if the information is available), and prices are formed accordingly. It is interesting to note that on a day-to-day basis the quantities of grains of different qualities arriving at a particular market place have no immediate influence on market price. This is so because the amounts in which different qualities happen to arrive at a place may be skewed towards poor quality on one day and good quality on another day. Also, there may be days with tall peaks in the frequencies of quantities sold at certain prices, while on other days the distribution may be even. Analysis of the coefficients of skewness and kurtosis of frequencies and prices over 15 market days has shown that on an average the skewness is not significantly different from zero, and the kurtosis is not significantly different from 3.00; i.e., over several days the grain lots of different qualities arrive in such a way that the frequency distribution of their prices can be considered as statistically normal. Thus, probably in anticipation of the normal distribution also of the qualities arriving, traders in the short run do not adjust price to quantities of different qualities.[2]

1. Market preferences for groundnuts, the fifth of the crops included in the ICRISAT Crop Improvement Program, have not been studied; the approach to be taken for this primarily commercial crop would not be comparable to that for foodgrains.

2. This assumption of a normal frequency distribution of qualities and of a perfectly elastic demand for quality can be tested only after all of the relevant quality characters have been identified so that a meaningful classification of quality and a test for consistency in pricing can be carried out.

On the basis of these observations, it may be assumed that in the short run, and at a single marketplace that represents only a small fraction of total quantities traded, the market demand for a given quality is perfectly elastic; i.e., on a particular day virtually any quantity of a certain quality can be sold at a price reflecting quality rather than quantity.[3]

A competitive market also ensures integration of rural areas into the commercial system. Even though the degree of commercialization is low, market prices in a competitive system are signaled to the villages. Farmers may sell little or even nothing at all of their produce. However, they know the price differences for different qualities; while witholding a particular quality, they are actually aware of the opportunity price they are paying for their home-consumed quality. Thus, in a competitive market, prices can be taken as representing the joint effect of rural as well as urban preferences, under given conditions of supply.

Measurement of Market Information on Grain Quality

There has been increasing interest recently in the analysis of consumer demand as a function of not only price and income (the traditional approach) but as a function also of consumer preferences and qualities of the goods consumed (the "new approach"). The consumer who acts in accordance with preferences and is given the opportunity to choose from some set Z of characteristic collections, will choose the collection that maximizes his utility function over Z (Lancaster 1971).

Lancaster has shown that consumer demand can be mapped from the "good space" into the "characteristics space" with the help of a "consumption technology matrix" that specifies the relationships between these two. Theil (1976) uses a similar approach: he defines a "composition matrix" for transforming individual goods into preference independent "transformed goods" before analyzing consumer expenditure on the transformed goods.

In the case of a particular foodgrain for which the basic characteristics relevant to consumer preference have yet to be identified, the demand analysis suggested by Lancaster/Theil can be (and for reasons of data availability has to be) simplified: by explaining price variability on a particular market day as a function of variability in quality, the analysis leaves out the quantity-consumer expenditure dimensions of the problem. In doing so, it is implicitly assumed that for the time being the price and income elasticities are independent of quality. This implicit assumption has to be accepted in view of the fact that: (1) the primary goal of this research is to identify relevant characteristics that will help plant breeders select for generally good consumer acceptance, and (2) data that would permit a Lancaster/Theil type demand analysis are not available.

To make use of the information on quality preferences contained in market prices, the following approach was evolved.[4] A central wholesale market, i.e., a major secondary wholesale market that draws arrivals from a larger number of primary local assembly markets, was selected. Centrality of the market is essential because in a central market wider ranges of qualities may be observed than exist in local assembly markets. At the selected market, over a period of one to several days — preferably during the main marketing season — grain samples (about 50 g each) were collected from all lots transacted. Price (as well as other information, if available) was recorded with the sample.

Laboratory analyses of the samples have been carried out as summarized.[6] This list of analyses may not be complete, and research is going on to find out whether there are additional relevant characteristics. Such research may increasingly have to concentrate on explaining why certain attributes are relevant in determination of consumer preferences.

In order to relate price information and quality information, a multivariate regression analysis technique has been developed. This analysis explains the differences in prices of

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3. This is not so in the long run and for the aggregate of all markets. In this case, prices of different qualities have varying elasticities at different supply positions (see von Oppen 1978b).

4. Nevertheless, there is need for further refinement, and we hope the discussion of this paper will result in such improvements.

5. See von Oppen et al. (1979, Appendix Table 1).

individual lots from the market day's average price as a function of quality differences in individual lots from average qualities of all lots of the market day. In other words, the average quality and the average price per market day are taken as references against which to compare the individual qualities and prices.[6]

Application of the Estimation Approach and the Parameters Derived for Sorghum and Pearl Millet

Progressive investigations to identify relevant characteristics for sorghum and millets have revealed the following:

- Cryptic as well as evident quality characteristics are of significance in explaining market price variation (Table 1).
- In sorghum as well as in pearl millet we find as a preliminary result that the swelling capacity,[7] dry volume,[8] and protein content[9] are reflected in market prices.

6. For more details on the mathematical formulation of the estimation model see von Oppen 1976.

7. Weight increase over volume increase after soaking, this variable measures the capacity of water uptake without swelling and should be probably more appropriately called swelling "incapacity", or resistance to swelling.
8. The volume of 10 grams of dry seed, measured by the water-displacement method.
9. Determined by Technicon autoanalyzer.

Table 1. Market price[a] as a function of quality characteristics.

Quality characteristics	Crops	
	Sorghum[c]	Pearl millet[d]
Evident		
Color Mix		
-white[b]	-	
-yellow[b]	.05**[a]	
-red[6]	-.1	
-white[b]		-.05*
-grey[b]		-
Glumes[b]	-.22***	-.02
100 seed weight[a]	.3***	.05*
Moldiness		
-light[b]	-.09***	-.06***
-severe[b]	—24***	-.12***
Cryptic		
Dry volume[a]	.52*	.43*
Swelling[a]	-.18**	-.12
Protein content[a]	.22***	.16***
R^{-2}	.77	.83
Observations	65	25

a. Variable was defined as the natural logarithm of the ratio of the observed value of a particular grain sample over the average value for all samples on the market day.
b. Variable was defined as the difference between the observed percentage of seeds with this quality in a particular grain sample and the average of all percentages of seeds of this quality for all samples on the market day.
c. Samples collected in Hyderabad market over four days In 1977.
d. Samples collected in Jodhpur market over two days in 1978.
e *•• - Significant at 1%
** - Significant at 5%
* - Significant at 20%
. Indicates variable does not apply.
- Indicates variable was not included.

The two sets of coefficients for all characteristics that are comparable between sorghum and pearl millet—i.e., molds and the cryptic qualities — have the same signs; in fact, a statistical test on an estimation model that includes only these comparable variables shows no significant difference in consumers assessment of these qualities, regardless of whether they occur in sorghum or pearl millet. The sorghum samples for this analysis were collected in Hyderabad in 1977 and the pearl millet samples in Jodhpur in 1978; thus, as far as they are representative, these samples indicate that consumer preferences for cryptic quality characters are probably of more than only regional relevance. Unlike the evident qualities, for which preferences vary considerably from one region to another, cryptic qualities would seem to face universal preference patterns, across similar crops and across regions.[10]

These estimated coefficients suggest that ceteris paribus, an increase in the protein content of sorghum from the average of 8.25% to, say, 10% would result in an increase in the market price of 4% above the average.

The other coefficients can be interpreted in the same way[11]; the ceteris paribus condition implies that all of the other quality characteristics remain the same while only one is being changed. Plant breeders' experience shows that these characteristics are to some extent related to each other, and that one cannot easily be changed independently of all of the others. The simultaneous impact of several different quality characteristics on consumer preference requires, when aiming at cultivars of higher consumer acceptance, the simultaneous consideration of all such relevant characteristics. The estimation equation, is, in fact, designed to form the basis for such a simultaneous quality assessment. It permits derivation of an index of estimated consumer preferences.

As an example, we collected 15 sorghum samples in the Hyderabad market and estimated the consumer preference for each. These samples were taken to a village in Maharashtra for ranking by farmers.[12] They were also tested by villagers in Karnataka.[13]

It was found that the Maharashtra farmers' ranking and the ranking based upon our quality index are positively correlated with a correlation coefficient of .60; the correlation between Karnataka farmers' ranking and our quality index ranking was .56; both correlations were significant at the 5% probability level. This indicates that the quality index derived from market prices in Hyderabad is representative of preferences of farm families in Maharashtra, as well as in Karnataka.

Even though these results demonstrate the feasibility of our approach, it is felt that the estimation of the quality index can be further improved. Consequently, the above results must be regarded as preliminary while our work continues in search of additional cryptic quality characteristics relevant in explaining consumer preferences as expressed in market prices. Similar work on quality preferences for pulses is under way. Here the major factors affecting price seem to be related to ease of dehulling, percentage of hulls, and cooking quality of the dhal (split pea). However, there are difficulties in producing standardized measurements of these qualities. Also the diffuse nature of the market channels for pulses, which generally do not pass through central market places in large quantities as do cereals, makes reliable price observations more difficult. For these reasons our work on quality preferences for pulses has not yet led to conclusive results.

Estimates of Supply Functions for SAT Crops in Andhra Pradesh

Compared with the large number of supply-response studies done in India for irrigated crops, only a few studies have been done for

10. It is interesting to note that in a study on wheat quality, Bhatia (1973) reported that protein content has a significantly positive relationship with market prices paid by private traders in two markets in Delhi.
11. An increase in 100-seed weight from an average of 2.75 to 3.75 g would increase the market price by 10% above the average price. For swelling capacity, an Increase from an average of 1.10 to 1.25 would reduce market price by 2 percent below the average.
12. The consumer preference test in the village was carried out under the guidance of Dr. S. L. Bapna and with the assistance of Mr. K. G. Kshirsagar (Report forthcoming).
13. Personal communication by Miss. T. Padmasini Asuri, Regional Home Economist, Bangalore.

rainfed crops.[14] In view of their importance for price policy decisions in the SAT, we decided to study the supply response of the five ICRISAT crops in India. This note reports first results obtained for Andhra Pradesh, which is an important SAT State in India. Andhra Pradesh contributes about 11% of the total area under the five ICRISAT crops, which makes it the fourth largest producer. Sorghum and groundnut predominate in the rainfed cropping pattern of the State, while the other three crops — pigeonpea and especially pearl millet and chickpea — contribute less. Sorghum and groundnut are mainly grown as nonirrigated crops. Sorghum is grown in two seasons *kharif* (rainy) and *rabi* (postrainy), while the other crops are only grown in *kharif* (groundnuts, pearl millet) or *rabi* (chickpea). In Andhra Pradesh, 29% of the total cropped area is irrigated; the main sources of water are canals and tanks.

Methodology

Past supply-response studies generally suffered from the lack of significance of coefficients and high level of aggregation, and they often provided conflicting estimates of supply elasticities. Further, these studies concentrated on area response and not production response.[15] The present study attempts to overcome these problems. Maximum use of the available data is being made by combining district-wide cross-sections and annual time series.

$$(1) \quad Q_{jt} = \alpha + \Sigma \ \beta X_{ijt} + e_{jt}$$

where

i = 1 . . . . . .M independent variables
j = 1. . . . . . N districts
t = 1. . . . . . .T years
Q = dependent variable
X_i = independent variables

The total number of observations available with this procedure are N x T. Estimating the above type of equation by ordinary least squares (OLS) would provide inefficient estimates, because the use of OLS assumes $Eee' = \sigma^2 I$. This does not hold true for this case, where the data are known to contain systematic variation in residuals across districts and across years. The residual term can be expressed as $e_{jt} = \mu_j + \nu_t + \eta_{jt}$, where μ_j is the location effect, ν_t is time effect, and η_{jt} is the interaction of time and location. To separate these components of the error term, an error components model was applied; it is based on generalized least squares (GLS) and provides best linear unbiased estimates (Wallace 1977).

Specification of Model and Variables

After a number of model specifications were tried, the following production and area response functions were fitted for sorghum, groundnut, and pigeonpea:

$$(2) \quad Q_{jt} = b_0 \, \bar{P}^{b_1} \, \bar{C}_{jt}^{b_2} \, W_{jt} \; e_{jt}^{b_3 W'} + b_4 I_{jt} + b_6 R_{jt} + b_6 M_{jt} + b_7 I'_{jt} \; U_{jt}$$

where

j = 1 . . . . . 20 districts in Andhra Pradesh
t = 1 . . . . . T years from 1957–58 to 1973–74
Q = production or area
b_i = regression coefficients, (i = 0, 1 . . . . . . 7)
$\bar{P}$ = expected product prices formed by weight average of prices of past 3 years
$\bar{C}$ = expected product prices of competing crops
W = rainfall in relevant time period in millimeters
W' = square of log of rainfall
I = percentage irrigated area in total cropped area
I' = percentage irrigated area under the crop
H = percent area under the high-yielding varieties of the crop concerned (in sorghum equation only)
R = road density in Km per 100 square kilometer of geographical area
M = market density in number of regulated markets per 1000 square kilometer of geographical area
U = residual term.

The above equation is linear for logarithms of

14. For details, see Bapna (1979).
15. For a detailed examination of the methodologies used, see Bapna (1977).

dependent variables and some of the independent ones; other variables appear untransformed.

Results

The results for the supply equations of sorghum, groundnut and pigeonpea are presented in Table 2. The price elasticities obtained for production of groundnut and pigeonpea are positive. The supply elasticity for groundnut is 0.53 and is highly significant; for pigeonpea the coefficient is positive (0.23) but only significant at the 10% level. For sorghum the supply elasticity is negative but it is not statistically significant. Sorghum in Andhra Pradesh is grown in two seasons; therefore, our estimation procedure may confound annual with interseasonal supply response. This problem could be avoided only if seasonal data were available, which they were not.

For area, all three crops have positive supply elasticities, but here again the sorghum coefficient is not statistically significant. The supply elasticities for area are 0.30 for groundnut, 0.29 for pigeonpea and 0.04 for sorghum. It is interesting to note that the elasticities for the three crops broadly correspond to the extent of commercialization of these crops, with groundnut being the most commercialized.

The area supply elasticities obtained here for groundnut are much lower than the estimate of 0.69 obtained by Cummings (1975) for Andhra Pradesh. For sorghum, the elasticity broadly corresponds to the National Council of Applied Economics Research (1969) estimates. For pigeonpea, no estimates are available for comparison.

Rainfall is a very important factor in the production of nonirrigated crops. To capture the effect of rainfall on productivity, the variable was included in log-linear and log-quadratic form. In all cases, the linear term yielded positive coefficients and the square term negative coefficients, as expected. Irrigated area exhibited negative coefficients for all the three crops, which indicates that with the expansion of irrigation, farmers devote a greater area to typical irrigated crops such as rice and sugarcane. An increase in the irrigated area under the crop concerned did not produce a measurable increase in production, except for pigeonpea. Road density seems to have a negative impact on the production and area of sorghum, an insignificant effect on the production and area

Table 2. Production and area supply aquations for sorghum, groundnut, and pigeonpea. in Andhra Pradesh.

	Regression coefficients*					
	Production equation			Area equation		
Explanatory variable	Sorghum	Groundnut	Pigeonpea	Sorghum	Groundnut	Pigeonpea
Intercept	2.99	-13.49	-9.81	3.88	-.53	-3.22
In (Rain)	0.64	4.26**	3.19*	0.35**	1.00**	1.62***
(In Rain)^2	-.05	-.31**	-.25*	-.03**	-.09**	-.16
% Total irrigation	-.04	-.11*	-.01	-.50*	-.12**	-.06[b]
.31@% Crop irrigated	-.17		2.54*	-.26	-.01	1.80***
% High yielding varieties	0.15	-	-	-.08 -		-
Road density	-.063***	.04[b]	-.006	-.035***	.045***	.001
Market density	-.21***	-.26***	—24***	-.13***	-.22***	-.07[b]
Deflated price	-.24[b]	0.53***	0.23*	0.04	0.30***	0.29***

a. The equations were fitted as double logarithm transformations of equation - (2) In the text.
b. Significant at 20%
*** Significant at 1%
** Significant at 5%
* Significant at 10%

of pigeonpea and a positive impact on groundnut production and area. Coefficients of markets were significantly negative for all the three crops.[16]

The estimation of supply elasticities — once it is extended to cover all districts of major producing regions of ICRISAT crops in India — will help in assessing the impact of priceand market policies. Wherever possible and not yet done, similar studies should be caried out in India and also in West Africa.[17]

Efficiency of Market Channels for ICRISAT Crops

A study was conducted to describe the market channels of ICRISAT crops in different regions, to measure market costs and market efficiency, and to identify criteria determining efficiency. Results of this research are reported in this section.

Methodology

Surveys were conducted in 29 regulated markets in seven SAT states of India. The markets for each state were selected on the basis of probability, proportionate to the proportion of ICRISAT crops entering the markets. The criterion for inclusion of markets in the sampling was that ICRISAT crops represent at least 25% of total arrivals. The selected markets and some of their particulars are listed in Table 3.

Primary and secondary data for 1974-75 were collected from market committees of all selected markets and also from farmers and traders. Farmers and traders in the markets were selected at random and interviewed to obtain estimates of marketing margins and costs (not reported here), on quantities produced and sold, as well as directions of sales. Pricing efficiency was measured in terms of the coefficient of correlation of weekly prices between pairs of markets. Multiple regression analysis was used to explain the pricing efficiency of all pairs of markets as a function of independent variables such as distance between two markets, average market turnover, market age, number of traders, telephones, market secretaries, market area, density of production, density of population, etc. Hypotheses were formulated stating in which way these independent variables were expected to affect pricing efficiency.

Estimates of Flows of ICRISAT Crops

On the basis of information collected from traders and farmers in the selected markets surveyed in different states, estimates of inflows into the markets and outflows from the market were made for each crop. Estimates of market arrivals based on farmers' reports indicate that only 22% of the sorghum produced came to the markets and the remaining 78% was retained on farms (Table 4). In the case of pearl millet, it was estimated that about 26% of production reached markets; for pigeonpea it was 35%; for chickpea 45%; and for groundnut 80%. These estimates of market arrivals are somewhat higher than those published by the Government of India. This can be explained by the fact that the 29 markets were selected to ensure that at least 25% of their arrivals were ICRISAT crops.

Estimates of outflows from selected markets of different states (Figs. 2 to 6) indicate that a large proportion of these crops were traded within the districts where the markets were located. A smaller proportion moved to other districts within the State. Nevertheless, the remaining trade, which often involved long-distance interstate transport, was not negligible. In comparison with sorghum and pearl millet, the quantities and distances involved in interstate exchange of pigeonpea and chickpea are much greater. Groundnuts seem to be mostly processed locally. These estimates show that interregional trade in sorghum and pearl millet is concentrated within the SAT areas of India where these crops are traditionally grown and consumed, while the pulses flow to other, non-SAT areas. In fact, the major producing areas for sorghum (Maharashtra) and pearl millet (Gujarat) turned out also to be the major importing regions for these crops in 1974-75.

16. Research reported elsewhere (von Oppen 1978c), indicates that market effects on production have a lag structure that requires careful specification. This problem is under study.
17. To our knowledge, the only study of this kind is Abalu (1975).

Table 3. List of selected markets and some of their particulars, 1974-76.

State[a] / Market name (District)	Year market regulated	Total market turnover ('000 tons)	Share of ICRISAT crops (%)	No. of commission agents	No. of wholesale traders	No. of telephones
AP/Warangal (Warangal)	1933	116	38	120	392	500
AP/Khammam (Khammam)	1937	35	61	130	139	250
AP/Tandur (Hyderabad)	1949	21	65	85	85	130
MP/Indore (Indore)	1953	184	46	160	504	680
MP/Ujjain (Ujjain)	1930	62	72	63	171	210
MP/Khandwa (Khandwa)	1964	34	21	77	135	200
MP/N. Gunj (Sehore)	1968	7	42	-	14	-
MH/Poona (Poona)	1959	136	34	159	443	650
MH/Latur (Osmanabad)	1931	84	51	127	326	400
MH/Malkapur *(Buldana)*	1917	38	17	24	47	70
MH/Malegaon (Nasik)	1949	24	38	19	86	100
MH/Dondiacha (Dhulia)	1939	20	39	52	76	50
R/Ganganagar (Ganganagar)	1964	79	17	152	253	450
R/Nadbai (Bharatpur)	1965	14	53	53	69	100
R/Hindone (S. Madhopur)	1965	14	63	88	118	85
R/Begun (Chittorgarh)	1970	6	37	37	60	26
G/Patan (Mehsana)	1951	52	7	176	337	300
G/Santrampur (Panchmahal)	1952	7	32	8	91	30
G/Damnagar (Amreli)	1954	0.1	49	9	20	10
K/Bagalkot (Bijapur)	1946	84	73	109	161	60
K/Gadag (Dharwar)	1943	45	57	103	293	150
K/Chitradurga (Chitradurga)	1951	28	42	77	84	15
UP/Shahabad (Hardoi)	1972	33	33	22	82	15
UP/Ujhani (Badaun)	1967	30	54	13	54	35
UP/Jafarganj (Sultanpur)	1973	20	25	5	22	-
UP/Orai (Jalaun)	1967	16	21	102	82	5
UP/Bendki (Fatehpur)	1968	13	36	10	53	20
UP/Jarar (Agra)	1969	8	29	26	32	16
UP/Panwari (Hamirpur)	1971	0.07	74	-	5	—

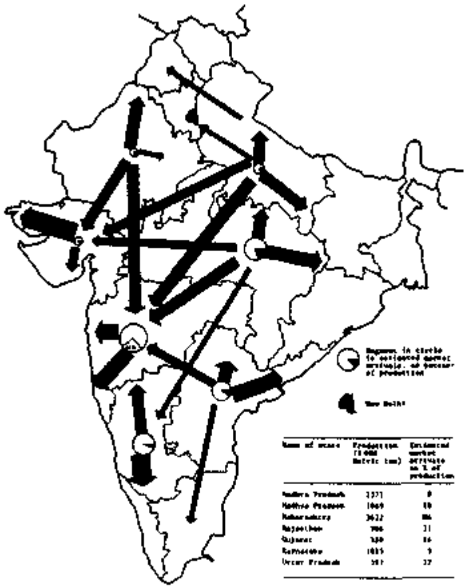
a. AP = Andhra Pradesh; MP = Madhya Pradesh; MH = Maherashtra; R = Rajasthan; G = Gujarat; K = Karnataka and UP - Utter Pradesh.

Pricing Efficiency

Generally it is accepted that the higher the correlation of prices between pairs of markets for a particular product, the better the markets for this crop are integrated and hence the more efficiently they are operating.[18]

Weekly market prices for 1974-75 of the five

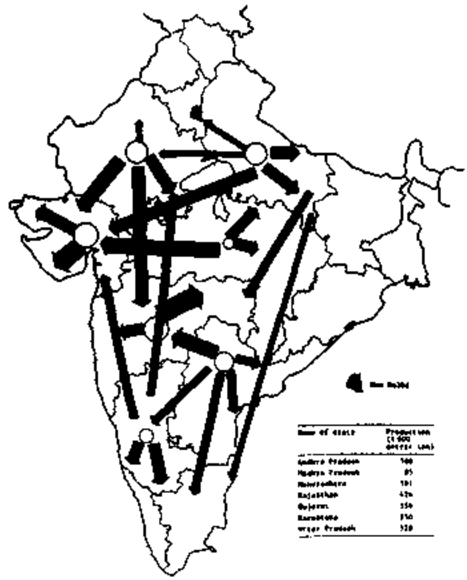
18. This logic may not apply fully if one considers only a limited number of market places (see Harriss 1978); for instance, if flows of a particular commodity between any two markets do not always have the same direction but, for reasons of varying supply and demand in both market regions, sometimes cease end then reverse, then the correlation of market prices will be reduced even though the two markets may be perfectly integrated. However, for the type of analysis proposed here, which involves all pairs of a relatively large number representing the major parts of SAT India, such a consideration and its impact on price correlation will not affect the analysis and its conclusions.



Short arrows (regardless of direction) represent flows to other markets within the district.
Medium length arrows (regardless of direction) represent flows to markets in other districts within the state.
Arrows across state borders represent flows to markets in other states.
Width of arrow represents relative proportion of flow.

For example, in Madhya Pradesh, about 22% of the sorghum arriving in the selected regulated markets flows to Maharashtra, 15% to Gujarat and 3% to Karnataka. Of the remainder about 35% goes to markets in other districts of Madhya Pradesh and the remaining 25% stays within the districts of the markets where first sold.

Figure 2. Production of sorghum, market arrivals as per cent of production, and total flows (as percent of market arrivals) from selected food grain markets in selected states of India, 1974-1975.



Arrows explained in Figure 2.

Figure 3. Production of pearl millet and total flows, as percent of market arrivals, from selected foodgrain markets in selected states of India, 1974-1975.

ICRISAT crops for every market surveyed were correlated (by pairs) with those of all other markets. Unweighted mean correlation coefficients between pairs of all selected markets for all five crops are given in Table 5. Most of the correlation coefficients were positive and significant at the 1% level.

Correlation coefficients were highest for chickpea and pigeonpea, the two crops with more interstate trade. Sorghum, pearl millet, and groundnut prices correlated positively and significantly but considerably below the levels of correlation measured for the other crops. For

Table 4. Estimates of arrivals (percentage of production) of ICRISAT crops In selected regulated markets, 1974-75.

Crops	Arrivals in selected regulated markets[a]	Arrivals in all regulated markets[b]
Sorghum	22	11
Millet	26	NR[c]
Pigeonpea	35	NR
Chickpea	45	28
Groundnut	80	NR

a. Source: ICRISAT Survey.
b. Source: Government of India (1976).
c. Not reported.

groundnut, the emphasis on local processing and limited interregional trade might be responsible for the low market price integration. In the case of sorghum and pearl millet, despite interregional trade, market prices were not well related, probably due to difficulties in price reporting, given the variability in quality of market arrivals, especially of sorghum (See Fig. 1).

Table 5. Mean correlation coefficients of 54 weekly market prices of ICRISAT crops, pairs of 29 markets in SAT India, 1974-75.

Crops	Mean correlation coefficient
Sorghum	0.24
Pearl millet	0.37
Pigeonpea	0.62
Chickpea	0.72
Groundnut	0.31

Factors Affecting Pricing Efficiency

Pricing efficiency can be affected by several factors, and in this study an attempt was made to identify with the help of the data collected, some factors for which the following hypotheses were postulated:

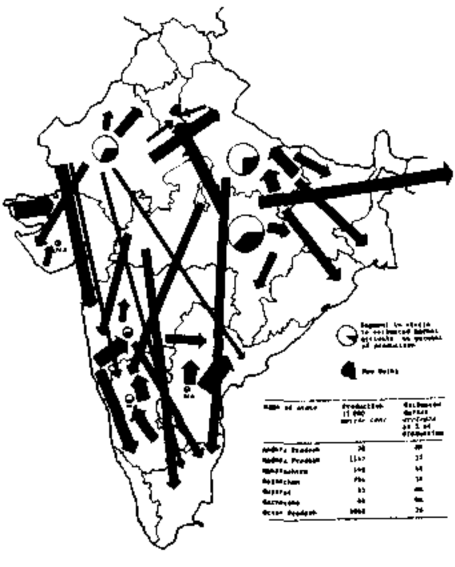
$$CC_{ij} = f\,(DT_{ij},\ SM_{ij},\ SI_{ij},\ MA_{ij},\ NW_{ij},\ NC_{ij},\ TM_{ij},\ TT_{ij},\ NS_{ij},\ MU_{ij},\ ST_{ij},\ PD_{ij},\ DP_{ij}).$$

where:

CC_{ij} = correlation coefficient between markets i and j.

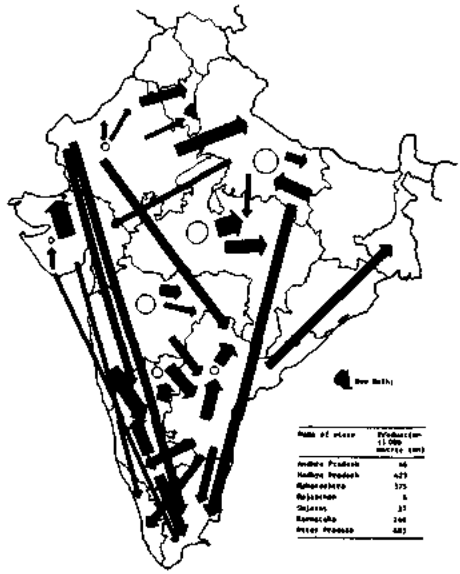
DT_{ij} = distance between markets i and j measured in kilometers. It is hypothesized that if the markets are distant their prices will not be highly correlated. Hence a negative sign is expected.

SM_{ij} = average size of the two markets measured in terms of total arrivals in thousand tonnes. Larger markets are more efficient in



Arrows explained in Figure 2.

Figure 4. Production of chickpea, market arrivals as percent of production, and total flows las percent of market arrivals) from selected foodgrain markets in selected states of India, 1974-1975.



Arrows explained in Figure 2.

Figure 5. Production of pigeonpea and total flows, as percent of market arrivals, from selected foodgrain markets in selected states of India, 1974-75.

pricing; a positive sign is expected.

SI_{ij} = average turnover of ICRISAT crops in percent of total turnover of the markets measured in terms of arrivals in tonnes. The hypothesis for this variable is that if the share of ICRISAT crops in total size is higher between the markets then these markets are efficient for ICRISAT crops. A positive sign is expected for this variable.

MA_{ij} = age of markets. This is measured in years by deducting the year of regulation from the year 1975. It is hypothesized that older markets are more efficient than new markets. A positive sign is expected for this variable.

NW_{ij} = number of wholesale traders in markets. The number of wholesale traders in a particular market measures the degree (not quality) of market access for farmers." The more traders in one market place, ceteris paribus, the fewer are the market places and the longer is the distance farmers have to travel to obtain market access; hence, market efficiency suffers and the sign of this variable is expected to be negative.

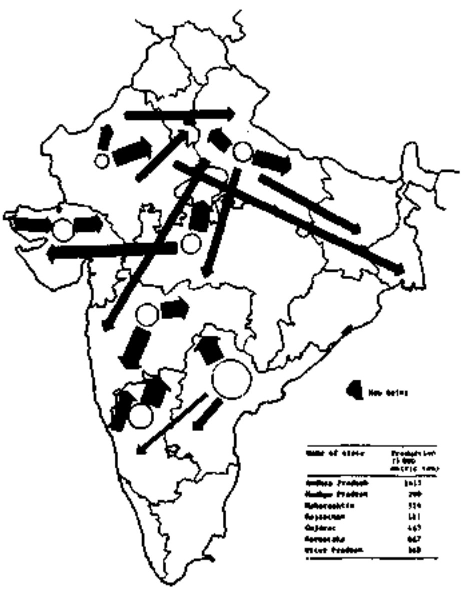
NC_{ij} = number of commission agents in markets. The hypothesis and sign for this variable is similar to NWij.

TM_{ij} = number of telephones per unit turnover in markets. It is hypothesized that the larger the number of telephones per unit turnover, the higher is the market efficiency and a positive sign is expected for this variable.

TT_{ij} = number of telephones per trader in markets. The hypothesis and sign expected for this variable are similar to

NS_{ij} = number of changes in market secretaries from 1965 to 1975 in the markets. It is hypothesized that the larger the number of changes in market secretaries, the higher is market efficiency. If a market secretary stays in a market for many years he is likely to be biased and tolerant towards collusion of traders resulting in inefficiency. A positive coefficient is expected for this variable.

MU_{ij} = utilization of market yards in the markets. This is measured in terms of market arrivals per unit size of the market yard. It is hypothesized that proper utilization of the market yard results



Arrows explained in Figure 2.

Figure 6. Production of groundnut and total flows, as percent of market arrivals, from selected foodgrain markets in selected states of India, 1974-1975.

19. Note that there are only two markets in our sample with fewer than 20 traders but 23 markets with more than 50 traders (see Table 3).

in market efficiency and hence a positive sign is expected for this variable, up to a maximum beyond which congestion leads to inefficiencies, thus a negative sign for the squared term is expected.

ST_{ij} = average turnover of the traders in the markets. This variable is measured dividing total market turnover by the number of wholesale traders in the market. It is hypothesized that markets will be efficient if their turnover is shared by many small traders rather than a few larger traders. A negative sign is expected for this variable.

PD_{ij} = population density in the district where markets are located. It is hypothesized that markets are more efficient where more people live. Hence a positive sign is expected for this variable.

DP_{ij} = density of crop production in the districts where the markets are located. It is hypothesized that more production of a particular crop is a sign of specialization which implies more market participation by farmers and better market efficiency. A positive sign is expected for this variable.

In addition to the above variables, dummy variables for states and crops were also included in the regressions.

Regression results are summarized in Table 6. This table shows that most of the variables have the expected signs and appear to be statistically significant.[20] Most of the hypotheses

Table 6. Summary of regression results.[a]

Variables with positive signs*	Expected signs
Market Size***	Yes
Age of market***	Yes
No. of Commission agents	No
No. of telephones per turnover***	Yes
Change of market secretaries***	Yes
Utilization of market yard***	Yes
Density of population	Yes
Density of crop production**	Yes
Distance***	Yes
Share of ICRISAT crops**	No
No. of wholesale traders***	Yes
No. of telephones per trader***	No
Average turnover of traders***	Yes

a. For the complete regression equation see Raju and von Oppen (forthcoming).
b. *** Significant at 1% level.
** Significant at 5% level.

proposed were not rejected. In two cases, the proposed hypotheses cannot be accepted as the variables have unexpected significantly negative signs. These were the share of ICRISAT crops to total market turnover, and number of telephones per trader. Two variables were not statistically significant, i.e. number of commission agents with an unexpected positive sign, and density of population with an expected positive sign.

The positive sign for share of ICRISAT crops suggests that markets are inefficient if they are dominated by ICRISAT crops. Thus markets tend to be more efficient the larger the variety of other crops arriving in this market. The negative effect of number of telephones per trader on pricing efficiency seems to imply that a few traders monopolize the telephones, and market efficiency is adversely affected.[21]

Conclusions on Market Channels

It is concluded on the basis of estimated arrivals

20. The significance levels as computed for standard regression problems should probably be used only as indicators of relative significance among variables, because of the nature of our data. Except for distance between markets, which represent actual observations, all independent variables defining market characteristics were generated by pairing markets, thus creating n actual observations and n(n-1)/2 data points. It is not dear to what extent such a data manipulation reduces the statistical significance of the results.

21. This variable should probably be included as a linear and a squared term with the expectation that the linear term Is positive and the squared term negative, thus indicating an optimum number of telephones per trader.

of ICRISAT crops into selected markets that sorghum and millet are produced mainly for home consumption. From the estimates of outflows of ICRISAT crops from the selected markets surveyed in different states, it is concluded that in comparison with the higher valued pulses, the lower valued sorghum and millets are only traded over short distances. This is because consumption of the latter crops is higher in the producing areas, while consumer demand is lacking in most other areas. Possibly trade restrictions imposed on coarse grains and other crops during the period of observation have also had an impact.

On the basis of price correlation analysis, it is concluded that for ICRISAT crops most of the selected markets are well integrated, and generally price formation is efficient.

Analysis of the price correlation coefficients between pairs of markets leads to the following conclusions: The fewer the traders per market the higher the pricing efficiency in the presently existing markets; therefore, without necessarily reducing the total number of traders, more regulated markets with fewer traders in each would increase pricing efficiency. This would imply more markets in the vicinity of farmers, providing better physical access; telephones should be provided in these markets, but telephones should be distributed equally among traders. Market supervision is important and market secretaries should be exchanged frequently so that they can properly oversee market activities without being influenced by vested (traders') interests. Market yards should be established to be of a size that avoids excess capacity and congestion.

The Effects of Interregional Trade and Market Infrastructure on Aggregate Productivity of Agriculture

Agriculture is spread over space and its productivity in any location depends upon the local and regional resource base such as soils, climate, topography, and people. To fully exploit this regional and, over time, changing diversity in resource endowments — given the spatial expansion of agricultural activity—efficient interfarm and interregional exchange and transportation is a sine qua non. The more efficiently farmers and regions are able to exchange their produce, the stronger will be their incentive to allocate resources according to personal and local comparative advantages; by making use of the diversity in comparative advantages through exchange, aggregate agricultural productivity can be increased.

The objective of this section is to evaluate the productivity of markets and market exchange net of other production factors. This involves measurements of the effect of trade restrictions in India on aggregate productivity by using (1) a normative activity analysis model of interregional trade, and (2) a positive regression analysis of statewide foodgrain production and food zoning. The removal of trade restrictions for agricultural products has, as we shall see, positive effects on aggregate productivity; it is agreed that these may affect — at least temporarily — equity and income distribution, and the policymaker may be right in asking whether the gains in aggregate productivity are worth their political implications.[22] The following discussion is restricted to the analysis of aggregate productivity. The approaches used may help to remove some of the uncertainties in assessing the gains associated with market development so as to have a better basis for planning physical and institutional investments into this vital factor in the agricultural production process.[23]

Interregional Trade and Aggregate Productivity: A Normative Approach

In order to demonstrate the impact of market flows on productivity, an activity analysis model has been set up. This model allows us to investigate commodity flows, pricing, and crop allocation at different productivity levels on three crops in three regions. The model is based on data that represent the following hypothetical case: In the three Indian states of Andhra

22. A study that aims to assess the differential impact of market access on small vs. large farmers is now being conducted.
23. For a discussion of these issues see Raj Krishna (1965). When justifying zonal food policies, Dantwala (1976) said: "The economic balance sheet of such disincentive in surplus states and incentives in deficit states is anybody's guess."

Pradesh, Madhya Pradesh, and Maharashtra, three crops — rice, sorghum, and chickpea — are grown, and all three compete for the same locally available resources, in this case land.[24]

Yield per hectare is restricting the supply, so that the total use of land for all three crops cannot exceed its limits in each state. Supply is further restricted by a linear function of area response to price multiplied by yield. The initial elasticities of supply are derived from available estimates and represent — as far as they are known — actual conditions. The model also incorporates demand as a linear function of price using elasticities available or derived from other sources (S. L. Bapna, personal communication). Transportation costs between regions correspond to official rail freight rates between centrally located places in each of the three states.

Given this environment, a quadratic programming model allocates crop production in each of the states so that producers' welfare plus consumers' welfare, minus total costs of transportation is maximized. Application of this model produces optimal allocation of land to crops, quantities produced, commodity flows, and accompanying price levels.

The initial data set (i.e. case A) represents initial conditions (1971-72); in other words, low yields and high costs of production "before the introduction of new technology." Suppose now that the governments of the three states decided to impose trade restrictions so that the quantities traded of each crop among all regions would not exceed 10% of the quantities traded without restrictions. The imposition of the trade restrictions under these conditions would change production on the three foodgrains in all three states as follows:[25]

- total output of rice remains unchanged;
- total output of sorghum decreases by 5%;
- total output of chickpea decreases by 13%; and
- total output of all foodgrains together decreases by 2%.

Suppose now that new technologies are found and adopted for all three crops in all regions so that yields increase by 50% in the states that have highest yields and by proportionally less in the states with lower yields.[26] Supply functions are allowed to shift, allowing productivity growth over initial levels in the same proportion as yields growth at the same time, an increase in demand in all regions for all crops of 25% is assumed. In this case B, the imposition of trade restrictions causes:

- total output of rice to decrease by 1%;
- total output of sorghum to decrease by 7%;
- total output of chickpea to decrease by 15%; and
- total output of all foodgrains to decrease by 4%

Under conditions of low yields and high production costs (Case A), trade restrictions have a measurable but comparatively small impact; aggregate productivity of all foodgrains is decreased by only 2%. If, however, with population growth, demand functions shift to the right, and if at the same time new technologies are adopted which increase yields, and shift supply functions to the right (Case B), differentially then regional specialization and interregional exchange increase, and consequently aggregate production rises significantly. Under such circumstances, a restriction on interregional trade as described above, decreases aggregate production of all foodgrains by about 4%, which is about twice the percentage decrease under the initial or low-demand, traditional supply conditions. In other

24. Other resources such as capital and labor, which are mobile in the long run, will tend to be allocated wherever most profitable. Under conditions of restricted interregional commodity exchange these resources would move from surplus regions (because of natural comparative advantages) to deficit regions, where higher prices ensure higher returns.
25. For more details of this model, see von Oppen (1978c, Table 4).
26. A comparison of wheat yields in eight major wheat growing states in India between the years 1954/55-1958/59 and 1970/71-1974/75, shows that after the introduction of new wheat technologies, yields had not increased by the same percentage in every state, but rather in a proportional fashion, i.e., percentage yield increases were higher, the higher the original yield level had been (with the exception of Bihar and Gujarat, where yield increases were high despite low initial yield levels). See von Oppen (1978c, Appendix IV).

words, trade restrictions are more harmful under improved technology (Case B) because they considerably depress total production below the possible level which could have been reached with unrestricted trade.

Food Zoning and Aggregate Yield of Foodgrains: A Positivistic Analysis

Indian food policies over the past 20 to 30 years have varied in their degree of control of trade in foodgrains. Figure 7 presents a general picture of the periods and states involved when food zones were imposed. The imposition of a food zone implies that the right to trade across the border of a food zone becomes the monopoly of the Central Government through its statutory agency, the Food Corporation of India (FCI). After 1956-57, various states were grouped into food zones for rice and wheat. While the wheat zones were abandoned in 1961, the rice zones continued until 1964. In 1964 it was decided that every state would form a separate food zone. The state governments were thereby given the authority to "organize" the foodgrain trade within the state; this often resulted in trade restrictions even at the district level, by imposing license systems that were intended to control the movements of grain from one district to another within the same state.

These statewide zones in the beginning controlled only the trade in wheat and rice, but after 1966 most foodgrains were included in the movement restrictions. Statewide food zoning continued — with varying degrees of stringency — up to 1976, when the three states of Andhra Pradesh, Karnataka, and Tamil Nadu joined again to form the southern rice zone; finally, in 1977, food zoning was abolished altogether.

A quantification of these changes in government intervention with the interregional trade in foodgrains is a complicated task. It will always remain imperfect because of two major reasons: (1) the imposition of restrictions as recorded in administrative documents does not provide full information about the degree to which the act was in fact implemented, especially at the interdistrict level;[27] (2) even though private trade was legally excluded from moving grain across food zones, and the FCI had the monopoly for interzone grain movements, this did not in all cases imply the same degree of restriction of exchange among all regions. The sometimes massive movements of foodgrains by the FCI have to some extent followed a flow pattern similar to trade flows that would have occurred in a system free of food zones. Consequently, the method adopted below to quantify "freedom of trade" can only be regarded as a conservative approximation towards a measurement of trade interference.

The degree of freedom in the trade of a particular state with other states, and in different crops for a particular year, was counted by adding the number of states in which trade was unrestricted for each of the four crops, rice, wheat, pulses, and coarse grains. This gives a rough but ready measure of freedom of trade (FOT) for a particular state overtime. For example in Gujarat in 1963-64, the existence of the Northern Rice Zone restricted the number of states with which Gujarat was free to trade rice to only three (including Gujarat), while for wheat, pulses, and coarse grains, no restrictions existed (Fig. 7). Thus for these three grains trade was free among 13 states; i.e. the FOT for Gujarat in 1963-64 was $(1 \times 3) + (3 \times 13) = 42$. In the following year the establishment of Gujarat as a separate food zone for wheat and rice implied that these two grains could be freely moved only within the state, while for the remaining pulses and coarse grains, all 13 states were open to trade. Hence the FOT in 1964-65 for Gujarat amounted to $(2 \times 1) + (2 \times 13) = 28$. In this fashion, the FOT of Gujarat in the year 1970-71 went up to 40, while in the next year it came down to 16.

In order to explain aggregate yield of foodgrains as a function of trade restrictions and other factors, state data from 1960-61 to 1973-74 were collected. For the estimation procedure a generalized least squares model was applied which combines time series and cross-section data.[28]

It was postulated that aggregate productivity

27. Government of India, (a and b).

28. For details of this method, see Barah et al. (1977). Discovery of a slight mistake in the earlier version of COMTAC required minor corrections of results reported earlier. However, the conclusion remains the same.

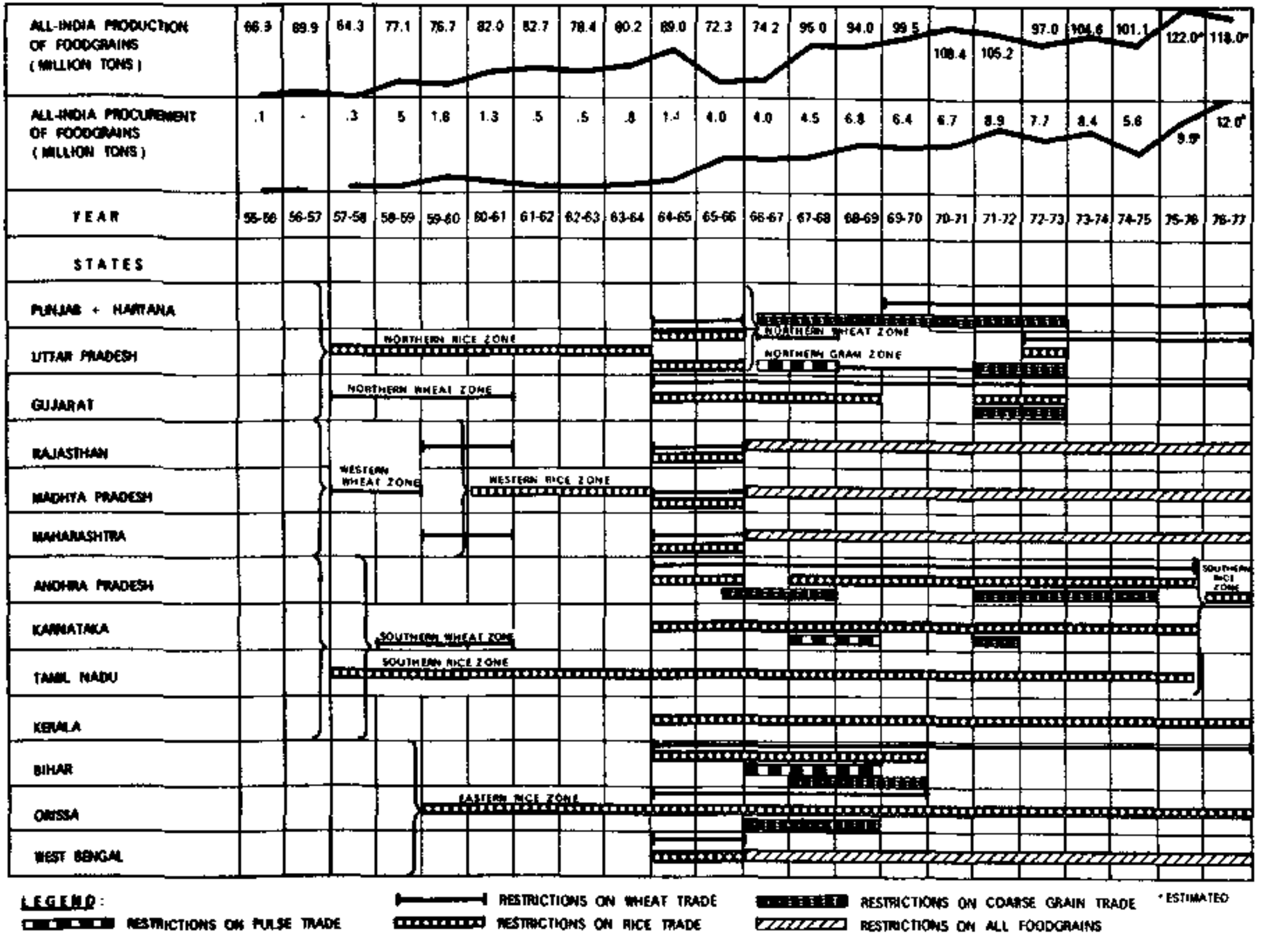


Figure 7. All India production and procurement of foodgrains and summary by states of food policies involving trade restrictions for different food grains.

of foodgrains was linearly dependent upon inputs, weather, infrastructural facilities, labor availability, and freedom of trade. The impact of freedom of trade was lagged. However, no a priori knowledge existed that would have allowed us to postulate a specific duration for the lag period. Consequently, lags from t to t-4 were jointly entered into the equation.

The joint effect of the lags in freedom of trade on aggregate yield was positive and the sum of all coefficients was 1.818. None of the coefficients appears to be significant, probably because of multicollinearity.[29] Regarding the coefficients of the remaining variables included in the estimation, irrigation has a highly significant positive relationship with aggregate yield, and the same is true for rainfall, fertilizers, and density of rural population, even though less significantly. Surprisingly, the proportion of area under high-yielding varieties does not appear to have a statistically measurable impact upon aggregate yields. Truck density is positively, but not significantly, associated with aggregate yields.

The average foodgrain yield over time and states was 837 kg/ha and the average value measured for the variable "freedom of trade" was about 31 degrees. If — ceteris paribus — a complete liberalization of trade (implying a value of 52 degrees) was introduced, this would be followed by an increase of aggregate yield by (52-31) 1.818=38.2 kg/ha, or by nearly 5% of the average yield. In other words, against the level of theoretical productivity under unrestricted conditions of 875 kg/ha the average restriction reduced aggregate yields to 837 or from 100 to 96%, i.e. by 4%.

Comparison of Results of Interregional Trade Analyses

It is interesting to note that both approaches to estimate the effect of interregional trade on aggregate productivity yield similar results. This tends to reinforce the credibility of the assumptions underlying each of the approaches. The major conclusions to be drawn at this stage are that the effects of interregional trade on productivity require a number of years to cause cropping patterns to shift. The shifts that occur are not dramatic. The farmer who adjusts his cropping pattern may hardly perceive his own effort in view of the variability of so many other factors, such as weather, pests, diseases, etc. to which he also has to adjust from one year to the next. Details of the spatial equilibrium model reported elsehwere (von Oppen, 1978a) show that slight increases or decreases of the order of 5 to 10% in areas under particular crops are all that is required to bring about aggregate productivity increases of the order of 4%.

Summary and Conclusions

The research reported in this paper is an account of our attempts to analyze information about agricultural marketing in India with the aim of deriving policy implications which are relevant for agricultural development. Much of the work reported is still in its preliminary stages and the results may have to be modified as further insights are gained. Our findings are as follows:

- Agricultural market channels in India are competitive and pricing efficiency in general is good. Consumer preferences for sorghum and pearl millet have a measurable effect on market prices. This includes preferences not only for evident attributes (color, seed size) but also for cryptic characteristics such as swelling capacity or protein content. A quality preference index can be derived from such preference measures for selecting "good quality" grain. This index may be of help to plant breeders who realize that the successful adoption of high yielding varieties also depends upon the consumer acceptance of the new variety.
- ICRISAT's foodgrains in India are primarily grown for home consumption. Nevertheless, price elasticity of supply of groundnut and pigeonpea in Andhra Pradesh is posi-

29. Further research in this field Is required to build a theoretical basis for explaining the lag structures in the relationships between markets and productivity. One suggestion for future analysis of this kind is to explore weighted averages of backward lags. Another approach of postulating a particular lag, e.g. FOT_{t-2}, yields a highly significant coefficient of the same order of magnitude as the joint effect reported, but this approach was dismissed as eclectic.

tive and sizable. Even though pricing efficiency of markets is generally high, it varies from market to market. Pricing efficiency — as measured in price correlation coefficients between market pairs — was analyzed and found to be determined by a number of factors such as distance between markets, age of markets and crops considered; other important factors were the number and size of traders, number of telephones, size of market yards, and number of different market secretaries employed over the past 10 years. More markets with fewer traders per market, equipped with equally distributed telephones and supervised by a frequently changing market secretary, would be conducive to improve pricing efficiency.

- Investments in improvements to agricultural market exchange have measurable payoffs. The removal of restrictions to interregional exchange was found to cause aggregate foodgrain production to increase. Positive effects to market exchange on productivity are brought about by relatively small changes in cropping patterns.

Given the measurable effects of investments in market infrastructure on productivity at the aggregate level, the question arises as to how these gains are distributed among small and large farmers. This issue is presently under study, the general hypothesis being that better market access is relatively more beneficial to the small than to the larger farmer; we expect that investments improving access to markets will lead to more equitable distribution of gains from it.

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Discussant's Comments

Balwanth Reddy*

My remarks will be limited to the paper by von Oppen and his colleagues.

I compliment von Oppen and others at ICRISAT for their interest in important problems of policy that are of great concern to policymakers in India as well as other semi-arid tropical countries. In some areas, their efforts are pioneering in nature. Further theoretical analysis, leading to better specification and more empirical work, should lay a sound foundation for the generation of research findings that will be usable by policymakers.

In the standard elementary demand analysis, economists either derive the demand function from the maximizing behavior of the households or straightaway specify in Walrasian or Marshallian form the relation between price, income, and quantity demanded. Thus the household's implicit preferences for commodities is reflected in the characteristics of the demand function. For plant breeders, quantitative estimates of these relationships per se do not provide adequate information to optimally incorporate the relevant properties or characteristics in the commodity they are designing or the grain seed they eventually want to propagate. However, assuming that some acceptable scaling of these properties is possible, breeders will be interested in the gain in the form of higher price that the produce will obtain by moving to a higher level along the scale of desirable properties. It is an important problem for researchers at ICRISAT, and von Oppen and his colleagues seek an answer to this question. Their approach has been to specify the price of crops like sorghum and pearl millet as a function of properties such as color mix, seed weight, moldiness, swelling capacity, and protein content to obtain tentative but meaningful estimates. These results, together with the associated costs of achieving these characteristics, should provide necessary data to determine the optimal mix which a breeder should aim at in developing new strains. We must note that the variability of some of these properties may be random and this may require further study to provide more reliable guidance to the breeders.

Plant breeders should be more interested in the nutrient content of various crops and their different strains. The present approach of single equation estimation has limited value in this wider context. Lancaster's contribution, as the authors have rightly pointed out, has a direct bearing on this issue. Only after establishing meaningful conditions for unique mapping from the commodity space to the attribute space will it be possible to estimate the precise impact of an attribute or quality on price. I am sure my colleagues at ICRISAT will explore these avenues in the coming years.

The problem of assessing consumer preferences for nutrient components can also be analyzed within the conventional framework by partitioning commodities into distinct categories on the basis of marginal differences in any one of their attributes. In principle if we have sufficient data, it is possible to derive a quantitative relationship between price differentials that are associated with variation in any of the attributes or nutrient components.

The second set of results that von Oppen and his colleagues have reported are extensions of the current work on supply response by adding some 'market' characteristics to the set of explanatory variables. These new variables are road density and market density. The empirical results do not justify the inclusion of these variables in their present form. Analytically, I would expect the impact of any 'market' characteristic to be reflected in prices and price differentials. Even so, in this instance as well as in others included in this paper, the authors should expect multicollinearity among some of the explanatory variables. Some of these difficulties perhaps can be overcome by formulating

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equations based on the behavioral postulates of the decision-making entities. If the object of this part of the exercise is to derive some implications for improvement in 'marketing' facilities, we do not have any usable results. I suspect that this approach may not yield such results. It would be preferable to measure the extra income that markets generate through a better primary wholesale price.

There can be more than one criterion to determine the efficiency of market channels, von Oppen and his colleagues choose pricing efficiency measured in terms of coefficient of correlation of weekly prices between pairs of markets, and attempt to explain this in terms of distance between two markets, average market size, market age, numbers of traders and telephones, density of production, density of population, etc. Though it is not explicit in this paper, higher price efficiency defined in those terms, apart from being a reflection of the efficiency of the information system, should help producers and traders in the choice of optimal delivery or transaction locations. In qualitative terms the empirical findings are consistent with expectations, except in the case of number of commission agents and the share of ICRISAT crops. If, as suggested by these findings, fewer traders increase market efficiency, the reason could be economies of scale; but this requires further theoretical analysis. Otherwise, measures to improve pricing efficiency that follow from this work are familiar to policymakers working in this area.

I am sure von Oppen would like to extend this type of work to cover alternative indices of marketing efficiency. One such candidate is the difference between the primary wholesale or farm gate price and the retail price. Efficiency measured in terms of this differential will throw considerable light on income distribution and potential incentives for higher production. My own interest in this area has been to look at the structure of submarkets that link the producer with the consumer. At an aggregate level, what appears competitive may turn out to be noncompetitive when we look at the structure of submarkets.

I am glad that the economists at ICRISAT are rightly concerned with the implications of various types of interventions in grain trade by the government. One that von Oppen and his colleagues have analyzed in the paper is the implications of food zoning. Their provisional conclusions, even though statistically not significant, are consistent with the predictions of liberal free-trade theory. Even if they were significant, I would have hesitation in using them to shape policies until I understood the role of other variables such as traders and their inventory policies. My own preference would be to structure a more comprehensive model that incorporates not only the major intervention variables, such as zoning, inventories, uniform prices etc., but also the various proportions of public and private trade. lam confident future research efforts will be deployed in this direction.

Chairman's Summary

Jock R. Anderson

The two papers, on marketing reforms in Mali and on related developments in India, opened up a topic that is discussed again in Chapter 6 — hence I can be brief knowing that the issues will come up again in discussions of the Harriss paper in that Chapter.

First, some general comments were raised during the discussion on this subject:

1. Marketing matters are important absolutely, and at least as crucial as production problems in considering development.

2. They are essentially more complex, involving challenging problems of defining and analyzing:

- market structures (supply and demand systems)
- information systems (and relevant data)
- institutional arrangements
- concepts of competition and efficiency (and consequently)
- economic philosophy and values of analysts and observers.

For technology design the main conclusion was that there was a need to understand the nature of consumer preferences (especially in the Indian work). However, it is useful to reflect that these are not inviolate and can, and may indeed, change over time. A good example of this was the change in tastes for chapatis after the release of HYVs of wheat in the mid-1960s in India.

Food grain marketing policy involves issues of political economy and the politics of donor and government agencies and recipient governments; this is, therefore, an intrinsically controversial topic. Given the profound ignorance of the economic realities, policy initiatives should seemingly be taken very cautiously.

For national research programs, data problems in marketing research are tremendous, and in this regard the challenges seem to be much greater for the African and Brazilian SATs than in India and Mexico. To take up the suggestion for greater attention to micro-level supply data will add to the challenge.

For ICRISAT socioeconomists, sadly, the implications are less clear to me. Although if these economists can continue to do the good quality work reported by von Oppen and his colleagues, we will clearly be much wiser sooner than later.

Being realistic, ICRISAT won't want to enter into major confrontations with Governments; perhaps the International Food Policy Research Institute may have more of a role in this forum.

One thing is clear: quality studies that can be facilitated by ICRISAT in one way or another will enhance debate, will enhance policy making, and we hope will enhance the welfare of producers and consumers.

Chapter 5

Socioeconomics of Improved Animal-drawn Implements and Mechanization

Observations on the Economics of Tractors, Bullocks, and Wheeled Tool Carriers in the Semi-Arid Tropics of India

H. P. Binswanger, R. D. Ghodake, and G. E. Thierstein*

Abstract

This paper reviews the available survey evidence on the economics of tractor cultivation for semi-arid tropical (SAT) India. We find that tractor cultivation, as generally practiced, does not improve cropping intensity or yields and it displaces labor. This provides a justification for the emphasis on bullock power in the Farming Systems Research Program (FSRP) of ICRISAT.

The evidence now available with ICRISAT on the economics of wheeled tool carriers is then reviewed. It is found that, even under the most favorable circumstances assumed, such machines cannot compete on a cost basis with the traditional implements in traditional agriculture. They must provide yield advantages of the order of 200 to 400 kglha to justify their higher costs. Experiment station evidence indicates that yield advantage in excess of this can be achieved with the improved soil management techniques made possible by using the tool carrier in Alfisols and deep Vertisols. However, such evidence is not yet available at the farmer's field level.

From its inception ICRISAT has made a conscious decision to attempt to improve existing farming systems by technologies that, as far as possible, are based on resources presently available in the SAT. For SAT India, in particular, this has meant an emphasis on labor-intensive technologies and on bullock power rather than mechanical power.[1]

The justification for an emphasis on bullock power rests on several grounds. First, Subrahmanyam and Ryan (1975) show that of the total animal + mechanical power input into Indian agriculture, 89% came from animals in 1966. For the predominantly SAT states of Karnataka, Madhya Pradesh, Maharashtra, the percentages were 89%, 96%, and 75%, respectively. Since1966 little mechanical power investment has taken place in the SAT of India, with the exception of additions of pump sets for well-irrigation. Tractor investment has been almost entirely concentrated outside the nonirrigated SAT areas (See Table B-3 in Binswanger 1978). Calculations made by Stout and Downing (1975) show that tractor power is yet of little importance in most areas of the African SAT. On the basis of 1970 FAO data, they show that of the total arable land in Nigeria and Tanzania, more than 98% is still cultivated by draft animals and manual labor.[2]

A second justification is that — where wage rates are low and where little potential for area expansion exists, as in SAT Asia — tractors have extremely low or negative private and social rates of return. There is evidence that tractors are used extensively for transportation and as a substitution of one source of power for another rather than as a means of improving management or cultural practices. In addition, they displace labor, and their economies of scale lead to further growth of large farms at the expense of small farms (Binswanger 1978).

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1. However, it is dear that for pumping purposes, mechanical power is replacing bullock power in the SAT, and this shift Is considered desirable.

2. We are not aware of similar more recent calculations for the SAT areas of Africa, Southeast Asia, or Brazil.

These conclusions hold for almost all of South Asia and, by extension, to all areas with similar land: man ratios and lack of scope for area expansion. But they cannot be applied to SAT countries in Africa and South America. In the first section of this paper we will review in more detail the available evidence on the economics of tractors in SAT India, and underpin more thoroughly the justification of ICRISAT's emphasis on bullock power.

A third consideration is that in the mechanization debate too much emphasis has been placed on the source of power rather than the implement attached to it. As Giles (1975) points out, it is the implement that converts the power into something beneficial to the plants that is important. With the few exceptions where machines require high speeds or concentrated power, improved implements can be pulled as well by bullocks as by tractors. In particular, the development of various types of wheeled tool carriers makes it *technically* possible to achieve with bullock-drawn implements most of the precision in field operations that is achievable with tractors.[3]

The second section of this paper reviews the testing and modification of wheeled tool carriers and their ancillary implements at ICRISAT. In the third section, we briefly compare the little we now know about the efficiency of new wheeled tool carriers with data from village-level studies (VLS). In the fourth section, we use simple partial budgeting techniques to attempt a rough economic evaluation of the wheeled tool carrier with traditional methods of cultivation. We will see there that, even under the most favorable assumptions, wheeled tool carriers will have to provide a distinct yield advantage to become competitive with traditional implements. The final section reviews the potential sources of such yield increases; it also briefly discusses the other directions of work in ICRISAT's agricultural engineering program.

It should be noted that the economic assessment presented here is preliminary in that experiments now under way and further analysis of the data from village studies may well lead to revisions in the assumptions underlying the calculations. Furthermore, these calculations are useful only for the Asian SAT, since tractor prices in other SAT countries differ widely and there is scope for area expansion in other countries.

3. An exception to this is mechanical harvesting in the absence of supplemental mechanical power. In the United States, for example, the utilization of reapers in the nineteenth century was conditional on a shift from low-speed bullocks to faster horses.

The Economic Impact of Tractors in SAT India

In a recent review of the survey research on the impact of tractors in South Asia, Binswanger (1978) reached the following conclusions:

> The tractor surveys fail to provide evidence that tractors are responsible for substantial increases in intensity, yields, timeliness, and gross returns on farms in India, Pakistan, and Nepal. At best, such benefits may exist but are so small that they cannot be detected and statistically supported, even with very massive survey research efforts. This is in marked contrast to new crop varieties or irrigation, where anybody would be surprised if he failed to find statistically significant yield effects, even in fairly modest survey efforts. Indeed, the fairly consistent picture emerging from the surveys largely supports the view that tractors are substitutes for labor and bullock power, and thus implies that, at existing and constant wages and bullock costs, tractors fail to be a strong engine of growth. They would gain such a role only under rapidly rising prices of those factors of production which they have the potential to replace.

In view of this finding, many of the benefit-cost studies reported may have overestimated the benefits, both social and private, that result from the agricultural uses of tractors. Except in situations where area effects are possible — or by renting or buying land from others — private returns to tractors from agricultural operations must be close to zero, or even negative at current fuel prices.

That these conclusions hold especially true for the SAT of South Asia can be seen from Tables 1 and 2. In these tables we use the following symbols to distinguish farm types:

B = Bullock farms
TO = Tractor-owning farms
TH = Tractor-hiring farms

Tables 1 and 2 are organized as follows. For

Table 1. Summary of results of tractor surveys in semi-arid tropical zones in Karnataka, Gujarat, and Madhya Pradesh.

Author/Area	Sample size study year (1)	Compa-rison (2)	Labor (days/ ha) (3)	Bullocks (no./ha) (4)	Inten-sity (5)	Value of gross output per ha (Rs./ha) (6)	Yield (7)			Inputs (8)		(9)	(10)
							Chillies	Groundnuts	Sorghum	Fertilizer	Commercial crops		
Chandramouli	100	B	(51.4)	(15.3)	(102.3)	(2077)	(Rs. 4261)	(Rs. 2840)	(Rs. 1244)	(Rs. 243)	(55.7)		
Dharwar Dist.,		B–TO	2.1	−44.3	1.3 NS	52.9	40.1	13.5	41.3	60.2	12.6		
							Cotton	Wheat					
Karnataka, Kundgol Tq.	1973–74	B	(26.7)	(13.1)	(109.3)	(923)	(Rs. 943)	(Rs. 651)	(Rs. 489)	(Rs. 118)	(35.8)		
Transition Zone		B–TO	−12.9	−42.7	−5.7	5.0 NS	12.8 NS	28.0 NS	5.4 NS	−4.9	8.6 NS		
Navalgund							Wheat (HYV)	Chickpea	Sorghum				
Dry Zone[a]				(i) (ii)									
Misra, Narsingh-	100	B	(57.5)	(52.4) *(0.58)*	(105.9)		(3500)	(800)	(1010)				
pur Dist.,	1974–75	B–TO	−52.0	−82.0 −54.0	8.2		20.0	26.0	16.4	Fertilizer			
Madhya Pradesh[b]							Wheat	Cotton	Sorghum	Wheat Cotton Sorghum		Education	*Irrigation*
Desai-Gopinath, Dholka	50	B	(41.0)	(4.5)	(103)	(1164)	(Rs. 1198)	(Rs. 1170)	(Rs. 762)	(15.2) (26.0) (7.9)		(5.8)	(Rs. 284)
(Ahmedabad Dist.)[c]	1973–74	B–TO	0.0 NS	−63.9	4.9	−4.6 NS	−7.6	17.4	−8.3	−23.0 12.4 −60.6		1.7	−41.2

a. Notes on K. S. Chandramouli (numbers in parentheses refer to columns)

The sample is not farm size adjusted.

(3) *Man-days per ha of operational* holding, Table 7

(4) Bullock days per ha of operational holding, Table 7.

(5) Table 2 and Table 5.

(6) Table 10, 11, Rs. per ha of operated area.

(7) Table 10, 11, Rs. of gross return per ha.

(8a) Fertilizer and manure expenditure per ha of operated area Table 7.

(8b) Table 2 and 5.

b. Notes on S. P. Misra

Sample not random, but size adjusted

Average farm size B : 40.4 ha., TO : 45.9 ha crops with high cash outlays *grown more on tractor farms.*

(3) Labor days per ha of gross cropped area Table 1.5

(4i) Bullock days per ha of gross cropped area, Table 1.5.

(4ii) Bullocks owned per ha of operated area, Computed from Tables 1.1 and 1.5

(5) Table 1.1

(7) Quintals per ha, Table 1.3

c. Notes on D. K. Desai and C. Gopinath

The samples are not farm-size adjusted. Tractor farms are almost twice as large as Bullock-and Tractor-hire-farms

(3) Man-days per ha of operated area, Table 4.1. After covariance analysis adjusting for size, irrigation, fertilizer, bullock labor, human labor, tractor power and crop cropping intensity, the *differences in labor use are not significant (Tables 5.7)*

(4) Bullock days per ha. (or more probably, bullock pair days. Computed from Table 4.24 using size from Table 4.3

(5) Table 4.13

(6) Table 5.4. Most probably on basis of operated area.

(7) In rupees of gross return per ha Table 7.9. The crops are in order of importance in cropping pattern.

(8) In kg per ha. Table 4.26

(9) Education index (years) computed from *Table 3.3*

(10) Value of irrigation investment per ha of operated area, Table 3.7.

Table 2. Summary of results of tractor surveys in semi-arid tropical zones in Maharashtra.

Author/Area	Sample size study year (1)	Comparison (2)	Labor (days/ha) (3)	Bullocks (no/ha) (4)		Intensity (5)	Irrigation (6)	Farm size (7)	
				(i)	(ii)				
Sapre									
Dhulia Dist., Rich	76	Before and	(n.a.)	0.12	0.16	(114)			Cultivated
black soil plain[a]	1966–67	after B-TO							area
			Zero	−12.7	−38.2	6.0			(39.3 ha)
									3.6
Pawar & Acharya									
Satara, Maharashtra[b]	100	B	(55)	(27.4)					
	early					(130.2)	(27.5)	(3.8)	
	1970s	B-TO	24.8	−65.6		−8.4	+85.1	+156.5	
				Stock	Flow				
						(111)			
Acharya et al	96	B	399	(Rs. 875)	(86)	−7.2			
Satara	1972–73	B-TH	+0.4	−25.1	−21.4	−6.3			
Maharashtra		B-TO	−6.3	−30.2	−63.5				

a. Notes on S. G. Sapre (numbers in parentheses refer to columns)
Sample not strictly random
(3) Permanent servants and family members only (p.51).
(4) Study of bullocks per ha page 51 and Table 3.4
i) refers to actual observed bullock pairs while (ii) is technological requirements to do the task on the tractorized farms
(5) Based on page 45
(8) Table 2.3 and page 39. Based on cultivated area. Of total increase in area, 2.2% came from land reclamation and improvement. No reduced leasing out reported!

b. Notes on Jagannatha Rao P. Pawar and T. K. T. Acharya
The paper reports results from Jalgaon, Satara and Ahmednagar districts. Only the Satara results are reported because only this district contains both bullock operated and tractor operated farms. Sample is not farm size adjusted.
(3) Per cropped ha Table III
(4) Bullock days per cropped ha. Table III
(5) Table I
(8) Table I. Irrigation as percent of operated area.

c. Notes on T. K. T. Acharya, Jagannatha Rao, R. Pawar Bhaskar Rao
The farm classes are not size adjusted and there are the following numbers in each class:
B : 16; B-TH : 62; B-TO : 18;
(3) Table 6
(4) a) Value of drought animals per ha. Table 4.
b) Bullock days per ha in sugarcane cultivation. Table 6.
(5) Labor days per ha in sugarcane cultivation, Table 6
(8) Table 1, as percent of operated area.

each study, column 2 lists the items compared. The first line has a B in column 2 and gives the absolute value of the variables for the bullock farms *in parentheses.* The following lines give the percentage difference between bullock farms and other farm types. For example, the line B-TO in column 3 of Table 1 indicates that labor use per hectare in Dharwar district was 2.1% higher on tractor-owning farms than on bullock farms, with the value of the bullock farm as the basis for the percentage difference.

All tables are on a per hectare basis. Human labor and bullock use is measured either in labor/bullock days or in labor/bullock years, depending on how the authors measured it. Bullock labor is reported for single bullocks, not pairs. Intensity means gross cropped area divided by net cropped area expressed as a percentage. The percentage differences of intensity are relative to the intensity value of bullock farms. Fertilizer use is given either in kg of plant nutrients (NPK) applied per hectare, or value in rupees of total fertilizer applied per hectare. Column 8 is used for various inputs, depending on information available or useful. Labor, bullocks, and production are measured per hectare of farm size. In Tables 1 and 2 the Alfisol (red soil) area is represented by Dholka Taluk in Gujarat, while the Vertisol (black soil) areas are represented by three areas of Maharashtra, Dharwar district in Karnataka, and Narsingpur district in Madhya Pradesh.

In the SAT areas, cropping intensity of bullock farms is slightly in excess of 100% and the intensity of tractor farms is in no case more than 10% greater. In Kundgol Taluk in Karnataka (a rainy season-fallow area), tractor farms have a statistically significant lower intensity (5.7%) and in Satara district in Maharashtra the tractor farms have an 8.4% lower intensity. Thus, evidence of higher crop intensities due to tractors is lacking in SAT areas. This lack of higher intensity is not so surprising since cropping is often restricted to one season by lack of moisture or management techniques in these areas. New techniques being developed should change this, particularly in deep Vertisol areas.

The Sapre (1969) study (Table 2, last column) attempted to measure the increase in cultivated area directly attributable to tractors and found it to be a modest 3.6%. Substantial area effects have therefore not yet been documented for the SAT of South Asia.

Yield advantages of tractors (Table 1, column 7) appear to exist in Kundgol Taluk of Karnataka district, which belongs to the relatively high rainfall transition zone, and also in Narsingpur district of Madhya Pradesh. In Kundgol taluk, however, tractor farms use 60% more fertilizer than bullock-operated farms, and the yield advantages fall far short of this figure. The required fertilizer information is not available for Narsingpur. As shown in the other South Asian studies reviewed, yield advantages on tractor farms cannot be attributed to the tractors but are, to a large extent — possibly entirely — caused by fertilizer differences and other factors.

On a per hectare basis, labor inputs on tractor-owning farms are the same or moderately to substantially lower than on bullock farms, with the exception of Satara district in Maharashtra (Table 2). However, in Satara the tractor farms have an additional 85% of their area under irrigation, and the increase in labor use is clearly an irrigation effect. As presently used, therefore, tractors are clearly labor-displacing in SAT India.

Evidently the use of tractors reduces bullock use. It is clear from the two tables that bullock stocks decline by a lower proportion than bullock flows (hours used) when tractors are present, and that in none of the areas have tractors enabled farmers to completely replace bullocks. The tractorization has been selective and concentrated on field preparation and transport, where concentrated power and high speed may provide the tractor with an advantage, even in this low-wage environment.

Technical Aspects of Wheeled Tool Carriers

From the beginning of the FSRP at ICRISAT Center in 1973, equipment development played an important role as a result of two related decisions: operational-scale systems research was initiated, and the ridge-and-furrow system was introduced as one of the major land management treatments. During the first 2 years, two equipment systems were used: (1) traditional bullock-drawn implements, and (2) conventional tractors and implements.

Tractors were not used after 1974, because it was concluded that bullocks were going to be the primary power source in SAT India. Hence only bullock power and human labor have been utilized for all cultural operations in operational-scale research since then. The broadbed-and-furrow system, introduced in 1975 as a replacement for the narrow ridge and furrow system, has shown superior results, particularly in the Vertisols at ICRISAT Center (FSRP Annual Reports 1975-76 and 1976-77). In the Vertisols, the practice of performing primary tillage immediately after harvesting the postrainy season crop was also introduced. This facilitated moisture conservation and permitted dry seeding before the onset of the monsoon rains. The use of double cropping in the Vertisols, and to some extent in the Alfisols, necessitated rapid tillage and seedbed preparation after the harvest of the first crop and before the planting of the second crop. While it was possible to perform all these operations with locally available animal-drawn implements, the performance generally was not good. For example, the time required for tillage operations was high, while planting precision was poor. It was also difficult to make uniform beds with this machinery.

An important objective of the equipment development project at ICRISAT is to reduce both the energy and time required to produce a given amount of crop yield. This approach is similar to that being used at IITA in Nigeria (IITA Farming Systems subprogram report 1978). In Figure 1, two isoquants are depicted in which, for illustrative purpose only, it is assumed that (energy x time) equals a constant. The K_1 isoquant represents the "conventional" system, characterized by tractorized farming with its high energy and relatively low time requirement at one extreme. At the other extreme is manual farming, using exclusively human labor with relatively low energy but high time requirement. The goal is to move to a lower K_2 isoquant of an "alternative technology," in which both time and energy inputs are reduced while maintaining the same output level. The optimum position on the K_2 isoquant will depend on technological, economic, and social factors appropriate to any particular location.

The broadbed-and-furrow system that is showing promise consists of a bed width of 100 cm and furrows 50 cm wide. The original narrow ridges of 75-cm width were not stable during the monsoon rains and therefore did not

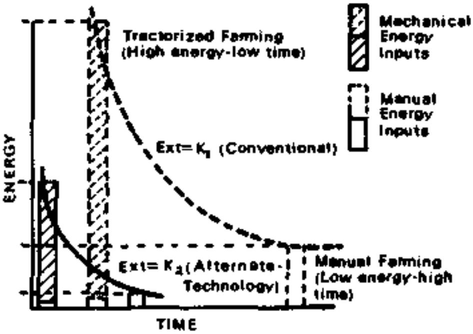

Figure 1. The concept of alternative technology options.

provide the required erosion control; that was one of the primary objectives in their use. In the broadbed-and-furrow system, the furrows are about 15 cm deep and laid out on a slope with a gradient of 0.4 to 0.8%, depending on soil type and land configuration. This provides erosion protection as well as improved drainage during times of excess rainfall. The furrows have also been used to provide supplemental irrigation during times of moisture stress.

In 1975 a search was initiated for bullock-drawn machinery that was better adapted to the cultivation practices being used in the FSRP and, at the same time, might provide an alternative technology option leading to a reduction in both time and energy. The machine with most promise was a multipurpose wheeled tool carrier. This is a frame supported on two wheels and pulled by a pair of bullocks. A range of implements can be attached to this toolbar with simple clamps. Depth adjustment and lateral spacing of all implements are relatively simple. Several tool carriers were subsequently evaluated, of which the best and most versatile was the "Tropicultor," initially designed by Mr. Jean Nolle of France.

Any good wheeled tool carrier design has two attractive features: (1) it has one basic frame to which a variety of implements can be attached, similar to a tractor; (2) a cart body can be mounted on the same frame, enabling use of the carrier for both agricultural operations and transportation and spreading the depreciation costs over a larger number of hours of use. The cart body of the Tropicultor can be mounted and dismounted in a matter of minutes.

An important feature of the improved farming systems being developed at ICRISAT is the matching of the wheeled tool carrier and the broadbed-and-furrow system. The wheel spacing on the wheeled tool carrier is adjusted to 150 cm so that the bullocks and wheels always travel in the furrow. The full width of a bed is covered in each operation that is performed. Thus the distance that must be travelled to cover 1 ha is greatly reduced with the wheeled tool carrier compared with most of the traditional animal-drawn implements currently used in India. Figure 2 shows that a farmer must travel about 66 km to cover a hectare when using a traditional *(desi)* single type plow with a working width of 15 cm. When a blade harrow of 75-cm width is used, the travel distance is about 13 km. However, with the wheeled tool carrier, covering 150 cm per pass, the travel distance is reduced to above 7 km. Even if the speed is reduced by 50%, because of the higher draft when plowing with the wheeled tool carrier as compared with the traditional plow, the operating efficiency is improved by a factor of five.

An essential element of the improved system is the maintenance of the beds as a semipermanent feature. Thus development costs are incurred only once. The use of minimum tillage practiced during the dry season is an additional attractive feature. Right and left moldboard

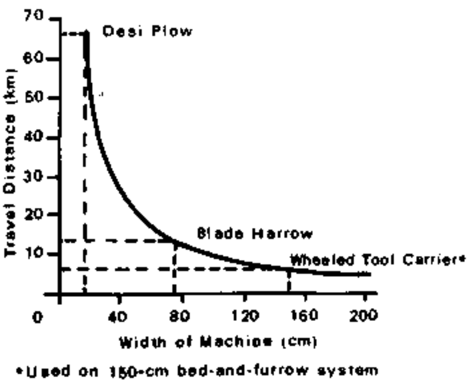

Figure 2. Width of bullock-drawn implement and required travel distance to cover one hectare.

plows are used simultaneously on the outer edge of the bed at a depth of 5 to 7 cm. Thus only 40% of the bed is plowed at a very shallow depth. In the Vertisols this is done early in the dry season immediately after the second crop is harvested. At that time bullocks are normally still in good physical condition, and there is some moisture remaining in the soil. Since these soils are self-mulching, any small shower during the dry season permits nature to take care of much of the secondary tillage. Only a bed-shaping operation needs to be done before planting.

Where the onset of the monsoon rains is usually quite distinct and rapid, as in Hyderabad, India, it is desirable to plant dry in the Vertisols just before the main rains begin. When soils are wet they are very difficult to work. In 1978 the planting rate on the ICRISAT operational watersheds was 21/2 to 3 ha/ machine per 12-hr day. A double shift was operated, using a different pair of bullocks for each shift. This planting rate was maintained with four wheeled tool carriers over more than 50 ha. Where planting was delayed until after the rains had started, the planting rate was reduced by 50%.

The planters presently in use are considered very good, but unfortunately they represent an additional investment of Rs 3200 over the cost of the wheeled tool carrier for a four-row planter. A much simpler and cheaper model that shows considerable promise is under investigation, and subsequent cost calculations are based on this implement. The furrow opener, which assures proper placement of the seed, and the press wheel, which assures good seed-soil contact to enhance seedling emergence, remain the same. The primary difference is in the seed-metering mechanism. In the low cost model the farmer dibbles the seed by hand. This is a traditional practice and experienced farmers are very skilled in it.

As indicated previously, the wheeled tool carrier is likely to prove costly for small farmers. Since the broadbed system shows promise as a means of improving yields and income, it is desirable to develop lower cost machinery so that these benefits can accrue to smaller farmers also. A local wooden bullock cart found in parts of Central India has recently been modified by the addition of a toolbar to make it suitable for use on the broadbed-and-furrow system. It is anticipated that the cost of this equipment will be about 25% of the cost of the Tropicultor. Its life will probably be half as long, its versatility will be lower, and it will not be capable of being used for transportation, except of people.

For those activities where there *are* restrictions or limitations on the use of animal power, the use of tractors is being developed. The reintroduction of the tractor into the research program will provide both technical and economic data to compare its performance with animal-drawn machinery. This information is currently not available. The range of machinery being developed will fill different requirements and meet a variety of needs.

Technical Efficiency of Wheeled Tool Carrier and Traditional Implements

In Table 3 we compare the bullock labor inputs of the broadbed-and-furrow system watershed treatments, implemented on an operational scale with wheeled tool carriers at ICRISAT Center, with the bullock labor inputs in areas with similar soils in the Village Level Studies of ICRISAT. The watershed treatments are those which, on the basis of past experience at ICRISAT Center, give the highest returns. These comparisons are comparisons of *systems,* not individual crops, and the following qualifications have to be noted: (1) in the Alfisols and deep Vertisols, the ICRISAT treatments imply higher cropping intensities than the traditional village practices. In the Alfisols, either a ratoon crop or pigeonpea in high densities is grown in the early postrainy season; in the deep Vertisols, use is made of the rainy season while land is mostly left fallow in the Sholapur area; and (2) the bullocks used to pull the wheeled tool carrier at ICRISAT Center are stronger than those used in villages.[4] For these reasons, the absolute values are not necessarily comparable but we want to compare trends.

4. Smaller bullocks encountered in the tests in the Vertisol villages had no trouble pulling the equipment, but such a reduction in bullock size would imply a reduction in operating speed for operations requiring relatively high draft input.

Table 3. A comparison of bullock labor inputs from preferred broadbed-and-furrow systems using a wheeled tool carrier with the traditional Implements in villages in a SAT India.

Soil type	Bullock pair hr per ha of net cultivated area under two preferred treatments of ICRISAT watersheds[a] 1976-77	1977-78	Data village average of 1975-76 & 1976-77	Proportion of hired bullock labor use to total bullock use in villages[g] (%)
Alfisols	87[b]	- (154)	182 (117)	10
	76[c]	-	(Aurepalle)[f]	
Medium-deep Vertisols	-	42[d] (146)	93 (105)	20
	-	30[e]	(Kanzara)	
Deep Vertisols	-	43[d] (154)	54 (105)	37
	-	30[e]	(Shirapur)	

Note: Figures in parentheses are average cropping intensities.

a. Data on Alfisols for the year 1977-78 have not been reported because of severe crop damage due to Insect attack. However, figures for 1976-77 on this soil could be used for observing the trend.

b. Sorghum followed by ratooning.

c. Pigeonpea intercropped with setaria.

d. Maize followed by chickpea.

e. Pigeonpea Intercropped with maize.

f. This is the only village in the studies where bullock labor used *Increased* sharply with increased farm size.

g. In all the villages studied except Aurepalle, there was a sharp *decline* in the proportion of hired bullock labor use with increased farm size.

First, note that the traditional systems make much larger use of bullock power on Alfisols than on Vertisols, and larger use on medium-deep Vertisols than on deep Vertisols. The last difference is easily understood because in the deep Vertisol villages studied, rainy season fallowing prevails, whereas in medium deep Vertisol villages studied the rainy season is the main cropping season. The high use of bullock labor on the Alfisols is difficult to explain. One possible reason could be the comparatively smaller sized bullocks present in Aurepalle village than in the Vertisol villages, which might result in more hours of bullock labor use on Alfisols without much difference in actual energy input. Besides this, the contribution of owned bullocks is 90% in Alfisol villages, while for medium deep and deep Vertisol villages, the figures are 80 and 60%, respectively. The higher proportionate use of owned bullocks obviously encourages higher total bullock labor use.[5]

Further, it is now well-evidenced from the research work on the economic aspects of weed control by Binswanger and Shetty (1977) that weeding and interculture operations are performed more intensively on Alfisols than on Vertisols, which further increases the per hectare bullock labor utilization on Alfisols.

The absolute bullock labor use figures per hectare of net cultivated area are always lower under watershed treatments than under existing village systems, despite the higher cropping intensity on the watersheds. When these figures are adjusted for cropping intensities and expressed on a gross cropped hectare areas basis, bullock labor use on the ICRISAT watersheds is still less than in village situations. The watershed treatments utilize only 28 to 47 % of the bullock labor used in corresponding village systems.

This demonstrates the much higher efficiency of bullock labor with wheeled tool carriers under improved systems. There thus appears to be scope for bullock labor saving under the improved system.

Table 4 compares the bullock labor inputs by operation on the medium-deep and deep Vertisols. The comparison between the "traditional" method on ICRISAT watersheds and the broadbed-and-furrow system of the new technology shows that the wheeled tool carrier appears to be able to achieve the largest increase in technical efficiency in tillage on the medium-deep Vertisols, while the advantages on the deep Vertisols appear to be more modest.

The comparison between existing village practices and the bed-and-furrow system with the wheeled tool carrier is most instructive for the medium deep Vertisols as well, since the traditional system there operates at nearly the same level of cropping intensity. It is clear that the wheeled tool carrier achieves substantial gains in efficiency for tillage (a reduction by a factor of nearly 2 or more) and for interrow cultivation where the reduction appears to be even larger.[6] Note, however, that when tried in the study villages during a very wet year, farmers seemed to prefer their traditional system for interrow cultivation in the Vertisols.

It is clear from the comparison that wheeled tool carriers (with stronger bullock pairs) would be able to perform the traditional operations in the villages at a much faster rate; perhaps a factor of 2 or more may not be an unreasonable expectation.

Wheeled Tool Carriers versus Traditional Implements: A Cost Comparison

The simplest way to look at the economics of the wheeled tool carrier is to compute a contract hire rate that an enterpreneur would have to charge his customers to make a profit on his investment in a sturdy pair of bullocks, the tool carrier, and the additional implements required. We have done this under various assumptions about machine costs, profit rates, and utilization rates of the bullocks and machines.[7] We can

5. If we look at bullock labor use trends under watershed treatments then a similar situation is observed, which indicates that the above factors may not be the only ones to explain this observation. However, in the absence of figures for 1977-78 under Alfisol conditions, one cannot be sure of the generality of this trend in the watersheds.

6. This may be due in part to the reduction in weed growth achieved by the higher competitiveness of the crops against weeds in the ICRISAT systems compared with the traditional ones.

7. The first such computation was done by J. G. Ryan in an internal ICRISAT memo, and we have borrowed his technique with minor modifications.

then compare this rental cost with existing bullock hire rates in our study villages, which center around Rs. 15 per day for a pair of bullocks with driver and implement or cart, and around Rs. 12 for a bullock pair without an implement or cart. To take into account the higher efficiency of the tool carrier we make a comparison for the medium-deep black soils. Computations based on field capabilities indicate that one machine covering 15 ha of land could be employed with the improved broadbed-and-furrow system for about 80 days. This implies a yearly bullock-with-machine input of 5.4 days per ha. Note, therefore, that all the *calculations* shown below assume a full use of the wheeled tool carrier for *all* operations. Such an assumption may be unrealistic if we take as a guide the experience with the introduction of tractors, where only a limited number of operations is initially carried out by tractors. Table 4 indicates an annual bullock labor input of 93 hours per ha for Kanzara, which leads to a bullock labor input of 11.6 days per ha. On average, to do what a sturdy pair of bullocks can do in 1 day with a wheeled tool carrier in the improved system, takes nearly 2.15 bullock days in the traditional system. Note that the comparisons of the last section also support an efficiency factor of more than two on average. We should, therefore, compare the rental rates for the wheeled tool carrier and bullock pair with the traditional rental with implements of Rs 32. We will call this *the equivalent rental rate.*

Table 5 shows such rental rates for various assumptions, which are described in categories 1 to 7. Rental rates are computed for all of the following combinations:

- Wheeled tool carrier plus bullock pair plus

Table 4. A comparison of annual bullock labor inputs for various operations by traditional methods and with the wheeled tool carrier.

Soil type/ village	Operation	Existing village practice (Average of 1975-76 and 1976-77) (pair hr/NCA).	Traditional method as defined on ICRISAT research watersheds 1977-78 (pair hr/NCA)	Broadbed-and-furrow system with wheeled tool carrier 1977-78 (pair hr/NCA)[a]
Medium-deep Vertisols (Kanzara)	Preparatory tillage	45.7	70.3	25.8* 18.0[c]
	Manuring & fertilization	2.4	—	7.I[b] 5.1[c]
	Sowing, trans-planting etc.	12.5	6.3	7.4[b] 4.5[c]
	Interculture	24.8		6.1[b] 5.2[c]
Deep Vertisols (Kalman)	Preparatory tillage	25.6	30.5	24.3[b] 1.84[c]
	Manuring & fertilization	1.5	-	6.6[b] 3.3[c]
	Sowing, trans-planting, etc.	10.3	12.2	6.6[b] 3.2[C]
	Interculture	7.6		7.6[b] 7.3[c]

a. NCA-Net cultivated area.
b. Sole maize followed by chickpea.
c. Mails intercropped with pigeonpea.

Table 5. Required average daily contract rate for a custom operator of a wheeled tool carrier and (in parentheses) the compensatory yield increase required to offset the additional machinery cost.

1. Equipment rented	Wheeled tool carrier + bullock pair + driver				Wheeled tool carrier only			
2. Days of utilization per year	80 agricultural days		80 agricultural days + 100 transport days		80 agricultural days		80 agricultural days + 100 transport-days	
3. Working life of bullock pair to 20% salvage value	8 years		6 years					
4. Profit to owner over and above borrowing rate of 20% interest on initial investment	10%	20%	10%	20%	10%	20%	10%	20%
5. Required contract rate (Rs/ha) Low cost machine with steel wheels and bush bearings, (Rs 4420)	71 (183)	82 (242)	39 (10)	44 (37)	24	35	13	18
6. Medium cost machine with pneumatic tyres and ball bearings, (Rs 6760)	84 (253)	97 (323)	46 (47)	52 (80)	36	50	20	26
7. High cost machine with pneumatic tyres and ball bearings, (Rs 8385)	96 (317)	112 (404)	54 (91)	61 (128)	48	65	28	35

Assumptions:

Price of bullock pair (robust) Rs 4000.

Tool carrier value depreciated linearly to 10% of its initial value in 10 years.

Repairs and maintenance charges have been assumed as 10%, 7.5% and 5% of initial ex-factory costs for high, medium and low cost machines, respectively.

Animal feeds: Rs 6 non-working day and Rs 8 working day

Labor charges: Rs 6 working day and Rs 0.15 non-working day.

For transport, investment for a tray is required, costing Rs. 520, the value of which is also depreciated the same way as other implements.

The machine costs are based on actual cost estimates of ex-factory values by two manufacturers. The ex-factory cost has been increased by a 30% marketing cost

Compensatory yield increase: Existing village practice requires 107 bullock pair hr/ha of cultivated land on medium-deep Vertisols at a rate of Rs 15 per 8-hrs day (including rests). This implies a bullock cost of Rs 201. Based on field capacity calculations, the ICRISAT system should require 5.4 days ha, which is multiplied by the implied rental rate. The difference is the required yield advantage.

driver versus wheeled tool carrier only.

- A utilization of 80 agricultural days versus 180 days, where the additional 100 days are assumed to be transport days. Note that in nonirrigated areas of India, bullock utilization for agricultural purposes varies around 60 days (Subrahmanyam and Ryan, 1975; based on Farm Management Studies). Without irrigation for a second crop, utilization rates of above 80 days for cropping purposes will be difficult to achieve. Since bullock life is partly dependant on the utilization rate, the working life has been reduced to 6 years in the case of an added utilization of 100 transport days.
- Profit rates of 10% and 20% to owners of machines and bullock pairs. These rates are over and above a borrowing rate (or opportunity cost of capital) of 20% and imply attractive total rates of return of 30% and 40%, respectively.[8]
- Three different cost levels for the wheeled tool carriers. Other assumptions are discussed in the footnote to Table 5.

It is evident that the *equivalent rental rate for the traditional implements of Rs. 32 cannot be achieved even under the most favorable assumptions* of a low-cost machine and a 10% profit rate, although the difference is only Rs. 3 in that case. Not surprisingly, increases in utilization rates imply large reductions in rental rates of nearly 50%. The machine thus must be made to work for nonagricultural purposes as well. Reductions in the cost of machines imply equally large reductions in the rental rate for the machine only. However, note that the cost of bullocks and the driver are the larger portion of the cost of the package under nearly all assumptions. Therefore, a 50% reduction in machine costs alone generally reduces the rental rate of the entire package by only around 27%.

In future research attention will thus have to be focused on how to increase utilization rates. Furthermore, efficiency increases of the machine itself become of primary importance since they would allow its operation with smaller and cheaper bullocks. Finally, It appears that reduction in machine costs are helpful only if they do not have to be purchased by design changes that reduce the efficiency of the machine, thus increasing the bullock cost component.

One of the main conclusions reached here is that all potential rental rates exceed the equivalent rental rate of traditional equipment at the factor price levels of Indian SAT farmers. These farmers, especially the small ones, cannot be expected to be interested in the package unless it provides them with sufficient yield gains per hectare to compensate for the added costs.

In parentheses we give the *compensatory yield increases* that farmers will require to offset the increased machinery and bullock cost implied if they switch from their traditional system to the wheeled tool carrier. These are given in rupees per ha, but since 1 kg of coarse grain costs a little less than Re. 1.00 we can think of the figures approximately as yield increases in kg of sorghum equivalents that must be generated by the machine to offset its higher costs.

At annual utilization levels of 80 agricultural days, the improved machines must give a yield advangtage of 200 to 400 kg/ha. This is no small requirement, and the next section explores its feasibility. However, if the machines can be used for transport purposes to a considerable extent, the compensatory yield increases become relatively small (10 to 130 kg/ha).

We should note here, however, that the *compensatory yield increase* does not yet give the farmer who rents the machine any benefit at all. It only covers his extra cost. To induce a small farmer who now owns his own bullock pair to undertake the change to renting the tool carrier requires that the yield advantage be even higher than that shown in Table 5. For a switch from owning to renting it probably must be much higher because the small farmer will have to be compensated for the added inconvenience of renting rather than owning as well.

The calculations can also be interpreted as applicable to a farmer operating 15 ha of land who may contemplate a switch from two or three small bullock pairs to one large one and a wheeled tool carrier. Since he will capture the rate of return on the investment, he may shift if the yield gains are equal to the compensating yield increase.

Under such conditions the proposed technology does imply economies of scale. Unless smaller versions of the tool carrier suitable for

8. Given the fact that these Investments ere risky because of the general riskiness of agriculture in the SAT, we believe that such high rates are appropriate.

smaller bullock pairs can be developed, and provide the same yield advantages as those of the larger models, successful introduction of the tool carriers favors large farmers relative to small ones. Furthermore, for each 15 ha farm 1.5 bullock drivers will become unemployed. Such unemployment can only be acceptable socially if the yield advantages of the machine are indeed large and consequently increase labor requirements in other activities.

Potential Yield Advantages

Information on the yield impact of improved soil management techniques described in the second section comes from the Farming Systems Research Program of ICRISAT. The first type of information is the Steps in Improved Technology experiments (SIIT) described more fully in Ryan, Sarin, and Pereira (1978), and in the Annual Reports of the Farming Systems Research Program. From these experiments, information is available for deep Vertisols (black soils). The operational-scale watersheds also provide information about plots on a much larger scale, similar to the sizes at which farmers would operate. Table 6 summarizes this information for the 2 years 1976-77 and 1977-78. Comparable information under farmers' field conditions will only become available in a year or two.

Table 6 gives the yield increase in rupees per hectare that can be attributed to the soil and crop management system associated with the wheeled tool carrier. From there we see that yield advantages in excess of Rs. 1000 are possible in the experimental setting when the improved cultivation practices are imposed on top of improved varieties and fertilizer levels. Without added fertilizer, yield advantages in the Alfisols were only around Rs. 250, whereas in the deep Vertisols they were around Rs. 500.

In the operational-scale watershed experiments, the largest yield advantage reported was Rs. 625 for the deep Vertisols. This is a little more than half of the Rs. 1046 achieved with improved varieties and fertilizers in the smaller scale SIIT experiments. On the medium-deep Vertisols the soil and crop management treatment appears to lead to modest losses.

On the basis of Table 6, we may conclude that yield advantages in excess of the *compensating yield increases* required to pay for the extra cost are a distinct possibility, even if the machines are used for only 80 days per year.

Conclusions

The available survey research evidence from SAT India indicates that it is not possible to expect social returns from tractors to be positive in this area in the manner in which they are

Table 6. Yield increases attributable to cultivation practices with wheeled tool carrier at ICRISAT Canter.[a]

	Steps-in-Improved Technology (SIIT) experiments, with improved soil management[b]				Watersheds	
Variety:	Local	Local	Improved	Improved	Improved	Improved
Fertilizer:	Local	Improved	Local	Improved	Improved	Improved
					Maize followed by chickpea	Maize and chickpea intercropped
Alfisols	234	802	262	1285		
Medium-deep Vertisols					-190	-206
Deep Vertisols	546	533	479	1046	+ 166	+ 625

Source: Ryan, Sarin, and Pereira (1979, Appendix Tables 1 and 2 and Table 3}. A fuller description of the experiment is given there. See also Annual Report, Farming Systems Program, 1976-77.

a. **Averages are for 1976-77 and 1977-76 and are expressed in rupees per hectare of net cropped area. The experiments reported here were carried out with seeding attachments that were more expensive than the ones used for the calculations in Table 5. However, the engineers expect to achieve the same precision with the cheaper devices budgeted.**

b. **During the year 1976/77 the Improved management treatment also Included a minor level of Insect control, but the differences in 1977/78 ere fully attributable to soil management techniques.**

currently used. However, the introduction of new technology could change this, so it is undoubtedly premature to discount tractors entirely. This premise will be investigated at ICRISAT in coming seasons. Nevertheless, at present, tractors seem even less appropriate in the SAT than in other areas of South Asia. The emphasis on bullock power is thus well justified.

On the basis of evidence from the Economics Program's Village Level Studies and experiments of the Farming Systems Research Program, we find that wheeled tool carriers will not be competitive with existing soil and crop management techniques unless they generate yield advantages in excess of 200 to 400 kg/ha. However, the experimental evidence suggests that the improved system may be able to provide substantially larger yield increases in the Alfisols and deep Vertisols. Therefore, work on this type of equipment and testing it in farmers' fields is amply justified, even in SAT Asia. Since the largest benefits occur in conjunction with reasonable levels of fertilizer use and improved varieties, testing at the village level should be concentrated on similar situations.

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Animal-draft Cultivation in Francophone Africa

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Animal-draft cultivation was introduced into Francophone Africa a long time ago. It is generally agreed that it dates back to 1930. But in research stations and administrative sectors it started in 1926, and in Madagascar, as early as 1900. Therefore, it has been through a very long stage of introduction.

Its promotion started more recently, generally after the countries became independent (1960-1962). This developed within schemes and projects initially for production and then for development. In this respect, it differs greatly from the effort in the Anglophone countries. At first, the initiative was taken by the scheme rather than the farmer himself. Since credit, when available, and marketing of purely cash crops were organized, the farmer was very dependent on this operational environment.

Brief History

Initially, all the equipment introduced into Francophone West Africa came from France: brabant plows (a technique directly transferred from European agriculture) in Madagascar; long-moldboard Bajac plows or short-moldboard Bourguignon plows in West Africa. EBRA equipment, with its more helical design and Huard equipment were also used. These were limited introductions, however, made by administrative authorities or research centers. Equipment from Yugoslavia, Japan, and USSR was introduced later.

After independence of the countries, the extension work by the traditional agricultural services had only a limited impact because both facilities and personnel proved inadequate. Moreover, supply of equipment took a long time and restricted the work. Some models were no longer manufactured in Europe and the others were not necessarily suited to the conditions. They were generally too heavy for the available animal power.

Between 1960 and 1965 several factors contributed to the large-scale development of animal-draft cultivation. Some manufacturers agreed to continue the production of animal-drawn equipment using more suitable patents (inventors such as Nolle and Bariani have played a prominent role here) and meeting the specifications given by the research and study centers and then 'transferring' these by sponsoring the first factory in Africa (SISCOMA in Senegal). Much later, other factories were established in Cameroon (Tropic), Mali (SMECMA), and other countries.

Agricultural research, — which is well-advanced in Senegal and Madagascar, — is now in a position after testing cropping techniques and equipment to recommend technical production systems based on soil cultivation with the aid of light and heavy animal-draft equipment.

Intensified promotion through the implementation of "production" operations (rice, cotton, groundnut, etc.) with international aid has helped the spread of animal-draft methods to the entire population.

Many tests and adaptations of animal-draft equipment have been carried out over the past 18 years. Such equipment now in use is probably viable except for that only recently introduced. We will now discuss the range of equipment presently available.

Specific Equipment

- SISCOMA or SMECMA single or double seeders for groundnut, millet, sorghum, maize, and, to a lesser extent upland rice. These are derived from the Fabre Super Eco seeders. A special hopper has been designed for cotton.
- Huard or Codamm type of 10- inch plows;

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these are generally fitted with a semi-digger body.

- SISCOMA or SMECMA hoes (ex Fabre "occidentale" model) drawn by donkeys or horses. They can also be coupled and *drawn* by a pair of bullocks. Their main function is weeding, and the use of duckfoot tines improves their working performance.
- Manga hoes are used more often for cultivation than for weeding.
- Donkey-drawn carts with a 400-kg payload, horse-drawn carts with a 1000-kg payload and bullock-drawn carts with a 1500-kg payload. The latter are less popular.

Simple Tool Carriers ('multiculteurs') for Tillage Operations

- The series based on Mouzon-Nolle patents. The best known are the Sine 7 and 9 hoes (with some local adaptations). These are manufactured in practically all the factories. The use of the Ariana plow is also spreading. Attachments include cultivation and weeding implements, cultivator tines, plows, ridger bodies, and groundnut lifters.
- The series based on Arara-Bariani patents. They are also manufactured in all the factories. The equipment is the same as the earlier series and is often used for cotton cultivation; it is considered heavier than the Sine equipment although the weight and function of the implements is quite similar for the two series.
- The new 'triangles' used in Upper Volta. Their frames are different from the Sine but have similar agricultural applications.

Multipurpose Tool Carriers

- The Nolle tool carrier (Polyculteur) is fitted with a cart platform but so far it is not widely used.
- The Nolle Tropicultor, a wheeled tool carrier, is also not widely used.
- The high-performance Bambey-SISCOMA tool carrier is limited to only one region in Senegal. It is equipped with conventional seeders of the Super Eco type.
- The Le Lous Tropisem which is being tested in another part of Senegal, has three seeders with plastic rollers.

Other equipment has been tested but does not need to be added to the above list.

At present the technical possibilities of animal-draft cultivation include:- plowing 12 to 15 *cm* deep; planting of most *annual* crops (except uncoated furry cotton used); weeding and cultivation operations for all crops and ridging for cotton; and-the lifting operation in harvesting of groundnut (lifting operation).

In addition, it is always possible to transport water and materials with reliable carts.

Present Research

- Equipment is being researched that will enable the following to become practicable:
- Seeders for undelinted cotton.
- specially shaped of tines (Jumbo buster), enabling work under drier conditions and thus extending the operation period.
- auxiliary equipment for herbicides (although this is not exactly part of animal-draft cultivation).

In spite of this diversity, technical systems based on animal-draft cultivation face the following constraints:

- Time constraints to carrying out tillage operations under good soil conditions;
- Technical constraints to burying organic material, if required.
- Labor constraints to completing mechanical weeding operations.
- Time and labor constraints at harvest and during conditioning or processing of produce.

Relative Importance of Animal-draft Cultivation

Animal-draft cultivation figures are often exaggerated to show its Importance in the Francophone countries of West Africa. We shall try to place them in the proper perspective by comparing them with the area under cultivation. Censuses — especially for areas under cereal and tuber crops — are often not very accurate. Thus, the data given below must be considered as indicators only and not as an accurate representation of the situation in 1977 (Tables 1 to 4).

In 1977-78,6000 farmers in the northern Ivory

Table 1. Equipment numbers in West Africa.

Items	Upper Volta	Mali	Mauritania	Niger	Senegal	Chad	Benin
Bullock-drawn plows	12 050						
Donkey-drawn plows	4 470						
Total plows	16 520	106 700	2400[1]	3000	8 000	58 056	7450
Tool carriers (multiculteurs)	2 500	40 555		4300			185
Cultivators (donkey-, horse-drawn)	21 000	14 058		900	204 000	1 727	
Harrows		10 739					
Seeders		9 707	100[1]	900	220 000		
Carts		52 204		3300	89 600	14 606	
Ridgers (ridgers and/or weeders)				1500	5 000	(3 883)	
Lifters				3300	88 000		

1. Tentative figures
Source: Author

Table 2. Average density of animal-drawn equipment in West Africa (ha/unit).

Items	Upper Volta	Mali	Niger	Senegal	Chad
Plow	190	12	900	278	19
Multiculteur or hoe	160	31	690	11	199
Ridger	-	-	–	445	199
Harrow	-	116	–	-	-
Seeder	8800	129	3020	10	-
Lifter	-	-	820	25	-
Cart	325	24	820	25	76

Table 3. Density of equipment on monitored dryland areas of West Africa (ha/unit).

Items	Cotton area, Mali	Groundnut area Mali	Cotton area, Senegal	Groundnut area, Senegal	Maradi, Niger
Plow	6	-	13	227	833
Tool carrier (multiculteur) or hoe	15.4	64	25	6.5-8.1	90
Ridger	-	-	13.4	-	111
Harrow	386	-	-	-	-
Seeder	373	71	-	3.9-4.5	268
Groundnut lifter	-	-	-	5.6-6.7	310
Cart	18	117	-	10.3-12.9	146
Pair of bullocks	15	-	-	-	-
Donkey	29	-	-	-	-
Hand-sprayer	4	-	3.6	-	-

Table 4. Density of equipment in selected areas of various countries (ha/unit).

	Rice	Rice	Rice	Sorghum/cotton
Items	Segou scheme, Mali	Office du Niger, Mali	Plaine de Kou, Upper Volta	Ibohamana, Niger
Plow	3.6	6	1	6.8
Harrow	14	10	-	-
Ridger body	-	-	-	6.8
Weeding tool	-	-	1	-
Sickle	-	-	1	-
Pedal-operated thresher	-	-	3	-
Cart	8.4	15	-	-
Sprayer	-	-	1	7.5

Coast were reported to be using animal-drawn equipment (multiculteurs). In Togo, animal-draft cultivation is practically nonexistent; the figure of 800 animal-drawn implements for the northern region is disputed.

Animal-drawn Equipment and Farms

Table 5 must be interpreted with caution as the concept of a farm can be difficult to define in a general way. We shall not consider differences based on social structure (patriarchy, extended family, households, etc.); although these are studied, they are not really included in a census. To be more factual, we shall examine the case of the cash crop producer. He is the only individual known in the schemes, as he comes to sell his produce and has an account (credit) with them. He may be the head of a large family or of a household. Consequently, the figures may be underestimated. Unfortunately, we do not have more accurate agricultural statistics.

As animal-draft cultivation has not developed uniformly, some areas are better equipped than others. It is surprising, however, that after many years of sensitization and extension, the general situation has not improved.

Table 5. Density of selected equipment on farms in various countries (farms/unit).

Item	Upper Volta (total agricultural sector)	Mali	Niger	Senegal
Plow	55	2.8	150	38
Hoeing unit	46	7.4	42	1.5
Seeder	2500	31	500	1.4
Cart	92	5.7	136	3

Source: Author

Factors Determining the Spread of Animal-draft Cultivation

The agricultural, social, and economic environment as well as the planning of the promotion of animal-draft cultivation present positive and negative aspects that may explain its slow spread in the development of rural communities.

Expected Yield Increase

Agricultural research has obtained important results in areas involving farm equipment, including the following:

- Timely sowing can generate yield gains of 50% on groundnut and sorghum; early millet is less sensitive to the planting date but can provide a yield gain of 20%. Cotton is particularly sensitive to the date of planting,
- Several mechanized crop weeding can allow yield gains of 50% for groundnut and up to 175% for millet.

- Much research has been carried out on tillage operations. Nicou summarizes the results obtained in Senegal in Table 6.

Only results that have already been published are mentioned here. Unfortunately, equally accurate data on no-tillage and minimum tillage practices, for example, are not available.

The effects of these improved cultural practices are not cumulative (i.e., the sum of the percentages given above does not represent the overall result). But the results of tillage operations can be considered since timely sowing, appropriate weeding operations, etc. were combined in the trials. In any case, it is worth noting that the simultaneous use of a number of animal-draft cultivation techniques significantly increases production.

Table 6. Percentage yield Increases from seedbed preparation with animal-drawn equipment In Senegal.

Crop	Effect of plowing alone	Effect of plowing-burying
Grain-millet	19	23
Grain-sorghum	24	24
Grain-maize	50	73
Rainfed rice	103	112
Cotton	17	31
Groundnut	24	9

Source: R. Nicon, Institute of Tropical Agricultural Research (IRAT), France.

Possible "Drift" of Yields

"Drift" denotes the inevitable difference between the results obtained on research stations and those in farmers' fields. This drift is not due to farmers alone, as some of them obtain excellent results.

In the preceding section, the need for applying yield-enhancing factors simultaneously was emphasized. But this is difficult for the extension services as they deal with heterogeneous groups who differ in their technical capabilities and receptivity. Moreover, they lack the financial means and personnel required for a widespread promotion of these techniques. Consequently, they proceed operation by operation (e.g. sowing, then weeding, followed by tillage, and so on). The yields fall short of the target and it takes some time for the farmers to integrate all the techniques.

Some techniques are extended imposed because of agronomic considerations such as a soil-regenerating crop and the inclusion of non cash crops in a rotation, and their advantage is rarely obvious to the farmer. The farmer's motivation is also reduced as the yield-related positive factors of animal-draft cultivation are not so apparent in their actual application.

Constraints in the Production System

These constitute the basic point in the development of any new technology. It is absolutely necessary to determine the constraints faced by a producer before proposing any technology package that attempts to overcome them. If the constraints are more or less artificially disguised, the problem is not solved and the technology may meet with obstacles.

For animal-draft cultivation, let us take the example of traditional farming communities who only practice manual cultivation. The figures in Table 7 *are not* comparable *as* they concern different countries using different techniques; however, they give an idea of the working process.

Let us compare the data used by Richard and Fall for establishing the 4 S model. These are the most recent and complete data on working times for animal-draft cultivation in Senegal. The accuracy of the figures in Table 8 may be questioned but the orders of magnitude remain valuable.

It should be noted that when using animal power, the work days of the operator driving the animals must also be considered (Table 9).

In manual cultivation, the size of the farms is reduced as it depends upon the working capacity of the farmer. The main problem here is the planting and maintenance of crops. The introduction of animal-drawn equipment enables farmers to increase the area cultivated without overcoming the planting/maintenance bottlenecks which remains high on a per hectare basis. It seems from this that the problem has been somewhat disguised because the figures show that only farms with a reserve of

Table 7. Working times for exclusively manual operations.

Operation	Groundnut			Maize	Millet		Cotton	
	Ivory Coast	Senegal	Chad	Ivory Coast	Senegal	Benin	Ivory Coast	Cameroon
	days/ha							
Tillage	40	15-20	10	40	-	13	8	15-20
Ridging	-	-	-	-	-	-	20	-
Fertilization	10	-	-	2	-	-	5	-
Sowing	5	10	9	6	4	7	8	5-10
Resowing	-	-	1	1	-	-	2	-
Weeding	30	15	20	24	12	31	60	30
Thinning	-	-	-	5	2	-	5	3-4
Harvesting	25	19	-	6	16	29	50	40-50

Source: Author

Table 8. Additional manual work raquired in a fully mechanized farm using ox- or horse-drawn implements in Senegal.

Operation	Groundnut	Maize	Millet	Cotton
	hrs/ha			
Furrow marking	–	–	24	6
Fertilization	5	5	5	5
Sowing	-	-	18	80
Weeding	80	-	-	-
Weeding, thinning	-	80	100	100
Harvesting	-	115	170	600

Source: J. F. Richard and M. Fall, Senegalese Agricultural Research Institute.

Table 9. Number of working days required to complete a working pattern (planting, weeding, thinning) In manual and animal-draft cultivation.

Crops	Pure manual cultivation (required days of manual work/ha)	Advanced animal-draft cultivation (additional days of manual work/ha)
Groundnut	25-35	10-14
Maize	36	10-14
Millet	18-38	18-24
Cotton	38-75	24-32

Source: Author

labor can extend the area and profitably use animal-drawn implements.

For tillage operations, work productivity has been increased with the introduction of plows and spring-time cultivators. Yields have increased requiring more labor at the time of harvest. The problem has not been solved; it has been shifted in time.

Equipment Standards

In Senegal, the need to coordinate the different means of production on a farm has become apparent since 1977. Studies were carried out using theoretical models in Bambey followed by on-farm models and, finally, testing in farmers' fields; these studies were carefully monitored by agricultural researchers in the Experimental Units in Senegal and have helped to determine the limits to the use of animal-drawn implements. These standards are good indicators for the Sahelo-Sudanese zone with one rainy season and for a balanced rotation of millet, sorghum, groundnut, cotton, maize, and even upland rice.

In 1977, Benoit-Cattin (personal communication) summarized these limits as follows:

1 seeder for 4 ha

1 Sine hoe for 3.5-4 ha (depending on the model)

1 "Occidentale" hoe for 3 ha

1 plow for 1.5 ha to be tilled

1 groundnut lifter for 4 ha of groundnut and a pair of bullocks

1 ridger body for 2 ha of maize/cotton (and a pair of bullocks)

1 Arara tool carrier (multiculteur) for 4 ha and a pair of bullocks

1 Ariana tool carrier (multiculteur) for 6 ha and a pair of bullocks

1 Ariana +1 Sine hoe for 6 + 4 ha

1 high-output Polyculteur for 8 - 10 ha

Draft power capabilities under similar improved technologies were defined as follows:

1 donkey for 2.5 ha

1 horse for 2.5-3.5 ha (depending on the age)

1 pair of bullocks for 3-6 ha (depending on the age)

1 pair of cows for 4 ha

1 pair of very strong bullocks for 8 ha

In fact these standards are close to those found in different African areas where animal-draft cultivation is practiced.

Nevertheless, to avoid the labor "trap" mentioned earlier, we shall add the following recommendation — in the definitions of animal-draft cultivation capabilities, the family structure involved in these types of models must be close to one working person/per hectare.

Inappropriate Economic Situation

Adverse economic circumstances often had direct consequences on animal-draft cultivation and restricted its development. Some of the important aspects include:

- The increase in equipment prices in relation to the relative stagnation of prices to producers, except perhaps in the Ivory Coast. In Mali, the price of tool carriers (multiculteurs) increased by 177%, plows by 101%, and carts by 86% over a period of 3 years.
- The increase in the price of draft animals due to a reduction of the herds in the North following the drought and as a result of competition with abbatoirs. It is not uncommon for a pair of bullocks to cost up to 150 000 F CFA (US$ 714.28) and donkeys up to 18 000-20 000 F CFA (US $ 85.71-95.24). These correspond to a 3-ha and 0.5-ha grain harvest, respectively.
- Credit facilities, if any, are selective. All the implements are not included, particularly carts; draft animals are rarely covered.
- Official marketing is exclusively focused on cash crops such as cotton and groundnut. Rice is given a special status in certain areas but that is insufficient. In areas where animal-draft cultivation is developing, it is not really possible to rely on an income from traditional cereal crops; the farmer has to depend on income from groundnut and cotton to pay for added inputs such as animals and equipment.

Conclusion

This discussion of the present problems does not mean that we are pessimistic about the future of animal-draft cultivation in Africa. But in view of the decreasing demand for equipment in Mali, where animal-draft cultivation has been an important option, and the recent stagnation in the Ivory Coast, it is essential to reconsider it. This is especially important as mechanized farms present a good picture. Gross margins per hectare (valued at market prices or monetarized) ranging from 60 000 to 100 000 F CFA (US $ 285.71-476.19) per hectare *are* common, along with food-crop production from 50% of the area for self-consumption and storage.

Among the negative factors, some are of a political nature (prices, marketing, etc.) and the technical person cannot influence them. But others are related to the system of production, which he can change. Two simple ideas should be considered for this purpose:

- Although animal-draft cultivation allows many technical solutions, its scope remains limited; some sectors of agricultural activity will never be involved. Therefore, from the initial stages, such an alternative should be directly conceived in association with other technical solutions. Weeding operations lead us to think of herbicides. There is a need for tractorized solutions for harvesting and processing of crops, resulting also in an increased availability of transport. The problems that arise from such situations are not really technical. They are related to the environment which must first be understood and where mechanized solutions must find a receptive audience — farmers, contractors, small groups, etc. Technocratic attitudes that farmers should systematically adopt solutions used in industrialized countries must certainly be abandoned. If the blacksmiths are establishing themselves more strongly in Mali, it is clearly because their role and working methods have been decided by the villgers themselves.

- Farms constitute dynamic and infinitely diversified systems of production. This is incompatible with the concepts of standardization or conformity to preestablished mathematical models. Although these may prove useful as working tools in envisaging several variants on production techniques, their role is limited.

To help a farm develop, its problems must be examined under existing conditions and specific solutions must gradually be proposed. This will lessen the appeal of owning a complete series of animal-drawn equipment. Initially, it would perhaps be more useful for a producer to purchase only a ultivator and not all the equipment. But a proper solution is perhaps to temporarily continue with manual cultivation techniques supported by the use of herbicides. Paradoxically, it is quite possible that the first step in the development of animal-draft cultivation will result in the introduction of power-driven implements for harvesting and crop processing.

In conclusion, it seems necessary that the options should be directed towards two key activities that predetermine the future of animal-draft cultivation:

- Research in all areas: study of different problems and solutions rather than an in-depth study of a few production systems; these will later prove to be inappropriate and will be rejected or modified by the farmers, which is the ideal approach but it does involve some waste of time.
- Extension activities: working directly with individual farms and giving advice about management of the farm rather than serving as a facility for distributing farm inputs.

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Socioeconomic Aspects of Improved Animal-drawn Implements and Mechanization in Semi-Arid East Africa

Bruce F. Johnston*

Abstract

This paper examines the socioeconomic factors most relevant to decisions concerning the role of animal-drawn implements in the semi-arid farming regions of Kenya, Tanzania, and Uganda. Structural and demographic features that should be taken into consideration in determining national policies for agricultural and industrial development also need to be considered in determining agricultural research priorities and development strategies for these semi-arid areas.

These relationships are especially evident in Kenya, where rural-to-rural migration has been mainly responsible for extremely rapid growth of population in the major semi-arid farming areas, most notably in Machakos and Kitui districts. Particular attention is given in this paper to the present situation and future prospects in Kenya, partly because they epitomize the fact that the technical problems of devising more productive and sustainable farming systems must be considered in relation to the broader problems of economic transformation and social modernization.

The principal hypothesis examined in this paper is that research and related rural-development activities in the semi-arid farming regions of East Africa should give a very high priority to promoting wider and more efficient use of animal-powered equipment and associated tillage innovations. It is thus intended as a contribution to the ex ante analysis of the allocation of research resources. This is in line with the view expressed by Binswanger and Ryan (1977 p 217) that economic research on the payoffs and distributional outcomes of agricultural research should shift its focus from ex post analysis to ex ante research concerning the allocation of scarce research resources.

In their paper, Binswanger and Ryan suggest that most decisions faced by research administrators concern *"marginal* research resource allocation problems" and that reliance can therefore be placed on the "simpler tools of benefit-cost and partial equilibrium analysis" (p 218; emphasis added). Some of the evidence derived from benefit/cost analyses of cultivation based on animal draft power and on tractors is summarized below. My approach will, however, be more in line with a broader view of the utilization of scarce resources for research. In the introduction to the important recent book on *Induced Innovation,* Binswanger and Ruttan (1978, p 4) assert that "the most powerful force that man can command to alter the direction of technical or institutional change is the capacity for innovation." And they go on to suggest: "If he is to deploy his innovative effort effectively, man must learn as much as he can about the complex matrix within which technical and institutional change interact with each other and with the physical and cultural endowments of a particular society."

It is important to recognize that it will be a difficult and time-consuming undertaking to devise and disseminate equipment and tillage

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innovations capable of achieving widespread increases in farm productivity in these areas. Moreover, in order to realize the full potential of expanded use of improved farm equipment in these countries it wiH be necessary to stimulate local manufacture of a widening range of animal-drawn implements and other inexpensive and simple items of farm equipment; and this will also be a difficult task. It seems clear that a necessary (if not sufficient) condition for mounting such an effort is the availability of evidence and arguments that are more persuasive than a cost-benefit calculation, especially since it might be supposed that the latter is relevant only to transitory situations.

In considering the role of equipment and tillage innovations in the third section of this paper, considerable attention is given to the implications of certain structural and demographic characteristics of these economies as well as to the farm-level factors that are the proximate determinants of increases in productivity and output. Before turning to the general issues that need to be considered in selecting the technological innovations to be emphasized in agricultural strategies for semi-arid East Africa, it is useful to review briefly the evidence concerning the relative profitability of animal-powered and tractor technologies and some recent historical experience in the three countries.

An Overview of Animal Draft Power and Tractor Mechanization in East Africa

Costs of Animal- and Engine-Powered Technologies

The evidence now available seems to be reasonably consistent in indicating that with prevailing labor-capital price relationships, reliance on animal draft power generally represents the most economical approach to overcoming the power constraint and labor bottlenecks that are major factors underlying the low levels of crop yield and labor productivity that characterize farming in semi-arid East Africa. On the basis of a number of farm management studies carried out in Sukumaland in Western Tanzania in the early 1960s, Collinson (1965, p 3) asserted that "there is no case for the introduction of tractors in areas where ox-plowing is established; these can perform the same function as tractors more cheaply." There has been considerable expansion of ox-cultivation in all three countries, beginning as early as about 1910 in Uganda. But that has been mainly a spontaneous process based on the importation of either a standard mold-board or a ridging plow. Other than a modest expansion in the use of ox carts, there has been virtually no spread in the use of a wider range of animal-drawn equipment.

A report on mechanization in Tanzania by Beeney (1975) includes a careful comparison of manual, oxen, and tractor cultivation. Beeney used partial-budgeting techniques and the best cost data available in 1974 when he carried out his FAO/UNDP study. He concludes that both for individual farmers and for communal cultivation in *ujaama* villages, animal draft power is more economical than tractor cultivation. The only exception, according to his analysis, is that in the larger and more successful *ujaama* villages, using tractors for minimum tillage might be superior, provided that the equipment was well operated and well maintained. Even under those circumstances, the use of a tractor in conjunction with oxen often would offer the least costly option.

A linear-programming analysis by Singh (1977) provides the most valuable evidence concerning the cost advantage of animal draft power over tractor cultivation. His LP models are based on input-output coefficients estimated from recent farm management surveys carried out in the Mwanza and Shinyanga regions of Western Tanzania. They permit an assessment of how the farming system as a whole will be affected by different levels of mechanization, including both a tractor-hire service and use of tractors in a communal *ujaama* farm as well as hoe cultivation with hand labor and cultivation with oxen. Singh also examines the effects on net returns and on employment of various combinations of mechanical and yield-increasing innovations, such as the use of improved seeds, fertilizers, and pesticides. His analysis confirms the clear-cut economic advantage of animal draft power over tractors. When all land in a village is cultivated as a single operational unit so that the ubiquitous problem of underutilization of tractors is minimized, the cost disadvantage of tractor cultivation is obviously reduced; nevertheless, net returns are higher with ox cultivation than with tractors, even when it is assumed that the price of labor is well above levels that now prevail.

Historical Experience

At various times and in varying degree the governments of the three countries have recognized the advantages of promoting improved ox-cultivation. This makes it all the more important to consider why the results achieved to date have been so limited.

Uganda

A promising program to test improved equipment and to disseminate the "Indian method" of training and controlling oxen (by the use of reins attached to a nose ring or a nylon rope passed through a hole punched in the nose of the animal), was initiated at the Serere research station in Uganda during the early 1960s. But that program was allowed to lapse because of the government's preoccupation with promoting the use of tractors imported under an aid program. This proclivity of policymakers to assume that farmers could and should shift directly from the current predominant reliance on the hoe and human labor to tractor-powered farming systems has seriously weakened efforts to foster the use of animal draft power in all three countries.

Tanzania

The Tanzania Agricultural Machinery and Testing Unit (TAMTU), set up near Arusha in 1957, has carried out considerable testing and development work on animal-drawn equipment. On a number of occasions official statements have indicated that major stress would be placed on promoting ox-cultivation. President Nyerere has been especially eloquent in his endorsement of expanded use of animal draft power. In one forceful statement he declares: "We are using hoes. If two million farmers in Tanzania could jump from the hoe to the oxen plough, it would be a revolution. It would double our living standard, triple our product. This is the kind of thing China is doing" (quoted in Smith 1971). Similarly, in his important statement on 'The Arusha Declaration: Ten Years After", Nyerere notes that

> ... the truth is that the agricultural results have been very disappointing. Modern methods have not spread very quickly or very widely; the majority of our traditional crops are still being grown by the same methods as our forefathers used... people still think in terms of getting a tractor for their farms — even when they are small — rather than learning to use ox-ploughs.

Tanzania's action — and lack of action—to foster wider and more efficient use of animal-drawn implements is especially interesting. It might be assumed that in a socialist country with a strong commitment to an egalitarian approach to development, the political pressures that have elsewhere contributed to the encouragement of inappropriately capital-intensive technologies would have been almost nonexistent. However, the gap between policy pronouncements and actual implementation has been wide. A recent monograph on "Agricultural Mechanization and Employment" asserts that "Tanzania is one of the few countries that adopted a policy of both selective and appropriate mechanization during the last few years" (Bodenstedt et al. 1977, p 112). The authors support that statement by a reference to the Second Five Year Plan (1969-1974), which proposed the widespread introduction of ox cultivation, especially through the establishment of oxen-training centers. However, An FAO Mission on agricultural mechanization, visiting the country in 1974, reported that they

> ... found it extremely difficult to find any concrete evidence in the regions of a concerted effort to promote a wider and more intensive use of animal power. The program of establishing ox-training centers, mentioned in the Five-Year Plan, appeared to be virtually non-operative... (FAO 1975, p 9).

My own inquiries and observations as a member of an ILO employment mission to Tanzania in 1977 seemed to confirm the conclusion of the FAO Mission and of the subsequent FAO/UNDP study by Beeney. In addition; there appeared to be renewed emphasis on large-scale tractor mechanization on state farms as a major element in the government's program to expand food production.[1]

Kenya

The government's policy to give priority to increasing the productivity of Kenya's small-scale farmers enunciated in the *Development Plan 1975-78* included an emphasis on animal-powered equipment and other "appropriate technologies." Prior to about 1975, however, very little had been done in Kenya to promote ox cultivation, and many policymakers and agricultural specialists in the government held the view that the country's farmers should shift directly from hoe cultivation to tractors.

There are no doubt many factors that account for the especially strong appeal of tractor-based technologies in Kenya, including the pre-Independence example of European farming in the Highlands and the post-Independence interest of many senior government officials in large-scale farms in the former European areas. However, a psychological factor associated with the "modernity" of tractors and a tendency to look down on animal-drawn equipment as an "inferior" and "backward" technology may have been especially strong in Kenya.

It should also be noted, however, that neglect of animal draft power in Kenya was probably influenced considerably by the priority that was very properly given — beginning with the Swynnerton Plan launched in the 1950s—to achieving rapid increases in farm incomes by promoting small-holder production of coffee, tea, and grade cattle for milk production in Central Province and other "high potential" areas. The steep slopes and the small size of farms in those areas alone are sufficient to limit the potential gains from introduction of ox cultivation. But because such profitable alternatives exist, the opportunity cost of land for producing fodder for draft animals is high, and this represents an important economic factor that reduces the profitability of introducing animal draft power (Adelhelm and Schmidt 1975).

1. I have suggested elsewhere that preoccupation with the problem of obtaining a marketable surplus for urban *centers* may partly *account* for this tendency to promote large capital-intensive state farms. This Is a problem in Tanzania because of the difficulties encountered by statutory monopolies in collecting and distributing food produced by several million small-scale production units. The lack of confidence In the village sector that this implies may well become a self-fulfilling prophecy because priority allocation of scarce resources of capital and trained manpower to the state farm sector is likely to mean that the great majority of farm households will be deprived of the resources needed to achieve increases in productivity and output (Johnston 1978 p 94).

Obstacles to the Identification and Diffusion of "Appropriate" Mechanical Innovations

Tractors as the Symbol of a "Modern" Agriculture

Reference has already been made to the fact that the appeal of tractors with their speed and other technical advantages has been an important factor contributing to the neglect of effective research to support wider and more efficient use of animal traction. Many government officials in East Africa and foreign advisers have tended to assume that the striking *technical* superiority of tractors must also imply superiority in terms of *economic* efficiency.

It has been said that in most cases "the implementation of exployment-oriented mechanization policies is essentially a political problem rather than a problem of the economic, administrative or technical feasibility of such policies" (Bodenstedt et al. 1977, p 108). The decision by the Ugandan government to shift emphasis from promoting animal draft power to tractors was related to a politically motivated desire to obtain a large allocation of foreign aid that was available only at that time for the importation of tractors from the United Kingdom. The essentially political decision in Tanzania to promote tractor cultivation under the block cultivation scheme of the 1960s also diverted attention from ox cultivation and other efforts to promote a broader and more progressive modernization of small-holder agriculture. It is estimated that, in addition to the scheme's heavy demands on capital and foreign exchange, some 40 to 65% of all agricultural extension workers in the country were assigned to it (Kline et al. 1969, p 2-113). Subsequently, heavily subsidized distribution of tractors to selected *ujaama* villages had similar adverse effects, including the tendency noted by President Nyerere: "People still think in terms of getting a tractor... rather than learning to use ox-ploughs."

Scarcity of Agricultural Research Resources

Research programs to identify equipment and tillage innovations adapted to the agroclimatic conditions in the semi-arid and other farming regions of East Africa are inadequate, largely because of the general scarcity of financial and manpower resources for research. These countries face a formidable problem in achieving a transition from a resource-based to a science-based agriculture (Johnston 1978). Expansion of food production has not kept pace with demand because of population growth, enlarged cultivation of export crops, and declining yields resulting from reduced fallow periods in the traditional bush fallow systems. As previously noted, the need to evolve more productive farming systems is acute in the semi-arid areas. Especially in Kenya the large number of migrants from densely populated, high-potential areas are using farming practices that are poorly adapted to the marginal areas, causing serious problems of soil erosion, which are exacerbated by cutting trees for firewood and charcoal. One serious consequence is an increase in the frequency and magnitude of the need for famine relief when there is a crop failure.

The strengthening of national agricultural research capabilities in these countries is a difficult task. The general difficulties faced by developing countries are compounded here because these countries are relatively small in terms of population and GNP, but their national boundaries encompass a great deal of diversity in rainfall, soil, and other agroclimatic conditions. Those ecological differences, together with considerable variation in the dominant and secondary crops produced in different areas, complicate the problems of crop improvement and of devising appropriate equipment and tillage innovations. The impact of past research on food production in these and other African countries has also been limited because both expatriate and national scientists have often lacked an intimate understanding of the conditions and constraints faced by farmers in various ecological zones.

It is noteworthy that agricultural research expenditures in African countries in 1974 represented only 1.4% of the value of their agricultural product in contrast to the countries of Western Europe and North America (and Oceania), where research expenditures were equal to 2.2 and 2.7%, respectively, of their much higher level of agricultural output. Probably more significant, however, is the fact that the 1974 figures of 1.4% in Africa represented a very modest increase from 0.8% in 1959, whereas the increase in the countries of Asia over that period was from 0.6 to 1.9% of the value of their agricultural output (Boyce and Evenson 197S, p8). It seems reasonable to infer that the threefold increase in the Asian countries reflected increased awareness of the value of agricultural research with the widespread introduction of high-yielding varieties of wheat and rice beginning in the mid-1960s, whereas research programs in Africa have not yet yielded comparable results.

Lack of an Effective Methodology for R & D Activities

The general problems that have limited the past impact of research appear to have been especially serious in the case of R & D activities aimed at achieving more efficient use of animal draft power. It has been noted that food crop research in East Africa has been focused almost entirely on plant breeding and fertilizer use, to the neglect of research on improved farm equipment (Vail 1973). It is not surprising that research stations have concentrated their efforts on varietal improvement, since a powerful methodology exists for generating biological-chemical innovations. Furthermore, these innovations can be used efficiently by smallholders, who account for the great bulk of the farm population in developing countries, and the achievements of the "green revolution" in Asia have enhanced the prestige of that research strategy. Indeed, the success of Kenya's hybrid maize program and the more limited but considerable progress in diffusing high-yielding varieties of maize in Tanzania are the principal examples of successful food crop research in East Africa.

In contrast, there are few examples of successful programs to identify and disseminate equipment innovations. In fact, there is reason to believe that the usual approach, which has concentrated on the development and testing of equipment by agricultural engineers, offers little promise. There appears to be much truth in the assertion that "Machines to fit into farming systems cannot be designed by farm machinery research engineers working on their own. It requires a team effort of all those concerned with analytical research for the development of all aspects of appropriate farming technologies" (Monnier 1975, p 224). On the basis of their experience in Francophone West Africa, Monnier, Tourte, and others argue for a "systems approach" that involves several phases of research and an integration of research and extension that incorporates feedback information from farmers. In an "analytical phase" various components of a farming system—soil and plant improvement, equipment, tillage, etc. —are studied separately but with careful attention to the labor requirements and other costs and to the returns associated with various alternatives. The goal is to design and test systems that are profitable and feasible, given the constraints faced by farmers.

> These systems to be extended are then demonstrated to farmers as a factor having relevance to their farming operations. It is not intended that they should apply the whole new package of innovations in one go, but rather that they should themselves decide on the intermediate steps they should take to arrive finally at a system of production that is logical and appropriate to their conditions. (Monnier 1975, p 226)

Equipment and Tillage Innovations for Increasing Farm Productivity

In this section I face up to the problem of defining "appropriate" innovations and suggest why "appropriate" equipment innovations should be an important element in strategies for increasing productivity and incomes in the semi-arid regions of East Africa. A useful point of departure is to consider briefly the general concept of technical change, using a pair of diagrams reproduced from Binswanger (1978, pp 19, 21). The production isoquant I-I in Figure 1 represents the production possibilities prior to technical change. The slope of the two parallel diagonals represents the relative prices of capital and labor. Thus point A is the economically efficient point of production because, being a tangent to the price line, it represents the minimum cost combination of capital and labor required to produce a "unit" of output given the state of knowledge described by the initial isoquant. The isoquants I'-I', I"-I", and I'"-I'" represent alternative possibilities after technical change has made available improved production possibilities resulting from research or learning by doing. The way that the isoquants are drawn, the same "unit" level of output can now be produced at points A' or A", using smaller amounts of both capital and labor or at A'", with a greatly reduced input of labor but a somewhat larger input of capital.

The technical change represented by the inward movement to I'-I' is "neutral" in the (Hicksian) sense that, with no change in the relative price of capital and labor, the point that is economically efficient, A', results in the same proportional saving in labor as in capital. Technical change that led to shifts to A" or A'" would, of course, be labor-saving because there is a proportional as well as an absolute reduction in labor requirements per unit of output. Figure 2 can be interpreted as describing an

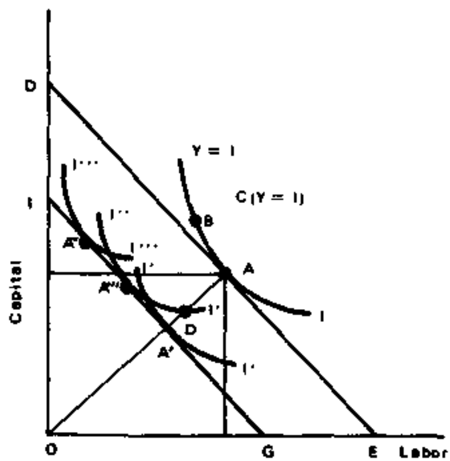

Figure 1. Rates and biases of technical change.

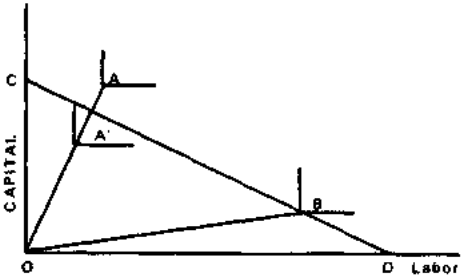

Figure 2. Neutrality and its reference point.

initial situation in which the capital-intensive technology represented by A and the labor-intensive technology at B co-exist. Even though point A is unprofitable as compared to B in terms of the "true" prices of capital and labor, large farmers might still find it privately profitable to operate with the capital-intensive technology represented by A, because they have access to credit from institutional sources at artifically low interest rates. (The three alternatives depicted in Figure 2 all represent fixed-proportion technologies to sharpen the contrast between the capital-intensive and labor-intensive alternatives.) Technical change represented by A', i.e., an inward shift along the capital-intensive ray OA, would now be more profitable even with the relative prices represented by the price line CD. However, in the East African context, such an extremely labor-saving technical change would be inferior as compared to the possibility of technical change along a more labor-intensive ray such as OB. Given the structural and demographic features of these overwhelmingly agrarian economies, large quantities of labor "released" from agriculture cannot find employment in the nonfarm sectors.

Because these features are typical of developing countries, it is common to partition increases in labor productivity into two components: mechanical innovations that mainly increase the area cultivated per worker and biological-chemical innovations that mainly increase yields per acre. Figure 3 (reproduced from Johnston and Kilby 1975 p 391) presents a schematic summary of the principal factors influencing labor productivity, based on this conventional partitioning. At a particular point in time, this partitioning is merely an identity, and output per worker (O/L) is equal to the product of acreage cultivated per worker (A/L) and output per acre (O/A). However, the rate of increase in O/L over time will, to a close approximation, be equal to the sum of the rates of increase in A/L and in O/A.

The schematic summary (Fig. 3) also directs attention to the fact that changes in farm labor productivity will depend on the interacting influence of various farm-level and socially determined factors. Increases in output per worker will depend not only on factors influencing agricultural capacity to produce but also on the growth of commercial demand and agricultural prices as they influence the actual rate of increase in farm output. In addition, the rate and direction of change in the size of the farm labor force is obviously an important determinant of changes in farm labor productivity. The implications of these structural and demographic characteristics are discussed in relation to projections of future changes in Kenya's population and labor force and their distribution between rural and urban areas.

Balance Between Mechanical and Biological-Chemical Innovations

In countries such as Japan and Taiwan, growth of farm productivity and incomes depended overwhelmingly on yield-increasing innovations, together with complementary investments in irrigation and drainage. It has only been since the mid-1950s in Japan and the late 1960s in Taiwan, when the absolute size of their farm labor force finally began to decline significantly, that engine-powered equipment became a major source of increases in productivity. However, in earlier periods, gradual development and spread of a widening range of simple, well-designed implements contributed to realization of the yield potential of improved varieties and greatly expanded use of fertilizers (Johnston and Kilby 1975 Chs 6, 8).

Thus the hypothesis stated at the beginning of this paper can be phrased more accurately: in East Africa, especially in the semi-arid farming areas, research programs should be concerned simultaneously with inexpensive equipment innovations and with yield-increasing innovations suited to rainfed farming. This hypothesis is based on four propositions:

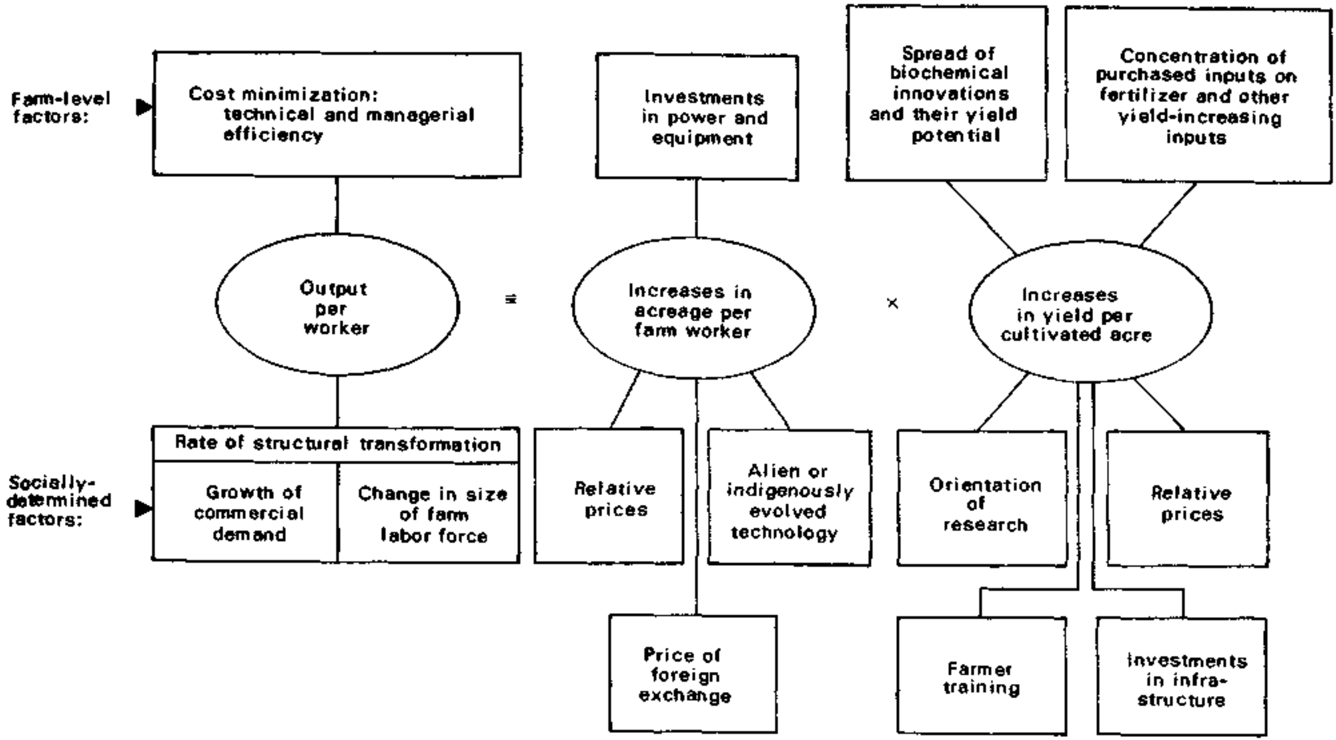

Figure 3. Schematic summary of the principal factors influencing changes in farm productivity.

1. Because of moisture limitations, the potential for increasing crop yields through varietal improvement and fertilizer use is considerably more limited than in irrigated areas where high rates of fertilizer application can be expected to have a very large and quite reliable impact on crop yields.

2. In the long run irrigation will make a significant contribution to the expansion of food production in East Africa, and some attention must be given to accumulating better hydrological information and to building up expertise in the demanding tasks of designing, constructing, and managing irrigation systems. But in the short and medium term it will be much more economical for research and development programs to concentrate on realizing the large potential that exists for expanding cultivation and raising yields under rainfed conditions.

3. In the semi-arid areas there is an exceptionally high complementarity between equipment-tillage innovations and biological-chemical innovations. This is related to the effect of the choice of implements and tillage methods on the extent to which crops are able to utilize the water available from limited and erratic rainfall, including such factors as infiltration, moisture retention, timeliness of planting, and weed competition.

4. Promoting wide use and local manufacture of a widening range of animal-powered equipment can make a major contribution to the goals of improving rural wellbeing and of transforming the structure of their overwhelmingly agrarian economies by making possible increases in farm productivity and incomes and by providing a stimulus to the expansion of local manufacturing capabilities.

Structural-demographic Factors and their Implications for Technical Change

The significance of the last proposition on the contribution of animal-powered equipment to rural well-being and structural transformation is especially evident in Kenya. As in all the East African countries, the manufacturing and other nonagricultural sectors in Kenya are still extremely small. In 1975 less than 15% of Kenya's total economically active population was in urban areas. This means first of all that the domestic commercial demand for food is small compared with the number of farm households. Hence the average farm unit faces a severe purchasing power constraint. Production of export crops represents a highly important source of farm cash income; nevertheless, the purchasing power constraint that results from the dominance of self-sufficient farm households in the economy severely limits reliance on "external inputs" purchased from outside the agricultural sector. The small size of the nonfarm sector also means that the annual additions to the labor force must mainly find employment in the agricultural sector.

Rapid growth of population and labor force in the three countries means that structural transformation will be a slow process. On the basis of optimistic assumptions about the extent to which Kenya's growing population of working age will be "absorbed" in urban areas, it has been estimated that during the half century ending in 2024, the share of the rural workforce in the total population of working age will decline only from 86 to 65% (Table 1A). Moreover, this projection assumes that the percentage of the urban population categorized as unemployed or inactive would increase from an estimated 36% in 1975 to 65% in 2024 in spite of quite rapid growth of urban wage employment and a very rapid (5.5% per year) increase in employment in the urban informal sector (Table 2).

These outcomes are, of course, strongly influenced by the rapid rate of population increase in Kenya. The Shah-Willekens (1978) projections that I am using include six scenarios of possible changes in population during the 50-year period ending in 2024. According to their "most likely estimate" there will be a fivefold increase in population from 12.8to64.3 million and also a fivefold increase in the population of active age. (Table 1B). Even their minimum estimate, which assumes a 25% linear decline in rural as well as in urban fertility between 1979 and 1999, involves a 3.6-fold increase in population; and the associated growth in active population would be considerably greater because of the time lag before a reduction in fertility is reflected fully in a reduced growth rate of population of working age. The assumptions used by Shah and Willekens in their location- and age-specific projection model yield an estimate of a 3.8-fold increase in the rural population of active age compared with a 12-fold increase in the urban active population. But, given the fact that population densities are already high in Kenya's high potential farming areas, absorbing a 280% increase of the rural work force in productive employment represents a formidable challenge. Unless early and substantial success is achieved in slowing population growth, the relative abundance of labor and low price of labor relative to capital are likely to be persistent features of the economy for several decades at least.[2]

These same structural and demographic factors also underscore the importance of the contribution that expanded local manufacture of animal-drawn and other simple items of farm equipment can make to the growth of output and employment outside the agricultural sector. Because of the small size and limited development of technical skills in Kenya's manufacturing sector, local manufacture of tractors and other sophisticated equipment would be uneconomic; however, ox-plows, cultivators,

Table 1. Projections of total population and of economically active population, Kenya.

A. Projection of economically active age.

Year	Rural	Urban (millions)	Total	Rural as % of total
1974	5.5	0.9	6.4	86
1994	9.3	2.6	11.9	78
2024	20.8	11.1	31.9	65

B. Alternative projections of total population.

Year	"Most likely estimate"	Maximum estimate (millions)	Minimum estimate
1974	12.8	12.8	12.8
1994	28.9	32.0	25.6
2024	64.3	77.6	45.8

Source: Shah and Willekens (1978).

2. From that point of view, it is worth noting that demographic as well as equity considerations seem to warrant an emphasis on labor-using and capital-saving innovations to enable widespread *improvement* in labor productivity and incomes. The available evidence strongly suggests that the changes in attitudes and motivation that lead to rapid reduction of fertility are much more likely to occur when the great majority of a developing country's rural population is actively involved in processes of technical and economic change. Moreover, institutional innovations capable of increasing the effectiveness of government population policies would also contribute significantly to an improvement in income distribution as well as to more rapid growth of average per capita GNP (Johnston 1978; Johnston and Meyer 1978).

Table 2. Employment projections In the urban areas of Kenya.

	1975	1999	2024
Total active-age population	876 000	1 600 000	11 100 000
Urban wage employed	387 210	896 900	2 151 600
Informal establishments	74 100	277 400	1 097 000
Higher education	100 000	232 000	556 000
Unemployed/inactive	315 000	1 193 700	7 195 400
% Unemployed/inactive	36%	75%	65%

Sources: Shah and Willekens (1978 p 38). The 1975 estimates are from Kenya, Statistical Abstracts, 1976, p 271, and Kenya, Economic Survey, 1977, p 40. The projections for 1999 and 2024 are based on the following assumptions:

1. **The annual growth rate in wage employment in urban areas in Kenya was 3.5% for the period 1966-75. This rate of growth is assumed to continue to 2024.**
2. **Informal establishments are assumed to grow at 5.5% annually over the periods 1975-1999 and 1975-2024. This is equivalent to half the growth rate of 11% over the period 1974-76.**
3. **The active age population receiving higher education is assumed to grow at 3.5% annually up to 2024.**

and many other implements can be manufactured with tolerable and increasing efficiency by small- and medium-scale workshops using labor-intensive techniques that economize on capital and foreign exchange. Thus it is important to stress that the existence of that "potential internal market can be used to foster the growth of a local farm machinery-manufacturing industry" (Swamy Rao 1977 p 100). An indication of the magnitude of that potential market is provided by an estimate that 84% of Kenya's arable area is still cultivated with hand tools, compared with 12% cultivated with oxen and 3.5% with tractors (Muchiri and Minto, 1977 p 57). Part of the land cultivated by hand is unsuitable for cultivation with oxen because of tsetse infestation or other reasons. However, some of the most promising opportunities lie in increasing the effective demand for new implements such as interrow cultivators in order to make fuller and more efficient use of the draft power available.

Metalworking skills are of pervasive importance in modern industrial processes and, by fostering local manufacture of farm equipment, they play a unique role in raising the technical and managerial capabilities of rural based workshops. In India, Pakistan, and especially Taiwan, such workshops have frequently progressed from the manufacture of animal-drawn plows and cultivators to seed drills, grain driers, electric motors, diesel engines, stationary threshers, or power tillers (Johnston and Kilby 1975 Ch 8). A recent study of rural small-scale industry in China provides further evidence of the role of decentralized manufacture of farm equipment in fostering the development of metalworking skills and evolutionary growth of an increasingly efficient domestic manufacturing industry (Perkins et al. 1977). By diffusing and upgrading technical skills, such rural workshops also perform a critical role as a technological training ground in developing the capacity to build the machine tools that permit a progressive upgrading of the processes and products of the domestic manufacturing sector. Since manufacturing capacity in East Africa is presently confined to small urban enclaves, this impetus to spreading the growth of such capabilities in the countryside is of special significance in fostering widespread increases in productivity, employment opportunities, and incomes.

Conclusions

In his opening address at the Rural Technology Meet for East, Central and Southern Africa held in Arusha in 1977, Prime Minister Sokoine of Tanzania made the candid observation that "our own efforts to develop appropriate technology... have been isolated, patchy, uncoordinated and sometimes have lacked a sense of seriousness" (1977 p 31). This paper has mainly examined the reasons why such efforts should be pursued seriously. It is thus merely an introduction to the problems that need to be confronted in determining research priorities for identifying a profitable and feasible sequence of equipment and tillage innovations adapted to the needs of farmers in the semi-arid areas of East Africa.

In fact, I have very little to add to an earlier attempt that Gichuki Muchiri and I made to suggest such priorities on the basis of ideas that we had solicited from a number of knowledgeable persons and our review of the literature (Muchiri and Johnston 1975). We examined the principal requirements for equipment and tillage innovations in relation to six problem areas: (1) improved equipment and tillage systems for seedbed preparation and weed control; (2) improved practices for seeding and planting; (3) use of narrow-based terraces, level terraces, bench terraces, or other land-development measures to conserve moisture and soil; (4) improved techniques for training, handling, and maintaining draft animals; (5) measures to secure the most effective utilization of the limited mechanical power currently available and likely to become available in the short and medium term; and (6) various crop production innovations that need to be considered concurrently with tillage and equipment innovations in order to devise more productive farming systems. Fortunately, Muchiri is now actively engaged in research to provide factual information pertinent to the first problem area (Muchiri 1978). Reference should be made to the FAO/UNDP Agricultural Equipment Improvement Project in Kenya, although work is only now getting under way at the Siakago subcenter, which will be carrying out equipment trials under semi-arid conditions. But considerable progress has been made in obtaining a range of equipment for testing and in devising evaluation procedures that include an assessment of an implement's "suitability for local manufacture" whenever that is a relevant possibility. Thus there is now some basis for hope that Kenya is initiating the serious and sustained effort required to make more efficient utilization of the indigenous resource represented by animal draft power.

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Discussant's Comments

S. D. Biggs*

It is a pleasure to open the discussion on these three papers because the authors have presented us with many of the important issues and problems associated with ex poste and ex ante analysis of agricultural technology. I think the most useful thing I can do is to focus our attention on a few general points that have important implications for the development and use of technology in the future.

1. *Determinants of Rural Technologies.* It is clear, both from Johnston's paper on East Africa and from the paper by Binswanger et al. for India, that actual past mechanization programs have been far from optimal in promotion of appropriate agricultural technology to meet government's declared production and equity goals.

In East Africa, governments made commitments to the promotion of improved ox-cultivation but, as a result of reasons such as (1) the tractor being seen as a symbol of "modern" agriculture, and (2) the terms and technological content of aid donor projects, these desirable policies were only feebly implemented, if at all.

In the case of India, one of the justifications given by Binswanger et al. for research emphasis on bullock power is because "where wage rates are low and where little potential for area expansion exists, as in SAT Asia - tractors have extremely low or negative private and social rates of return. There is evidence that tractors are used extensively for transportation and as a substitute of one source of power for another rather than as a means of improving management or cultivation practices. In addition they displace labor, and finally their economies of scale lead to further growth of large farms at the expense of small farms."

Unfortunately the authors of the Indian paper do not go into the *reasons* why inappropriate technology has been promoted in the past. Was it because the Planning Commission got its "choice of technique" analysis wrong and unwittingly promoted inappropriate techniques? Or was it because, although straightforward economic principles were (or could have been) applied, other factors had more influence on the decision-making process of policy makers? I suspect that the latter is true. Because of this, I would suggest if social and technical scientists are interested in influencing the process of agricultural technology decision-making, that we place more emphasis on what Johnston calls "obstacles to the identification and diffusion of 'appropriate' mechanical innovations." Such analysis will quickly lead us into issues of political economy, dependency relationships, the activities of multinational firms and aid agencies as well as the professional training of those who are supposed to analyze technological problems. It seems to me that unless these types of determinants of technology are more explicitly taken into account we shall, I fear, in 10 years again be looking back at a decade of government action and function where the poorest group in rural areas of low income countries have not been the main beneficiaries of technological change.

2. *Resources for Research and Development (R & D).* Johnston suggests that a scarcity of resources for agricultural research is one of the reasons we do not have more appropriate technology available and being promoted in low income countries. While I would agree with him that there could be more investment in research, I feel this type of investment is like any other investment — it depends on the composition and timing of the investment as regards who gains and who loses as a result of the investment decision. I can think of many examples of agricultural universities, agricultural research institutes etc., where teaching and research are not oriented towards rural productivity and equity goals. In my opinion, the more important and difficult issue is

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The opinions expressed in this paper are those of the author and do not necessarily reflect those of CIMMYT or any other institution.

how to change the system of incentives and rewards in teaching and research institutions (in high and low income countries) so as to encourage and support those people who are working on problems facing poor farmers, agricultural laborers, and rural artisans in the low income countries.

3. *Methodologies for Developing New Technologies.* I agree with all three papers that this is an area that needs far more attention. I would suggest that the main thrust in the future must be given to having social and technical scientists work together with village people right from the start, and throughout, any research and extension program. The main focus of this workshop is on how social and technical scientists can effectively work together in analyzing technological problems and help promote new technologies, relevant to the problems facing the poorest groups in rural areas of low income countries. Le Moigne, in his concluding remarks on research in West Africa, places emphasis on a diversified approach to solving specific problems in order to find practical solutions, rather than creating entire new systems of production that are impractical *or* have to be modified to a major degree by farmers. He also calls for extension systems that provide good advice and technology to farmers of different types, rather than extension programs which are mainly concerned with the distribution of inputs. I would agree with his emphasis.

In the paper by Binswanger et al. they describe their experience in the development of a wheeled tool carrier. So far they have found that even under the most favorable circumstances, such machines cannot compete on a cost basis with the traditional implements in traditional agriculture. This is a disappointing result for a group of researchers and for the farmers for whom they are working; however, without being unfair, I suspect that the methodology they are using is not one which is most likely to result in the rapid finding, development, and dissemination of useful agronomy and agricultural engineering technologies. Their machine comes out of a research process where: (1) animal-draft power is the focus of attention rather than a specific cultivation problem that might be solved through various types of draft power, management methods, or other agronomy and agricultural engineering techniques; (2) the machines are *first* developed and tested *on the research station,* then sent out for further testing to *cooperating centers* as well as to villages; and (3) suitable manufacturers are identified at an early stage of *the testing program* in order to have the input of production engineers.

As I see it, the problem with this approach is that farmers, rural artisans, rural service enterprises etc. are not the starting point of the research and extension process and are not totally integrated into the R & D process throughout. I would suggest an alternative approach where:

(i) Engineers (and other technical scientists) as well as applied social scientists spend 2 or 3 weeks *together* in rural areas conducting exploratory research, i.e. *talking* to rural people about their problems, coming up with alternative hypotheses of what might or might not be critical problems and constraints on technological development. This is likely to result in jointly having a whole range of academic solutions rapidly *dismissed* because of such factors as what villagers say about their environments, what the engineer says is technically feasible, what the economist says about current and future factor and product markets, what the researchers learn about people's motivation with respect to production and consumption goals, risk, and uncertainty and attitudes to dependency relationships etc.

(ii) The agronomy and agricultural engineering research is, as far as conceivably possible, conducted in the environment for which it is being designed. There is certainly a place for on-station research, but it has to be justified in the context of the harsh multidisciplinary problems being faced by farmers. In my experience I have not found a situation where you cannot find some farmers who will not give some land for experimentation purposes. This is not surprising, as many farmers and rural entrepreneurs are innovators who are always conducting informal experiments in agronomy and agricultural engineering and finding ways to develop markets for goods and services. In the past not enough agronomy and agricultural engineering and institutional research has been done in villages by researchers of the formal R & D system.

Many of the problems in the "transfer of technology" would not arise if irrelevant technologies and associated institutional structures that governments are trying to transfer to villages had been screened out by discussions between social scientists, technical scientists, and villagers, at an early stage in the formal research and extension process.

(iii) Collaboration with "cooperating centers" is seen as a *starting point* of a research process rather than a relationship where techniques are *sent out for further testing.* These "peripheral" cooperating centers should be seen as a major source of information to influence the objectives and programs of the "central" program. If it is thought that the cooperating centers don't have the skills and capacities to take on such a role, then it would seem necessary to place major emphasis on strengthening these local capacities.

(iv) Multidisciplinary groups of researchers who are working on developing agronomy and agricultural engineering technologies start to use the "informal" R & D system, which is in place in most communities and is already effective in developing new viable technologies. Village people are researchers and innovators, and it is time we started to keep up with them.

I am not sure of the case in the semi-arid tropics, but certainly in the northern part of India and in Bangladesh it has been farmers, village artisans, entrepreneurs of local machine shops etc., who have carried out much of the agronomy and agricultural engineering R & D on cropping patterns, irrigation technologies, management techniques, threshers, animal-drawn disc plows etc., as well as having found methods of repairing and maintaining equipment when similar public sector activities have remained inactive because of a lack of foregin spare parts, a lack of effective demand for the services etc. Not only is it necessary for us to find methods to keep up with the results of this dynamic research system, but also I expect we can learn a lot about relevant methods of research from people who have to worry about the cost-effectiveness of identifying correctly their research priorities and methods.

4. *Analysis on the Effective Demand for Technology.* The last point concerns the future effective demand for technologies. I would suggest that a multidisciplinary macro-analysis be conducted on the likely effective demand for proposed technologies in the future. What are the future relative prices for fuel and forage that are implicitly assumed when a research program embarks upon an animal-draft power program rather than a power-tiller or large-tractor program? What are the cooperative structures or markets for services that we implicitly assume will work when we develop large equipment, for technical reasons of economies of scale, rather than smaller 'divisible' equipment that fits other institutional structures? What are the implicit relative prices of different crops that we assume when we develop one cropping system because we say it is better than another? Have we assumed that rural people will have employment and be able to buy foodgrains and thereby keep up the effective demand and prices for cereals, or have we assumed high unemployment and a lack of an effective market demand for food? What are the minimum policy conditions that will have to prevail in order to enable the poor to benefit from the new technologies?

It seems to me that a considerable amount of current research could be improved if some of these assumptions and questions were clearly laid out and stated at the start of a research program. It is my impression from the African papers that little attention was given to these factors in the preparation of past research programs on ox-cultivation. Unfortunately, it is farmers and other rural people who are left to face these harsh realities when they are expected to "adopt and benefit from" technologies in environments that are not conducive to the use of such technologies.

Emphasis on multi-disciplinary ex-ante analysis on the future effective demand for technology, and for the goods and services that flow from that technology, brings me back to my opening remarks about what are the determinants that promote technology to meet rural production and equity goals. In the past many far-sighted technical scientists have worked on technologies designed to address the problems and needs of the poorest groups of society. However, these scientists have often not been rewarded by their profession or had the satisfaction of seeing their technologies used because government policies to induce the use of those methods and techniques were not implemented.

Chairman's Summary

R. J. H. Chambers*

Three papers were presented at this session. The paper by Binswanger et al. examined the economics of tractors, bullocks, and wheeled tool carriers in SAT India. The situation in French-speaking Africa was reviewed in M. Le Moigne's paper. Bruce Johnston dealt with the East African scene.

The discussion centered around three main issues. Firstly, it was felt that past research in mechanization, both in India and Africa, was generally not consistant with either the stated goals of government policies or the real needs of the farming communities. For example, while weeding is perhaps the most important constraint in African agriculture, preparatory tillage receives primary attention in research. Similarly, while intercropping is an important characteristic of SAT agriculture, it has been largely ignored in mechanization research. It was felt that noneconomic considerations often play a role in promoting mechanization technologies that are inappropriate.

This led to a discussion on appropriate methodology for designing technologies. It was argued that usually field testing under the actual farm environment comes at the last stage, often ending up with frustrating conclusions regarding economic viability of the machine as pointed out by Binswanger et al. It was suggested that it would be far *more* efficient to substitute an approach based on an intensive preliminary interdisciplinary reconnaissance of the actual farming environment in target villages, discussions with farmers regarding immediately obvious solutions and unacceptable alternatives, and then coming back to the experiment station and working on the basis of very specific objectives. The subsequent work also must involve constant contact with the target group.

This generated some discussion on past experiences with testing of technologies in farmers' fields. It was pointed out that the African as well as Indian experience in this regard does not indicate that this is an easy task or that it yields the kind of results described above. The difficulties were recognized to be serious and it was mentioned that such an effort will be wasteful unless it is accompanied by a significant change in attitudes of scientists towards such work and also in the reward and incentive systems in the scientific profession.

The following recommendations resulted from the discussions:

1. Technology design. Programs for research should be drawn up only after a careful multidisciplinary appraisal (by engineers, agronomists, and economists) of the problems of the target group and area. While this was extremely crucial for national programs, the international centers would need to look at the problem in an optimum-mix context.

2. Agricultural policy. A careful evaluation of government policies is needed — particularly in the field of mechanization — and economists must play a leading role in this evaluation.

3. Socioeconomic research at national institutions. National systems must take a very careful look at their research programs in mechanization and examine the relevance and cost-effectiveness of this research in relation to the needs of the target population.

4. Socioeconomic research at ICRISAT. ICRISAT should have a diverse program of research in mechanization in view of the widely differing resource endowment and farm production costs in different SAT countries. In all cases, however, the emphasis must be on real power bottlenecks and cheap implements and/or machines.

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Chapter 6

Analytical Reviews of Literature on the Semi-Arid Tropics of West Africa

Farm-Level Studies in the Semi-Arid Tropics of West Africa

M. Newman, I. Ouedraogo, and D. Norman*

Abstract

This paper presents a brief analytical review of earlier studies on socio-economic problems of farm and village production systems of the semi-arid tropics (SAT) of West Africa. It is to help identify high-priority areas for research by ICRISAT and help provide crop-technology guidelines for those areas. Because new technology may increase inequalities in income distribution at the village level, the authors argue that in designing support systems developers of technology must recognize the heterogeneity of farmers, so that small poor farmers are not ignored and growth is accompanied by equity. Limited knowledge of data-collecting and analytical techniques, coupled with discipline insularity, have ignored distributive justice in the past, but interdisciplinary work can now be done by technical personnel, scientists, anthropologists, sociologists and agricultural economists. Such interdisciplinary work should develop appropriate strategies for the future; this is where the authors envisage a definite role for ICRISAT. With regard to West Africa, they suggest a concentrated input by ICRISAT in one or two localities for several years and going beyond the five crops currently under its mandate so that the entire farming system (including livestock) is considered as a unified whole and developed with firm linkages to national institutions.

The Area

The geographical area discussed in this paper consists of Senegal, Gambia, and Upper Volta, and substantial parts of Mali, Niger, Chad, Northern Nigeria, Ghana, Benin, and Cameroon — the main part of the semi-arid tropics (SAT) of West Africa (Table 1). It constitutes about 17% of the world's total SAT area and includes 23% of the world population living in such areas. An unusually high proportion of the total area is in the SAT ecological region; 67% (average) of the West African countries are in such a region, compared with an average of 33% for SAT countries in the world.

The SAT is defined by Troll (Lindsberg et al. 1966) as areas where the precipitation exceeds potential evapotranspiration for 2 to 7 months of the year. In the SAT of West Africa, the economies have been traditionally dependent upon agriculture, particularly rainfed agriculture, which tends to be seasonal in nature because of the short growing season. Cochemg and Franquin(1967) found that the coefficient of variation of rainfall was inversely related to the average annual rainfall. Consequently, together with the decrease in the annual rainfall and length of the growing season as one moves north through this area, there is a concomitant increase in rainfall variability, particularly at the start and end of the rains. In general terms, cash crops (cotton and groundnut) and millet and sorghum in the south give way progressively to short-season millet as one moves north.

Terms of Reference

This paper is a brief summary of some of the major points in a report requested by ICRISAT (Norman, Ouedraogo, and Newman 1979).[1] The

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1. In the interest of brevity, few quantitative empirical data are presented here; rather, emphasis is laid on giving general conclusions arising from the review, supported by a selected, rather than a complete, list of references.

Table 1. The semi-arid tropical areas of West Africa.[a]

Country	Semi-arid tropical area ('000 sq. km)	Proportion of country semi-arid tropical (%)	Semi-arid tropical population (million)	Number of references[b]
Senegal	196	100	4	187
Gambia	10	100	1	23
Mali	721	60	5	70
Upper Volta	274	100	5	76
Niger	507	40	4	113
Nigeria	693	75	42	216
Chad	514	40	3	16
Ghana	119	50	4	34
Benin	92	80	2	3
Cameroon	119	25	1	29
Total	3245	67	71	767 (1052)[c]

Source: Ryan and Associates (ICRISAT, 1975).

a. These areas are defined as in the text.

b. Includes all references in the partially annotated bibliography submitted to ICRISAT (Ouedraogo, Newman and Norman, 1979).

c. Includes references that are not country specific.

terms of reference included, among others, an analytical review of the available research studies — published and unpublished — on socioeconomic aspects of farm and village production systems of the SAT areas of West Africa, to help identify high-priority topics for research by ICRISAT and to "provide guidelines for the design of viable crop technology for these areas."

The focus of ICRISAT plus the limited time available for the review imposed certain restrictions. For example, neither irrigated agriculture nor livestock (pastoralism) were considered, except where they directly interacted with rainfed crop production.

Methodology

The methodology used in data collection depends on a large number of factors: objectives of the study, degree of accuracy required, research resources and time available, knowledge and discipline(s) of the investigator(s), etc. The methods used range from the case study-direct observation approach to one utilizing a statistical sampling method, where a sample is subjected to various interviewing procedures ranging from single to frequent, and unstructured to structured questionnaire approaches. Although generalizations may be dangerous, if appears from the literature that anthropologists, sociologists, geographers, and most individuals working in the Francophone countries tend to use the case-study approach while agricultural economists tend to use statistical sampling procedures, particularly in Anglophone countries. Depending on the data needs, both approaches have validity, and it is interesting that, increasingly, there are attempts to find common ground between the two. Too often the methodology used in data collection has been inappropriate to the objectives of the studies and in terms of measuring specific variables, thereby decreasing the validity of the results and making comparability between different studies virtually impossible. For example, labor flow data having a continuous nonregistered characteristic (Upton and Moore 1972) require the use of a direct observation or frequent interviewing approach, if measurement errors are to be reduced to a reasonable level. Unfortunately, however, other approaches that severely limit the value of the results have on occasion been used, such as infrequent interviewing, which is valid only for single-point registered types of data. Fortunately, increasing attention is now being focused on rationalizing the approach to be used in data collection (AMIRA 1978; Collinson 1972; Connell and Lipton 1977; Palmer-Jones 1978a).

A detailed discussion of all the specific problems of data collection and analysis is not possible in this paper. However, three problem areas should be mentioned because they are crucial to the subject matter of this review. These are:

(1) In the micro-level studies it is apparent that three biases of the research workers tend to influence their investigation of farmers (farming families):

- "Point" bias is the tendency to consider the farmer at one point in time. This bias causes researchers to overlook the fact that the farmer today is a product of what has happened in the past, and that what he or his descendants will be in the future is partly a function of what happens now. The "vertical" dimension (which can be subdivided into the "historical" sub-dimension in terms of the past, and the "prospective" sub-dimension with reference to the future) is often missing from studies.

- "Individualistic" bias occurs when researchers consider the farmer as an independent decision-maker. But a farmer's decisions are partly the function of his dependency on and relationships to the world around him (i.e., the community he lives in, linkages with the world outside the village, etc.). That type of relationship, which constitutes the "horizontal" dimension, is often ignored by the studies.

- "Homogeneous" bias occurs when farmers as a group are assumed to be homogeneous. Studies with that bias fail to show the dimension of "heterogeneity."

A number of reasons, some unavoidable, cause one or more of these three dimensions to be neglected. This produces severe ceteris paribus conditions in most studies. A reduction of such conditions, which are sometimes not explicitly stated, brings with it a greater recognition of the dynamic environment the farmer operates in, being a product of the "historical" and "horizontal" dimensions, which in turn will help determine the future.

(2) There is the difficulty in defining a sampling unit representing a production decision-making unit (*exploitation agricole*) (Kleene 1976; Maymard 1974; Monnier et al. 1974) that is variably synonymous with a consumption unit (i.e., the farming family). To obtain some correspondence between the two is important in societies where much of the labor on the family farm is from family sources and much of the production is consumed within the household. Complications arise in defining the family because of the progressive breaking up of the traditonal family system, the increased significance of individual decision-makers with the families (Rocheteau 1975; Kleene 1976), and seasonal fluidity in composition of the units resulting from changes in the level and composition of economic activity at different times of the year (Hill 1972).

(3) There is difficulty in measuring work by different family members and in reducing it to a common denominator in terms of productivity. The different approaches to this problem have led to the *actif* concept in the Francophone countries (Echard 1964; Ancey 1975a) and the male adult equivalent, characteristic of the Anglophone countries (Matlon 1977; Lowe in Dunsmore et al. 1976). *The actif* concept is often used in situations where only the stock of labor is measured.[2] Therefore, it should include in its weighting system both the productivity per unit of time and the length of time worked by such individuals.[3]

The male adult equivalent approach, however, is often used in situations where labor flow data are being collected. In such situations, the weighting system needs to reflect only differences in the productivity per unit of time of labor. The weighting systems employed are critical in determining the validity of the results. Unfortunately, it is not always clear what a weighting system was employed and why specific weights were chosen. The relevant weights to be used are further complicated by the fact that the productivity of individuals of different sex and age will vary according to the task and its

2. The Experimental Units in Senegal have recognized the expense and difficulty of collecting accurate information on labor flow data and have in general, therefore, decided that such data should not be collected in their work.
3. It in fact often ignores work done by children (i.e.. usually those under 15 years old.)

urgency (Delgado 1978; Haswell 1975).[4] In view of the seasonality of agriculture in the SAT of West Africa and the resulting variability of labor input, this is a major problem and makes comparisons of different studies difficult.

Schematic Framework

A simplistic framework of some of the possible determinants of the farming system practiced by a farming family is given in Figure 1. The farming family in West Africa is both a production and consumption unit. In order to achieve a specific farming system, the farmer allocates certain quantities and qualities of basic types of inputs — land, labor, capital and management — to which he has access, to three processes — crop, livestock, and off-farm enterprises — in a manner which, within the knowledge he possesses, will maximize the attainment of goal(s) he is striving for. Some of the underlying determinants of the farming system, however, are outside the control of the individual farmer.

Simplistically, the environment can be divided into two parts (IER 1977): the technical (natural) element and the human element. The technical element determines the types of, and physical potential of, livestock and crop enterprises and therefore forms the necessary condition for what the farming system can be. Constituents of the technical element include physical and biological factors, often modified to some extent by man as a result of technology development. However, the farming system that actually evolves is a subset of what is potentially possible. The determinant that provides the sufficient conditions for the presence of a particular system is the human element, characterized by two types of factors: exogenous and endogenous.

Exogenous factors (i.e., the social environment), largely outside the control of the individual farmer, will influence what he will do and/or is able to do. They can be divided into three broad groups: community structures, norms, and beliefs; external institutions which on the input side include extension, credit, and input distribution systems and on the output side include markets; and other influences such as population density and location.

Unlike exogenous factors, the endogenous factors are controlled by the farmer himself; he ultimately decides on the farming system that will emerge, influenced and sometimes constrained by the technical element and exogenous factors.

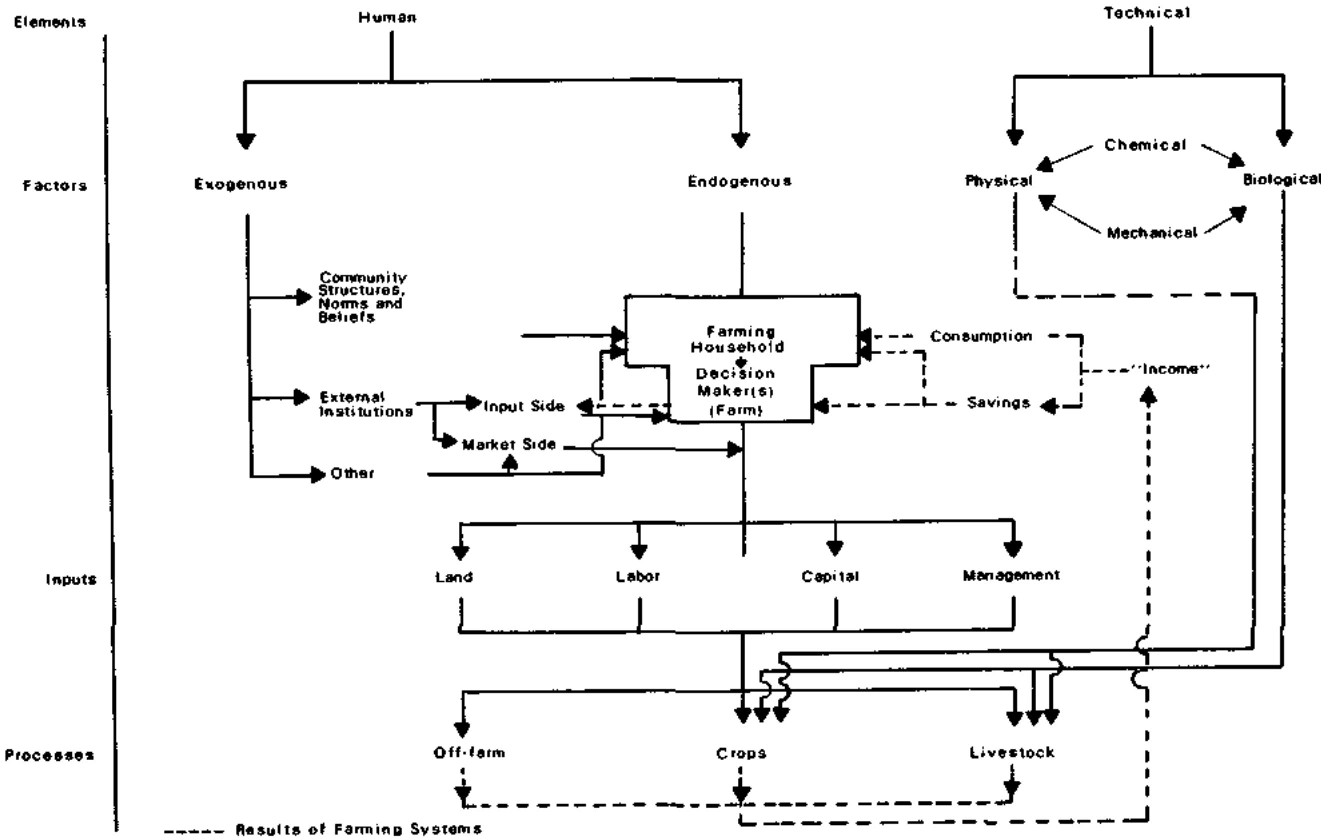
The schematic framework in Figure 1 explicitly takes into account the "horizontal" and "heterogeneous" dimensions. The "vertical" dimension, though not explicitly considered in Figure 1, is the cumulative function of what happens in terms of the "horizontal" and "heterogeneous" dimensions over time. The relationship is schematically represented in Figure 2.

The holistic view of the farmer and his place in the environment is important, we feel, in spite of the considerable problems it created when we tried to limit the content of the review requested by ICRISAT.

We believe that constraints faced by farmers may be articulated in one or more of the dimensions enumerated and that the types of technology that might be developed by ICRISAT, in order to be relevant, must take cognizance of the "historical" and "horizontal" dimensions and must recognize the heterogeneity of farmers. It should also take cognizance of what might happen in the future as a result of its adoption ("prospective" dimension) such as increasing inequality in terms of benefits and increasing divergence of short-run private benefits and long-run social costs. Therefore, put rather crudely, improved technology, in order to be relevant, must be time-, place-, and, to some extent, individual-specific — a daunting task!

In the rest of this paper we discuss some of the major points arising from the review, using the schematic framework in Figure 1 as a backdrop. In each section, along with a brief description of the characteristics, implications that are considered important in terms of the developmental process and the ICRISAT mandate are also mentioned. Although an attempt is made to divide the paper into sections for easier reference, it should be noted that the

4. This discussion considers using the data for work units only. Consumption units would Involve a different weighting system. Unfortunately this difference is not always recognized in the studies reviewed.



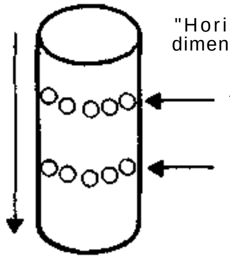
Note: The farmer has to make decisions outside the farming household box (i.e., schematically there is no attempt to internalize all the decisions within the box).

Figure 1. Schematic representation of some determinants of the farming system.

1. The common approach

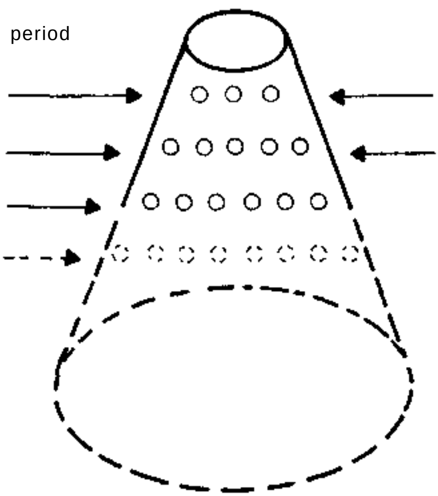
Note: The farmers are assumed to be homogeneous and *ceteris paribus* conditions often ignore the "vertical" and "horizontal" dimensions.

2. The ideal approach



Note: The interaction between the "horizontal' dimension and the "historical" sub-dimension is important in influencing the heterogeneity that exists at present.

3. Hypothesis concerning what is happening over time



Note: It is hypothesized that the breakdown of community structures, norms and beliefs, together with the increased influence of external institutions,may be leading to increased heterogeneity and inequalities developing over time.

Figure 2. The farmer and the dimensions in his environment.

topics *are* interdependent. In certain places, this may cause some duplication in the discussion.

External Institutions

The "historical" dimension is important in determining the type and organization of external institutions. Even in the post-colonial era, it is apparent that the different colonial experiences of the Francophone and Anglophone countries have left their mark (Kohler 1971; 1976; Amin 1975).

In countries of both types, some commonalities exist, such as commodity-based research programs, a bias towards research on cash crops during the colonial era (Lele 1975) and to a lesser extent in the post-colonial era, and traditionally an absence of linkages between the social and technical sciences (De Wilde 1967; Kleene et al in IER 1978).

However, the differences are more striking. Until recently, much of the research in the Francophone countries was directed from France (Kassapu 1976) while much greater decentralization characterized the research sphere in the Anglophone countries. Furthermore, the link between research and implementation, particularly for cash crops (i.e. groundnuts and cotton), has been much stronger in the Francophone countries where support systems on both the input and product side have been strongly coordinated with respect to a particular crop (e.g. SODEVA for groundnuts in Senegal, CMDT for cotton in Mali, etc.).[5] In general, commodity-based implementation programs are not widespread in the Anglophone countries.[6] Consequently, the levels of yields of cotton and groundnuts, and the relative degree to which oxen have been successfully introduced, tend to be superior in the Francophone countries. However, the implementation of integrated rural development projects — popularized by the World Bank — that embrace both food and cash crops is bringing an increasing degree of congruency between the Anglophone and Francophone countries.

Two major factors have influenced government policy on food production, particularly in the Francophone countries: the importance of encouraging export cash-crop production to provide much needed foreign exchange and the desire to provide cheap food for the vocal urban sector (Stryker 1978; CRED 1977).[7] These factors have created problems of stimulating food production for the market. Partly because of the drought in the early 1970s and the general absence of improved technologies for millet and sorghum, some countries have increasingly emphasized rice production on the lowlands (e.g. Gambia, Senegal, Mali). Efforts *are* to be made to reverse the consumer preference for rice (Government of Senegal 1977), which is nutritionally of less value than millet and sorghum. However, Harriss (1978) has suggested that for political and economic reasons, it is unlikely that governments, through pricing policies alone, will be able to stimulate the production of millet and sorghum. It would appear that the only practical way of reversing the trend towards increased rice production is to generate relevant improved technologies for the other *crops.* However, the success of such a program is likely to hinge to some extent on the competitive position of rice. Unlike the Francophone countries, the Anglophone countries have mainly had a free market in millet and sorghum.[8]

The external institutions (i.e., support systems) play a crucial role in creating favorable conditions for the development and adoption of improved technologies for millet and sorghum by farmers. Without this support, it will not be possible for research agencies, including ICRISAT, to develop technologies that will be adopted by farmers.

5. These parastatal organizations have evolved from French-based organizations.
6. Tobacco and tomatoes are rare exceptions (Norman, in Hunter, Bunting, and Bottrall 1976).
7. This has met with only limited success (Harriss 1978).
8. Nigeria has within the last 2 years taken the first tentative steps in government involvement in the marketing of food crops. Indeed it could be argued that even in the Francophone countries the market has in practice been fairly free, since well over 70% of the marketed cereals usually go through private channels (i.e., the parallel market).

Community Norms, Structures, and Beliefs

Traditionally, villages in the SAT of West Africa, whether nucleated or dispersed in a settlement pattern, had a strong sense of community, often with a strong hierarchical system of control (Remy 1977; Ramond, Fall, and Diop 1976). This control was not considered to be very exploitative, however, especially since individuals can only possess usufructuary rights to the land (Hill 1972; Maymard 1974).[9] Haswell (1975) has pointed out that communities have had a "shared poverty" concept, with poverty being primarily determined by the technical element — climate and soil. However, recent population increases, concomitant with increasing contact with the outside world, have resulted in a breakdown of the community spirit, an increase in individualization,[10] and less assumption of responsibility for one's fellow man. Some of the developments associated with this breakdown can be summarized as follows:

1. There is a trend in many areas for the farmers' goal of selfsufficiency to be partially sacrificed in order to produce cash crops. There are no longer serious social sanctions for failing to have enough food in the granary to feed the family until the next harvest.

2. Poverty is becoming individualized[11] and new power groups in the village (traders, money lenders, etc.) who may or may not be members of the traditional elite, are holding economic power over the more disadvantaged groups, without the feeling of responsibility epitomized in the patron-client relationships of traditional communities (Haswell 1975).

3. There is an increasing tendency towards individualization of land tenure (Kohler 1968) although in most areas this is not recognized by law. Usufructuary rights to the use of land are increasingly being rented, purchased, and pledged, particularly in areas where population pressure is becoming a problem (Goddard 1972; Raynaut 1976). In certain areas, where some preferred types of land are very limited, cases have been reported of land being commandeered by the elite who have acquired the benefits of that land for their own use (Agbonifo and Cohen 1976).

4. The characteristics of non-family labor, although not a major component of farm labor for many areas in the SAT of West Africa, have changed. The traditional systems of communal and reciprocal labor are being replaced by more impersonal labor paid in kind or increasingly in cash, by the job or by the day (Raynaut 1973; Unite d'Evaluation 1976). Even the stranger farmer, or the *navetane* system, strongly associated with the cultivation of cash crop groundnuts in Gambia and Senegal, is becoming increasingly monetized.

In spite of rapid social changes taking place, the traditional hierarchical structures are still important in influencing like at the village level and, as a result, care should be taken to draw on such leadership in the introduction of agricultural change (Dunsmore et al. 1976). However, it is also important that inequalities in living standards at the village level are not greatly increased through reinforcing traditional social power with newly obtainable economic power.

Goals

To our knowledge, little rigorous empirical work has been done on the goal(s)[12] of farmers and farmers' attitudes to risk and uncertainty. Indirect evidence is often given that farmers are risk averters (e.g. the practice of mixed cropping including different species and different varieties of the same species, crop diversification, etc.). Implicitly and sometimes explicitly, the authors of the studies reviewed have assumed that the goal of meeting food needs from farm production is important. They have also often

9. Others have, however, questioned the lack of exploitation in traditional societies (Ernst 1976; Kafando 1972). But for reasons mentioned in the paper, we believe that the potential for exploitation is likely to be exacerbated as time goes on.

10. Unfortunately, many development programs have concentrated on individualization to the detriment of the traditional strengths of the community.

11. Haswell (1975) terms It "institutionalization" of poverty.

12. Ancey (1975b) has provided a useful discussion on the multiplicity of goals that are likely to exist in farming families in West Africa.

assumed that spare resources over and above those required to meet the subsistence goal are devoted to maximizing profits through producing products for the market.[13] Some studies have suggested that, on occasion, as a result of external pressures — such as skewed support systems (Lele 1975) or the compulsion and need for money to pay taxes (Campbell 1977; Nicolas 1960), changing desires (as for independence on the part of individual members of the family Rocheteau 1975; Albenque 1974) or economic necessity (Matlon 1977)— there has been a diminution of the subsistence goal in favor of profit maximization involving the production of export cash crops. There is no question that much more work needs to be done on the goal(s) and attitudes of famers towards risk and uncertainty.[14] Such knowledge is an essential ingredient in designing relevant improved technology. It is also important to assess the impact of increasing integration of farming families into the market economy on their perspectives, management, and goal(s) and to ascertain how this will influence the way in which their resources will be allocated in the future.

Land Input

As mentioned earlier, individuals in the SAT of West Africa usually only possess usufructuary rights to land. Rights can be inherited through the operation of the customary or Maliki law.[15] In areas of low population pressure, the amount of land farmed is in general a function of family size (labor force) and the quality of the land. As population density increases, two and perhaps three significant changes are taking place:

1. Farm size is decreasing (De Wilde 1967), with the result that the short-run private opportunity cost of leaving land fallow is increasing (Norman and Pryor 1979). The problem of finding new ways to maintain soil fertility becomes more and more urgent, since both the length of fallow and amount of land fallowed is decreasing.

2. Distribution of land among producers may become an increasing problem. Land, because of the mode of tenure and the historically low population pressure, has been fairly evenly distributed. Unfortunately, statistics giving trends over time are not generally available. However, there is fragmentary evidence that inequalities are growing. Increased population pressures have on occasion encouragd influential groups in villages to increase their relative share of the land cultivated (Swanson 1978; Dubois 1975). Such moves have been encouraged by the overall shortage of land and/or by the introduction of certain types of improved technology, such as dry-season tomato production in northern Nigeria (Agbonifo and Cohen 1976), and oxen in the Gambia (Weil in McLoughlin 1970). Increased monetization of the economy and the trend towards individualization of land tenure mean that usufructuary rights are more frequently being obtained through pledging, purchase, leasing, and renting (Goddard 1972). Such trends obviously have serious implications in terms of the future and, because of the apparent increasing heterogeneity of farmers in terms of resource base, for differentiation in terms of the development of relevant improved technologies.

3. In much of the area, particularly where the Maliki law applies, there is progressive fragmentation of farms. Although there are occasional references to attempts at spontaneous consolidation of land (Goddard 1972), much of the impetus tends to come from the outside (e.g. in the Experimental Units in Senegal as described by Faye and Niang 1976; near Fana in the CMDT area of Mali). Although a certain degree of fragmentation has some advantages it does cause particular problems when mechanization is being introduced.

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13. Both of these goals or that of simple profit maximization have been assumed in the few linear programming studies done in the SAT of West Africa (Richard, Fall, and Attonaty 1976; Ogunfowora 1972; Bourliaud, Boussard, and Leblanc 1975). Hopkins (1975) also using a linear programming approach, has attempted to come to grips with the problem of uncertainty by incorporating a game theoretic approach. Barnett, working at Purdue University, is at present completing a goal programming study.
14. Work of the type that is currently being undertaken by Binswanger (n.d.) in India could prove to be of particular value.
15. Changes towards forms of individual tenure are taking place as a result of increased population pressures, particularly In and around urban areas, settlement and irrigation schemes, and large, mechanized farms utilizing tractors.

Labor Input

Family Structure

Mention was made earlier about defining a family or decision-making unit. A common trend in the SAT of West Africa is that the traditionally preferred extended or complex family unit, consisting of more than one married man plus dependents, is breaking up into nuclear simple family units — one married man plus dependents — within the same compound, and these then may eventually form separate compounds (Nicolas 1960; Benoit-Cattin 1977b; Buntjer in Mortimore 1970). The underlying reasons, as with the changes discussed in community structures, norms and beliefs, revolve around increased contact with the outside world and monetization of the economy. However, the rate at which this change is taking place depends on a number of complex interactions. It has been suggested that the introduction of cash crops, secular education, increased off-farm employment opportunities, new settlements, and migration encourage this breakup, although the speed at which this takes place may be tempered by the strength of the traditional hierarchical structure, the ethnic origin of the people concerned, the ownership of cattle, etc.

A number of important implications arise concerning such a trend. Two of them are:

1. Fields farmed by families are traditionally divided into common and individual fields. The common fields — controlled by the family head —traditionally provided food for all members of the family. An increasing proportion of the fields are, however, coming under the control of other individuals in the family. There is a decrease in the obligations of family members to work on the common fields, and there is no longer the assurance of food from the family farm to meet subsistence needs. Increased individualization of fields and the need for cash to pay taxes have both contributed to encouraging the growth of export cash crops for the market. Decisions are increasingly made by individuals within families rather than the family head; this creates problems in introducing improved technology, especially if an extension or institutional credit program is involved, because such programs tend to be directed at family heads.

2. In many areas the breakup of families is resulting in smaller farms (although with similar land-per-resident ratios), increased fragmentation of fields, younger and relatively inexperienced family heads, and often increased dependent-per-worker ratios, with resulting poorer net worth and cash liquidity levels. Such trends raise questions about the appropriateness of certain types of technology (e.g. oxen)[16] and processes (e.g. cattle ownership).[17]

Total Time Worked

Farm work in the Sahelian and Savanna areas revolves around crops, livestock, and off-farm enterprises. In much of the area labor, not land, limit the expansion of production (Unite d'Evaluation 1978; Ogunfowora 1972; Lewis 1978). However, it is unfortunate that there are very few detailed labor flow data by season, job, age, and sex. Nevertheless, some generalizations are possible:

1. The major input on the family farm tends to be provided by family members (Lowe in Dunsmore et al. 1976) and often by family male adults (Matlon 1977). The significance of female adult labor on the farm varies according to custom (Hill 1972), tasks to be performed (Norman 1972), urgency of the work, and the crop grown (Lowe in Dunsmore et al. 1976). In terms of hired labor, age-set, reciprocal and communal labor have, as mentioned earlier, increasingly given way to labor paid by the hour and job (i.e. contract), remunerated in kind, or increasingly in cash, with contract work receiving the highest remuneration when reduced to a per-hour basis.

2. The annual total work by family male adults often appears to be rather low. However, in evaluating it, one must consider the overriding significance of the seasonality of agriculture. The coefficient of variation for monthly inputs on the family farm increases as one moves north through the region (Norman and

16. This observation concerning oxen Ignores the possibility of hiring them or using them to do contract work for other farmers.
17. The poorer net worth and cash liquidity levels are likely to reduce the possibility of purchasing cattle while ownership would, due to labor limitations, entail management by herders.

Pryor 1979). This creates two problems: labor bottlenecks during the rainy season, and underemployed labor during the dry season.

Seasonality

The allocation of time worked by family members in each of the three processes attempts to even out the annual flow of labor. For example, off-farm work is emphasized during the dry season but substantially reduced during the rainy season. Nevertheless, for a number of reasons, complete compensation resulting in the same amount of total work each month during the year is not usually achieved (Norman and Pryor 1979) although obligatory social activities can account for a lot of so-called spare time during the dry season (Delgado 1978). Efforts to increase the productive use of labor during the dry season also involve cultivating the limited amounts of low land by using residual moisture or irrigation (Lahuec 1970), going on short-season migration (Faulkingham 1976), etc. Attempts *to* increase annual labor productivity results in longer term migration to new settlement areas (Benoit-Cattin 1977a), urban areas, or more humid areas to the south (Byerlee et al. 1976).

A number of seasonal labor bottlenecks have been identified in different studies. These must be assessed with care because labor bottlenecks can be a function of the aggregation period (e.g. week or month), length of the growing season (the shorter it is, the more peaked its labor activity), the type of technology employed, and the power source. At the risk of over-simplification, the following generalizations appear to be possible:

1. With only hand labor using indigenous (traditional) technology, weeding is often considered to be the most demanding operation (Norman and Pryor 1979).[18]

2. Introducing improved land-intensive technology (e.g. seed and fertilizer) without changing the power source shifts the bottleneck period from weeding to harvesting the increased yields that result from its adoption (Norman in Kowal and Kassam 1978). However, care should be taken in interpreting this since timing is a particularly critical factor in the weeding operation (Haswell 1953; Matlon and Newman 1978). Analysis of the labor flow data in aggregation periods of less than a month would probably enhance the weeding bottleneck period compared with harvesting.

3. A change from hand to animal power, using indigenous technology and ridging equipment, accentuates the weeding bottleneck bacause it enables preparing larger areas of land, which then have to be weeded mainly by hand (Tiffen 1971). Also, the harvesting bottleneck may under certain conditions be somewhat more concentrated because land preparation, and hence planting operations, are carried out more efficiently and quickly.

4. The combination of animal power with ridging, planting, and weeding equipment — together with improved land-intensive technology — tends to accentuate the harvesting bottleneck even further (Faye, personal communication), although this can be eased somewhat by carting the harvest from the field.

Traditionally, farmers have used a number of strategies to alleviate labor bottlenecks such as weeding. Some well-established ones are: working more days and longer hours per day on farm work at such periods (Jones in McLoughlin 1970); reducing time spent *on* off-farm work (Matlon 1977); in some areas using relatively more labor of women and children; when possible, hiring labor (Kohler 1971; Lewis 1978) although for a number of reasons this has limited potential;[19] and growing crops in mixtures.

In view of the seasonal labor bottlenecks discussed above, the implications for develop-

18. Land preparation is also sometimes stated to cause a labor bottleneck. This Is particularly so when timing is important due to the shortness of the growing season (Unite d'Evaluation 1978).

19. Unlike India, West Africa at present has no class of landless laborers in rural areas. The opportunity cost of hired labor, which comes mainly *from* other farming families, is therefore high. An additional complicating feature is that such labor is often required when the cash liquidity levels of families are poor (Matlon 1977). It could therefore be argued that In West Africa the negative effects of labor bottlenecks are more important than the possible positive effects that have been suggested in India in providing a source of employment for landless laborers.

ing relevant improved technologies are important. Too often, the technological development aim of maximizing yield per unit area, or of increasing the area cultivated, has resulted in the development of irrelevant improved technology, which, if adopted, would result in even greater seasonal bottlenecks (Kafando 1972). Use of animal power to alleviate specific bottlenecks has been most widely applied, while chemical methods (e.g. herbicides) and biological improvements (e.g. varieties and practices avoiding demand during peak labor periods) are still in their infancy. But efforts to improve labor productivity in such periods as weeding are of critical importance. This is illustrated by the fact that the marginal productivity of labor at such a period can be as much as three to four times higher than the wage rate (Norman 1970). It should also be recognized that, in developing improved technologies, overcoming old problems may result in the creation of new ones.

Capital and Cash Input

Traditionally, the capital owned by farming families, apart from livestock, consisted largely of goods produced by them through a direct embodiment of labor, such as hand tools, grain stores, etc. Consequently, capital levels have tended to be low (Hopkins 1975; Ernst 1976). Livestock have multiple uses: they are a form of savings and investment (Eskelien 1977), sources of meat and manure and, depending on the type, draft power and/or by-products. Ownership of livestock, apart from cattle, tends to be widely dispersed, both between and within families. Cattle ownership, on the other hand, tends to be unevenly distributed, being concentrated towards the wealthier, often more influential, families (Lowe in Dunsmore et al. 1976).[20] Ownership and management function are sometimes separated, the latter being in the hands of nomadic herders, usually the Fulbe, who also own cattle in their own right. Such differentiation causes potential problems in the improvement of livestock husbandry (Eriksen 1978).

With the introduction of improved technology, there has been a change in character of capital to a type that involves purchasing in the market, and which is *no* longer simply produced through utilizing labor at the farm level (e.g. inorganic fertilizer, animal equipment, etc.).

Traditionally, most explicit farm expenditures have been for payment of nonfamily labor (Norman and Pryor 1979). Such payment was often in kind, although this is being replaced increasingly by cash, particularly when cash is available, as after harvesting. The seasonal cash flow, which tends to be inversely related to the level of agricultural activity, has caused particular problems. The time when the level of agricultural activity is approaching its peak — June to September — coincides with the time when cash resources are at their lowest ebb. With the introduction of improved technology, this problem is likely, initially at least, to be exacerbated. Traditional sources of credit, often obtained for reasons of consumption during the preharvest season, reputedly often carry high implicit, if not explicit, interest rates (Dubois 1975), although this is to some extent a function of source (King 1976), position, and collateral (Haswell 1975). This has led to attempts to introduce institutional forms of credit, both short-term (e.g., fertilizer, improved seeds, etc.) and medium-term (e.g., oxen, equipment).

Two criteria are often used in evaluating such credit: repayment rates and, perhaps less commonly, equitability of access. In terms of repayment rates, it appears in general that high levels are only achieved when such programs are carefully coordinated with other external institutions and support systems, particularly input distribution and marketing of the product (King 1976). Certainly this has been true with respect to the introduction of oxen draft systems, which are closely correlated with the presence of a viable cash crop (e.g., groundnuts in the Sine Saloum area of Senegal and in the Gambia, cotton in Mali Sud and the Gombe area of Nigeria). Cooperatives or "precooperatives" have often been used by government to encourage equitability of access to institutional credit (e.g., Senegal, Niger, Nigeria). However, because in traditional village societies the preconditions for true cooperatives to function cannot be met, or have not been met, success is often limited (King 1976; Gentil 1971; Storm 1976).

In India, oxen are an integral part of the

20. Management, and maybe also ownership of cattle, is also a function of ethnic origin.

subsistence sector; in West Africa, however, it is difficult to envisage millet and sorghum, which are mainly food crops, sustaining the economic viability of oxen and equipment via credit programs. This is at present being tried in areas where no export cash crop exists (e.g., Operations Mils in Mali) but the present pricing policies — and their implementation — on such crops in Francophone countries, together with a lack of improved technologies, would appear to reduce this possibility even further.

Cropping Systems

Crops Grown

The crops that can be potentially grown are, as mentioned earlier, determined by the physical and biological factors that comprise the technical element. However, the crops that will be grown are a subset of this and reflect both the "horizontal" (i.e., exogenous and endogenous factors) and "historical" dimensions. These perspectives are necessary to appreciate the dynamic and evolving nature of the crops grown in the SAT of West Africa. Several writers have, as noted earlier, recognized the impact of colonial and post-colonial policies in encouraging production of export cash crops. Probably one of the best documented studies has been that undertaken by Haswell (1975) who studied a Gambian village at different times *over* a period of 25 years. She found, for example, that:

1. Early millet and hungry rice, the traditional early-harvested crops that help shorten the hungry season, had decreased in importance because of the decreased labor available from women and children who had traditionally cultivated the crop. Women had changed from working on upland (rainfed) crops to swamp rice, made possible when the government built causeways.

2. Groundnuts, due to favorable government policies, had increased in significance in terms of both area cultivated and proportion of total production harvested.

3. Nevertheless, until the introduction of oxen in a government supported scheme in the 1960s, there was a downward trend in the area of rainfed land cultivated, a trend that had commenced with the move of women to swamp-rice work. With the introduction of oxen, this downward trend was reversed. Although some of the increased cultivated area went to groundnuts, there was a resurgence of interest in growing late millet, particularly mixed with groundnuts. Weil had also noted in McLoughlin (1970) the trend back to food crops as a result of the introduction of oxen. However, the food/cash crop ratio is still lower than earlier *on* upland crops, although some of the slack has been taken up with the increase in swamp rice, where the yield potential is much higher.

As the preceding example shows, it is important when developing an improved technology, to understand the dynamic environment in which the farming family operates. It is important to assess the possible relevancy of the technology, not only in terms of the target group to whom it is being directed but also in terms of the external institutional support system required for its adoption. Also an attempt needs to be made to assess the possible ramifications of its adoption, such as, changing responsibility and reward ratios, particularly among the sexes within the family (Eskelien 1977), increasing inequalities in the society, etc.[21] There is no question that these issues have often been ignored in the technology-development[22] and implementation phases.

Cropping Practices

It is not possible to discuss the cropping practices of farmers in detail. These practices have evolved through generations (Swift 1978; Johnson 1972) and reflect adaptation to the environment. The relatively recent accelerated population increases have, however, upset the

21. We recognize that such an assessment ex ante is likely to be crude but we believe that such an attempt is necessary in order to provide a breathing space for determining possible research priorities, developing possible corrective development strategies, etc.

22. Also, most research has ignored the determinant factors related to the marketable surplus of food crops, preferring to assume that a certain proportion of total production will be marketed. For ICRISAT purposes, it is important to understand the effect on farmers' behavior of the differential risk attached to an assured market price for export crops without a similar assurance for food crops.

traditional adaptation process, which requires time. This highlights the necessity of developing relevant improved technology. This does not mean that traditional practices should be ignored. Indeed, it is apparent that while many of these practices are firmly entrenched within the farming systems and will be difficult to change, there are many which can be used as building blocks for developing improvements. Practices discussed in some detail in various studies include ridge, mound, and flat cultivation systems; use of plant indicators in assessing soil fertility; burning bush, crop residues, and sometimes manure; and explicit (year to year) and implicit (within year)[23] rotations. There are, however, two additional specific practices that deserve special mention in the context of West Africa: "ring" cultivation, and mixed cropping systems.

"Ring" Cultivation System

Throughout many parts of the savanna areas of West Africa, a system has traditionally been practiced that involves the permanent cultivation of some fields, usually near the compound, where fertility is maintained through manuring. Fields farther away *are* cultivated for a few years, after which soil fertility is restored through fallowing (Marchal 1977). However, increasing population densities have upset this balance. In some areas, the increasing land shortages are resulting in a higher proportion of permanently cultivated fields, while the remaining fields are left fallow for progressively shorter periods. Traditionally, there have been symbiotic relationships between livestock herders and sedentary crop farmers in which manure for fields is an important element. There is certainly evidence that rates of manure applied increase as the proportion of land that is permanently cultivated increases, and that it becomes more of an economic good (Norman and Pryor 1979). However, it has also been noted that, apart from a few exceptional areas (Mortimore and Wilson 1965), this has not forestalled the decrease in yields, a problem that has been of particular concern in Francophone countries where attempts have been made to alleviate the problem with the introduction of oxen.

Mixed Cropping

Results in three areas in northern Nigeria (Norman and Pryor 1979) indicate the overall dominance of mixed cropping[24] over sole crops. While yields of individual crops were depressed when grown in mixtures, such reductions were more than offset by other crops in the mixture, resulting in a higher return per mixture when expressed in value terms. Annual labor inputs were higher per hectare for crop mixtures, although the differential was reduced when the labor put in during the labor-bottleneck period was considered. In spite of the higher labor inputs, the returns per annual man-hour and to an even greater extent, per man-hour put in during the labor-bottleneck period, were higher for crop mixtures than for sole crops. The latter results indicate that mixed cropping helps alleviate the problem of the labor-bottleneck period, which in this case was weeding (Ogunfowora 1972). Finally, the results show that growing of crops in mixtures under the existing technological levels in the areas studied was not only more profitable but also more dependable (Abalu 1976).

In general, the traditional practices in growing crops have been neglected in the development and introduction of improved technology. The situation as it exists today is once again the function of the interaction of the "vertical" and "horizontal" dimensions. For example, in Francophone countries, where export cash crops were introduced and yields of such crops substantially increased, much of the crop is grown in sole stands. This is probably a reflection of the technology having been developed for sole stands and the success of the external support systems (i.e., external institutions), which encourage the growing of these crops according to the official recommendations. In areas where yields have not been raised so dramatically.

23. By this is meant the practice of growing crops in mixtures. Splitting ridges every year (Buntjer 1971) means that the crops grown on a particular piece of land will vary from year to year although the same mixture may be present as a whole.

24. For the purpose of this paper, *crop* mixtures will be defined as a combination of two or more crops of different species or varieties present on a given piece of land at the same time.

because the improved technology has not been adopted, the export cash crops are still often grown in mixtures (e.g., Nigeria).

The practice of mixed cropping is still very dominant in food crops[25] where, as mentioned previously, improved technology is not generally available. Mixtures of millet or sorghum and cowpea — for grain but also as forage — are very common throughout the area (Republique du Niger 1973) with millet/sorghum and millet/groundnut or sorghum/groundnut mixtures sometimes found. Although such combinations are often mentioned, empirical analysis of them is generally lacking.

ICRISAT studies in India have observed that the high-yielding varieties have increased the significance of sole cropping (Jodha 1977). It is tempting to conclude that adoption of improved technology will and should lead to the demise of mixed crops. However, technology development and extension programs have concentrated on working with sole crops and only recently has empirical work undertaken by technical scientists — particularly at ICRISAT and the Institute of Agricultural Research in northern Nigeria — demonstrated the potential for growing crops in mixtures, using improved technology. It has also been demonstrated that, although the number of crop mixtures apparently decreases with the introduction of animal traction, it is certainly not imcompatible with its presence (Unite d'Evaluation 1978).

In the light of these results, there appears to be considerable justification for increased emphasis on developing improved technogies for mixed crops in the SAT of West Africa, especially as the potential for sequential cropping is circumscribed by the shortness of the rainy season. Such emphasis should concentrate on working with crops that, exhibit complementary relationships. Complementarity will be enhanced when one or more of the following characteristics offset the competitive relationships between the species under consideration: different growth cycles, different rooting habits, symbiotic relationships between different species, compatible labor demands and practices, etc. One criterion in evaluating the results of some crop mixtures should be the multiple use of the products, for both human and animal consumption. As mentioned earlier, it is likely that in some areas crop residues from cowpeas for livestock food may be a more important product than the grain, which is used for human consumption.

25. This is true in both the Anglophone and Francophone countries.

Crop Livestock Interaction

Other than Animal Traction

The potential benefits of some degree of integration between crops and livestock have long been recognized in the SAT of West Africa. The integration of crops and livestock can lead to more efficient use of land unsuitable for crop production, provide a use for crop residues and by-products, provide manure, and be a source of income, savings, and investment. This relationship has developed in spite of the fact that often livestock ownership and management is in the hands of nomadic herders, while crops are grown by farmers. Such a symbiotic relationship developed traditionally in areas with relatively favorable land/labor relationships. However, large increases in population density have forced and are forcing changes in the traditional relationships. The diminishing availability of land is resulting in problems concerning alternative use of land, conflicts between herders and farmers (Campbell 1977), conflicts concerning other resources such as labor and capital being devoted to products for human consumption or to animal production (Delgado 1978) and declining soil fertility. It is one of the paradoxes of the ever-decreasing land/labor ratio that the increasing conflict between devoting land to crop or animal production inhibits the beneficial effect that livestock can have in preventing the decline in soil fertility. It is of paramount importance, in the interest of long-run ecological stability, that the present competitive relationships that are developing be reversed and symbiotic relationships be reestablished. Apart from present research on animal traction, this is a neglected area in terms of technology development and implementation programs in the SAT of West Africa.

Animal Traction

Animal traction in the West African context, in contrast to that of SAT India, has a history of less than 50 years (Hasif 1978). The introduction of animal traction can help increase the productivity of labor through the use of equipment designed to increase the efficiency of labor at seasonal bottleneck periods. The more traditional idea of draft power to aid in increasing the area of cultivation (i.e., extensification) is being replaced, particularly in the Francophone countries, by the concept of draft power as a way to increase the productivity of soil (i.e., intensification) through manure application, deep plowing enabling the burial of crop residues, etc.

How successful has animal traction, including not only oxen but also donkeys and horses, been on lighter soils? Animal traction in the West African context is, as mentioned earlier, closely linked with the commercialized economy. Its successful introduction has required the production of an export cash crop[26] to provide the revenue to pay for the equipment and sometimes the animals, complemented by a strong support system (i.e., external institutions) in the form of an input distribution system, institutional credit, extension service, and market for the product.

Many studies have considered various aspects of animal traction.[27] However, some of the problems mentioned earlier include:

• lack of trained animals and operators, especially for inter row cultivation (De Wilde 1967, Wilcock, personal communication);

• weakness and insufficiency of draft animals, caused by lack of supplemental feed (Weil in McLoughlin 1970);

• inappropriate equipment (Lowe in Dunsmore et al. 1976, Rocheteau 1975);

• inadequate facilities for repair and servicing of equipment;

• nonavailability of suitable equipment—such as ridgers and plows — during peak periods (Tiffen 1971);

• under utilization of animals during the year as a whole (Zalla 1976);

• fragmented holdings[28] that reduce work efficiency;

• damage to equipment from the large numbers of tree stumps[28] in the fields; and

• lack of finances to help farmers hire draft animals.

There are in addition two major problems that deserve special mention:

1. The economics of animal draft power is being questioned, even for families that previously had large enough farms and were located in areas where export cash crops could be produced. In recent years, prices of cash crops have increased relatively less rapidly than prices of animals and equipment (CRED 1976; Traore and Toure 1978). This trend is slowing down the adoption of animal draft power and reducing the beneficial interaction between crop production and livestock. Another danger further aggravates the dual economy that appears to be developing between farmers who own oxen and equipment and those who do not.[29] Relationships between families, who own draft animals and those who do not, in which services provided in the form of plowing are paid for in terms of labor, are reported in various studies (Ernst 1976). The potential for exploitative relationships developing is obvious, especially if such labor is demanded at times when its opportunity cost is high.[30]

2. Incorporating residues by deep plowing (*enfouissement*) after harvest, which is the cornerstone of the intensification policy, has not

26. Lowe (Dunsmore et al. 1976) and the IER studies indicate that it is extremely difficult for animal traction to be profitable when land Intensification techniques are not used to raise yields of export cash crops. However, somewhat in contradiction to this are the results from the Gombe area in Nigeria, where yields of cotton, although higher than those obtained traditionally, were still well below the level at which they potentially could have been (Tiffen 1971). Even so, animal-traction introduction has met some degree of success in this area.

27. Much of the work of CNRA, Bambey, has addressed this issue.

28. The Experimental Units have specifically addressed these issues by giving incentives to farmers to destump their fields and by encouraging consolidation of fields (Faye and Niang 1977).

29. Of course, there always have been farmers who could not reasonably expect to have oxen. Those either have farms that are too small or are located In areas where there is no viable export cash crop.

30. It would appear that this will always be apparent to a certain degree, although the potential for this is likely to be higher when relatively few families own oxen.

been successful to date (Hopkins 1974). Farmers have tended, certainly initially, to have seen the use of draft animals more as a means of extensification rather than of intensification (Millevelle, personal communication). Although this is likely to change over time as population density increases, it is apparent that there is a divergence between the short-run benefits of deep plowing and the long-run social costs of doing nothing, which will result in declining soil fertility.

The central problem is that deep plowing is extremely time-consuming, and the period available for doing it — following harvest but before the soil hardens — is too short for the operation.[31]

Technical Change, Levels of Living, and Income Distribution

Comparison of levels of living in rural West Africa is virtually impossible on the basis of research to date. Income figures are difficult to determine because many of the farm inputs and products do not pass through the market place and because incomes are rarely reported from all sources. Hence figures derived are time and location-specific, and not often related to the cost of living.

Of specific interest, in terms of this review, would be information on inter- and intra-year variations in the level of living and on what is happening to the distribution of resources that raise the standard of living within communities over time. Haswell (1975), in expressing farm production in kilograms of rice equivalent per head per year, indicates that the average level of living has increased in the rural area she studied in Gambia *over* the last 25 years.[32] Also, evidence of the proliferation of metal roofs, iron beds, transistor radios, and bicycles would indicate that this is true, especially when draft animals are being satisfactorily employed. However, obvious breaks in the trends are found in a time of drought such as occurred in the early 1970s. Various strategies encouraging or forcing families increasingly into the market economy have made them more vulnerable to drought (Lewis 1978)[33] and hence these strategies potentially increase the annual variation in levels of living, unless incomes can be raised substantially above the subsistence level.

Mentioned frequently in the literature is the seasonal variation in levels of living, referred to as the hungry gap (*soudure*) (Raynaut 1973). Food availability is often at its lowest level when the demands of the agricultural cycle are highest. Severity of this period is inversely dependent upon the supplies of food remaining from the previous harvest, the ability to purchase food during this period, and the success of early maturing crops. If a hungry gap develops, there is often a loss of body weight because of the reduced food intake in relation to the increased working burden (compare Grant 1950 with Platt in Banks 1954). At the same time, this has a further debilitating effect in increasing the chances of nutritionally related diseases and a reduced resistance to other illnesses (Chambers and Longhurst 1978). Seasonal hunger is important in terms of both research and implementation programs. Two important implications arising from a consideration of this are as follows:

1. It is unlikely that increased productivity of labor, except perhaps through changing the power base, will be possible for many farming families during peak labor demand periods, without an improvement of their nutritional levels.
2. The hungry gap has particularly adverse effects on the more disadvantaged members of the society. With the hypothesized change from shared poverty and social power to increased individualization and an economic power base, such families are becoming more vulnerable to exploitation, resulting in what we earlier termed individualized poverty. This change results

31. The Experimental Units in Senegal are trying other possibilities. However, these will Involve a move to tractor mechanization, a scheme that is unlikely to have any wide applicability.
32. Whether these increases are satisfactory, especially when compared to the nonagricultural sector, is not discussed in this paper. However, the increases in rural-urban migration (ORSTOM 1975) would indicate that such increases are not keeping pace.
33. For example, through decreases in the amount of food grain kept in traditional grain stores.

from such families selling their labor to better-endowed farmers to the neglect of their own farms, and therefore having to accept a lower income from their own farms for short-term survival until the next harvest (Matlon 1977). Another strategy with equally severe long-run consequences is for such farmers to obtain consumption credit which is repaid at high explicit or implicit rates of interest at harvest (Dubois 1975).

Apart from Matlon's (1977) research in Northern Nigeria, little rigorous empirical work has been done on the distribution of incomes. Both Hill (1972) and Matlon have suggested that there is a degree of heterogeneity among farming families, but laws of inheritance, a relatively egalitarian land tenure system, availability of surplus land, traditionally handpower-based technologies and presumably traditionally community-minded ruling elites meant that incomes were fairly evenly distributed in traditional settings. However, Matlon also presents evidence supporting comments made earlier in this paper that the degree of equality is inversely correlated with village size, population pressure and the degree of involvement in cash markets. The trend towards increasing inequalities in income distribution at the village level that this implies needs to be viewed with some concern. We may ask: is this unavoidable? To the extent that technology development has not recognized the heterogeneity among farmers and also that the support systems (i.e. external institutions) have been geared towards the better endowed or more influential farmers, the answer is yes.[34] In such cases, if the societies of the West African SAT have a genuine concern for the goal of growth with equity, it is extremely important that organizations such as ICRISAT develop potential strategies that will avoid such potential abuses.[35]

Why have distributional problems in terms of societal power, inputs, and incomes not received such attention in the West African setting? We believe that two reasons are: limitations of relevant data-collection techniques and analytical techniques, and discipline insularity. Much of the work undertaken by agricultural economists, for example, has been based on a neo-classical marginalist framework and involved transferring, with little modification, ideas and approaches that have been "learnt" in the so-called "capitalist" societies (Palmer-Jones 1978b). A "classical" approach has been used, for example, in arguing that farmers allocate their resources to products in an economically efficient manner. As a result, it is often argued that they have a goal of profit maximization and that the only way to improve their level of well-being is through development of improved technology (Norman 1970). The preoccupation with allocative efficiency has detracted from the importance of also looking at technical efficiency. There is increasing empirical evidence that differences in technical efficiency can and do exist among farmers (Matlon and Newman 1978). Another area that has been neglected has been that of institutional support systems and their efficiency in terms of ensuring equality of access.

The implications of these are very important and return us to an important theme of the paper — trends in distribution. The differences in technical efficiency, which can be caused by a number of interdependent factors, go far beyond economic variables to embrace technical and non-economic (societal) variables, and, if not recognized and corrected by appropriate strategies, may result in the development of further inequalities. The role of interdisciplinary work — that is, technical personnel, scientists, anthropologists/sociologists, and agricultural economists — in correctly diagnosing the interdependences and in developing appropriate strategies is obvious.

Implications for ICRISAT

In recommending an approach to be used by the Economics Program in the SAT of West Africa, it is important to bear in mind the official objectives of ICRISAT (ICRISAT 1977). Although these do not explicitly state a distributional objective, the former director has stated that the

34. Whether it is possible to avoid the breakdown of traditional community structures, norms, and beliefs without a basic change in ideology is beyond the scope of this paper and, indeed, the mandate of ICRISAT.
35. For example, a range of improved technologies should be developed that are sensitive not only to the heterogeneity in the technical element but also in the human element.

job of ICRISAT is to help the poorest segment of humanity (ICRISAT 1976). This would imply the need for developing relevant types of technology for all classes of farmers. Space does not permit a detailed discussion on all the factors that contribute to what might be termed relevant improved technology, but in the light of the above and remarks made earlier in the paper, its components should definitely include the following (Chambers 1978):

1. Compatibility with the technical element, exogenous and endogenous factors (i.e. "horizontal" dimension), so that the level of livelihood is improved — net livelihood intensity in Chambers' terminology — through increased productivity of scarce resources.

2. The recognition of the heterogeneity of farmers ("heterogeneous" dimension) in terms of both resource base and social and/or economic power — that is a product of both the "historical" and "horizontal" dimensions — through adapting different technologies that fulfill equity considerations.

3. A recognition of possible repercussions from the adoption of the technology (i.e. "prospective" dimension), not only in terms of environmental instability, but also in terms of unequal distribution of benefits, and the design of technologies and institutions that would ensure that such abuses would not develop.

Throughout this paper there have been references to specific items bearing on the above criteria, but we contend that it is necessary to approach these in a complete and holistic manner. We believe that an appreciation of the interdependency between the technical, economic, and noneconomic variables is essential to understanding the farmers' environment and in developing and disseminating relevant improved technologies. Without such an approach, it is unlikely that practical results will be achieved that could fulfill the criteria discussed above. This implies the need for ICRISAT to use an interdisciplinary team of technical scientists, agricultural economists, and anthropologists, adopting an approach to farming systems "from the bottom up." Obviously, there is in principle nothing particularly innovative in this suggestion, either in terms of ICRISAT's present work or in terms of work at present being undertaken or proposed in the SAT of West Africa. However, we believe there is considerable room for innovation in terms of methodology and analytical procedures to be employed. We believe that ICRISAT can and should play a role in developing this area. If this approach is to be successful, it is of prime importance that ICRISAT accept the following: a concentrated input in one or two localities over a number of years; a more holistic approach that goes beyond the five crops under the mandate of ICRISAT and considers the whole farming system, including livestock; and the development of very firm linkages with local and national institutions, both in order to help build up local expertise through providing training possibilities for nationals and to enable coordinated work to be undertaken on the institutional aspects so important in the development and dissemination of relevant improved technology.

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Discussant's Comments

W. H. M. Morris*

I find the Newman, Ouedraogo and Norman review excellent and have no differences to find in their observations, although sometimes I do not agree with their conclusions.

I have only few comments:

Basically, I see farmers throughout the region attempting to meet their subsistence needs with a margin of safety; the subsistence crop market with its price cycles discourages farmers from using it as a vent for surplus; this place is taken by cash export crops.

There is a real question as to whether intensification or extensification is the best path to increase farm income.

The farmers exploit all the ecological opportunities that are available to them; employment of labor in production opportunities outside the rainy season crop production period has a very important potential as a means of increasing income. These opportunities include flood recession, *bas foods,* and small-scale irrigation.

There is an important area which might be of special interest to ICRISAT, the question of long-term trends in fertility and yields in overpopulated areas.

One purpose of this session is to suggest what the intervention of ICRISAT's Economics Program should be in the Sahelian countries. Jim Ryan has outlined a rather comprehensive program. However, a contract proposal was offered to U.S. Universities to launch a farming systems unit in Upper Volta in association with ICRISAT/SAFGRAD research unit at Kamboinse, Upper Volta. My University, Purdue, has won this contract and will be starting research in April 1979. Obviously this is a collaborative research between Purdue and ICRISAT scientists.

The development of institutional linkages is, obviously, essential to the long run benefit of the research program. Although we can train Voltaic and other Sahelian state students, our ability to train professionals in our work in Upper Volta is limited by the inability to obtain counterparts for our research workers.

The major problem that all of us face in doing research in the region is how to check the continuous decline in the real per capita net income of the farmers.

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Going Against the Grain

Barbara Harriss*

Abstract

This paper examines, through an interpretive review of the literature, interrelationships between interventionist policy, private grain marketing systems, and grain production in the semi-arid tropics of West Africa. It analyzes how the domestic marketing system may contribute to rural inequality and may depress grain production; how the interventions of the State exacerbate this process, fail to achieve their ostensible objectives and contribute in other ways to the stagnation of grain production; and how the indigenous production and marketing system, in turn, affects the form of State intervention and contributes to "an intractable structural crisis in commercialization." The author concludes that the latitude for either reformist or radical change within the present socioeconomic structure of the West African SAT appears to be extraordinarily limited.

This essay "goes against the grain" metaphorically in four ways. First, it analyzes how the "domestic" marketing system may contribute to rural inequality and may depress grain production. Second, it examines how the interventions of the State exacerbate this process, fail to achieve their ostensible objectives, and contribute in other ways to the stagnation of grain production. Third, it assesses how the indigenous production and marketing system, in turn, affect the form of State intervention and contribute to an intractable structural crisis in commercialization. And fourth, it goes against the grain personally for it is *not* written from the experience of direct field work; its sources are confined to isolated, and regionally and topically unsystematic, published and semipublished material, so that it will appear to some blithely to disregard important regional variations and to other to be dangerously ahistorical (for some remedies, see Meillassoux, 1971; Hopkins, 1973); it is tentative, far from definitive; it suggests hypotheses for further research rather than presenting the substantive contribution based on the original fieldwork that these topics really require.

Agricultural marketing systems play a dual role in economic development in states whose resources are primarily agricultural. On the one hand, they are channels along which money commercializes a not necessarily static but noncapitalist peasant society. Increasing demands for money with which to purchase other goods may lead to a increasing sensitivity to relative prices on the part of producers, to their specialization on those crops where returns are greatest subject to particular cultural, ecological and economic constraints, and thus to an increase in total production. Clearly it is the marketing system that transmits the crucial price signals. On the other hand, and in order to sustain nonagricultural development, resources have to be extracted from the agricultural sector— physical resources to guarantee supplies of food and raw materials for agro-industry and financial resources for investment in all aspects of the nonagricultural economy as well as for reinvestment in agriculture. Taxation is one way of transferring resources. So is the action and relationships of the internal terms of trade as mediated by the exchange systems. Even with ceteris paribus assumptions about production, the marketing system has to put constraints on any production increases powered by a response to comparative advantage by denying production its full resources to expand. Naturally the form and direction, the size and the pace of this transfer of resources can be highly varied.

Most exchange systems in the semi-arid

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tropics today are simultaneously acting as resource allocators and resource extractors.

The net effect of an agricultural marketing or exchange system upon society depends very much on the relationships of people to the system of production. These relationships determine who consumes how much, where, and why and therefore also determine distribution or consumption. The three spheres of the economy interact, as outlined simply in Diagram 1.

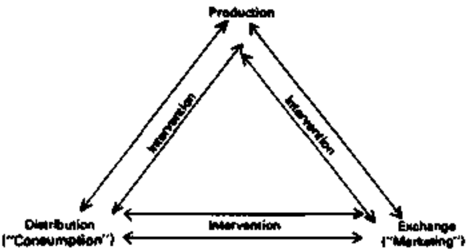

DIAGRAM 1. **Interactions between economic spheres**

The theoretical problem we are to flush out with facts and are to analyze in this interpretation of literature is the simultaneous occurrence of potentially contradictory processes (the processes of resource allocation and resource extraction by the market, the simultaneous occurrence of petty subsistence trade allowing no accumulation of capital and monopoly trade by various institutions allowing large-scale accumulation of capital), the effects of these processes on the cultivation of food crops of the semi-arid tropics of West Africa — most notably millet and sorghum — and the implication of these effects for technological change.

It follows that it is necessary to examine interactions between the economic spheres of Diagram 1. The nature of each sphere and all combinations of interactions have been reviewed elsewhere (Harriss 1978). Here we will focus on the interactions between production and exchange in our effort to understand the role of the agricultural marketing system. This is, of course, not to deny the importance of the forces and relations of production in transitional economies (see Post 1970 for an analysis). Because the state has intervened in complex ways in the mobilization and distribution of resources in the economies of the Sahel, it is clear that this intervention must have profound implications for the marketing of agricultural products. Accordingly, it is necessary for the purpose of an analysis oriented towards marketing to subdivide the sphere of exchange into that of the private sector and that of the state, and to examine the interrelationships between these two subspheres and between each of them and production. We are at the mercy of the literature, as befits a review, in the details accorded to each interrelationship.

In the Sahel, agriculture absorbs 76 to 90% of the population but, significantly, provides 40 to 55% of the GDP. Rural incomes are stagnant or declining (CILSS 1977, vol 1, p 11; Wilhelm 1976a, p 91). Production of grains — millets and sorghum — stood in 1977 at 1.2 million tonnes per year in Upper Volta, 850,000 in Mali, 1.3 million in Niger, and 620,000 in Senegal (Nacro 1977, vol 1, p 23). Where cereals are monocultivated, there are few regions that are not deficit areas. Elsewhere they are cultivated with groundnuts and cotton. Cereal yields are low — millet at 250 to 600 kg/ha in Upper Volta; sorghum at 300 to 900 kg/ha (Minister© du Developpement Rural 1976; Broekhuyse 1974); millet at 450 to 800 kg/ha in Mali, sorghum at 300 to 1000 kg/ha (Operation Mils Mopti 1973; Outtara 1977). All these ranges mask modal yields towards the low end.

Since 1960, while population has grown at 2.2% per year, agricultural production increased at 1 to 1.7% (Wilhelm 1976a, pp91-92). Cash crops fared better than cereals, production of which is either stagnant or has declined as in Upper Volta and Niger (CILSS 1977, vol 1, p 27). Because of their historical lack of urbanization, the West African states of the Sahel have the highest rates of urbanization in the world (Wilcock 1978, p. 258), so pressure for crop expansion comes from the demand side and cities are in such chronic undersupply that some Sahelian states resort to imports of rice and wheat. However, there is no production deficit attested in the region as a whole in a "normal" year for rainfall (Nacro 1977, vol 1, p 13). In an average year, Mali, Upper Volta and Niger all can and do export millet and sorghum. Marketed surplus varies from 5 to 20% of production, and the states of the Sahel market between 20 and 50% of this surplus.

The following sections look in detail at the operation of the market in this paradoxical situation.

The marketing systems we study first are neither traditional (they are not sunk in a historical stasis) nor natural in the sense that they have not been interfered with; nor are they indigenous, since this carries the implication of having avoided the involvement either of the state or of outside trading communities. We shall call them "private" for want of a better adjective. We shall try to consider systematically the interactions between this marketing system, that of the State, and grain production.

The Interactive Roles of the Domestic Marketing System and Agricultural Production

The interrelation between grain marketing systems and grain production in Sudano-Sahelian West Africa has been explicitly investigated by a number of economic anthropologists. Their data must be considered valuable because of the careful and direct manner in which it is collected, a manner that maximizes accuracy though this is at the inevitable expense of geographical coverage (a problem that survey research does not automatically escape).

Our first sets of evidence relate to *Hausaland,* a region embracing northern Nigeria and southern Niger with "a high degree of cultural, linguistic and religious uniformity" (Hill 1972, p xiv) with the unusual characteristic for semi-arid tropical West Africa that "the population is so dense that farmers are obliged to farm all the cultivable land every year. This agronomic system, which has been practiced for centuries, does not necessarily lead to a progressive deterioration in yields. Not even in the densely populated area of the "groundnut basin" of Senegal is there anything comparable (Hill 1972, p 21). As Hill herself stresses, and as we shall see, this agronomic and cultural distinctiveness does not lead in a deterministic way to an economic uniformity, and in fact population density is not uniformly high.

Probably the clearest statement encountered of the rural grain marketing system's role in agricultural production is from Clough's case study work in a millet and cotton-growing hausa village (1977a). Here 30%of farmers whose production does not meet their food needs have to sell grains required for subsistence directly after harvest at low prices in order to meet the cost of taxes, debt repayment, household repair, and ceremonies involving the purchase of manufactured goods, against which the agricultural terms of trade are secularly deteriorating. Much of this grain is exported to deficit regions or towns creating an aggregate nutritional deficit in a producing settlement. In the hungry or lean preharvest rainy season (the *"soudure"*) this group of farmers is forced to work as seasonal, paid labor on the farms of others in order to obtain food at double the postharvest price, work that reduoes their capacity to farm their own lands. Or in Clough's case they are forced to borrow money at seasonal interest rates of between 50 and 140%, to be repaid in kind at postharvest prices. Their body weights may decline and morbidity increase during this period (Hunter 1966, Chambers 1978) further reducing these farmer's capacity for productive physical work.

Successful middle farmers have bimodal selling patterns, also contributing to the postharvest glut because of heavy social pressures for ceremonial or marriage expenditure. However, they tend to sell relatively less and, because they are better risks, borrow more than poor farmers. During the cultivation season, grain will be sold to raise money to pay wage labor. Muslim farmers, not using female labor, will produce less than pagan ones, but, not drinking millet beer, they will also consume less.

Big farmers are able to withhold grain against midseason price rises when they sell in order to pay wage labor and to invest in cattle, trade in which yields large speculative profits. However, their accumulated wealth is qualified by correspondingly larger social obligations that are socially redistributive.

The same large farmers buy and sell grain. Prices offered vary with the quantity of the individual lot sold and therefore with the wealth of the seller. The market is highly volatile at the micro level. In Clough's case studies, rates of return on capital over a 2-day transaction by farmer-traders vary from 8 to 27%. Farmer-traders may also store grain in villages against off-season price rises, and lend out money borrowed in turn from intervillage wholesalers. The latter specialize in trade (though not in the grain trade); they frequent periodic markets as well as marketless villages, have higher average rates of return than the farmer-trader to whom they lend money, and operate in turn on money borrowed from a few urban wholesalers with whom they share profits and from whom they clandestinely siphon capital. The urban wholesalers receive between 73 and 114% on capital loaned out seasonally to finance the rural storage of crops destined for rural final destinations (Clough 1977a).

Thus the social relations of trade have forced many farmers to sell grain when prices were low or to go into debt to be repaid at harvest, at high interest rates. Through this market structure a hierarchical trading system, financed by urban merchants and hereditary notables and tied by patron-client dependency relations, accumulates large financial and physical surpluses through its control of production (Clough 1977a, 1977b). Yusuf (1975) adds corroborative evidence for Kano; Watts (1978; cited with permission) gives a very similar analysis for a village near Katsina.

Long distance rural-urban or interregional trade enables the rural-urban flow of money to take place. These create a system of debt that perpetuates and reinforces itself, enabling the extraction of a distress surplus on unfavorable terms from disadvantaged farmers. Farmers are forced to work as wage labor to obtain food whose earlier sale was equally forced on them; their labor input on their own farms is reduced[1]; and, since agricultural production in northern Nigeria is overwhelmingly a function of land, labor, and rainfall, production of both cash crop and subsistence crops is constrained by the action of the market for "subsistence" crops. Thus the market mechanism that progressively commercializes the rural economy simultaneously reduces returns to farmers and thus constrains its own progress.

While Clough identifies the system of production and distribution over long distances as articulating inequality, Raynaut's work, which is focused on a deficit millet-producing but surplus groundnuts-producing Hausa village near Maradi in Niger (1973), shows the same mechanism at work within the intimacy of the village. Here, however, it is activated by taxation, which has been at significantly higher levels than in Nigeria; although even in Nigeria, the need for cash for paying taxes has been identified as a major cause of distress sale (Shenton and Freund 1978). Raynaut in Niger emphasizes that the cash requirement for taxes alone amounts *on average* to 65% of the value of the groundnut crop, forcing the poorest deciles into the sale of their subsistence crop. Fifty per cent of family heads sold 35% of their millet. Raynaut estimates that two-thirds of the goods traded are for this small-scale rural redistribution. Little even appears at periodic market places from where it may be exported (4% of grain purchases and 17% of sales). Most is house or honeycomb trade, not necessarily just between houses but sometimes involving non-local foodgrains. This trade is carried out by itinerant traders and by women in the seclusion of their compounds with children as go-betweens for price information (see also Hill 1972, p. 138). In Hausa, Niger, there are *very* few individuals who do not derive a supplementary income from trade (Raynaut 1975, vol 2, p 31).

Large numbers of women are involved in centuries-old marketplace trade in millet and sorghum and their cooked dishes (Nicolas 1962, 1965, 1968). There is an intense circulation of goods, which pass from hand to hand without enriching anyone (Mainet and Nicolas 1964). Raynaut also describes the role of women as accumulators in the sexual division of labor in exchange. Women produce 37% of total cereals, sell 10% of all sales, but buy 24% of all purchases, notably from men at harvest, reselling prepared food to them before harvest.

Raynaut concludes: "Cereals commerce does not indicate the existence of a surplus, nor does it assure better distribution between members of the community. Everything points to its origin in the economic vulnerability of certain family heads and it operates to accentuate their weakness and dependence, fueled by their intense need for money" (1973, pp 34-35, my translation).

Money circulates with extreme rapidity through the community, but because it originates in the sale of cash crops or subsistence crops for taxes, most of it is immediately restored to the "coffers of the State". Money is therefore highly scarce (Raynaut 1977, p. 171). Because food has to be repurchased later, the terms of trade for farmers selling distress

1. A reduction in labor input is a crucial constraint but it is not the only one.

surpluses are automatically worse than for those whose surpluses are not for distress (Gore 1978; Post 1970, p 10).

We see once again from Raynauts analysis how the action of the marketing system (here tied in with the fiscal system) may constrain grain production. Raynaut feels domestic grain production is "seriously distorted." Obligatory taxes, payment for labor, socially essential gifts and essential clothes, given the declining terms of trade for groundnut and the lack of demand, or alternative infrastructure, for other crops, *require* a perverse supply response to price, with both production and supply of groundnuts increasing as producer prices fall. This behavior is corroborated in Niger by Nicolas (1977), in northern Nigeria by Forrest (draft, 1978), and in Mali by Ballan et al. (1977, vol 2, pp 47-48).

For the larger number of farmers these mechanisms leave no surplus money for investment in new technology and may lead to the physical overexploitation of the land. Increasing monetization leads to an expansion of wage labor (though *not* of total landlessness). The longer the period of wage labor, the less the possibility of working one's own land, the lower the yield on self-cultivated fields, the greater the deficit, the greater the need to sell at harvest and buy preharvest, the greater the need to work as wage labor, on seasonal migrations if necessary. Greater also is the need to borrow money. Loans with interest (often 100% and taken because the debtor needs seed) are more common than are friendly loans without interest. The civil administration exists to suppress such activity but often participates in it (Mainet and Nicolas 1964, p 113; BCEOM 1978, p 37). Since production is intractably constrained, profits from grain marketing come from retrogressive activity, such as hoarding over time, which reinforces the constraining mechanism.

Clough, Raynaut, and Hill report 100% seasonal swings in price; Gore 100 to 400% in Ghana (1978). As Polly Hill (1972, p 137) says: "Seasonal price swings are not more severe in Hausaland than to the south but the economic consequences are much more far reaching" because of the inability of consumers to substitute and their consequent, predictable vulnerability.

Watts (1978) for Hausaland, Gore (1978) for Ghana, Lallemand (1978, p 49) in Upper Volta, and Meillassoux (1974) in West Africa generally assert that interseasonal price fluctuations have increased through time, as might be expected from a combination of increased seasonal oscillation of demand and constrained supply. Comparison of the percentage seasonal variations for 1960-61 in various Nigerian grain markets — normally in the range of 25 to 40%—with those occurring now (bimodaly distributed around 60 and 140%) would support this contention (SEDES 1963, p 17-24; CILSS 1977, vol 2, Niger p 50), though more research is needed. There is some evidence that storage strategies for several years' consumption requirements, ensuring the integration of the household through time — strategies well-adapted to a risky environment — have decayed and that smaller farmers stock less. Once again this fits logically with an argument involving the deterioration of the land, the reduction of land down to cereals with an increase in cash cropping, the stagnation of aggregate production and its decline on smaller farms and the increase in the relative importance of cash for taxes and marketed consumption goods (Wilhelm 1976a).

Watts (1978) remarks "there is no inevitability about seasonal food shortages, just as there is no logical, automatic or predetermined relation between drought and famine." However, if these analyses of the effects of the marketing system on agricultural production are correct, then there *is* an inevitability about the seasonal behavior of the market; and if evidence is assimilated on adaptive land-use strategies made during the drought that lead to a further decline in lands sown to subsistence crops (Faulkingham 1977), then there *is* now an automatic relationship between drought and famine. And this understanding of the social causes and effects of increasing seasonality has to be set in the context of possible secular climatic and environmental deterioration, partly caused by the action of man himself. In addition, extreme events such as the Sahelian drought exert an irreversible "ratchet effect" (Chambers 1978), in this case towards the individual appropriation of land and herds (Le Moigne and Memni 1973; Wilhelm 1976a; Spitz 1977; Swift 1978) and the marginalization of significant numbers of people for whom there is no alternative employment as remunerative as their marginal agriculture had been.

But is this logic correct? Polly Hill in her two books on rural inequality, which consider trading in detail stresses in her explanation of rural poverty (1) environmental factors (short farming seasons and uncertain rainfall), (2) lack of production factors (such as capital and cattle manure), (3) lack of alternative opportunities outside agriculture, even including long-distance trade by donkey caravan, which has been replaced by the urban-based trade of lorry owners, (4) socially redistributive practices (though Watts argues that these are on the decline). Hill also argues that labor is not fully utilized, which is not supported by Norman's evidence from Zaria and which appears to contradict the assertions of Clough, Raynaut, and Watts that wage labor is *diverted* from self-employment rather than acting as a supplement to it. However, it is seasonal underutilization that most concerns Hill, while it is the peaking of labor demands during the cultivation season when untimeliness has high opportunity costs that concern the other writers (see Hill 1972, p 190; 1977, p 100). Hill, nevertheless, does expose the "balance of payments" problem of her village which "exports" 2500 pounds of groundnuts and would need to import foodgrain to the tune of 4000 pounds to nourish everyone adequately. Invisible remittances do not redress the balance, and one section of the population — the poor who sell after harvest, are forced to work for a living, and are most dependent on the market economy even for grain seed — is likely to be undernourished.

Hill states that the yields of the poor are lower than those of the rich per unit area because their poverty prevents them from applying manure, let alone modern inputs; she even identifies a category "too poor to farm" in a land surplus economy, a statement that she regards as controversial (Hill 1977, p 162-64). She identifies large farmers, mostly men but some women, who deliberately store for speculative profits over time — speculative because there is *some* risk of loss when the prices fall before harvest as farmers offload old stock onto the market, a practice attested by other writers. But she does not see the process as self-reinforcing, stressing instead the dissipation of accumulated wealth at death. However, that "death is a great leveler" may be an exaggeration. She says: "Rich men may have rich fathers yet most sons of rich fathers will not be rich men" (1977, p 100). Hill is not distinguishing convincingly enough between the extent of inequality and the extent of transmission of that inequality. I conclude that the differences between Hill's exposition and those quoted earlier are ones of qualification rather than being fundamental.

Matlon in his thesis on Hausaland (1977, pp 419, 432) argues somewhat differently: that income differentials were small and due mainly to differences in the physical productivities of land and labor which "reflected at least approximately interpersonal differences in aptitude and work motivation." Palmer-Jones, in an exceedingly thorough critique (draft, 1978), shows conclusively that the analysis of the data on which these conclusions were made is statistically naive and that, similarly to my own critique of standard marketing methodology and conclusions (Harris 1978, Annexe 3 and earlier in the main text), Matlon's conclusions do not follow from either his own or any possible reinterpretation of the data presented by him.

Palmer-Jones (1978, p 4) argues that "Non-market relations may mediate access to land, labor, manure, chemical fertilizers etc. in such a way that poorer farmers cannot farm efficiently... a considerable portion of their surplus product and surplus labor time is appropriated by these non-capitalist relations, making it difficult for them to break out of their impoverished positions."

Matlon (p 425) categorically denies the existence of the mechanism of usury: "No interest payments were reported on cash loans repaid by the poorest 40% ... and ... credit charges were not... biased against poor households." So does Hays (1975, p 90); "There was no evidence that marketings tied to credit extension were significant for these two grains" (millet and sorghum). So does Ejiga (1977, p 255): "None of the traders in all the samples said they advanced any money to farmers. Nor had any taken any loans themselves. No farmers had borrowed money or given cowpeas in exchange for debt." Ejiga (p 41), however, deliberately identified himself with the Government "in order to improve his rapport." Polly Hill, in her critique of Hays, reminds us interalia of the exceedingly secretive nature of storage and of allied subjects such as debt in Hausaland (1976, p. 86). All three authors did fieldwork using paid assistance unlikely to be able to retrieve "statistically respectable" data on debt. Finally, Palmer-Jones agrees, as I do, with Wood (.1978, p 42 on Bangladesh) that subjects such as moneylending "are institutionally disguised at the level of social relations in the village, both consciously through verbal agreement and informal arrangements backed by sanctions, and more pervasively through the class based management of the hegemonic egalitarian Muslim kinship ideology which denounces interest rates and the like."

Kohler's study (1977) of the traditional grain-marketing system for Niger states categorically that there is little distress sale since peasants can store at little cost on the farm; he notes almost parenthetically that "farmers get cash from agricultural laboring not from the sale of grain." He also states that whereas seasonal price fluctuations are rarely 100%, his data show that 40% of interseasonal price variations were between 100 and 150%. He also does not mention the role of agricultural rates, (CILSS 1977, vol 2 Niger, p 50).

The observation of the earlier 1960-61 study of grain commercialization in Niger by SEDES, that there was even a region where the (then much lower) seasonal grain price swings were evened out or reversed, is an isolated observation still not inconsistent with a marketing system reinforcing inequality in the production system, (1) if the postharvest grain price rise was due to the clogged and glutted groundnut market where prices were low, and (2) if the off-season grain price drops involved the shedding of grain in anticipation of a big harvest, which would reduce prices further (see SEDES 1963, p 17-18).

Hays' work in northern Nigeria on the structure and performance of the grain trade in a rural-urban distribution system (1975) shows that larger farmers sell more grain and sell it later at higher prices than do small farmers. His categories (large and small) are crude ones of landholding, unramified by household size (Hill 1976, p 85-86). As we have seen, Hays concludes that resource allocation in marketing is "approximately optimal" — the value judgment so characteristic of conventional "structure-conduct-performance" analyses; but he does not question the role performed by the marketing systems in changing the income distribution. Dough's analysis of the relation between overhead costs and net trading profits showed that the latter were two to four times the former, and he also queries the value judgments of Hays and Kohler (1977a, p 22-25). Clough tells us that profits from the grain trade are invested in highly profitable cattle trading, enabling the wholesaler to employ wage labor on his farm and to lend out money at high interest rates to this labor. The pseudo-scientific analysis of structure, conduct, and performance to investigate market efficiency (see Harriss 1978 annexe 3, for a major critique) usually fails to incorporate ramifying social and economic linkages, nor a systematic pursuit of the circuit of money in commerce, which is actually as important as the circulation of the commodity. The quality of the data in West Africa (about whose use much bickering has occured) does justify skepticism about the meaning of market performance results, and the aggregates mask precisely those micro-level variations that give traders their profits. A low average rate of return to trade can still be perfectly consistent with large-scale accumulation by a few, in the commonly occurring combination of subsistence and monopoly trade. Finally, the action of the market in constraining production and reinforcing inequality generally takes place at levels of disaggregation in time and space below those for which there is statistical information. The analysis of trading profitability over space, without incorporation of time lags, ignores the higher levels of profit achieved through the greater control over time, form, and place "utility". (See Harriss 1978 Appendix 3 for a detailed elaboration of these points). The cost effectiveness of long-distance trade (rural, urban, or interregional) if proven, would not imply that local redistribution is similarly efficient, nor does the the efficiency of periodic marketplace local exchange necessarily imply that either house trade or long distance trade is just as efficient. All these channels have to be examined, both separately and in their interrelationships with each other, and their complexity cannot be overemphasized.

We have contended that the marketed surplus of food entering trade is much larger in volume that is the net marketable surplus because of postharvest distress sale and preharvest buy-back. We have also contended that at the micro level, the observed variations in the interpretations of the role of the marketing system in Hausaland are more likely to be ideological (affecting the interests of a group) rather than grounded in substantive differences in the relation between agrarian and commercial systems. What variations occur in the rest of semi-arid West Africa?

Polly Hill refers to Hausaland as "socio-economically *the* great underexplored region of West Africa" (1972, p xiv). My particular search in the rest of semi-arid, formerly French West Africa suggests precisely the reverse.

For Upper Volta, Berg (CILSS 1977, vol 2, U-V, p 24) quotes the following ministerial note on grain price stabilization: "The peasant is currently in debt to the local trader who gives him a loan during the preharvest time. At harvest time he reimburses this trader by selling his crop at a very low price. Sometimes he sells his whole crop, although he is later obliged to buy part of it from the trader at extremely high prices. Then he gets into debt again and will never be free from this vicious cycle." Berg then says: "The least that one can say about these assertions is that they are not based on any systematic study of rural markets and peasant behavior in Upper Volta. To our knowledge there are no such studies in existence." But this is something of an exaggeration, or a confession of disciplinary blindness. Most research is on the Mossi, the most numerous of the many tribal groups of Upper Volta.

Wilhelm (1976b) describes heavily-populated Mossi country south of Ouagadougou where maize, red sorghum, millet, and beans are grown for subsistence and groundnut, tobacco, and cotton for cash. Here the harvests no longer assure self-sufficiency in staples. Lallemand (1975, p 44-50) observes precisely the same phenomenon in Yatenga. The smaller the enterprise the larger the importance of purchased cereals, the greater the likelihood that market purchases have to be put off until the *soudure* and the greater the likelihood of distress sale after harvest.

Broekhuyse's survey (1974) of the Mossi plateau shows that about half of farm revenue is spent on taxes and ceremonies (a too easily aggregated category comprising nonfood purchases) and that approximately the same proportion is spent on repurchasing millet and sorghum (1974); similar conclusions are reached in a general study by Bollinger (1974). The "surplus" in Wilhelm's study area is bought by merchants from Ouagadougou, whose supplying dominates the reallocation of surplus and which supplies the countryside from urban stocks during the *soudure.* This is perfectly consistent with Berg's findings that seasonal price swings are greater in rural areas than in Ouagadougou, which he could not explain other than by blaming inaccurate data (CILSS 1977, vol 2, U-V, p 55). Ouedraogo corroborates Wilhelm's analysis in her study of the cereals merchants of Ouaga (1974): "Groupes au sein du syndicat des marchands de cereales ils ne craignent aucune interpellation des autorites voltaiques aux yeux desquels ils font miroiter le poids politique qu'ils representent."

To recover the surpluses yielded up after harvest, farmers may migrate for work, which reduces the strength of the work force engaged in agriculture. Much of this migration is seasonal. In Kombassiri 34% of the men between 15 and 59 are absent in the dry season (Wilhelm 1976b). Based largely on data from the early sixties, Amin (1974, p 73) estimates an annual flow of seasonal migrants of 120,000 from Upper Volta into the cocoa-coffee belt. While this is prompted by cash needs, it may prevent the adoption of production-enhancing "innovations" in the source areas. Gugler (1975, p 197) cites a source which reports that an effort to introduce cotton production among the Mossi failed because it interfered with the existing pattern of seasonal labor circulation.

This response has become permanent, and Upper Volta, Mali, and Niger are performing the role supplying cheap labor for the farms and industries of the Ivory Coast and Ghana (Amin 1973; Wilcock 1978). As with seasonal circulation, these migrants support with remittances the cash demands of an increasingly unself-sufficient agriculture whose production may be dominated by women, apparently unable to manage innovations in tillage because of agricultural extension oriented to males exclusively (Gissou 1977). On the migrants' return to marry, these workers resume their subordinate position in the family. They tend to begin in petty trade because, as Berg notes, there are few entry restrictions (CILSS 1977, vol 2, U-V, p 25-27). Furthermore, they have no outlet in agricultural production for their accumulated capital. In the studies of Mossi migrations this is attested to be because decision-making on land use is based on seniority, and because those with social power do not need money alone to enhance it, and because, most importantly, geographical expansion of territory now faces sharply diminishing returns to labor and capital. This reinforces the domination of the market over production and micro-level social inequality (Ancey 1975, p 212-13; Ancey 1977; Capron and Kohler 1975, p 39-41). The latter comment: "Tout se passe actuellement comme s'il etait etabli (entre les detenteurs du pouvoir economique et ceux du pouvoir social) une sorte de consensus tacite destine a geler (provisoirement) ov a mettre entre parentheses la masse monetaire circulante." Ancey concludes that there is an asymmetrical liaison between the external capitalist system and the internal precapitalist one that is self-perpetuating. However, Capron and Kohler doubt this equilibrium and Kohler argues that insofar as this incomplete spread of the market economy connected with demographic expansion leads to the land's acquiring value and becoming actually negotiable (rather than being accumulated indirectly through "borrowing") we can expect a reinforcing of inequality (Kohler 1968); but the process is slow.

The large number of intermediaries seasonally evident in rural petty commodity markets appearing to satisfy structural conditions for perfect competition gives us little indication of the process underlying the pattern; and it detracts attention from the accumulation of physical and financial surplus by interregional traders where even Berg finds price differences substantially in excess of transport costs (CILSS 1977, vol 2, U-V, p 25-27). Explaining this with reference to lack of information, accounting skills, and transport detracts from the fact of the profits and the social and economic process of which these profits are a part.

In Mali, there really are no studies of the role of the evolving grain-marketing system and of its effects on production. We agree with Panhuys: "Des etudes specifiques d'anthropologie economique de terrain seraient susceptibles d'apporter des resultats d'une portee non negligeable pour la politique commerciale a mettre enoeuvre" (FAO 1973, p 10). This being so we have to read between the lines in a rather speculative fashion.

Two studies of grain production point to inequalities in farm size. In the region of Mopti, farms vary from 3 to 20 ha, bunching around 7 ha (Operation Mils-Mopti, 1973), while in Sikasso to the South, a more "advanced" region, they vary from 1 to 40 ha, bunching around 5 ha (Institut d'Economie Rurale 1978). Of course we cannot conclude a process of rural differentiation from this static evidence, and to some extent, size of farm reflects size of family. Two further major surveys of agricultural practice in the south of Mali show a reduction of land down to millet and sorghum. In 464 villages covered by the Compagnie Malienne de Developpement des Textiles (Ouattara 1977) between 1973-76, land under cereals had declined from nearly 80% to 65% along with a "rural exodus," a reduction of labor on subsistence crops and a transfer of land to cash crops, notably cotton, the price of which is more remunerative and for the marketing of which better infrastructural facilities exist. Individualization of land is on the increase, as is the hiring of migrant Bembara workers (Lemoigne and Memni 1973, pp 58-67; Operation Mils Mopti 1973, p 12). Ballan et al., surveying 28 villages in the Bamako, Segou, Sikasso, and Mopti regions, show that the increase in yield of millet and sorghum from fertilizer residuals in an experimental millet-cotton rotation is quite insufficient to maintain the marketed surplus of millet or to counteract the adverse effect on production of a reduction in land by an increase in the acreage under cash crops (1977, vol 3, pp 32-34). The correlation coefficient between the marketed surplus of millet and the percentage of land under cotton is -0.97. The relationship could hardly be more explicit. And the relative official price of millet against cash crops is deteriorating against millet (Ballan et al. 1977, vol 1, p 47). Again this does not prove that the mechanism at work in Nigeria, Niger, and Upper Volta works in Mali; but given the rising demand for wheat and rice from urban areas and deficit regions, effective demand for millet and sorghum must be relatively declining.

Obligatory postharvest sales to meet cash requirements for taxes are frequently mentioned as an important source of supply (e.g. Ballan et al. 1977, vol 1, p 45-46; vol3, p 34). This team actually relegates all the redistributive activity within villages and via local periodic markets (where according to Bah, women have a dominant role) to the cadre of "subsistence", not to be considered as trade (Bah, in CILSS 1977, vol 2, Mali p 67). Millet is described as a stabilizer for food security.

Interregional trade, dominantly rural-urban, is fueled from 'supplies at periodic markets picked up by the agents of urban nonspecialist wholesalers owning transport. Whether or not they trade in millet or sorghum does not jeopardize their livelihoods (Ballan et al. 1977, vol 1, p 134). Their trade is characterized by diversity, precisely in order to minimize risk. Very considerable profits are made by these traditional urban wholesalers from international smuggling caravans; for Mali, in spite of its declining acreage to cereals and low relative and absolute prices, is a surplus country in a normal year. It is estimated that 50 000 to 100 000 tonnes may cross borders in this way in years when Mali receives food aid, indicating not only the likelihood of large profits through long-distance trade but the collaboration between these traders and a partisan bureaucracy (CILSS 1977, vol 2, Mali, p 30; FAO 1973, p 14) for: "Lies aux 'aristocraties religieuses' qu'elles soient animistes ou musulmanes, les commercants n'hesiterent pas, non plus, a financer plus tard le jeune mouvement nationaliste, se menageant ainsi des alliances utiles dans la future equipe dirigeante du pays" (Diop 1971, p 135).

The distinguishing economic features of these mercantile groups are their speculative behavior, collective organization, interregional and international tradecrossing ecological zones, their versatality in dealing with cash, credit, barter, etc. The outstanding trading group is that of the Dioualas whose crucial importance to the Malian economy has had to be recognized by all Governments. But in the absence of a modernized nonagricultural sector, their accumulated reserves and entrepreneurial dynamism are said to be "unproductively" reinvested in commerce (Diop 1971, pp 141-51; Amselle 1969).

We may conclude tentatively that the distinguishing feature of the cereals marketing system in Mali is prices that give a low rate of return to production, allowing trading groups to profit at the expense of cultivators from whom these traders are socially defferentiated, unlike elsewhere. With greater profits to be made from cash crops, the acreage to millet and sorghum declines; this renders not only the rural population but also the urban population vulnerable to the power of trader-bureaucrats.

In Senegal, where both towns and countryside are increasingly provisioned by imported wheat and some rice, paid for from the foreign exchange earnings of a stagnant export trade in groundnuts, sorghum and millet are rather little marketed (Yaciuk 1977, p 56). The role of the goundnut marketing system in extracting financial and physical surplus from peasant producers at highly deteriorating, double-factorial terms of trade is well known and will not be recapitulated here (see Amin 1973). Suffice it to recognize that to a certain extent the two commodity markets are interrelated; production and sales of millet depend either directly on the relative prices of the two crops (CILSS 1977, vol 2, Senegal, pp 43-50) or on the relative prices of groundnut and rice, the latter being preferred over millet in urban areas and some rural areas. Also the timing of cash demands (not only in tax but also for the repayment of groundnut seed) determines the pattern of postharvest sales.

There are three kinds of millet and sorghum surplus; first, the sporadic residuals from the "disaster plantings" of larger farmers, released when the following season's crop can safely be predicted; second, the continual small supplies of millet cultivated by women and bartered for petty comestibles and consumer goods in villages or at local periodic markets (Minvieille 1976, p 45; Sar 1973), where the price received by women for their surplus may be 75% that of men, resulting in and from differentiation within the household (SONED 1977, p 81; Kleene 1974). The Yaciuks (1977, p 43), studying eight villages, found that 85% of all sales were of this type, with occasional sales by men of grains exchanged for prepared food cooked by women. Most sales in rural markets were under 10 kg in consignment size, and 40% of transactions were by women (Richard 1974). This type of very small-scale (barter) exchange may result from micro-level regional specialization. In the region of Matam studied by Minvieille (1976), within a radius of 10 km there is specialization in the production of (1) fish and irrigated rice, (2) *souna* millet, (3) sorghum on dry land, and (4) cattle, based on comparative environmental advantage. The third type of surplus is the familiar distress surplus of smaller cultivators, triply penalized in price by having to sell postharvest, to sell in small quantities, and to rebuy when prices are high (Richard 1974), though this activity seems much less important than in the other countries we have studied (Yaciuks 1977, p 43).

As Rocheteau (1970, p 74) says in his study of the Muslim mouride sect in West Saloum, the survival of families during the off-season from the moment when the stores are empty until the harvest and the cash begins to flow... depends on the sales, loaning, and sales on credit of private traders and big local landlords. "Le caractere encore tres personnalise de la relation entre paysan et commercant n'est pas, on le voit, exclusif de pratiques commerciales sans concessions." Rocheteau, Dione (1975) and SONED (1977, p 70-75) in their micro-level studies of the cereals economy warn that usury is a dominant element in such transactions. Seasonal interest rates of 50 to 75% are increasing because of the canalization of agricultural surplus away from private traders and through the cooperatives dominated by *marabouts* (Rocheteau 1970). The kind of hierarchical credit arrangements attested by Clough in northern Nigeria are hinted at in the SONED study of grain marketing, as by Rocheteau, though there are remarkably few large-scale African traders (Diop 1972, p 158). A further unique feature of Senegal is the diminished importance of inter-regional and long-distance trade. This has been attributed to tighter state controls on the geographical direction of trade though the state is certainly compromised by its independence on the approval of traders in its commercial policies (Cruise O'Brien 1975). Wide regional price discrepancies and fluctuations occur nonetheless (Dione 1975, p 27; SONED 1977, p 78) giving rise also to short-distance sporadic cross-border smuggling to Gambia, Mauritania, and Guinee Bissau. Haswell (1975, pp 207-217) documents the similar internal economic process within the Gambia.

It is irresistible to conclude that even with the sparse and patchy information available to us, the Sahelian grain-marketing systems are generally quite closely linked with that for money, and control of both is concentrated. Financial and physical resources are being transferred from country to town via rural markets. Together the commodity and money markets simultaneously work to expand commodity production and to constrain agricultural production by inhibiting savings by the peasantry who might reinvest it in agriculture. The strength of this domination will vary regionally depending on factors such as the productivity of the land and the population resource relationship, migration patterns, the tenure system, the political strength of trading lineages, household storage capacity and practice, and the organization of markets for competing agricultural produce.

It has been quite impossible to consider the effects of the marketing system on production without considering the effects of the production systems on marketing. It has been argued here that given declining land productivity over much of the Sahel, given increasing population pressure and a slowly increasing compulsive involvement in the cash economy, rural poverty is increasing, both in an absolute and relative sense. The fiscal demands of the State reinforce the action of the market economy.

But the State makes other demands.

State Intervention in Marketing

Although it is most likely that the socially sensible form of State intervention would be to use public resources to regulate the use of, rather than replace, private resources in an otherwise free grain trade, most of *the ex-French Sahelian states have intervened on paper on a massive scale.* The stated objectives have been to supply urban areas and rural regions most regularly in deficit, to stabilize producer prices, to keep consumer prices low, to organize infrastructure and emergency stocks (Wilcock 1978, p 253) and to organize the export of grain. They have also been justified in terms of the uses to which the resources transferred are put in comparison with the pattern of savings and investment of private trade.

Similar measures have been used in every Francophone state. To *summarize* they are characterized by:

1. Institutional fission and proliferation. Agricultural marketing parastatals are only part of this explosion. In Senegal, for instance, 97 parastatals have been established since 1973. In Niger, the parastatals administer one-third of the formal sector economy with a salariat of only 2,000 in a country of 5 million people (BIT/PNUD 1977). Many of these parastatals

form parallel roles to, and duplicate, the civil administration.

2. A tendency to expand regardless of financial viability. The fundamental internal contradiction is that financial, technological, and manpower resource requirements for State intervention are high whereas surpluses of millet and sorghum are small in quantity and sporadic in time and space, as is also a significant component of demand. Parastatals are required to pay producers more than the free market prices, to sell to consumers at less than the free market prices, and to trade where private trade either cannot or will not go, all this with the social aim of reducing the cost of marketing (CILSS 1977, vol 2, Niger). The cooperatives are the only parastatal institutions vulnerable to bankruptcy; the others are maintained on subsidies.

3. Chronic instability in structure and in functioning (CILSS 1977, vol 2, U-V, pp 7, 11). In multifunctional parastatal institutions, millet and sorghum account for insignificant percentages of total turnover (see Harriss 1978, Historical Annexe 1) and thus are affected by decision-making on other commodities often imported and subject to external influences. In Niger there are no policies for the parastatal sector on the following areas: its role as a promoter or regulator; the economic and administrative limits of monopolies; price policy; investment policy, especially the relative roles of local and international capital; taxes and dividends and their distribution; financing of agricultural parastatals with the trading profits of uranium; organizational restructuring; the attitude to employment creation; the autonomy of the administration; training in relation to education; and finally the legal status of parastatals (BIT 1978). In Upper Volta there is a notorious series of inconsistencies in the allocation of responsibility between public and private sectors and no policy that coordinates the four sets of parastatal bodies connected with grain marketing (CILSS 1977, vol 2, Upper Volta, p 7). In Senegal there is no policy on consumer prices, on crop subsidies (either their size or their duration), or on the taxation of agricultural crop surpluses (Min. de Devt. du Rurale 1978).

4. The key grain marketing parastatal is invariably out of direct contact with both producers and consumers; its control over resources is weak and uncommensurate with its great responsibility; its finances are precarious and dependent on foreign subsidies.

5. Parastatals are in any case an unstable coalition of multiple unstable financial interests, both private and public, indigenous and foreign capital.

6. Administration is overcentralized and characterized by acute discoordination. Price policy and fixed-trading margins are determined in various government committees in special Caisses de Stabilization des Prix. The dates delimiting putative monopoly trading by the State are established politically. Trading quotas, sacks, and sometimes power may be arranged by the general administration, or the parastatal. Purchases and sales are intermittently in the hands of cooperatives, licensed private traders, and (sometimes internationally financed) regional or crop-specific production parastatals. The State marketing boards organize transport. This may involve several means, all organized differently (donkey, camel, boat, railway, truck) and the cooption of the private sector as well as relevant parastatals. Restrictions may be placed on the movement of grain by private individuals on anything but a local scale. The boards also organize storage. At least until recently this was characterized by relatively high centralization and high losses, in comparison with the peasant sector, as will be explained in detail later. What emergency reserves there were, were not in appropriate locations for deficit regions other than the capital cities. The parastatals organize finance, in one case simultaneously negotiating each cash receipt with a multiplicity of banks. Storage and transport have been the targets of expansion everywhere. This expansion is usually externally financed by bilateral foreign loans or gifts and thus subject to external pressures (see CILSS 1977 for the whole region; Ballan et al. 1977, for Mali; CRED 1977 for Mali; Wilcock 1978 for Upper Volta; and SONED 1977 for Senegal). As commented in Mali: "L' execution de ce travail n'est pas toujours faite avec joie" (Operation Mils-Mopti 1973, p 5) and in Senegal: "II" faut souligner cette confusion institutionnelle" (SONED 1977, p 9).

In view of this "confusion" and given that the dismantling of State intervention is extraordinarily unusual, there really is little point in debating, as is still done (see OECD/FAO 1977), whether private trade, cooperatives, or parastatals are separately or in combination "optimal" or "most suitable." Nor, given the patent "gap between formulation and implementation" which "may be not entirely the result of an inability on the part of the State to act" (Collins 1974, p 5), is there point in evaluating these institutional phenomena in terms either of stated objectives or of textbook objectives for marketing intervention "which exist only in Government speeches or in the hearts and minds of outside observers" (Collins 1974, p7), or in terms of testing unproven assumptions on which current policy rests. This is especially true if there is no coherent policy and if the testing of assumption gives ambiguous results (e.g. CILSS 1977, vol 2, sections on Upper Volta and Niger). Here, we explicitly reject the Keynesian interpretation of State intervention as being above and outside civil society and as existing to abolish crises by economic planning. It is clear from the condensed generalization about interventionism presented already that the State at worst may cause crises and at best has multiple, inconsistent, and changing objectives.

The relevant issues for review are the historical evolution of, reasons for, and distributional effects of this complex situation. To study this properly, it must be recognized that, although most of the best literature confines its assessment of intervention in terms of unidirectional causality, more is involved than the effects of "Government" (regarded as a monolithic unity) on the "traditional" distribution system. In fact, both sectors may have coexisted for a fair while in a dialectical relationship, tied together in unity and in contradiction. State intervention itself is a set of relationships. In the case of agricultural marketing they short-circuit the private spheres of production, exchange, and distribution with effects now to be analyzed.

The Effects of State Intervention on Domestic Grain Marketing Systems

It is difficult to tease out the disaggregated effects of the various types of intervention from an inadequate (because differently oriented) literature. We shall assess in the following order the effects of the "monopoly" and infrastructural interventions, trading restrictions, and the effects of consumer price subsidies.

The first salient feature is that the domestic grain marketing system has been legislated out of existence. The efficacy of the state monopoly varies from country to country but, as has been seen from the preceding sections and as is generally acknowledged, it is weak. The unstable state monopoly dates generally from about the time of the Sahelian drought. Until after the drought in Niger the parastatal, OPVN, operated in a regulated free market. Since then it has operated either with the cooperatives or by using large-scale licensed private traders, or village headmen for collection and retailing (BCEOM 1978, p 11). In Upper Volta the private sector had responsibility for supplying deficit regions and urban centers until 1970, operated under license to the parastatal OFNACER until 1974, and was "replaced" by the Regional Development Organizations from then onwards (CILSS 1977, vol 2, U-V, pp 11-16). In Mali private trade still supplies urban centers in production zones and undercuts the parastatal OPAM (Ballan et al. 1977, vol 1). In Senegal private purchasing on license to the parastatal ONCAD was abolished in 1976, but licensed traders are still allowed to sell ONCAD's millet and sorghum (SONED 1977, p 77). In view of the recentness of the suppression of private trade, it is too early to judge effects.

The purchase "monopoly" is merely a postharvest campaign, limited in duration and ceasing everywhere when State funds dry up for whatever reason, or when sacks are not available, and inappropriately lagged so that farmers with pressing needs for postharvest cash are forced by lack of alternatives onto the parallel market. This fact has led traders with money to buy at low postharvest prices and stock for the soudure, the hungry season. This is thought to have exacerbated, rather than stabilized the processes resulting from the interlinkage of commodity and money markets and increased the amplitude of rural price fluctuations (BCEOM 1978 for Niger; CILSS, 1977, vol 2 U-V, p 16 for Upper Volta; Ballan et al., vol 2, pp 40-45 for Mali; SONED 1977, pp 82-86 for Senegal). The prices at which small-scale redistribution in the soudure is effected may be inflated because coercion by the parastatals during the campaign has creamed off subsistence crops (therefore increasing off-season demand), and because these commodities have been removed from the locality (therefore reducing supplies) (see Ballan et al 1977, vol 2, p 20; Dione 1975, p 27). Traders may prospect for standing crops to mortgage-in (Ouedraogo 1974, p. 25), which is the first stage in the private acquisition of land. The fact that the State agents of the parastatals will only buy round sackloads swells the contribution of the most vulnerable petty sellers to the parallel market in producer areas and forces the vast majority of consumers, unable to afford whole sacks, to buy grain privately. It is known that bureaucrats with access to the parastatal sometimes legally buy lots of whole sacks, break bulk and either distribute small lots on a breakeven basis to subordinates, or at a profit, which is illegal (Ouedraogo 1974, p 25; Wilhelm 1976b for Upper Volta; Ballan et al. 1977, vol 1, p 40 for Mali). Direct sales from individual producers to mobile urban consumers in a markedly imperfect market may also occur — flows were estimated at 2200 tonnes in Senegal in 1976 (SONED 1977, p 72). The suppression of private trade during the monopoly may result in the temporary drying up of petty grain sales in periodic markets, and as a result, put special pressure on the incomes of the women for whom trading is an independent means of improving economic status. The whole process of State intervention may replace employment for women in private trade by that for men in parastatals (although we would concede that the involvement of women in traditional long-distance trade is unusual but, as in the case of Togo, not unknown). Finally, it is probably incorrect to conceptualize State and private trade as separate activities. Rocheteau (1970) makes the important point that the marketing cooperatives in Senegal are dominated by Mouride *marabouts* and used as a battle ground for economic power between them and private bush traders. Similar processes are at work in consumer cooperatives (SONED 1977, p 74). State intervention thus enlarges the scope for excess profit-making in private trade.

The intervention of the State in marketing infrastructure has probably exacerbated the costs of interegional trading in traditional goods relative to export sector goods. Colonial road and rail systems neglected interterritorial communications. Railways have been built using four different gauges, and they do not interconnect. The fact that there are three major currency zones with only the franc easily convertible also hinders interregional trade, as do cumbersome international customs dues and nontariff commercial policies within the macro region (Ilori, 1973).

Interregional cereals trade is restricted not only by the marketing parastatals but also by the separate civil administration. In Senegal, *prefets* control trade in lots under 100 kg and *Gouverneurs* consignments under 10 tonnes, and the rest is controlled by the Economic Police (*Controle Economique*). In Nigeria, local emirs historically held the reins of the grain trade while the native authorities (the Colonial State) were unable to enforce trade restrictions (Tiffen 1976, pp 40-45, 60; Gilbert 1969, p 211). In Mali and in Niger, permission to trade interregionally is in the hands of the prefets and the economic police (CILSS 1977, vol 2, p 13; Ballan et al. 1977, vol 2, p 9). Chronic problems of discoordination and discretionary decision-making may play into the hands of large private traders (who may also be bureaucrats).

We have the best indications of the effects of the parastatals' restrictions on the pattern of interregional trade in Mali, where it has been historically of greatest importance. The major effect is to induce spatial compartmentalization. Here the State concentrates its purchasing resources in the southern regions with 26% of the population and 41% of the millet and sorghum production; and over one-third of its employees are actually located in Bamako (CRED 1977, p 140; Richard et al. 1975, p 56). Even in such surplus-producing areas the private marketing system grows in importance with increasing distances from towns (Ballan et al. 1977, vol. 3, pp 32-38) because of the increase in the costs of State control and "the price decline to cultivators really accentuates the economic disadvantages of isolated populations" (USAID 1976, p 24). Meanwhile, the severely deficit district of Gao (the sixth region on the desert border proper) may be starved of supplies because provincial governors may refuse OPAM's legitimate trade — refusing to part with their local buffers. Or red sorghum (surplus cattle feed from the U.S. imported under food-for-cash agreements) is distributed, for which consumers have very low preferences. In any case, given the fluctuations in production, OPAM cannot predict in advance its regional requirements; free interregional trade varied between 19 000 and 738 000 tonnes of millet and sorghum between 1967-73 (Richard et al. 1975, p 36). Hardly surprisingly, long-distance and interregional trade thrives clandestinely, and profits from speculation over space and time increase in security. Given that official prices for grain in Mali are 32 Fr Maliens/kg whereas 50 Fr M equivalent may be obtained in Upper Volta, 80 in Senegal and up to 100 in Mauritania, there is much smuggling across Mali's vast and unpoliced frontiers. CRED gives a very conservative estimate of 15 000 to 30 000 tonnes (1977, p 143 footnote), some of which may be bartered for cattle and salt in short supply domestically (Richard et al. 1975, p 24).

Less is known about the effects of international or long-distance trade in the other countries. In Senegal, where trading lineages have never attained the power of those in Mali, interregional grain trade appears to be suppressed (SONED 1977, p. 78). In both Upper Volta and Mali, private transporters and truckers (who may also be general traders) have had to be enlisted, sometimes coerced to operate at below cost, with losses to be made up by hoists on prices in private trade (CILSS 1977, vol 2, U-V, p 19; Ballan et al. 1977, vol 1, pp 25-28; Richard et al. 1975, pp38-45). The accumulated profits from tolerated illegal grain-trading tend to be invested in transport facilities, urban property, and in the import-export parastatals created from the old European merchant capitalist firms and sometimes still financed in major part by international capital.

In theory, the State subsidies on official consumer prices should limit private trading profits just as they increase urban demand and work to transfer the financial surplus potentially accumulable by the parastatal to private consumers instead. As Stevens (1978, p 14) explains in his study of food aid to Upper Volta: "If the quantity of food aid is too small to influence general price levels, this may be the only effect." The same argument applies generally to consumer subsidies; if not, and if the lowering of the general price level is transferred along the parallel market to producers, then farmers' incomes will also be deleteriously affected. Steven's modest conclusion for Upper Volta is that "while subsidies are Government policy, price levels are not unaffected by market forces" (1978, p 56). We have already seen that it is petty consumers who frequent the parallel market. And it is not irrelevant to note that the rich urban bourgeoisie were remarkably protected over the period of scarcity of the drought. In Upper Volta, while the rural/African consumer price index, in which grain is weighted heavily, increased from 135 (base 100 = 1964) in 1970 to 221 in 1974; that for urban/Europeans went up from 116 to 126 (Bollinger 1974, p 89). In Senegal, traders' profits in millet and sorghum are affected by State-pricing policies on rice for which millet and sorghum are substitutes (Dione, 1975, p 9-12 & 33). Here a third of marketed surplus goes to ONCAD (Yaciuks 1977, p 43) which appears to exert more effective regulatory controls than elsewhere in the Sahel: "La double menace du monopole et du prix officiel garanti semble avoir un effect serieux sur le commerce prive" (SONED 1977, p 86), though this literature may refer to years of good harvests.

Elsewhere, it is important not to overemphasize the regulatory effect of the inefficient operation of the parastatals. Throughout much of the Sahel they may be of small importance in controlling the domestic market. Even in Senegal: "Le circuit commercial traditionnel ne va pas disparaltre meme s'il devient clandestin" (SONED 1977, p 86). However, there is not much evidence that State intervention does anything but accentuate the power of private traders over producers.

The Effects of State Intervention on Grain Production

A negative has to be established at the outset. We are not considering the effects of interventionist projects deliberately designed to increase production; we are confining ourselves to marketing intervention. We shall concentrate on the effects of price and infrastructure on production, for it is widely contended that the (low) producer price policy is the most important single reason for stagnation in the production of millet and sorghum (see the Colloquium, Nacro 1977, vol 2).

It is difficult to determinethe relation between official prices and production. The Colloquium's case study of Upper Volta argued that at the official price for millet and sorghum, the average return on production was between 39 and 56% of the price which would pay agricultural wage labor at the State-decreed *Salaire*

Minimum Agricole Garanti. In Senegal, the relationship is 55 to 70% depending on the region (Sivilia/CGPA 1978), and in Niger it is 44 to 71%. In Mali, the current official purchase price is 90% of the price based on covering the labor input at the planned minimum daily wage — not necessarily the same level as in Upper Volta, of course (FAO 1973; Ballan et al. 1977, vol 1, p 21). The subsidies on consumer prices represent an invisible tax on producers of 66% in relation to world market prices minus transport costs from the West African coast to Bamako (CILSS 1977, vol 2, Mali, p 19). The producer gets a third of the world market price. Peasant labor is obviously valued at a social rate far beneath that of the wage labor market or that of the States' decrees. Berg interprets the input-output cost ratios as favorable (CILSS 1977, vol 2, U-V, pp. 17, 38) as he does the relation between marketed surplus and relevant cash crops — groundnut and cotton. Sivilia's work shows that in Senegal millet and sorghum prices should be raised by 25 to 30% to return thesame net margin per unit area as groundnut (CGPA 1978). Panhuys (FAO 1973) and Ballan et al. observe that the Malian terms of trade between official prices of cash crops and millets turned against the latter during the sixties and towards millets after the drought. They have not yet returned to the parity of the early 1960s, however; and whereas in Upper Volta the official price for grain was relatively high at the inception of monopoly, its attractiveness is tarnished by the reduction of subsidies on cash inputs (CILSS 1977, vol 2, U-V, pp 16-38), admittedly not of crucial importance to most peasants. The contention that official prices are not low, which appears in the general summary of the CILSS/Club du Sahel (1977, vol 1, p 13), though qualified as "highly tentative," is also highly controversial.

There is some evidence of the depressing effects of low relative prices on grain production throughout the region (FAO 1976a, p 41) though production statistics are notoriously unreliable (production sometimes being calculated simply as a function of rainfall for which there is better datal) and though the treatment of price by FAO is crude. In Upper Volta, it is *feared* that there will be a further shift from grain to cash crops (CILSS 1977, vol 2, U-V, p 58). In Mali, the marketings of traditionally surplus regions are declining; the lack of differentiation in price by the parastatal between millet and sorghum — a feature of pricing policy throughout the Sahel in contrast to the detailed schedules for paddy and rice — may have led to an increase in sorghum acreage, which has lower labor requirements and thus higher returns (USAID 1976, p 8). Recent shifts to cash crops are reported (CILSS 1977, vol. 2, Mali, p 34 ; FAO 1973). Further intervention to commercialize crops other than millet and sorghum in southern Mali has reduced the area under millets — and therefore the production of millets—by more than the residual fertilizer from cash crops has raised yields (Ballan et al. 1977, vol 3, p 30-36).

However, to hold that official price policy is causing this stagnation assumes a marketed surplus significantly responsive to price — an as yet unverified article of faith of the Sahelian technocracy — and we must surely question this. We do not actually know whether the marketed surplus of Sahelian food grains is sensitive to price at all. The one case study of the price elasticity of grain production for sorghum in the Sudan (Medani 1972, 1975) yielded median short-term elasticities of 0.19 and long-term elasticities of 0.3, with distributions skewed to low values — hardly very exciting and suggesting a strong insensitivity. It would be very surprising to find generally a net surplus highly responsiveto price, given (1) the priority assigned by peasants to domestic storage (which will mean that this year's physical surplus is a function of this year's production and previous year's stocks); (2) the (declining) practice of overplanting to ensure a guaranteed minimum production in a risky cropping environment; (3) distress sales before the campaign and repurchases after it; (4) possibly different responses to price between the stocks from fields cultivated by individuals and from those cultivated communally within the family unit; and (5) the crop rotations necessary in the environment. There is no reason to suppose a linear aggregate response either, in view of the complex production system. There is no research to show whether "present stagnation" is a result of a high response to low official prices (often announced too late in the year to influence plantings) or a low response to high parallel market prices, or a high response to parallel market prices that are lower than official prices. Alternatively, it might be an amalgam of responses to a parallel market that differentiates In price between varieties and qualities, between types of seller (women, small farmer/male and large farmer/male), a market that changes seasonally in its relations to the static official price. Little is known about the relations between official and parallel market prices, except what has been already reported on the higher volatility of the latter as a result of the former, more so in rural areas than in urban ones (see CILSS 1977, vol 2, U-V, p 58) though this will depend on the amount of marketable surplus entering official channels. In Upper Volta, this is low and market prices are little affected (Wilhelm 1976b). In Mali, one source finds OPAM's prices consistently exceeding those of private trade in surplus regions (Ballan et al. 1977, vol 1, p 20, 34) and therefore *succeeding* in lifting producer prices during the postharvest campaign. Panhuys states the reverse: that parallel market prices exceed those of OPAM by 10 to 100% (FAO 1973, pp 14-15), and Richard and Vandenberg (1975, p 24) state that private purchase prices can be higher and yet consumer prices be lower than the respective prices of the parastatal, because private trade monopolizes the least-cost flows, leaving OPAM with problems of distributing to the costly residual areas in addition to high-overhead costs. In Senegal, too, opinion differs as to whether free market producer prices exceed the official ones (Ross in CILSS 1977, vol 2, Senegal, pp 43-50) or the reverse (SONED 1977, pp 86, 102). To some extent these relationships must depend on the size of the harvest. But to sort all this out is an important research priority with considerable policy implications.

It is equally reasonable to suggest that non-price factors are important conditioners of agricultural stagnation, that it is the poverty of physical and financial infrastructure for grain marketing — especially the dislocation of trading from the limited state production credit — that is crucial. Sincethe marketed surplus in any one year is difficult to predict, it is hard to organize finance for trade and repayments for farmers. Funds may be untimely in all these countries. Purchase of cultivators' subsistence requirements may be coerced. Peasants' transport costs to centralized depots may not be reimbursed. The physical removal of subsistence stocks from zones of production exacerbates the vulnerability of farmers to the soudure (see Wilcock 1978, Wilhelm 1976a and CILSS 1977, vol 2, U-V, pp 43-44 for Upper Volta; Ballan et al. vol 1, USAID 1976, CRED 1977 p 138, and Guggenheim 1978 for Mali; SONED 1977 and Financial Times, February 1978 for Senegal).

Thus producers may also be starved of capital, not only by the action of private trade but also by the State. The existence of efficient marketing infrastructure for cash crops may influence cropping pattern decisions away from millet and sorghum, irrespective of the relative price relationships. Also, the cultivators will have a reduced and untimely quantum of capital unlikely to be channelled into innovations, of which few are available for millet and sorghum anyway. In Upper Volta, *encadrement* of cultivators has been hindered by their distrust of the Regional Development Boards, which were not adequately equipped to handle a monopoly purchasing system (Wilcock 1978, pp. 197-198; CILSS 1977, vol 2, U-V, p 19), and these production parastatals are rejecting the mercantile role. In Senegal, it is alleged to be lack of capital that prevented peasants from responding to a 30% rise in the official price of grain after the drought (FAO 1976a, p 15). Both price and non-price factors clearly work to slow the formation of a rural market.

The Effects of Grain Production and Marketing Systems on Intervention

We cannot find any research at all that has considered this subject or its implications in an explicit way.

The main effect of production on the nature of State intervention is that the agricultural system does not generate sufficient resources — either financial or physical—for intervention to be organized so as to have bite in relation to its stated objectives. The impoverished nature of the increasing number of producers who are (net) consumers will reinforce the very same cheap food policy that is causing their poverty in the first place, since it is not in their interests to pay out higher prices for food. The first response of the Sahelian peasant is, if he can, to "hoard" (a most value-laden verb) — unto store so as to enable his dependents to survive a long but unpredictable production scarcity. This is a strategy highly adapted to a risky and uncertain production environment, but it is unsuited to the consumption needs of a rapidly urbanizing market economy. Attempts by the State to transform storage practices (mistaking the distress sales and rural redistribution for a "true" surplus) extract excessive resources from the control of the rural sector and increase its vulnerability. Small wonder that some such projects are meeting with stubborn resistance from peasants. Nonetheless, policies aiming at the reduction of household-level stocks apparently continue to be pursued (USAID 1976). Meanwhile, urban demand increases and supplies are diverted from the parastatals, which are thus caught in a double bind.

Local trade is proving impossible for the State to replicate. It consists of small quanta of "surplus," sporadic in space and time, sold whenever cash is required by both poor and rich, and sold by the rich when prices are high. These supplies are diverted from parastatals whose minimum capital investments are high, whose technology is imported and capital-intensive, and whose manpower requirements are large. In turn, to ensure its minimum current obligation, let alone create a buffer, the para--atal is sometimes forced to order its agents to coerce peasants into parting with grain, as in Mali and Upper Volta. Alternatively, it indulges, as in Senegal, in sanctioning increasing imports of rice and wheat, which are changing the structure of demand in rural as well as urban areas towards economically superior, though nutritionally inferior, food (Yaciuk and Yaciuk 1977, p 56). "Les consequences de l'evolution de la demande interieure tendancielle sont catastrophiques pour la nation" (Ministere du DeVeloppement Rural 1977). Butthe researches required to reverse this trend: a stable and higher yielding production technology for millet and sorghum, a product transformation technology, but most importantly control over what rich urban classes choose to eat, show no signs of being available.

In Mali, where the deficit regions are territorially vast and sparsely populated, the parallel marketing system competes effectively with that of the State in surplus districts, leaving the latter to cope with reduced supplies and higher cost distribution to deficit regions.

According to FAO (1976a, p 109), "15 to 20% of the marketed surplus is sufficient to control the market," but this depends on the structure and performance of the market. We have seen that the domestic marketing system, certainly in Mali and Upper Volta, is too powerful to be controlled in this way by a competing parastatal. Only in Senegal, where marketed surplus is small and until recently ONCAD marketed a supposedly higher percentage of this surplus, was there any indication of successful control.

Furthermore, the lack of resources with which to monitor borders is an open invitation to smuggle. It is impossible to implement the monopoly, and the lack of financial resources feeds back continually into an inability to accumulate adequate physical resources.

There is thus a structural crisis in the parastatals. It is expressed most obviously in lack of financial viability in grain trading, necessitating bailing out by international aid. In Mali, for instance, this involves increasing dependence on external supplies of millet and sorghum. During the drought, some 350 000 tonnes were supplied, two-thirds as gifts sold at subsidized prices to consumers but one-third at 191 Frs. M/kg, when the producer pricestood at 32 Frs/kg (Ballan et al. 1977, vol 2, p 2). Gifts as well as loans are continually being given to the parastatals by external agencies, which usually demand some internal organizational rationalization and reform in return. If there is any response it takes the form of reform by a process of institutional fissions (see IBRD 1977), spawning further parastatals and sharpening the internal contradictions. It would seem that the expansionist forces exceed the internal capacity to operate effectively.

In Mali and Upper Volta, members of trading *ethnies* have been closely involved in the operation of state trading (Diop 1971). They have an interest in sustaining its inefficiency; fargreater private resources accrue from the clandestine international trade that is inevitably provoked by present policies, and bureaucrats may invest in trade and transport (Bollinger 1974, p 44).

The production and marketing system thus creates conditions that help expand a type of intervention that exacerbates pressures exploiting the agricultural sector. With external funds injected periodically, the administrators have no interest in phasing out what they control. Thus this analysis shows that constraints on institutional reform are very much narrower than has been concluded, for example, from the large study carried out for the Club du Sahel (CILSS 1977), where the dismantling of most State commercial institutions is set out among policy options.

Conclusions

We have examined the effects upon one another of grain production, private grain marketing systems, and State intervention. We cannot quantify the interacting role of the marketing system on production, nor do we pretend to deny the importance of relations of production in explaining the stagnation of the subsistence sector.

It is due to external metropolitan economic power that the agricultural marketing systems' allocative role has favored export crops, not food crops. Change in agricultural production technology is still subject to this power and, in the medium-term future, an appropriate ecologically sound, widely replicable modern grain production technology, capable of employing and feeding the growing population, will almost certainly be absent. It is an unstable coalition of external metropolitan and national economic power that uses the marketing systems for export crops to extract resources, and for which the general failure of State marketing systems for foodgrains to generate similar resources is problematical. External economic power is thus both the key to and the barrier to productive and progressive change in the agrarian economy.

Commerce is not just a constraint on agricultural development on a par with absence of water or presence of river blindness (as in FAO 1976 and many other documents using a commodity approach to rural development); commercial activities are part of a system of particular social relations from which they cannot be divorced. And the agricultural production systems of the Sahel are being impoverished, as the general orders of magnitude of the remarkable statistics assembled by Szczepanik and Iaccoacci (1975) show (Table 1)

State intervention appears to alter the structure of private trade in favor of monopolies, thereby exacerbating what it intervenes to restrain. Intervention has apparently failed to quash anything but information on private trade, though the evidence reviewed here is in major part supportive of the notion that these composite marketing systems inhibit grain production. It is quite impossible to identify single constraints on production, or single interest groups or classes who benefit from the operation of the composite marketing system, though it is obvious that the poorer peasantry and poor urban consumers are the losers.

Table 1. Income per active worker in agriculture as a percentage of income per active worker in nonagriculture.

	1960-62	1969-71
Upper Volta	11	10
Mali	8	8
Niger	11	9
Senegal	11	11
All Under Developed Countries	28	27
France	37	39
UK	103	108
USA	61	73
All Advanced Countries /	54	55

The latitude for change within the present socioeconomic structure appears to be extraordinarily limited. It is not at all clear how further reformist measures can improve market efficiency. It is clear that any local political mandate to liberalize trade is insufficiently powerful. It is not altogether clear that the liberalization of private trade would necessarily improve currently stagnant grain production since the parallel market still functions, albeit under peculiar circumstances. And evidence suggests that the private commodity marketing systems, linked with the marketing of money, suppress and exploit as much as or more than they encourage and expand. The liberalization of international trade is politically inconceivable as well as subject to the same caveats.

It is possible that the literature reviewed is excessively critical (in the tradition of applied social science) and/or written too early on in the current multiplicative phase of State intervention. Since 1977 technical delegates of African countries have expressed concern to increase "true surpluses," necessitating actions to alter what they perceive as the priorities of relative neglect but what we have suggested is deliberate action (see Nacro 1977, vol 2). However, the resources of their economies are very limited. Fragile domestic budgets (even of the most robust economy) do not balance, so any reallocation of resources from internal funds has to be diverted from an alternative use. External funds are rarely allocated for purposes actually articulated by nationals (Meillassoux 1974). Furthermore, we are not dealing with a *tabula rasa.* There are precious few reformist precedents for the dismantling of any institutional structures (apart from village level cooperatives built up not so much for the staples considered here as for the cash crops grown for export). Intervention expands because it creates monopolistic trading sources of income both for bureaucrats *and* for private traders. In so doing it creates privileged employment as well.

Finally, the literature treating price policy for millet and sorghum is curiously silent on the most important point: that low producer prices for grain must be designed not only to keep urban prices low (for they do not always do that for many of the urban poor) but also to ensure stability in, or an increase in, the production of cash crops. In the absence of a uniquely and widely appropriate production technology (see IBRD 1978, pp 45-51), increases in grain production would reduce acreages to cash crops that earn the foreign exchange (largely controlled by State institutions) and, in turn, sustain an evolved structure of powerful *non*agricultural demand for nonagricultural goods, mostly imports. The import of wheat and rice, preferred over millet and sorghum by urban populations, in reducing effective demand for local crops also works to lower the general price level for millet and sorghum, and the food crop/export crop price ratio. Taken *together,* these explanations for current price policy represent formidable obstacles for reformist change.

We have to face the question of whether any "development" involving substantial reversals of present trends, as would be necessary to affect the changes in demand in Senegal for instance (Ministere du Developpement. Rural 1977; Min. du Plan 1978) is *possible,* given what we know about the Pandora's box of interventionist measures) even though it might well be *"necessary".* Until peasant producersdecide of their own accord to take initiative in the arena of political power and economic decision-making (an event that seems unlikely in the time-span of conventional economic planning) then this puzzle, under the *status quo* of the Sahelian political economy, appears to be intractable.

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Discussant's Comments

Elliot Berg*

Dr. Harriss has been given a difficult task — to survey a diffuse and disparate literature, much of it consisting of fugitive materials (reports of agencies, government documents, etc.) covering many different countries and many complex issues. She has clearly done an extraordinary job of synthesis and analysis. This is evident in her paper, and even more evident in the reports she has written for ICRISAT.

It is a difficult paper to critique. It is full of critical observations, fresh ideas, assertions, set out in rapid order and in great variety. This makes for stimulating reading and new insights. But it also results in frequent obscurities and occasional nonsequiturs and irrelevancies. We are told, for example, that in Senegal: "The role of the groundnut marketing system in extracting financial and physical surplus from peasant producers at highly deteriorating double factoral terms of trade is well known and will not be recapitulated here." The State can, by paying producers less than world prices, "extract a financial surplus from groundnut growers; but whether the double factoral terms of trade are rising or falling has nothing to do with it."

A few pages earlier we are told that in Mali "... very considerable profits are made by... traditional urban wholesalers from international smuggling caravans, for Mali, in spite of its declining acreage to cereals and low relative and absolute prices, is a surplus country in a normal year." But whether Mali is a surplus country or not is irrelevant; smuggling occurs whenever Mali's prices are lower than those of its neighbors, and this would be true whether or not the country is in "surplus" or "deficit".

The paper has other statements of this kind, deriving perhaps from its broad scope, the sweep with which it is written, and the author's attempt to compress a great body of material into a relatively short paper. But rather than pursue this further, it is more interesting to consider the general issues, or at least some of them, raised by Dr. Harriss.

First, a word about general methodology and the matter of values and biases in social science research. Dr. Harriss has elsewhere aimed some sharp and cogent criticisms at "conventional" economic analysis in marketing. She has also quite properly observed that none of us is value free — in particular in what we choose to study and how we study it. It is perhaps not improper to look at her paper from this perspective.

With regard to choice of problems to be studied, one point stands out clearly: the impact of the marketing system on income distribution. Of the two functions of marketing systems which she mentions — the "allocative" and the "extractive" — she is mainly concerned with the "extractive." If any central theme runs through the paper it is that marketing systems in the West African SAT reinforce inequality in the production system and in the distribution of income.

Now, the interaction between marketing and income distribution, and the "extracting" aspect of marketing arrangements, are certainly interesting and important issues. But among the range of problems and issues in the marketing area, does it really deserve so central a place? The impact of the functional state monopolies on equity and production presents issues of perhaps more importance to peasants and to policy makers. The disorganization of grain markets, the existence of coercion; the discouragement of traders' skill development; the use of productionist development agencies (ORDs in Upper Volta, Operations in Mali, for example) to do primary grain marketing with potentially devastating effects on their main objectives; problems of price policy; issues related to on-farm storage — all are clearly high priority matters in West African marketing.

Dr. Harriss discusses many of these issues,

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and in her research priorities paper as well.* But her emphasis is on distributional questions. Midstream in the paper she rejects consideration of options for public policy and instead affirms "the relevant issues for review are the historical evolution of, reasons for, and distribution effects of this complex situation."

if West Africa's SAT had a merchant class of sizable proportions, or if there was firm evidence of widespread monopoly profits or of significant shares of income to grain traders, this priority would be understandable. But despite Dr. Harriss' valiant efforts to show the possibility of accumulation of surplus on a big scale, most of the evidence runs the other way. In highly monetized regions of Senegal (Kaolack and Diourbel), a recent study[1] indicates that the six biggest traders in Kaolack buy on an average 500 to 1000 tonnes of grain annually; it is believed that in Diourbel only five traders buy morethan 500 tonnes a year. Casual empiricism, visits to grain traders in the Sahelian cities, as well as virtually all studies of grain trading, indicate a consistent pattern of small inventory holdings and relatively small-scale operations. It is certainly hard to see a *compradot* class i n the making, at least for some time. Given the relatively burdensome problems that exist in the allocative side, the "extractive" focus in Dr. Harriss' paper seems disproportionate.

Let's turn briefly to Dr. Harriss' principal conclusion about the nature of the private marketing system and how she reaches that conclusion. It's often said that to believe is to see. Dr. Harriss believes that immediate post-harvest (distress) sales are common, and that rural indebtedness, incurred at usurious rates, is widespread. Shesees confirmation of this in a number of studies. She stresses particularly the findings in an unpublished work by Clough, though she marshals other evidence as well. She concludes (P. 5) that "the social relations of trade thus force *most farmers* (emphasis mine) to sell grain when prices are low or to go into debt to be repaid at harvest at high interest rates..."

In reaching this conclusion, she rejects or ignores contrary findings in the literature. Thus the three most intensive studies in this field (by Hays, Ejiga, and Matlon — all done in Hausa areas of Northern Nigeria) found little in the way of distress sales and relatively little indebtedness, especially to traders. These findings are confirmed by the SONED study in Senegal and are suggested in the CEGOS (Ballan) study in Mali. But Dr. Harriss rejects the conclusions of the village-level survey type studies on the grounds that farmers are secretive about indebtedness, so the findings on debt incidence are suspect. This is to impute uncommon carelessness or thoughtlessness to the researchers in question, each of whom spent many months in dose contact with the villagers. Incidentally, it is worth noting that while Polly Hill, in her review of Hay's book, does note the secretive nature of debt information, she also records her enthusiastic agreement with the general findings about the competitiveness of the grain trade and presumably about the apparently small amount of distress selling. In any case, why should findings that show high levels of indebtedness be accepted while those indicating the contrary are rejected?

From a policy point of view, the conclusions of Dr. Harriss' paper are grim. The private trading system is exploitative. The State trading system is ineffective, inequitable, and disruptive; intervention makes things worse, not better. Moreover, there is not much hope for ameliorative change, for reform. The bureaucrats benefit from it. So do the international agencies that support the grain parastatals.

Dr. Harriss' pessimism is not without some foundation, but it is excessive. Among other elements, the international donor community is seeking reform. Dr. Harriss implies that these agencies created the parastatals in pursuit of a rational goal: development of local institutions useful to donor purposes. But this is only partly so. External policy was conditioned partly by the drought and partly by bureaucratic inexorability: the acceptance by local governments of poor programs.

Dr. Harriss also underestimates, I think, the ideological factor — the fact that intellectuals and civil servants believe that traders are essentially unproductive and exploitative and

* *Editors' note:* This paper, entitled "Relevant and Feasible Research", is in the document by Harriss (1978) cited in her paper in this Proceedings.

1. SONED, Etude Sur la Commercialisation et le Stockage des Cereales au Senegal, 1977.

have therefore eagerly pursued interventionist trading policies.

It is worth recalling also that the present confused state of grain marketing in West Africa dates only from the middle or late 1960s in most of the region. Private traders did the job before, and in more developed countries further south (Ghana and Nigeria) there existed until very recently a highly complex and apparently efficient food trading network. The unsatisfactory performance of the present system may lead to a willingness to consider new options.

A final word on research priorities. What we need is to know more about the structure and functioning of grain markets. More specifically, we need a large set of in-depth village-level studies of crop disposal. This would involve closely linking marketing with production and labor use studies and would basically start at the harvest. The questions to be asked are: how much grain is stored, sold, given away, bought? Who buys and who sells, when, whereto whom and at what price? The link to the first market — whether house trade, local periodic market, or other — should be explored in depth. There is also need for more standard types of marketing studies, following the flows of grain through the distribution channels from producers or local markets to major consuming centers. The important point is that the basic structure of these markets is so poorly known that studies of this general type would seem to have first priority. Whether this is a priority in accord with ICRISAT's comparative advantage is another question.

(*Editors' note:* Considerable discussion followed Berg's comments, and much of it was critical of Harriss' paper. The substantive issues are summarized here, along with Harriss' responses.)

B. F. Johnston expressed his uneasiness about Harriss' criticism of standard "structure, conduct, performance" marketing research of the type done in the many West African studies she reviewed. He and others were especially concerned about her assertions that many researchers had drawn wrong inferences from their data on marketing in West Africa. Johnston also doubted whether acting on marketing systems in West Africa is an effective way to reduce inequalities. He sees emphasis on technologies aimed at progressive modernization of the great majority of small-scale farm units as the most important priority.

Harriss responded that a more detailed critique of the "structure, conduct, performance" marketing research in West Africa is being published in a separate monograph ("The marketing of Food Grains in the Sudano-Sahelian states: an Interpretative Review of Literature"). She doubts if studies concluding that there are no debt or moneylending relationships can be based on reliable data. Harriss believes that, historically, changes in production systems tend to change marketing systems also, rather than the reverse. However, at certain stages of development, commodity marketing systems linked with money markets may dominate production systems, often for long periods. She agreed with Johnston in welcoming emphasis by ICRISAT on devising technologies that assume the perpetuation of the peasantry rather than its elimination. At the same time she believes marketing research to be equally important.

Regarding Berg's comment that her paper overemphasized the extractive role of markets in West Africa and distributional issues, Harriss responded that the history of market policy interventions in West Africa is such that major regressive effects have resulted. Furthermore, contrary to Berg's view, there is considerable evidence (cited in the Harriss monograph mentioned above) of sizable merchant or trading "ethnies" or groups, and trading is almost always an income supplement for rural families. There is also evidence of considerable monopoly profits from grain trading. These are further reasons why emphasis in Harriss' paper was on distributional issues in grain marketing rather than on allocative issues, which have already been studied (although, according to Harriss, with major flaws in both data and analysis).

Harriss concurred with Berg that the multiplicity of government agencies involved in cereal marketing has led to confusion and inefficiency. Berg concludes that in 1965, before the spate of national and international intervention, grain flowed satisfactorily; he said that it would do so once again if these interventions were dismantled. Harriss stressed that her research was aimed at understanding why interventionism had grown and to identify the forces constraining liberalization. Berg believes rational organization of trade is possible. Harriss believes that because of the histories of the Sahelian countries, it cannot be assumed that rational organization of trade can occur there.

Chairman's Summary

J. C. Davies*

It was a pleasure to chair this session when two thought-provoking and interesting papers were read *on* "Farm Level Studies in SAT West Africa" by Norman and "Going Against the Grain" by Harriss. It would be invidious for me to attempt, in the few minutes available, to summarize these since they are already summaries of detailed and comprehensive consultancies carried out by the authors. All I can do, as a Daniel in a den of economists, is to hopefully pick out certain areas where it appeared there was some agreement or disagreement in the stimulating and lively discussion which frequently — owning to the time factor — had to be curtailed, but which I am sure will continue over the next few months while ICRISAT's plans for economics research in West Africa develop. I must add a disclaimer in the approved style that the statements and conclusions I draw here are not necessarily those which you as a body of economists drew — they are those of an interested observer with possibly an axe to grind.

The following points to my mind emerged:

1. There was some misunderstanding about the ICRISAT proposals for production and marketing research in West Africa, in that several commentators stressed that they were very broad-based, rather ambitious, and that they would require focus. I believe that the intention was to use the Workshop as a mechanism to do just this and, to an extent, the discussions succeeded. That is not to say that the discussions to date do not need further consideration and digestion.

2. There was unanimity that in the production and marketing research field ICRISAT should be concerned with development of suitable methodologies for conducting economic research and obtaining base data for SAT Africa. There was clearly a need to modify and build on the experience gained in the Indian context. In particular, some of the methodology used in the villagestudies in India would require modification for use in Africa. Care will have to be taken to integrate fully with national programs and institutions at the outset and to include a training element in projects, in view of the acknowledged shortage of personnel in many of the countries of interest in West Africa.

There was some disagreement on the amount of base information already available in SAT West Africa, and a feeling that in several countries a great deal of information would be accessible to ICRISAT, as an international organization, if ICRISAT was interested. In general, it was felt by ICRISAT staff that this information was best obtained and summarized by national staff. The subject of price levels over time for cereal crops was specified as one example where data were apparently available in such countries as Nigeria. It was agreed that such data were crucial, that price cycles were important but difficult to follow, but that they did have an effect on production economics. ICRISAT could contribute in collection of base data and play a valuable role in assessment of available information since independence from local systems could be an advantage.

3. On the production technology side, several areas were mentioned as likely target areas for research, including research on the effects of introduction of animal power and the economics of doing this. It was particularly noted that issues other than straight-forward economics had to be taken into account in assessment projects. The impact of improved technology, introduction of new cultivars, and possibly hybrids, on production of cereals would have to be quantified and closely monitored since the effects on the rural poor might conceivably be double-edged, particularly in view of the lacunae in our knowledge about actual disposal and movement of cereal surpluses. The question of the impact of improved technology on soil fertility, and associated with this, the benefits of deep plowing, rotational systems, and mixed cropping, were fruitful areas for project development in economics. Associated with rotational systems is the perplexing problem of integration of animals into the pattern of ICRISAT agricultural

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research in the SAT. Animals are an integral part of the system in the soil fertility and economic sense, the importance of which ICRISAT has acknowledged, but for a host of reasons chosen to ignore.

4. The dangers of ignoring the dose interrelationships between the West African SAT areas and the humid tropics to the south of them were noted. The economies of these countries were linked, sometimes subtly but almost always. Possibly studies of production could be linked to studies of intercountry movements of cereals. There appears to be little definite information on the effects of fiscal and policy decisions on movement and production of cereals between West African nation states, and in the course of discussion different speakers placed different interpretations on the importance of Government marketing policies on production. Government statistics, for instance, often conveniently ignored the flourishing illegal trade. There was a clear indication that ICRISAT should study the nature and scope of private marketing systems since again there were areas of disagreement on how exploitive they were, particularly in the historical context. It was acknowledged that recently there had be'en considerable changes in private trade. A study of grain markets and flows was a high priority, particularly the relationship between the private and parastatal marketing systems. This, irrespective of one's stance on the use, abuse, efficiency or inefficiency of the latter was a grey area, particularly in view of the disruptions in supplies of food grains of recent years in West Africa. It was felt by many that at present there is no detailed, unbiased, study of grain flows from farm to final point of sale in West Africa. Clarification of differing views on the extent of enforced sales is vital in view of their importance in seasonal flows. Such studies will be necessary in several countries and possibly in several areas within a country in view of the great diversity found in West Africa.

5. A definite need for economic research in the area of on-farm food storage was expressed. While the purely technical aspects had received considerable attention, there was little information on the relative economic benefits of small farmer versus trader storage. There were differing views on the extent and effects of enforced post-harvest sales on indebtedness and on the benefits of on-farm versus bulk (which could often be equated with state) storage. This study would link with the study of grain movement from homestead to point of final sale and the vexed question of food security.

6. Several participants reinforced the point made in the Harriss paper that the sum total of policies currently in operation was to reduce the income of the "man who produced the goods." In these circumstances, the overall incentives for increasing production of cereals were probably nil. It is a moot point whether ICRISAT can, other than in a very oblique way, instigate research that will highlight this fact. Certainly related to this field, was the request that ICRISAT study labor constraints to production and assess the importance of off-farm employment, which appeared to be playing an increasingly important role in the economics of the rural areas and in peasant farming households. Also, what is the effect on farm and rural communities of the vast input of aid into these countries?

7. Related to these are studies that are undoubtedly required on emigration from rural areas—both local and long distance. Emigration is having profound effects in various ways on productivity; and by repatriation of cash to areas of origin, it greatly affects the budgets, incentives for increased productivity, and the life styles of the remaining population. To date little research in these topics has been done in West Africa.

8. There was an appeal for the socio-economic/anthropological side of research notto be swamped by the sheer weight of feasible economic projects identified in the workshop.

9. The implications of the Harriss' paper on relevant and feasible research,* and particularly the criteria to be adopted in assessing projects, needs further careful and in-depth study by the program research committee at ICRISAT before final decisions are taken on project formulation.

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* *Editors' note:* A copy of this paper entitled, "Relevant and Feasible Research," was made available to Workshop participants but is not Included in this volume. It was written by Dr. Barbara Harriss at ICRISAT's request as an addendum to the complete report she prepared on research policy in food grain marketing in West Africa, which her paper in this Chapter summarizes.

Chapter 7

Nature and Significance of Risk

Nature and Significance of Risk in the Exploitation of New Technology

Jock R. Anderson*

Abstract

This paper is essentially contemplative rather than attempting an empirical review of the issues canvassed. However, questions are posed — sometimes in the form of hypotheses intended to be susceptible to empirical examination. While the subject of overt attention is farming in the semi-arid tropics, the author's hope is that the opinions marshalled here may have general relevanceto matters related to risk in farming everywhere.

This essay is essentially contemplative and is not geared as closely as the author would wish to the realities of the lives of farm families. Without doubt, had it been possible, it would have been much more rewarding to present a cogent empirical review of the issues that are canvassed. However, in the second-best approach adopted several questions are posed, sometimes in the form of hypotheses intended to be susceptible to empirical examination.

While the subject of overt attention is farming in the semi-arid tropics, often by people who are categorized as peasants, the hope is that the opinions marshalled here may have general relevance to matters related to risk in farming everywhere.

The word 'exploitation' has replaced 'development' in the title for two reasons. First, the author's ideas on the interplay between risk and the development of new technologies for small farmers have changed little from those elaborated in Anderson (1974) and Anderson and Hardaker (1978). Second, especially in less developed agricultures, there is a difficulty that many research and extension workers have little empathy for farmers and little understanding of what farmers do or why they do it — with consequent impact on the validity of their comparisons of possible new technologies with prevailing practices. While there have been some appropriate studies (e.g., Misra 1964, Miracle 1968, Bell 1972, Herdt and Wickham 1975, Barlett 1977, Cleave 1977, Gladwin 1977) there still seems to be a need to comprehend the decision environment in which new technologies may be exploited, before the question of development of technologies can be adequately tackled.

Some Thoughts on Farmers' Pursuit of Satisfaction

As in most human communities, the family is the basic unit of farming societies. The family enters farming typically in a pssive way that reflects previous family history and tradition and the confined openings of rural upbringings. Its initial endowment of rural resources is largely predetermined and open to restricted enhancement through whatever credit markets are available.

The associated human resources are also subject to various constraints. Social status is largely inherited. Limited educational facilities restrict direct development of human capital capable of easy redeployment in other sectors.

The picture sketched is one of tightly constrained physical financial and human resources. Decision makers, during their custody of the physical resources, have to chart a course

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The views expressed are those of the author and are not the responsibility of the Australian Bureau of Agricultural Economics, to which he is presently seconded.

that in some way generates the best possible accumulation of satisfaction for the respective families. Their task is demanding of adaptability, patience, and resilience.

The operating environment is intrinsically unstable and, for planning, uncertain. The decision makers have to plan to exploit favorable events and to survive the unfavorable. This they do from a background of cultural and personal attitudes to all aspects of life. Concerning risk in particular, their attitudes are most unlikely to be neutral (Anderson, Dillon and Hardaker 1977).

Risk aversion is now seldom challenged as the 'norm' of attitudes towards risk generally and especially in peasant farming communities (Johnson 1971; O'Mara 1971; Moscardi and de Janvry 1977; Wiens 1977; Binswanger 1978a, b, c; Dillon and Scandizzo 1978). Accordingly, there is no point here in dwelling on or attempting to review the growing body of conventional wisdom on the implications of risk aversion in these communities for resource allocation, investment, efficiency, etc.

In spite of a paucity of reliable empirical investigations of risk a version, the only features that in anyway remain controversial are (a) the degree of aversion held on average in various communities and (b) the proportions of attitudes that differ significantly from the average levels of aversion (e.g., risk preference or extreme risk aversion). It might be observed in passing that the procedure of drawing inferences about 'average' levels of risk aversion on the basis of matching optimal enterprise combinations from risk-averse aggregative programming models against observed combinations, seems fraught with potential errors that are sensitive to the specification of the models (see, e.g. Simmons and Pomareda 1975).

Over the lifetime of any farm family there will be a succession of environmental crises and catastrophes, challenges and changes (see, e.g. Jodha 1978). Especially in semi-arid tropical areas, the unpredictability and severity of climatic events is rivalled by the dispersion of relevant probability distributions and the human difficulty of comprehending and managing probabilities of relatively rare events.

Positive opportunities, such as technological innovations, will appear and be available for uptake. Each will be reviewed by decision makers and, on the basis of whatever information is at hand, personal judgment made about the desirability of the innovation and about the extent and timing of possible exploitation. Farmers may feel that some innovations add more to the riskiness of their operations than they add to anticipated gains on average. There is sketchy investigative support for some such farmer appraisals (O'Mara 1971; Anderson and Hardaker 1973, Perrin et al. 1976, Gladwin 1978).

The criterion presumed here to underly the judgment is the lifetime satisfaction of the farm family. Unfortunately, this topic is shrouded in clouds of ignorance that are symptomatic of the sparseness of pertinent investigations. More research on decision criteria of farmers is required if analysts hope to advance from mere presumptions to well-tested hypotheses. But this is demanding work. The general reasoning being advanced here is thatthe implementation of new technologies by farm families will only be satisfactorily comprehended if there is a good understanding of the human characteristics behind the pursuit of satisfaction (see also Cleave 1977).

As a possible lead to future research on this theme, some speculations are assembled on the nature of the preferences of the farm family, in these speculations, the biological (Hirshleifer 1977) and social (Barlett 1977) underpinnings of economic behavior are emphasized.

Hypothesis 1

Preference functions of farm families are evolutionary and:

a. depend on the composition of the family, and relatedly, the stages in life cycles of the members of the family, and
b. feature arguments of flows of consumption and stocks of wealth, and
c. depend on social status and family self-esteem.

Pride in the present social position of the family, and low utility associated with the (perhaps remote) possibility that status and thus self-esteem might slump, can plausibly contribute to ultra-conservative attitudes to experimentation, innovation, change and risk. Perhaps the factors in Hypothesis 1 c should be extended to include educational level, off-farm employment, religion and group memberships? (See, e.g. Moscardi and de Janvry 1977.)

Hypothesis 1 b is tantamount to a call for an integration of the New Household Economics (e.g. Sant'Ana de Camargo Barros 1976, Barnum and Squire 1977) with Multiattribute Utility Theory (Keeney and Raiffa 1976). With the recent advancements in these fields, the time seems right for an insightful union of the ideas and methods of both, before the specialists in each spawn the specialized deafness that follows more esoteric developments (Weinberg 1975).

In Hypothesis 1 a, there are many sub-hypotheses that could be tested to glean deeper insights. For example, what are the relative contributions of marriage partners (when there are at least two)? One suspects that the rote of wives is much more significant than has been recognized in previous surveys and models of decision making on farms. Case studies of farm-family preference functions before and after separations (by death or divorce) might be a discriminating source of data on this question. If the role of wives proves to have the speculated high level of significance, there will be related implications for education in general and farm management training in particular for rural girls and women.

A further area of ignorance is the potentially conflicting preferences that impinge on intergenerational transfers of ownership and control. Longitudinal family studies of attitudes towards risk would help to elucidate some aspects of intergenerational problems. Cross-sectional studies may, in the meantime, help to extend understanding. One could usefully confront a more detailed disection of Hypothesis 1 a such as:

Hypothesis 2

Attitudes towards risk:

a. are highly heritable,
b. vary systematically with age,
c. follow a general pattern of increasing aversion to risk with age, and
d. tend to be matched similarly in marriage contracts.

Testing of Hypothesis 2 will be especially challenging because of the need to control for other important hypothesized effects, e.g. the effect of arrival of children of different sexes on attitudes to risk, and the much-discussed effect of changing wealth levels on attitudes to risk. Hypothesis 1 a might thus be partitioned further as follows.

Hypothesis 3

Attitudes to risk:

a. change as children enter or leave the family unit,
b. follow a general pattern of increasing aversion to risk with:
i) increasing numbers of dependent children and either
ii) increasing feminity of dependent children when a dowry system prevails, or
iii) increasing masculinity of dependent children otherwise.

It is not intended to imply that testing the above hypotheses, or even gathering the required data will be easy. Indeed, as Tversky (1975) has argued and Binswanger (1978c) has demonstrated, this is a challenging field of inquiry and the difficulties should be well-appreciated before empirical work is embarked upon.

Perceptions of risk are as important in decisions about new technology as are attitudes to risk (Misra 1964). They are just as difficult to study as attitudes because of the requirements for eliciting the inner feelings of people unaccustomed to explication of such vague and unfamiliar concepts (see Tversky and Kahneman 1975). Ignorance of the way in which risk perceptions change in response to new information from either on-farm experience or sources beyond the farm is profound. The Bayesian learning model seems reasonable and appropriate on a conjectural basis. However, there is need for empirical work on validating the model in terms of the component distributions— prior, likelihood, and posterior—, and on integrating the learning model with the on-going experimentation on and management of the farm (O'Mara 1971, 1979). Some researchable possibilities are embodied in the following compound hypothesis.

Hypothesis 4

Perceptions of the risk associated with new technologies:

a. can be modelled adequately as Bayesian revision of subjective probability distributions,
b. feature 'pre-experience' prior distribu-

tions that differ systematically with:

i) extent of formal education,

ii) length of farming experience in the respective agroclimatic region, and

iii) number of previous severe droughts and other extremes encountered:

c. differ between farm families and developers of new technology in thatthe likelihood distributions of the latter group are less disperse for any given pieces of experimental evidence.

Optimality, Cognition, and Cognitive Dissonance

The framework thus far has been cast in the style of optimising agents who populate the models of modern economics. With due regard to transaction costs associated with change, and to the perceptual limitations of human beings, the appropriateness of implicit assumptions about the unqualified pursuit of optimal levels of satisfaction can be challenged. As a disciple of Bernoullian decision theory, this writer sees no problems with the notion that decision makers should, in their own interests, seek to maximize expected utility (Anderson 1978).

The power of the maximizing assumption is in the enrichment of the analysis of the consequences of an appropriately specified model. However, this is not to suggest that decision makers really do actively seek to maximize *anything* (Lipton 1968). The crucial presumption is that analysis of maximizing models leads to relevant conclusions about actual behavior. This presumption must also be subjected to critical test. Perhaps one day the non-maximizing Simonian models may be exploitable in analysis of farm decision making. But that day is seemingly still far off.

As decision makers proceed through their sequences of confronted decisions, their cognitive limitations constrain their perceptions of opportunities, and their perceptions of the differences in satisfaction associated with alternative decisions. A characteristic of optimality is that near-optima are indeed very nearly optimal in terms of the opportunity cost of the forgone value of the objective function (Anderson 1975). For many decisions in the dynamic existence of a farm family, the perceived costs of change (which may include evaluations of personal discomfort with unknown or foreign ideas) will exceed the perceived gains in satisfaction. Persistence with familiar and possibly traditional technologies will be rational for the family in such instances (Gladwin 1978).

Finally, it must be stressed that farm families do not evolve their individual attitudes, in isolation. Group pressures from local communities serve to reduce cognitive dissonance so that, in spite of individual conservatism, inertia and circumstance, attitudes and perceptions will tend to move in the same general direction.

Second-Party Appraisal of Innovations for Turbulent Farming Systems

People who are so bold (impertinent?) as to attempt to judge what changes are 'good' for farmers must run a daunting gauntlet beset by needs:

a. for economy and thus simplicity in their work,

b. for a certain elegance in approach for their own self-esteem,

c. for relevance in grappl ing (and being seen to grapple) with the fundamental issues at stake, and

d. for responsibility in avoiding the role of disaster agent for families who are possibly in much more fragile circumstances than their appraisers and advisors.

Tricky tradeoffs among these needs are readily apparent, which is perhaps why such people tend to take a rather singleminded 'strong-line' personal approach to their work. This writer holds an evolving and still ambivalent position. On the one hand, the dangers of potential self-delusion and irrelevance in not taking formal account of the rich preferences of affected people should be emphasized (Anderson, Dillon and Hardaker 1977). On the other hand, the prospective difficulty of adequate formal but economical modelling of complex systems should also be recognized (Weinberg 1975, Anderson and Hardaker 1978).

A working compromise that may be reasonable, especially in view of the above remarks about optimality, is as follows. Highlight the potentialities for human intuition to deal with the complexities informally. However, let this intuition be played out against a backdrop of formal case studies of the importance of the multifarious components of the decision-making environments of farm families.

Much appraisal work will be directed primarily at assessing what is 'good' for a lending agency, perhaps a government. In this case, the foregoing remarks are still apposite, although there is probably greater scope for more formal modelling than when farmers themselves are the clients. Such modelling should probably involve consideration of risk aversion and stochastic aspects of the environment routinely. To the present time, however, techniques of investment appraisal under risk have seldom found application in practical farm-economic analysis (Wong 1978).

Concluding Remarks

As with only science, from astronomy to atomic physics, and with any nonscience, from psychoanalysis to Pandora's Box opening, deeper investigation does not necessarily make life more comfortable or knowledge more certain. Yet Science, including science bearing on families and their farms, cannot turn back in its methods — even when 'refinement in modelling eventuates a requirement for stochasticity' (Mihram 1972, p. 15). So it is that further careful study of the decision processes and environment of farm families will yield many revelations and many new uncertainties. The revelations should help to render better futures for farm families, particularly if potentially new technologies are subjected to scrutiny more attuned to the realities of farm life. The uncertainties will be the new challenges for future investigators.

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The Nature and Significance of Risk in the Semi-Arid Tropics

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Abstract

This paper reports on a series of research projects on the role of risk in the semi-arid tropical (SAT) agriculture of India. The projects are based on (1) macro data of yield, price and income variability, (2) microlevel data of income and expenditure levels of rural households over drought cycles, and (3) on a set of psychological experiments on risk attitudes. So far this research has yielded the following conclusions:

1. *Levels of income risk in the Indian SAT are high and come mostly from production rather than price risk.*
2. *Virtually all farmers in the SAT Indian sample are risk-averse although not to an extreme or severe extent.*
3. *Farmers do not have access to cheap self-insurance and risk-diffusion devices enabling them to even out their consumption streams in the face of risky production. We are therefore forced to conclude that risk and risk-aversion lead to underinvestment in SAT agriculture.*

Agriculture in the SAT is almost universally characterized by low farmer investment in agricultural inputs such as fertilizers, pesticides, and seeds. Even labor inputs and investments in land improvements and irrigation are usually low compared with other regions of the developing world. Over the past 3 years the authors have carried out research aimed at testing whether these low investment levels are partly or fully caused by the risky nature of agriculture in these areas, by the aversion to risk of farmers, and by the lack of mechanisms and policies aimed at stabilizing the income of farmers. In this paper we report what we have found so far in a research project that is still far from completion.

Risk and risk aversion of farmers is not the only potential source of low investment or "underinvestment"; low investment could also result from generally low profitability (measured as expected returns) or from credit constraints. To establish that it is risk and risk aversion that lead to underinvestment, empirical knowledge on these questions is required.

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First, of course, investment in SAT agriculture is risky. This riskiness is a well-known fact and needs no further research, except for more precise quantification. However, to deal with policy alternatives later, we must be able to quantify the relative importance of yield risks and price risks in total production risks; the effect of crop diversification on those risks; the relative importance of drought risk in total yield risks; and the effect of modern inputs such as high-yielding varieties, fertilizers, and supplementary irrigation on yield risks. Some evidence on the sources of risk will be presented in the next section.

Second, riskiness or increases in riskiness with input use will lead to underinvestment only if farmers are risk-averse rather than risk-neutral. Risk-neutral individuals will try to maximize average or expected net returns regardless of the extent of variability in these returns. This is also a strategy that leads to the highest returns on investment in the long run. On the other hand, a risk-averse individual will forego some expected returns if this also reduces the extent of variability of his income stream. Thus he will underinvest relative to the risk-neutral or socially optimal level. The question is whether the overwhelming majority of farmers in the SAT are risk-averse. Also necessary is the quantification of the extent of pure risk-aversion of farmers and landless laborers and the relation between risk-aversion and the riskiness of agriculture of the region, the size of farm, and the size of the investment to be undertaken.[1] In the third section we present experimental evidence on risk aversion.

Third, it is important to realize that underinvestment need not necessarily occur if agriculture is risky and if farmers are risk-averse. If they have effective mechanisms at their disposal for self-insurance or risk diffusion, they may still invest up to the risk-neutral optimum. For example, an effective crop insurance system would allow farmers to shift the risks to the insurance system as a whole, i.e., risk would be diffused over wider areas and across years. Such systems generally do not exist at present and farmers have to rely largely on their own means for self-insurance and risk diffusion. We distinguish two types of adjustment measures: (1) Risk-reducing measures that are used before damage may occur and that include crop diversification, intraseasonal adjustment of sowing times and cropping patterns, soil- and water-management techniques, etc.; (2) Loss management, or risk diffusion measures that are designed to deal with the consequences of losses and include storage, salvage operations, accumulation of financial assets, reduction of financial commitments in drought years, borrowings, and many more. They are aimed at temporal and spatial, risk diffusion, as well as diffusion among individuals. Efficient risk-reduction and loss-management devices would allow a farmer to take substantial levels of risk without being exposed to severe reductions in his customary consumption or without loss of productive assets even in drought years. The fourth section is devoted to this issue while the final section will indicate what conclusions we can already draw from our findings and indicate future directions of the research program.

Riskiness of Semi-Arid Tropical Agriculture

One of the major problems of working on the role of risk in agriculture is the near total lack of the farm-record type data over extended periods that would enable us to measure probability distributions of yields for individual plots, farms, or techniques of production. To measure riskiness of crop production across agroclimatic zones we therefore have to rely on aggregate data for fairly large administrative units. In India, the smallest such unit for which statistics are available is the district, and they are often small enough to be entirely allocated to specific zones.[2]

For farmers who participate in the market, what is important is the variability of gross returns to owned factors of production, i.e., gross return minus variable costs such as fertilizer and hired labor. We do not know what variable costs are or how they vary with output levels and therefore use the variability in gross value of total agricultural production per hectare as a yardstick to measure the level and source of risk to which farmers are subject.

The easiest measure of riskiness of farming as a whole is the coefficient of variation of value of output per ha. Barah (1977) has developed a technique that permits the decomposition of the (square of the) coefficient of variation (cv) into four components:

1. variability in yields,
2. variability in prices,
3. the covariance between yields and prices,
4. a residual measurement error due to various interaction terms.

This technique has been used in a pilot study of 20 districts of Andhra Pradesh, which contains irrigated rice-growing districts in its coastal zone and mostly SAT districts with predominantly irrigated agriculture on red soils (Alfisols) in the interior. The study will be

1. Even if all farmers were risk-neutral, investment in SAT areas would have to be lower than in assured zones. In good years, crops in both zones would yield the same under given management and soil conditions, but in the SAT the frequency and severity of negative deviations from the good year yields is much larger. Thus, for any given investment level, the rate of return would be lower, reducing the risk-neutral optimum investment level.

2. While data are reported on a district basis, the sampling frameworks on which they are based are designed to achieve a certain level of accuracy for state level estimates. Thus the district level estimates have a fairly high sampling error.

extended to several other states in the near future. The major conclusions emerging from the pilot study are as follows:

1. Coefficients of variation of gross value of crop output per ha for the SAT districts range from 18 to 31%, with a mean value of 22%. Those for the coastal (irrigated) zones vary from 15 to 20% with a considerably lower mean of 17%. Not surprisingly then SAT agriculture is substantially more risky, and policies aimed at risk reduction should first be directed towards these zones.

2. The decomposition of the total variability of gross crop returns into a yield component, a price component, and a yield-price interaction component, indicates that in most SAT districts the contribution of yield variability to total variability exceeds that of price variability, and often by a factor of close to 2 or more. Conversely, in the irrigated coastal districts, the price component of variability usually exceeds the yield component, often by the same factor. (However, in both zones exceptions occur.)

For both types of zones the yield-price interaction components are usually small relative to the sum of the individual yield and price effects. The largest *absolute* value of the yield-price component is only 22%, and on average the *absolute* value is only 8%. Furthermore, the yieldprice interaction component is positive in 10 cases and negative in 10, which means that individual districts are sufficiently small relative to the national market and their weather conditions sufficiently independent of national weather conditions that yield and price components contribute to total variability in an almost independent way. This result is somewhat surprising but of importance to those interested in price stabilization schemes.[3] Alternatively, the low interaction components could have been caused by the persistent price intervention of the Indian government over the study years 1953-1973.

3. Barah has also computed the amount of revenue stabilization that arises from the diversified cropping patterns farmers prefer to sole cropping. He computes an "insurance value" of crop diversification as the increase in coefficient of variation of total revenue that would arise if the yields and prices of all crops actually planted were perfectly correlated, i.e., were behaving like a single crop. This insurance value ranges from 31 % to as high as 154%, with an average of 78%. In sharp contrast to the failure of a negative price-yield correlation as a variance reducer, crop diversification, on average, reduces coefficients of variation dramatically. Interestingly, there appears to be no clear correlation between the extent of irrigation in a district and the amount of "insurance" farmers receive from crop diversification.

These results suggest that if at all necessary, income stabilization policies should first concentrate on the SAT zones where variability is higher rather than on the irrigated zones. Furthermore, since yield risk is the major component of overall variability in those zones, policy should first be aimed at yield stabilization or direct income stabilization rather than price stabilization.

The Extent of Risk Aversion

Over the past 3 years Binswanger (1978a, 1978c) developed an experimental technique to measure pure attitudes towards risk. The experiment has practically no theoretical restrictions; individuals choose among alternatives where increasing expected returns can only be purchased by increasing risk or dispersion of outcomes. In contrast to most work in experimental psychology and in economics, the experiment used large real payoffs to induce participants to reveal their preferences. The highest expected payoffs for a *single decision* exceeded monthly incomes of unskilled workers. Furthermore, the participants consisted of a random sample of the rural population of some regions of southern India that contained a large variation in

3. The recent literature has been concerned mainly with the following problem of price stabilization. In the absence of price stabilization, yields and prices should usually be expected to move In opposite directions, i.e., there should be a negative correlation between them. Any such negative correlation tends to *stabilize* revenue in the presence of yield instability, and a price-stabilization scheme could therefore *destabilize* revenue rather than stabilize it if it breaks that negative correlation. Since farmers are ultimately interested in revenue stabilization, a price scheme could therefore do more harm than good. See for example Hazell and Scandizzo, 1977.

wealth, education and other personal characteristics.[4]

The experiment, carried out with 330 individuals selected at random from six villages of the SAT regions of Maharashtra and Andhra Pradesh, consisted of a sequence of games. People were offered a set of eight alternative choices in which higher expected returns could only be "purchased" for larger standard deviations. The alternatives A to F are described in the top panel of Table 1. Each consists of a "good luck" and a "bad luck" outcome with probability of 50%, which is decided on the toss of a coin. Alternative zero is a certain outcome in which the individual is simply paid Rs 50, whereas alternative F pays nothing or Rs 200 with equal probability. The alternatives D* and D and F are stochastically dominated by alternatives B, C, and E respectively. Each alternative is given a name classifying the extent of risk aversion of the person who chooses it. These names are arbitrary, and more precise measurements of risk aversion are discussed in Binswanger (1978b).

The game was played and payments actually made seven or eight times over a period of 6 weeks or more, with from 1 day to 2 weeks time left between games for reflection. In the first five games all amounts shown in panel 1 of Table 1 were divided by 100, i.e., the alternative F paid Rs 2 on good luck while alternative zero paid Rs 0.50 for sure. This game level is therefore called the Rs 0.50 game level. At least 2 weeks later, two games at the 5-Rs level followed (all amounts in Table 1 divided by 10). After 2 more weeks a subsample of 118 household heads played the 50-Rs game of Table 1 and only the results for this subsample are shown in panel 2 of Table 1. Chi-square tests showed that at the 5-Rs level the risk-aversion distribution of the subsample whose results are discussed here could not be distinguished statistically from the risk-aversion distribution of the other household heads or their wives who did not play the 50-Rs game.

The results in panel 2 show that, when payoffs are small (0.50 Rs), we find nearly 50% of individuals in the intermediate and moderate risk-aversion categories (B and C). Over a third of the individuals show a nearly neutral or risk-preferring behavior pattern (E and F), and fewer than 10% are extremely or severely risk averse (O and A). When the stake levels rise, the proportion of individuals in the intermediate and moderate categories rises till it reaches 80% of individuals in these two classes. Near-neutral and risk-preferring behavior virtually disappears; only one of 118 individuals choose F. On the other hand, the fraction of extreme and severely risk-averse choices stays below 10% up to the 50-Rs level and rises to 16% at the 500-Rs level (a hypothetical question). The extreme risk-averse fraction never exceeds 2.5%. At higher stake levels, the risk-aversion distribution is thus single-peaked, with most of its weight in the two intermediate and moderate risk-aversion classes.

The main conclusion arising from this experiment is that in the SAT regions studied, virtually all farmers have intermediate or moderate degrees of risk aversion, once the stakes of a game come into the neighborhood of small- to medium-size agricultural investments. We observe almost none in the risk-neutral or severely risk-averse classes of behavior; i.e. attitudes are strikingly similar, despite the fact that the individuals involved have widely different income and wealth levels. In particular, at the higher stake levels we are unable to establish clear statistical relationships between risk aversion and the personal characteristics of wealth, farm size, sex, age and tenancy status. On the other hand the following variables are generally associated with very modest decreases in risk aversion: schooling, salaried employment, receipt of transfer income, and the number of winning draws in the sequence of experiments.

These results are in many ways surprising. Earlier work in Brazil by Dillon and Scandizzo (1978), based on interviews rather than experiments, had indicated a much wider spread of risk aversion; in particular, they found fairly high proportions of extreme risk-avoiders and risk-takers. Second, economists are very surprised at the weak relationship between risk aversion as measured in the experiments and

4. For a more detailed description of the experimental methods and results see Binswanger (1978c). The sample is random and taken from the rural population that has agriculture or agricultural labor as primary or secondary occupation. The mean physical wealth of the sample was Rs. 22 370 with *a* coefficient of variation of 137%. Mean years of schooling was 2.6, with a CV of 130%. Mean age of the sample was 42 years, with a CV of 30%.

Table 1. Effects of payoff size on distribution of risk aversion and on partial, absolute, and relative risk aversion coefficients.[a]

	Risk Classification								
	Extreme O	Severe A	Intermediate B	Moderate C	Slight to Neutral E	Neutral to preferred F	Inefficient D*	Inefficient D	No. of[b] observations
Possibilities			1. The Alternatives at the 5-Rs Level						
Bad Luck (50%)	50	45	40	30	10	0	35	20	
Good Luck (50%)	50	95	120	150	190	200	125	160	
Stake Level			2. Frequencies of Choices at Different Stake Levels						
Rs 0.50 (No. 2)	1.7	5.9	28.5	20.2	15.1	18.5	10.1		119[b]
Rs 5 (No. 7)	0.9	8.5	25.6	36.8	12.0	8.5	7.7		117
Rs 50 (No. 12)	2.5	5.1	34.8	39.8	6.8	1.7	9.3		118
Rs 500 (No. 16)	2.5	13.6	51.7	28.8	0	0.9	2.5		118
(no payment)									
			3. Tradeoff Between E and SE: $Z = \Delta E / \Delta SE$[a]						
	.90	.735	.585	.415	.165	$\leqq 0$			
			4. Partial Risk Aversion S[a]						
	$\geqq 7.5$	3.615	1.189	.506	.168	$\leqq 0$			

a. Risk-aversion measures can only be computed for indifference points between any two efficient alternatives. Therefore, one can only assign an interval to each of the alternatives O to F. To compute a unique value for each alternative, one can take the mean of measure at the endpoints of each interval. In the case of Z, the interval length did not vary greatly and the arithmetic mean was used. For S, the interval length increased sharply from alternative O to F and therefore the geometric mean was used (with the exception of alternative E which has a zero endpoint and where the arithmetic mean was used). Partial risk aversion was computed by solving the equation for indifference between alternative X and Y, using the constant partial risk aversion function $U = (1 - S) M^{1 - S}$, where M is certain income.

b. Due to temporary absences of some individuals from the villages selected for the Rs 50 game, the number of observations varies slightly and never reaches the full number of 120 selected in the panel.

measures of wealth such as asset holdings and farm size. The theoretical implications of these findings have been explored in Binswanger (1978b). The implications of these results for agricultural research and economic policy in the SAT will be explored in the last part of this paper.

Self-Insurance and Risk Diffusion

Risky production and risk aversion need not necessarily lead to lower investment levels than the ones that maximize expected or average returns. We perceive the goal of a risk-averse individual as one of achieving low fluctuations in his consumption stream over time, regardless of the fluctuations in his production and income levels. It has been long established that if an individual has costless means available to him for evening out his consumption stream in the face of a variable income stream he will act as if he were maximizing expected income; he will invest up to the level that is optimal from society's point of view and no "underinvestment" occurs.[5] We know, of course, that no economic system ever allows individuals to even out their consumption streams without cost; we are therefore interested here in determining whether the farmers in the SAT have *low-cost* mechanisms available to even out consumption streams. If this were the case we would then argue that there is little need to worry about risk aversion as a source of underinvestment and no justification for any policy intervention.

How should we judge the effectiveness of the farmer's self-insurance and risk-diffusion mechanisms? The first criterion is whether they achieve the goal: Do they stabilize *real* consumption levels, i.e., are farmers in a position to consume essentially the same *quantities* of goods during drought years as during normal years? This, of course, is a fairly strong condition and would indicate perfect self-insurance and risk diffusion. We may, therefore, weaken the criterion successively and ask whether farmers are at least able to maintain the quantity of food consumption and — as the weakest criterion — whether they are able to maintain their foodgrain intake (as an indicator of calorie consumption).

Farmers will always attempt to even out consumption levels by some mechanisms. Independent of the degree of their success in evening out their consumption streams, we can ask what is the cost of the various mechanisms they use? This will be our second criterion, considering high-cost mechanisms as expensive insurance and low-cost mechanisms as cheap insurance. Economics also tells us what mechanisms we should look for. Price risks are usually "insured" (or rather diffused) through the economy via future markets in risky commodities, whereas production risks are diffused via crop insurance or other disaster insurance. Both of these mechanisms are absent in the SAT. The next best alternative is "insurance" via the capital market. Individuals or small regions should accumulate financial assets during good years and be able to borrow at essentially the same rates of interest for consumption during drought years. Indeed if savings institutions offer sufficiently high interest rates and official credit agencies lend out at only slightly higher rates during drought years, the capital market could act as a very effective substitute for crop insurance and future markets.

If, however, capital markets are imperfect, individuals have other options to even out their consumption streams. First, they can store food. However, such storage is not a low-cost insurance even if storage costs and storage losses are low. The cost of holding these stocks is equal to the rate of return on investment of the value of the stocks in some other form, such as additional fertilizer applications or financial assets.

Second, individuals will have to even out consumption streams via purchases and sales of assets. Gold and jewelry as well as consumer durables can fulfill that function. Note, however, that the cost of storing gold is again the rate of return that could be had on the capital. Furthermore, transactions costs with such capi-

5. Arrow (1970) shows that a system of contingent future markets in *all* commodities will be a sufficient condition to achieve Pareto optimality in an exchange economy, with the future contracts acting as "Insurance" for the individual. Economists usually assume that a system which operates with only a few insurance and/or futures markets is all that is necessary to achieve Pareto optimality.

tal items — especially consumer durables — are usually high; they can be sold only at lower prices than they can be bought.

Third, producers can also sell producer durables, such as cattle, during drought years and repurchase them in the good years. As long as transaction costs — the difference between the sale price and the repurchase price, adjusted for the cost of carrying the animals over the drought — are low, nothing is wrong with this adjustment mechanism. For example, if a drought hits one small area, farmers from neighboring districts may come in and buy up producer durables that can be repurchased immediately after a drought for only a small cost differential. This points to the importance of effective interregional markets for agricultural factors of production as a risk-diffusion device.

Finally, the government operates relief projects in drought areas. Since agricultural labor demand is low during drought years, the possibility of earning income on a public works scheme affords insurance not only to farmers but also to landless laborers, who may often be harder hit by drought than farmers, since they usually cannot borrow easily for lack of collateral and have few assets to allow them to absorb the income fluctuations.

One adjustment mechanism also worth considering is the postponement of "nonessential" consumption, especially marriages and other socioreligious expenditures. Of course, no one likes to be subject to such rescheduling and therefore it is not an insurance mechanism in the strict sense. However, it is usually assumed that such postponement is associated with little discomfort or disutility, and we consider it along with the other mechanisms.

The evidence presented below has been assembled over the years by N. S. Jodha in a number of studies covering parts of or entire drought cycles in five districts of the SAT and arid tracts of India (Jodha 1978a, 1978b).

Table 2 shows indices of drought year consumption *expenditures* (not quantities, except for foodgrain) compared with postdrought years. Unfortunately, we do not have the quantity or price information to correctly deflate the consumer expenditure to real expenditures. However, Table 3 contains such information for one drought cycle from 1962-63 to 1964-65 in Rajasthan. Note that the price index constructed on the basis of these numbers for the food items stood at 100 in the predrought year 1962-63, at 177 during the drought year 1963-64 and fell back to 128 in the postdrought year.[6] Constancy or near constancy of expenditures in Table 2 thus implies sharp reductions in quantities consumed during the drought years. In Table 2, note that although we are looking at nominal expenditures, the totals drop in all areas by 8 to 29% compared with the normal postdrought year. Furthermore, the *quantity* of food grains consumed, which is probably the most conservative index of fluctuation in consumption levels, drops by from 11 to 19%. Total food *expenditures* remained nearly constant. In the face of the price rises in the drought years, to maintain calorie consumption at tolerable levels, individuals had to reduce the expenditures on protective foods (milk, fats, sugar, fruits, etc.) by up to 57% in the case of small farmers in the Barmer area. In the face of these price rises, the drop in quantities consumed must have been even larger. Larger adjustments were also made in ceremonial expenditures. This is the category with the largest expenditure reduction, which is not unexpected. Overall this table indicates that farmers are not able to maintain foodgrain consumption, much less any other component of consumption, at a customary level during a drought cycle.

Table 3 examines indices of *real* asset positions, relating to predrought years, for drought and postdrought years. It indicates substantial reductions in both productive and nonproductive assets over the drought cycle, with the smallest reductions in productive assets occurring in the Banaskantha and Sholapur areas.

A detailed examination of Jodha's evidence shows that most reductions in productive assets are sales or outright losses of livestock. Large losses occur when households temporarily migrate to other areas in an attempt to keep their livestock alive or to find work. Further-

6. If a small region is hit by drought, an effective marketing system should result in prompt shipment of commodities to this region from other regions and prevent substantial price rises. If a whole country or a subcontinent is hit by drought, price rises will occur even in the presence of a good marketing system.

Table 2. Indices of consumption expenditure and foodgrain consumption by households in drought years relative to postdrought years in different areas[a]

Items of expenditure	Jodhpur (Rajasthan) Small farms	Jodhpur (Rajasthan) Large farms	Jodhpur (Rajasthan) All Households[b]	Barmer (Rajasthan) Small farms	Barmer (Rajasthan) Large farms	Barmer (Rajasthan) All Households	Banaskantha (Gujarat) Small farms	Banaskantha (Gujarat) Large farms	Banaskantha (Gujarat) All Households
	(Postdrought year index = 100)								
	Areas (District and State)								
Total food items	95	99	98	93	110	103	90	97	94
Protective foods	52	85	64	43	74	58	87	98	72
Clothing, fuel, etc.	79	85	84	84	83	85	72	76	69
Socioreligious ceremonies	23	56	36	69	50	52	63	18	66
Others[d]	60	82	65	89	46	59	111	58	130
Total	71	83	87	91	74	92	92	88	90
	(1287)[c]	(2002)	(1677)	(1183)	(1898)	(1611)	(1731)	(4643)	(2223)
Foodgrain consumption per day per adult unit	81	87	86	83	86	88	89	86	78

a. Sources of data: *Jodhpur* (Jodha 1975), *Barmer and Banaskantha* (Chaudhari and Bapat 1975).

b. "All Households" include labor and artisan households and medium-size farms, in addition to the small and large farms which together constituted the total sample in the respective areas. For number of households in each category and drought years in each area, see Table 5.

c. Figures in parentheses indicate consumption expenditure (in rupees) during drought years. As drought years were different in different areas, all expenditure figures have been expressed in terms of 1972–73 prices to ensure comparability.

d. Includes education, medical care, recreation, services of village functionaries, travel and transport cost (including migration) etc. Transport expenditure was very high in Banaskantha.

more, from Table 4 we see that transaction costs associated with asset sales are extraordinarily high. They are Rs.1060 per bullock pair at 1972-73 prices, which is around 50% of the price of a bullock pair in normal years.

Also note that in most areas households appear to be unable to substantially recoup the stock of productive assets during the post-drought years, which indicates a real weakening of their production potential as a result of the drought year.

Table 5 indicates the sources of sustenance income of households during drought years. Credit in all forms provides rarely more than 10 per cent of sustenance income, which is indicative of a very severe capital market imperfection, since credit would be the most efficient source of "insurance", next to futures markets or crop insurance. The detailed evidence (Jodha 1978a, 1978b) also indicates that official credit institutions sharply reduced their lending during these droughts, except in the Banaskantha and Sholapur areas. In fact, many official credit agencies are prevented by their constitution from lending for consumption purposes, which in drought-prone areas is a totally counter-productive policy. Table 4 also shows that for the Rajasthan area, where price information is available, the average interest rate of formal and informal credit sources rose from 15% in the predrought year to 23% in the drought year, a further indication of substantial capital market imperfections.[7] In addition small farmers seem to have more interregional difficulties obtaining credit in drought years than large farmers.

With the exception of the Jodhpur area, wages from relief works were the single most important source of sustenance income for all farmers combined. (In Jodhpur sales of assets were slightly more important). Such wages are predictably more important for small rather than large farmers. Contrary to impressionistic evidence and evidence focusing on the potential waste and corruption associated with public works, such programs seem to be remarkably efficient as an "insurance" mechanism.

We conclude that the combination of farmers' own efforts, official credit agencies, and public works, are insufficient to provide effective smoothing of essential consumption streams, much less of overall consumption streams where *quantity* variations are very large. The official and unofficial credit systems appear to be particularly ineffective. Furthermore transaction costs in markets for physical capital are so large as to make the disposal and acquisition of assets a particularly unattractive tool for financing drought-year consumption. The only bright spot appears to be public relief programs.

Implications

Our joint research so far has yielded the following conclusions:

- Levels of income risk in the Indian SAT are high and come mostly from production rather than price risk;
- virtually all farmers in our SAT Indian sample are moderately risk-averse;
- they do not have access to cheap self-insurance and risk-diffusion devices enabling them to even out their consumption streams in the face of risky production.

We are therefore forced to conclude that risk and risk aversion lead to underinvestment in SAT agriculture.

However, two important caveats are in order. First, we do not yet know the quantitative importance of the underinvestment; further research is needed to assess this. Second, we now know that underinvestment exists in situations where individuals either are risk-neutral or act as if they were (because they have access to cheap loss-management and risk-diffusion devices). However, unless new economic and social policies can be designed to improve self-insurance or risk-diffusion devices so that the "insurance cost" goes down, our findings are not of much operational significance. If public risk diffusion mechanisms simply replace the private ones without reducing their costs, not much is gained. Social science research must therefore be directed into finding these new or improved mechanisms. Dandekar's (1976) work is a significant step in that direction.

7. Rates of interest on savings, deposits, and other financial assets potentially available to rural people are usually below 7%. The large difference between these rates and the borrowing rates make financial savings and borrowings poor insurance mechanisms for consumption streams.

Table 3. Real indices of asset position in drought and postdrought years relative to predrought years in different areas.[a]

(Predrought year index = 100)[b]

Farm size groups, years	Areas (District and State)									
	Jodhpur (Rajasthan)		Barmer (Rajasthan)		Banaskantha (Gujarat)		Aurangabad (Maharashtra)		Sholapur (Maharashtra)	
	Assets[c]		Assets		Assets		Assets		Assets	
	Productive	Non-prodv.	Productive	Non-prodv,	Productive	Non-prodv.	Productive	Non-prodv.	Productive	Non-prodv.
Small Farms:										
Drought year	63	72	82	98	59	61	74	50	69	50
Postdrought year	73	68	95	99	79	73	NA	NA	60	29
Large Farms:										
Drought year	75	89	40	46	87	97	79	62	95	88
Postdrought year	83	91	42	47	93	97	NA	NA	88	108
All Households[d]										
Drought year	63	69	66	79	84	85	77	87	84	69
Postdrought year	83	64	76	77	97	85	NA	NA	78	66

a. Source: See note a, Table 2. Sholapur data are from ICRISAT's Village Level Studies (Jodha, 1976). Aurangabad data are from Borkar and Nadkarni (1975).

b. Since all assets are valued at 1972–73 prices, the declines represent real reductions in asset stocks due to sales, mortgages and losses.

c. Productive assets include livestock, farm implements, machinery, etc. It excludes land. Nonproductive assets include jewelry, financial assets, and consumer durables.

d. Includes labor and artisan households and medium-size farms in addition to the small and large farms which constituted total sample in the respective areas. See Table 5 for number of households in each category as well as drought years in different areas.

Table 4. Price of farm assets and products in selected Rajasthan villages in drought and nondrought years and losses in the asset depletion-replenishment process.[a]

Items	Nominal prices during the years[b]						Total losses per unit using:		
	1962–63		1963–64		1964–65		Nominal prices	Indexed prices[c]	At 1972–73 prices[d]
	(Rs.)	(No.)	(Rs.)	(No.)	(Rs.)	(No.)			
1. Bullocks (per pair)	875	(30)	431	(66)	988	(38)	557	631	1060
2. Camel (per animal)	684	(15)	515	(27)	740	(21)	225	393	680
3. Cow (in milk, per animal)	422	(18)	220	(35)	612	(41)	392	354	612
4. Cow (dry, per animal)	220	(12)	45	(44)	195	(9)	175	195	337
5. Sheep (per animal)	42	(238)	17	(780)	50	(465)	33	32	55
6. Goat (per animal)	35	(85)	47	(205)	40	(317)	–	9	16
7. Bullock cart (per cart)	630	(7)	380	(13)	690	(4)	310	415	718
8. Pearl millet, grain (per 100 kg)	32		51		43				
9. Pearl millet stalk (per 400 bundles)	11		29		11				
10. Sorghum stalk (per 400 bundles)	24		57		26				
11. Ghee (per kg)[e]	5		9		8				
12. Milk (per litre)	.25		.70		.40				
13. Dung cakes (per 300)	8		5		8				
14. Interest rate on borrowing (%)	15		23		15				

a. Table adapted from Jodha (1978). Data were collected from three villages from Jodhpur, Jaisalmer, and Nagaur districts in Rajasthan for a study of capital formation in arid agriculture. The year 1963–64 was a severe drought year, while the remaining years were normal years in the selected areas.

b. Prices for items 1 to 7 are averages of actual sale/purchase transactions, the number of which are shown in brackets. They include items transacted in cattle fairs as well as items purchased on credit by outmigrating farmers during the drought year. Bullock carts (item 7) were carts with rubber tyres. For items 8 to 12 averages of prices that prevailed during the whole year in the villages are presented. Goats are the only animals whose value rose during this drought year, as they can remain productive with negligible maintenance cost.

c. Asset (item 1 to 7) prices were deflated by an index constructed using prices of products (items 8 to 12) during the 3 years. The weighted price index used for deflation was 1962–63 = 100, 1963–64 = 177, and 1964–65 = 128.

d. The real losses indicated by deflation procedure c, expressed in 1972–73 prices.

e. Clarified butter.

Table 5. Sources of sustenance income of rural households during drought years in different areas.[a]

Details	Areas (Districts and States) and Drought years														
	Jodhpur (Rajasthan) 1963–64			Barmer (Rajasthan) 1969–70			Banaskantha (Gujarat) 1969–70			Aurangabad (Maharashtra) 1972–73			Sholapur (Maharashtra) 1972–73		
	Small farms	Large farms	All[b] House-holds	Small farms	Large farms	All House-holds	Small farms	Large farms	All House-holds	Small farms	Large farms	All House-holds	Small farms	Large farms	All House-holds
No. of households	57	23	144	31	24	100	36	11	100	50	10	128	20	20	80
Sustenance income per household (Rs)[c]	2632	4208	3333	2236	3470	2998	2062	4651	2627	2534	4154	2715	2474	4768	2944
Share of sources in:															
– Cultivation	1.7	8.5	2.1	–	–	–	–	–	–	–	18.0	6.8	8.7	23.0	14.4
– Livestock	4.3	13.6	10.2	0.4	12.1	7.2	3.2	13.3	4.8	NA	NA	NA	4.3	–	1.0
– Wages from relief works[d]	47.1	22.8	24.9	58.7	45.0	52.8	44.3	6.1	31.7	66.0	33.5	56.2	48.9	34.5	46.5
– Sale of assets	17.1	23.4	25.9	6.1	18.7	12.5	2.3	39.9	24.9	17.5	33.7	13.5	14.5	18.7	17.3
– Borrowings[e]	6.9	11.2	10.4	12.6	13.6	12.8	5.3	15.3	11.7	10.8	–	6.3	8.3	17.0	7.9
– Others[f]	22.9	20.5	26.5	22.0	10.5	14.7	25.0	29.8	26.9	5.7	14.9	17.2	15.4	6.7	12.9

a. Source: See notes a, Tables 1 and 2.

b. "All Households" include labor and artisan households and medium-size farms in addition to small and large farms. For details see original sources of data mentioned under notes a, Tables 1 and 2. For range of operational holdings considered as small and large farms see the text.

c. Sustenance income defined as total inflow of cash and kind including borrowing except term loans unrelated to sustenance during the drought year. Value of sustenance income expressed in terms of 1972–73 prices.

d. In the case of Barmer and Banaskantha it also includes institutional help in terms of free or subsidized food and fodder including those provided by government and charitable institutions during the migration. This also includes free supply of milk powder, vitamin tablets, medicine, clothing, transport facilities, etc.

e. All borrowings—in cash or kind taken against mortgage or labor/land lease contacts and others. This does not include credit in terms of postponement/cancellation of recovery of land revenue and other dues. It excludes terms loans.

f. Includes income from other casual or agricultural wage employment, handicrafts, transport, remittance, free help from affluent relatives etc. In the case of Jodhpur villages, it includes the value of old stocks of foodgrains and fodder.

After this important qualification of the results, some policy conclusions still emerge. First, it clearly makes no sense to advocate the development of risk-graded technologies in SAT India so that small farmers may adopt the low-yield, low-risk ones and large farmers adopt the high-yield, high-risk ones. There is not enough difference in risk attitudes among small and large farmers in our SAT Indian sample to warrant such an approach. Small farmers should accept the same technologies as large farmers but are prevented from doing so by differentially higher costs of credit and inputs, or by other constraints. Furthermore, techniques to measure differences in riskiness among technologies are still very complicated and data-intensive, which makes such a differential research strategy even less appealing. One may legitimately search for a "low-input optimum" with a given technology. For example, in a wheat variety one might explore the best combination of fertilizers if, instead of an optimal dose of all fertilizers, one could only afford one-third of the money. Since the low ranges of production functions are usually the ones with highest marginal returns, pushing small farmers towards varieties that do not require fertilizer on account of their higher risk aversion is not doing them a service. This is another case in which removal of the disadvantages of small farmers requires institutional policies aimed at equalizing access to factor and product markets or to land rather than technology policy. (For other such cases see Binswanger and Ryan 1977).

Second, if it can be shown in other regions that risk attitudes vary as little across farm size groups as they do in SAT India, we have to reconsider in a new light the debate about risk aversion versus credit constraints as explanations for low fertilizer use. If all farmers in a given area underinvest in fertilizers (relative to the risk-neutral optimum), this underinvestment is more likely to be caused by risk aversion than by credit constraints. The reason is that it is hard to imagine how a uniform credit constraint across farm size groups could emerge, whereas rather uniform risk aversion has now been shown in at least the SAT Indian case. On the other hand, if in a given area fertilizer adoption increases systematically and rapidly with farm size (or other indices of asset holdings) the underinvestment of small farmers must be caused either by adoption cycle phenomena such as slower access to information and inputs, or by credit constraints. If differential fertilizer use persists long after completion of an adoption cycle, it is most likely caused by differential credit or input costs (or constraints) across farm sizes, since such differentials are not hard to document.

Third, if it can be further demonstrated that progressive farmers are not much less risk-averse than other farmers, then rewards for innovation are not rewards for superior risk-bearing ability, as Schumpeter hypothesized, but are instead returns to superior human capital and superior ability to recognize and adjust to new opportunities and constraints. It is unlikely that some intrinsic attitude holds the less progressive ones back; it is more likely to be the lack of human and physical capital.

The future directions of this research program are as follows: First, we need to quantify the apparent underinvestment in SAT agriculture, at least as a rough order of magnitude. Second, strengthening of self-insurance and risk-diffusion mechanisms through public policy is required. Credit policies must be changed to allow credit markets to play a more important intertemporal and interregional risk-diffusion role. Further work on the effectiveness of public relief as insurance is also required. Such schemes have usually been advocated on equity grounds; that they may be able to provide important efficiency benefits by insuring farmers is probably a new insight. Crop insurance deserves much closer study, especially schemes such as area-based insurance which can overcome such problems as high administrative costs. We will not, in the near future, look at price stabilization or buffer stock schemes since such policies would primarily affect the lower cost irrigated zones which, in our view, deserve less priority on account of their lower income variability.

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Risk and Uncertainty in Peasant "Decision-Making"

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Abstract

This paper provides a theoretical framework for studying the role of risk and uncertainty in the farmer's "decision-making" process. The author urges that the distinction between normative and descriptive economics, sometimes blurred, be maintained. The patterns he traces in this paper suggest that poorer farmers would take a greater role in technological change than they have often been accorded and that past hesitancy on the part of farmers who are well off in local terms may be due more to rank protection than to intransigence. The author believes that what a person does is importantly influenced by his or her position in the community.

In most parts of the world risk and uncertainty play important roles in the management of production by small farmers. Farmers can seldom be sure how much their investments of effort and resources will yield. This is particularly for those engaged in rainfed agriculture in areas where rainfall is not consistently adequate, and also for those who employ new and unfamiliar technology.

The research literature related to these situations conceptualizes decision-making under risk and uncertainty in various ways. Because the present paper does not fit comfortably into the research tradition, I want to lay out a deliberate plan for its development. The paper will:

1. distinguish between risk and uncertainty for the farmer making production decisions that involve new techniques or physical inputs,
2. briefly characterize and discuss the use of "risk" and "uncertainty" in economic analysis,
3. elaborate a theory consistent with the risk/uncertainty distinction made in the present paper,
4. report on extensive empirical tests of that theory,
5. draw out the policy implications of the findings.

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As the title suggests, the paper's argument turns on the distinction between risk and uncertainty. The conclusions are that it would be useful to distinguish between "uncertainty-averse" and "risk-averse" farmers, and that the distinction leads to different policies, depending on the degree of adoption of new technologies and practices and the relative wealth or poverty of the farmers who are principal targets of policies.

Risk and Uncertainty

My consideration of risk and uncertainty begins with an imaginary farmer about to decide whether to adopt a new seed variety or a very costly recommended level of fertilizer. I see both knowledge and ignorance as components of his decision-making process. On the one hand, he has knowledge, even if it is only probabilistic, about factors like rainfall and the likely yields of the traditional seed variety under various rainfall levels. He may be less than perfectly informed about yield and rainfall patterns, but let us assume an old, intelligent farmer who observes widely, remembers well, and processes rationally. On the other hand, even this farmer may be profoundly ignorant of the relevant characteristics of the new seed variety or of the effects of fertilizer in the recommended amounts. Thus, if he is choosing between, say, traditional seed and new seed, his level of knowledge/ignorance about his alternatives varies greatly. He knows fairly well what the traditional seed will do and he generally knows nothing about what the new seed will do.

Of course, new seed varieties and other innovations are usually preceded by information campaigns, but even so there are apt to be many moments of the kind just described. In fact, most decision making by most people can be characterized as involving substantial components of both knowledge and ignorance (Arrow 1971, p. 1). In ordinary discussion and analysis we usually emphasize the knowledge, because we know what to do with it. The ignorance is harder to incorporate into our thinking.

Given this vision of the world, Frank Knight's classic distinction between risk and uncertainty is useful. In 1921 Knight distinguished measurable uncertainty or "risk" from true, unmeasurable, uncertainty (1971, p. 20 and Chapter VII). In simple terms, it is "risk" insofar as you know the probabilities of various outcomes, "uncertainty" insofar as you cannot specify the probabilities.[1] With these definitions, risk and uncertainty may vary independently of one another. In fact, the research described below looks at a situation where risk remains constant while uncertainty varies. Its interpretation will be clearer if we first look at other uses of "risk" and "uncertainty."

A Selective View of Other Uses of the Terms

Broadly speaking, other uses of the terms *risk* and *uncertainty* are of two kinds: (1) those that distinguish the concepts in ways distinct from Knight's, and (2) those that see the concepts as indistinguishable in practice.

An example of the first kind is provided by Roumasset (1977, p. 1) who says:

> In modern decision theory, *uncertainty* is a state of mind in which the individual perceives alternative outcomes to a particular action. *Risk,* on the other hand, has to do with the degree of uncertainty in a given situation.

His distinction, stated in a report of the seminar on "Risk and Uncertainty in Agricultural Development" held in Mexico in 1976, makes uncertainty a useful cover term to define the space in which the discussion of the conceptualization of risk may take place (see also Roumasset 1976, Chapter 2, and Roumasset, et al in press). In a definition that is consistent with Roumasset's, Berry (1976, p. 2) uses "uncertainty" to indicate incomplete knowledge on the part of the actor and defines "risk" as the possibility of incurring a loss in the course of productive activity.

It seems to be more common to use the terms "risk and uncertainty" to indicate a single concept. This awkward usage and the failure to distinguish the concepts is largely explained, I think, by a position stated by Hirshleifer and Shapiro (1977, p. 81). They note that there is a tradition that "attempts to formulate a distinction between risk and uncertainty based on ability to express the possible variability of outcomes in terms of probability distribution," but reject it because: "This distinction has proved to be sterile. Indeed we cannot in practice act rationally without summarizing our information (or its converse, our uncertainty) in the form of a probability distribution (Savage 1965)."

Though it is presumptuous for an outsider (an anthropologist) to tell insiders how they have lived their lives, this merging of the risk and uncertainty concepts in modern decision analysis is best understood, I think, through an "origin myth" about the development of normative analysis in economics. As the story suggests, I believe that a major barrier to success in the study of behavior results from neglect of the distinction between positive (descriptive) and normative analysis, and an unfortunate attempt to use the immense power of advances in normative analysis to model what people actually do. In this story the simple

1. While I use Knight's distinction, our purposes are radically different. Knight sought to explicate a quasi-philosophical framework for understanding the origin of profit. I want to predict behavior from social position. Though they, appropriately given their goals, limit themselves to individual and derived institutional characteristics, Balch and Wu (1974, pp. 4-5) give a fully Knightian definition of uncertainty. In this they depart from common practice. I am not competent to evaluate the implications of the more technical essays in the volume their essay introduces.

normative approach starts off with perfect knowledge about alternatives. From this and the decision-maker's goals or values, the appropriate choice can be calculated.

Where risk is involved, that is, where the decision-maker lacks perfect knowledge and certainty, but does know probabilities of various alternatives, normative analysis produces an expected value solution. It uses the odds to specify the decision that will maximize goal attainment over the long run. Even though he/she may lose at first, the decision-maker is advised to toss a fair coin with a person who will give 51 cents for heads and take 49 cents for tails. Risk is involved, but by assuming that outcomes can be treated as aggregatable independent events, it is possible to make probabilities equivalent to the perfect information employed in the simple decision-making model. This transformation is the first step down the road that leads away from simple utility maximization under certainty.

The next step is the big one. The real problem for normative analysis comes when the decision-maker does not know the probabilities, for the apparatus of calculation depends on being able to fix the odds (or their functional equivalents). What is to be done when the odds are not known? That is, what is to be done when there is uncertainty?

L. J. Savage's (1954) work on subjective probability solved the problem for normative economics. Simply stated, Savage showed that under uncertainty the best way to achieve the maximum is to use whatever is known to make best guesses about the probabilities. That is, he showed that uncertainty mitigated by even a little bit of "information" in the unspecifiable intuition of an expert (or client) is distinctly better than no information at all in reaching the goal of maximization (given the aggregation assumption). The subjective probability estimate provided by the decision-maker is based on an act of will that transforms uncertain reality into a calculable probability. With this step Savage effectively expelled the noncalculable part of uncertainty from normative economic analysis.[2] This made it sensible for economists to talk about "risk and uncertainty" as a single concept in economic analysis, for, from the subjective probability point of view, they cannot be distinguished.

In sum, the uses of the terms risk and uncertainty mentioned above, and the developments in analysis associated with them, emphasize the probabilistic definitions of risk. They do not call attention to the ignorance Knight labeled with the term uncertainty. It seems to me that the probabilistic definition of risk and uncertainty does not adequately capture (model) the lack of knowledge under which most actors often operate. I hope that what follows will show that active separate conceptualization of that ignorance in terms of (in this case) the uncertainty concept will lead to useful empirical results that are not routinely produced by relaxing the perfect information assumption in conventional economic analysis.

Decision-making under Uncertainty

Theory

The adoption of innovations by small farmers is, for many reasons, a good place to start exploring descriptive analysis. Such adoption is interesting because it offers great potential for improving the human condition. It has therefore been widely studied. More specifically, it has been the focus of studies of risk aversion by agricultural and development economists. And, finally, adoption typically occurs across a substantial knowledge (ignorance) imbalance between what is known about the alternatives in the decision situation, i.e., about the traditional practices (what was done last year) and the new practices (what might be done next year).

Below I will:(1) elaborate the definitions of risk and uncertainty in terms of a specific research context, (2) state a theory that makes

2. The expulsion of uncertainty may be traced in texts like Kassouf's *Normative Decision Making* (1970). Kassouf discusses decision-making "in the absence of probabilities" but introduces the subject by saying that, "There is no completely satisfactory way to handle these situations" (p. 66). Though I am not technically competent to evaluate the approaches to decision-making in the absence of probabilities that he covers and the more sophisticated ones he does not cover, none seems to reverse the reduction of uncertainty inherent in Savage. Like Savage, they require the decision-maker to crystallize complexities by an act of will.

distinctive predictions about behavior under risk and behavior under uncertainty, and (3) specify a test of the theory that provides an illustration of the utility of the original distinction for descriptive analysis.

The classic-diffusion of innovation study done by rural sociologists (Rogers and Shoemaker 1971; Rogers 1976) provides a good opportunity to specify the distinction between risk and uncertainty. Suppose a new, high-yielding seed is being introduced (it could be hybrid corn in Iowa in 1935 or dwarf wheat in Pakistan in 1968). Individual farmers must decide between buying the seed and sticking with local varieties for another year at least. In this situation it is likely that they face both risk and uncertainty.

The risk involved as the farmer faces his decision is in part the same risk that would be involved with traditional practices. Uncontrollable factors such as future temperature and rainfall will affect the yield. Presumably an experienced farmer has substantial knowledge about the likely variance in outcome and can, in effect, calculate probabilities of various outcomes or estimate the likelihood, given his reserves, that he will be pushed into a situation of severe hardship. This risk involves the predictable variation in yield from year to year.

The decision to adopt the new seed would involve uncertainty as well as risk, for nobody really knows whatthe seed will yield under local conditions. There is no local experience with which to estimate its response to locally available inputs. The probable outcomes cannot be calculated very well compared to the probable outcomes for the traditional seed. Thus, at the outset at least, uncertainty adds a new element to the considerations of the decision-makers considering the new seed, and it is an element that is likely to be substantially less calculable than the known variance of yields from the traditional seed.

This distinction between risk and uncertainty sets the context for a theory that relates the adoption behavior of richer and poorer farmers to stages in the spread of an innovation. Since the full theory has been stated elsewhere (Cancian 1972), here I will give only enough background here to permit elaboration of the implications for the understanding of risk and uncertainty in descriptive analysis of decision-making.

Stated in terms that are compatible with the decision-making framework, the theory relies on the notion that poorer farmers are relatively risk-averse and uncertainty-preferring while richer farmers are relatively uncertainty-averse and risk-preferring. The basic prediction, which will be empirically specified below, comes from the idea that, under uncertainty, where the decision-maker cannot predict the outcome, the rich farmer has more to lose and less to gain from adoption (because it offers random results). In the same situation the poor farmer has more to gain and less to lose from a random change. The farmers are understood to be interested in maximizing their *rank* in a community of relevant alters. It is assumed, realistically I think, that all farmers operate in a social situation that is likely to save them from starvation resulting from crop loss. Thus, effort to maintain rank by avoiding uncertainty has more to do with the acceptability of falling back to the social level of support. Such a fall is likely to be more unacceptable to higher ranking farmers.[3]

Under risk, as it is understood here, financial ability to withstand known potential setbacks would dominate adoption behavior much more. Other factors, such as indivisibility of innovations, that favor richer farmers, contributetodetermining who will adopt when uncertainty is low (see Cancian 1967, 1972).

It is possible to test these prediction because there is a natural situation where uncertainty

3. It may be useful to think of the situation covered by the theory using the following image. The decision-makers are located in total darkness on high and low platforms. All wish to be on the highest possible platform to see the sunrise; and all know that there are other platforms that may be reachable from theirs — though groping for them could lead to a fall.

The conservative behavior of the higher rank people may be understood as "leave well enough alone behavior." This has some parallels to Simon's satisficing, but is made different because *"leave* well enough alone" acknowledges that people start from somewhere, i.e., that they havea position that is not totally recreated with every decision (action). The satisficing notion is better adapted to the microeconomic vision of the world, for that paradigm is not designed to take account of the initial (relative) position of actors. It is more suited to isolated individuals and marginal analysis.

varies while risk stays fairly constant. When an innovation is introduced to a community of farmers from outside, some farmers adopt it immediately, and some adopt it in later years. Later adopters usually use the experience of early adopters to inform their decision. Thus, uncertainty is greater for the earlier adopters than it is for the later adopters. Risk remains fairly constant.

This gives us a critical test: if uncertainty is meaningfully distinguished from risk, poor farmers should adopt more than to rich farmers in the early stages of the spread of an innovation. In later stages, the rich should be relatively faster adopters. All this theory is illustrated in Figure 1.

In the real world various special considerations apply to the very rich and the very poor (Cancian 1967, 1972, 1979). Thus, I have confined my predictions to the behavior of the middle of the wealth continuum in agricultural communities. These predictions are illustrated by the solid lines in Figure 2. In the language of concrete research: the Low Middle Rank is predicted to have a higher adoption rate than the High Middle Rank in Stage 1 of the adoption process, and it is predicted that that relationship will reverse in Stage 2 of the process.[4]

Data and Tests

The two predictions stated above and illustrated in Figure 2 were tested with data from surveys of sixteen communities done by rural sociologists, anthropologists and agricultural economists. The 16 cases include more than 3000 farmers in eight countries.[5] Despite the diversity of data sources, it was possible to employ fairly uniform variables across all the communities. The independent variable was economic rank within the community measured by farm size or farm income; and the dependent variable was percent (of a given rank) adopting before the end of the specified stage. Details of the data gathering and analysis are described in Cancian (1979).

Manipulation of the data was straightforward and can be best understood by looking at Figure 3, where 173 Wisconsin (USA) dairy farmers studied by F. Fliegel are divided into approximate quartiles by income. The Stage 1 side of the figure shows the percentage adopting in Stage 1 by rank, where Stage 1 includes the first approximate 25% of the overall population to adopt. Stage 2 is defined as the next approximate 25% to adopt, and the Stage 2 side of the figure shows the cumulative figures after half the population has adopted.

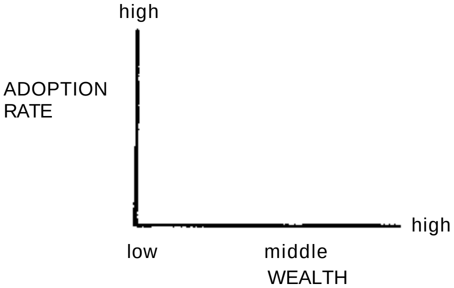
Some of the data sets collected permitted using a 20% band of percentile rankto calculate a moving average rate of adoption. The results of this calculation for 105 Pakistani wheat farmers studied by R. Rochin are displayed in Figure 4.

Both predictions are clearly confirmed by the selected data sets displayed in Figures 3 and 4. In the larger study, 14 of the 16 communities confirmed the first prediction, that is, they showed a higher Stage 1 adoption rate for the Low Middle Rank than for the High Middle Rank; and 12 of the 16 studies confirmed the second prediction. Despite the complications and doubts that are inevitable in a comparative study of this scope, the principal predictions are

4. Note that while this theory sees poor farmers as having a comparative advantage in uncertainty bearing, it does not necessarily predict any empirical situation in which poor farmers adopt more than rich farmers. Rather it predicts only that, compared with rich farmers, poor farmers will adopt relatively more the higher the uncertainty. This complication is discussed further in Cancian 1979.

5. Of the 16 cases, one each came from India, Japan, and Kenya, two each from Mexico, the Philippines, Pakistan, and Taiwan, and five from the United States. Full documentation on the data sources is given in Cancian (1979). Here I want to thank the original investigators who gave permission to use their data and others who helped me collect and analyze the data sets, especially Joseph Alao, Susan Almy, Randolph Barker, Frederick Fliegel, John Gartrell, Peter Gore, Barbara Grandin, Herbert Lionberger, Max Lowdermilk, G. Parthasarathy, Robert Poison, Refugio Rochin, Everett Rogers, Alice Saltzman, and Eugene Wilkening. Each of the cases includes a reasonable approximation to a random sample or a complete census of a community of farmers. Sample size ranges from 91 to 540. In the communities outside the United States, the medium size of holding for the fulltime farmers included in the analysis was in no case more than 2.5 ha.

KEY



WEALTH = Rank on size of farm or size of farm income

ADOPTION = Percent adopting before end of specified stage

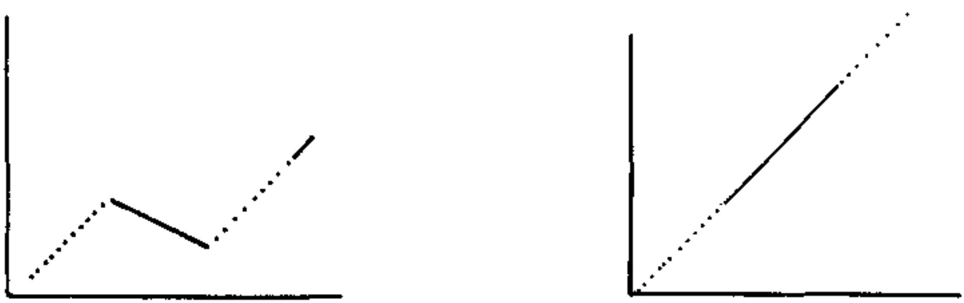
Early Stages

UNCERTAINTY HIGH relative to risk

Later Stages

UNCERTAINTY LOW relative to risk

Figure 1. Theory



Stage 1

UNCERTAINTY HIGH relative to risk

Stage 2

UNCERTAINTY LOW relative to risk

Figure 2. Predictions

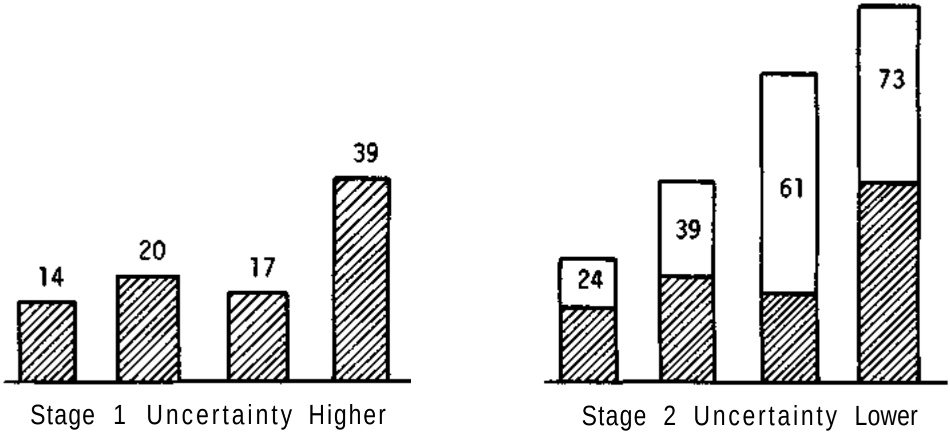


Figure 3. Histogram test

173 Wisconsin (USA) dairy farmers

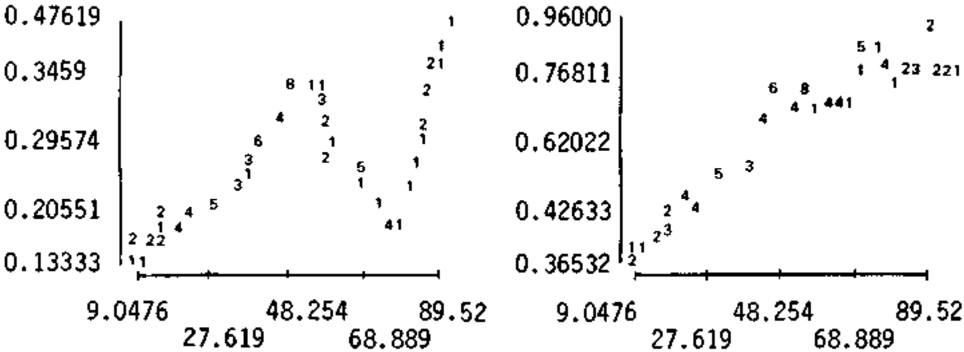


Figure 4. Moving average test

105 Pakistani wheat farmers

Notes: Stages 1 and 2 are best approximations to the first 25% and the next 25% to adopt. In Figure 3 the actual stages are 23 and 27%, in Figure 4 they are 30 and 40%.

In Figure 3 the ranks are the best approximations of quartiles. Figure 4 uses a 20% band of percentile rank to calculate the moving average.

strongly confirmed. It is clear that, early in the process of spread of an innovation, farmers of lower middle rank in a community are more apt to adopt than farmers of upper middle rank; and that the process usually reverses itself in the later stages of the process.

Policy Implications and Discussion

The findings reported above have two major policy implications. One is straightforward; the other is complex and intertwined with the questions about risk and uncertainty raised at the beginning of this paper.

The straight forward one stems directly from the finding that, in the early stages of the spread of an innovation, the "low middle" rank farmer is more apt to adopt than the "high middle" rank farmer. This finding contradicts the received wisdom that "Wealth and innovativeness appear to go hand-in-hand" (Rogers and Shoemaker 1971, p. 187), and suggests that program designers must take into account the apparently strong innovative inclinations of poor farmers. This is especially important when planners and technicians are matching innovations to the financial resources of the target population. Under the received wisdom, an innovation that is adopted by the rich but rejected by the "upper middles" — even when it is made economic for them — would properly be abandoned as inappropriate for the poor majority on the grounds that they are less innovative than the "upper middles." The findings reported above show that the "lower middles" are not less innovative than the "upper middles." They imply that redesign to the scale of the lower middle rank farmer might lead to a substantial further surge of adoption. In general, programs intended to help the small farmer should not be tested for viability on the upper middle ranks of the community. This is an important caution, because, in the real world, these upper middle rank farmers frequently appear to be the poorest among local people for whom there is much hope within the existing socioeconomic framework.

The second area of policy implications involves what I have labeled "uncertainty aversion" in approximate parallel to current usage of "risk aversion." This usage of uncertainty aversion is meant to call attention to the ignorance that is crucial to decision situations, like the spread of innovations, where even knowledge of probabilities is in relatively short supply. The parallel to risk aversion cannot be exact, of course, because risk aversion is commonly defined in terms of elicited or imputed choice among bets with known odds and payoffs. The whole point with uncertainty aversion is that it refers to situations in which very little secure information about outcomes is available.

While uncertainty aversion is fundamentally meaningless — or at least totally unanalyzable — with regard to individual decision-makers, it becomes fully interpretable with regard to decision-makers operating in a community where they seek to maximize their own standing. In this situation where relative position is the goal, uncertainty has clear implications for decision-makers who are lower and higher in the existing hierarchy. These implications help explain the observed patterns of lower middle rank innovativeness and upper middle rank conservatism under conditions of high uncertainty that are reported in this paper.

The implications for policy derived from this picture of the world are seemingly perverse, for they might be stated as follows: planners who wish to give an advantage to the small farmer over the large farmer should promote maximal ignorance in the countryside. Such a promotion is inconsistent with the nature of ordered planning and is unlikely to occur, but the less perverse implications remain and are practical within established institutional arrangements. Knowledge is less advantageous to the smaller farmer, for he is less concerned with securely maintaining the status quo and more concerned with changing the current situation. Larger farmers are more interested in trading off production for security and therefore less interested in innovation, i.e., they are uncertainty averse.

Given the choice between allocating research resources to develop better small-scale technology and educating farmers to use what is available, the planner who aims to help the small farmer should probably consider the former alternative a little more favorably than he/she did in the past.

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Discussant's Comments

J. L. Dillon*

Over the last decade the nature and significance of risk to farmers' decision-making has come to be much better appreciated. Many issues, however, remain unresolved. Both how far our understanding has been increased and the ignorance we still face is well illustrated by the three papers presented in this workshop session. In opening discussion on these three thought-provoking papers, I would emphasize the two primary aspects of decisions under risk (i.e., decisions where the outcome is not sure). These two aspects are, first, the attitude to risk of the decision maker and, second, his perception of the risk that he faces. I should also note that I am presently persuaded that both these aspects are quantifiable — risk attitude through elicitation of a utility function for the decision maker and risk perception through specification (either explicitly or implicitly) of the decision maker's subjective probability distributions for the risky alternatives which he faces. Overall, I would say Anderson's paper adequately recognizes both risk attitude and perception but with some bias to the former while Binswanger et al. pay virtually no attention to risk perception. The third paper, that of Cancian, stresses risk perception in both a provocative and — to my mind — confused way.

Let me now comment on the papers individually. With Anderson I have no disagreement. The hypotheses he proposes about risk attitudes and risk perception are, I think, reasonable and certainly deserve some investigation. However, in so far as they represent a refinement rather than a transformation of existing knowledge, I would be loathe to see too much emphasis on them in our research portfolio. At this stage what we need in the risky decision area are more Binswanger-type estimates on the distribution of risk attitudes in a variety of physical, social and cultural environments together with systematized information (we have virtually none at present) on farmers' risk perceptions in their current environment and under possible changes to that environment. It might also be noted that Anderson poses his hypotheses in terms of the farm family. As I know he well knows, group utility considerations—even for such an integrated group as the family — present a qualitative jump in difficulty of elicitation as compared to research on individual decision makers. Nonetheless, I like his recognition of the family and the roles of spouses.

As with Anderson's paper, I have little to disagree with in the paper by Binswanger et al. They well substantiate their conclusions for the Indian SAT of high income risk derived mainly from production risk, of virtually all their sample farmers being moderately risk averse, and of risk and risk aversion leading to underinvestment. To these conclusions I would add another which is of methodological importance. This is that from the risk attitude elicitation work using real payoffs which they report, it is apparent that mind experiments without some means of standardization appear to be a most unreliable means of eliciting risk attitudes. I have only one criticism of the Binswanger et al. paper, In their discussion of riskiness of agriculture in the SAT, they emphasize only frequency-based measures. From a policy orientation, this has some logic. However, in the farmer's decision making, it is his personal perception of the risk he faces here and now that is important, not the frequencies given by the historical trace. Because of this, farmers having the same risk attitude, through differences in their risk perceptions, may choose differently from among the same alternatives — as is implicitly recognized by Binswanger et al. in their penultimate paragraph. Thus I would urge that they also investigate risk perception among their village samples. A good starting point would be Anderson's Hypothesis 4. Such work would be facilitated by the knowledge already gained of the risk attitude of their sample members.

I turn now to Cancian's paper. To an avowed subjective expected utility decision theorist like me, his paper is highly provocative. One doesn't

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like to see one's favorite theory dismissed. So I disagree with the thrust of his paper, but I hope on logical ground. The essence of our difference is my belief, and that of other subjective expected utility theorists, that the preferences of decision makers who make non-random choices (i.e. most people) can be expressed in a utility functi.on and that for any choice they make from an array of risky alternatives, this choice corresponds to an implicit subjective probability distribution for the possible outcomes. Further, as proved by Savage, preference and probability are sufficient to model choice. Cancian doesn't accept this. He argues that as well as preference and probability, we should add a further consideration of degree of ignorance or information corresponding to our degree of belief in the probabilities used. Stated this way — i.e., in terms of a probability of a probability— his position is untenable since a probability of a probability is just a probability. In short, I believe this proposed theory — which we might note is somewhat akin to Shackle's theory of focus-loss and potential surprise and Fellner's slanted probability approach — is wrong because it assumes that the decision-maker's state of information about a risky alternative cannot be fully described by his (if need be implicit) subjective probability distribution for the unsure outcomes associated with that alternative. To this, Cancian might respond that I'm talking normative while his concern is descriptive. I don't agree. To me, nonrandom choice must imply utility maximization. Subjective expected utility theory with its possibilities of multiattribute (including lexicographic and status) considerations is rich enough to encompass, I believe, all modes of nonrandom choice, including safety-first type procedures. Whether expressed explicitly or implicitly via intuitive mechanisms, degrees of preference (i.e. utility) and degrees of belief (i.e. subjective probability) are sufficient to describe behavior.

What then of the adoption patterns shown by Cancian's empirical analysis? Could subjective expected utility theory explain his result that "early in the process of spread of an innovation, farmers of lower middle rank are more apt to adopt than farmers of upper middle rank; and that the process usually reverses itself in the later stages of the process?" The answer is yes. Such a result would occur if lower middle rank farmers initially saw greater expected utility in adoption than did the higher middle rank farmers in the same community. This could occur either if lower rank farmers had more optimistic risk perceptions or were less risk averse — both of which are reasonable hypotheses though, so far as I know, are not yet adequately tested. Since it is a potentially far simpler explanation, I prefer this hypothesis to Cancian's more complicated approach — not least because it avoids such perverse policy implications as suggesting that small farmers would be advantaged by the promotion of maximal ignorance.

All this may sound like a rejection of anthropological and sociological considerations. It is not. Appraisal of prospective technology must involve both financial and social considerations, i.e. be socioeconomic. I trust that the example of ICRISAT in this regard will be followed elsewhere.

Editors' Note:

Due to Dr. Dillon's substantive criticisms of Dr. Cancian's paper, and in interests of further interdisciplinary dialogue on this important topic, Dr. Cancian's response to Dr. Dillon is also presented here.

Response to Discussion — F. Cancian

I appreciate Dr. Dillon's attention and his clear statement. I want to thank him for giving me an advance copy of his remarks. His kindness has given me a chance to collect my thoughts around two points.

First, please note that the two policy implications of my paper stand in very different relation to the theoretical disagreement.

The idea that the lower middle rank is a usually untapped source of innovative inclinations is not affected by the disagreement. It stems quite directly from the finding that the lower middle rank is more innovative than the upper middle rank even when no special attention is paid to its economic limitations. The implications of this finding stand, despite the controversy about my theory. I do not want these implications to be lost in the theoretical shuffle.

Things are different for the second implication. The idea that small farmers are better off in comparison with large farmers under conditions of uncertainty, and the negative implications of this for traditional extention and education programs, is probably too mired in the theoretical controversy to save. So I leave it to a later time.

My second topic is a comparison of expected utility theory and my theory about behavior under uncertainty.

Expected utility theory is immensely powerful as a normative theory. It provides a powerful way to use information to calculate future decisions given stated goals. However, as a positive theory, i.e. as a theory that helps us understand behavior, it has mostly this success as normative theory going for it. Dr. Dillon himself has written about the limited success of expected utility theory as an aid to prediction in the real world.

Expected utility theory interpreted as a positive theory has two major problems. First, it is so flexible, so all-encompassing, that it is fundamentally not testable. Second, it is, of course, individual-oriented (microeconomic) and as such it provides little guidance in assessing the role of social relations in influencing behavior.

I want to suggest that, for purposes of understanding behavior I may have a viable alternative to expected utility theory. But I do not want, in this setting, to be contentious. My theory is compatible with Dr. Dillon's. We could say that I am concerned with *specifying* the risk preferences of various ranks of farmers at the beginning of the adoption process. Thus stated, my theory is complementary to his. I am happy to state it in this manner if it makes it easier for him and the many who share his viewpoint to accept it and its claims for the role of social relations (specifically economic rank) in determining adoption behavior.

I feel compelled to say, however, that as I see it, it is possibleto make my small addition to his large theory because he has an analytical framework, not a theory. It is an analytical framework because it states that people will act according to risk preferences and subjective probability estimates and leaves the content of these categories unspecified. Anything, including my substantive propositions, will fit.

As a social anthropologist, I find my original statement simpler and better but recognize that economists may see the world differently.

Finally, I want to call your attention to the substantive propositions about social relations. They provide an example of the importance of social structure to change in production systems. Social inequality defined in terms of the local community is an important determinant of adoption behavior. Technology development should be responsive to those facts about the real world.

Chairman's Summary

J. G. Ryan*

As the papers presented in this session have already been summarized by Dr. Dillon this summary will cover only the major issues and conclusions which arose out of whole discussion. These are discussed under the headings suggested to the chairpeople by the organizers.

Policy and Technology Design

At least for the areas studied in SAT peninsular India there seem to be clear policy implications arising from the work done on risk attitudes of farmers. There would appear to be little reason to design technologies with basically different risk characteristics for small and large farmers. Contrarily from extensive cross-country empirical evidence of adoption of innovations by farmers, it appears that in the early adoption period when information is lacking on new technologies— the so-called 'uncertain' phase — small farmers adopt more readily than upper middle-level farmers. The policy implication of these cross-country results, though contentious, suggest that ignorance is bliss for small farmers and that hence a more bewildering array and larger supply of prospective technologies would be a preferable course to more widespread education and extension in order to enhance adoption by small farmers and hence to achieve equity goals. It would be an inventor's dream if indeed this were true, and certainly make life much easier in agricultural research. In fairness it must be said this view was challenged and again counterchallenged.

In the SAT Indian regions, it appears that where irrigation is much less dominant, production variability dominates price variability, whereas the opposite occurs in the highly irrigated regions. Technological innovations in the nonirrigated areas would thus appear to offer significant potential for reductipn of overall risk, as measured by variability, a concept that was questioned in the discussion.

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The role of public relief in alleviating adverse effects in drought-prone areas of India was found to be critically important, both in terms of efficiency and equity considerations.

Future Research

The session seemed to conclude that we require a far better methodological and empirical basis on which to make judgments related to the importance of risk and uncertainty in the semi-arid tropics. Bernoullian decision theory was suggested as the foundation upon which to build the empirical framework of subjective risk perceptions. Explicit recognition of the role that subjective risk perceptions and probabilities play in the decision-making process was something that seemed to be lacking in many studies of risk attitudes and responses of decision-makers.

There was no clear consensus on the role of institutions such as universities and ICRISAT in further refining methodological approaches to risk attitudes and perceptions. More research is clearly indicated on the role that social structure and the farm family play in the process of formation of risk attitudes and perceptions, and their effects on the adoption of new technologies. There would seem to be some contradictions at present between approaches to technology design and adoption that emphasize the role that social structural characteristics play, and those that examine and measure risk attitudes across socioeconomic strata. I believe both approaches have a lot to offer each other, as was the tenor of the session. The dialogue has been initiated on this critically relevant factor in the technology design process, and it is my fervent hope that it fruitfully continues.

There was general agreement that the basic methodology of utilizing real monetary choices in eliciting attitudes of farmers to risk is much preferred to the traditional interview techniques. The need now seems to be to employ such techniques in other SAT regions to see to what extent the conclusions arising from the studies of farmers' risk attitudes in SAT peninsular India hold true elsewhere. Further studies should also embrace questions of the role of the family and its components in the formation of risk attitudes. The policy implications that flow from such work both for design of technology and infrastructural support systems are obvious. It would seem that here is a prime example of where useful collaboration between social scientists from national programs and ICRISAT could ensue.

Further research on the way in which public relief programs can be made more effective as risk diffusing devices in the SAT was clearly indicated.

Chapter 8

Rural Labor Markets

Rural Labor Use and Development Strategies in East Africa and India

Janet Benson*

Abstract

This paper discusses the existing division of labor in East Africa and India and its implications for the design of new agricultural technology. Primary emphasis has been placed on smallholder cultivation rather than large-scale production, and the author has attempted to focus on labor use in dryland cropping systems whenever possible. However, since useful data on such subjects as seasonality and time allocation (Particularly by sex and age) are not often available, information from other geographic regions is introduced where relevant. Methodological problems are discussed.

This paper discusses the existing division of labor in East Africa and India and its implications for the design of new agricultural technology. "Division of labor" refers to the fact that tasks are differentially allocated within any society so that specialization is possible; that is, no single member need be responsible for carrying out all activities necessary to social life. The most fundamental bases of allocation are sex and age. While some of the simplest societies (e.g. gatherers-hunters) are characterized by a division of labor affected mainly by these two criteria, complex social orders such as preindustrial agrarian states or industrial societies exhibit much more elaborate occupational structures. Even in these societies, however, task-allocation is related to sex and age. Some anthropologists now believe that division of labor within the family, which includes food-sharing, was fundamental to the development of human society and remains an important distinction between man and other primates. I will first examine the sex variable and then age.

Division of Labor: Sex

All known human cultures maintain conventions concerning sex-specific activities, though considerable variation occurs in the rigidity of such task-allocation. Certain near-universal patterns seem clearly related to reproduction; since women in preindustrial societies spend much of their adult lives in a pregnant or lactating condition, their physical mobility is more restricted than that of men, and child care is defined as a female responsibility.[1] As a matter of convenience, work in and around the home such as cooking, firewood and water collection, and kitchen gardening is commonly assigned to women, while men are allocated tasks that require more physical mobility, risk, and sheer strength. Beyond this, much task-specification is based more on arbitrary convention than on any biological base; that is, there is often no cross-cultural consistency concerning which sex performs a particular task. Given a certain number of activities that must be carried out for survival and reproduction, sexual specification establishes clear responsibilities for males and females in a given culture or ethnic group and facilitates household production, an issue further discussed below. The economic roles of men and women are typically complementary rather than competitive, and childhood socialization prepares the sexes for eventual partnership in the formation of a new household and family (Benson 1978).

It should be stressed that conventions concerning sex-typed tasks are by no means immutable; even in societies that clearly distin-

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1. See Brown 1970 for a fuller discussion.

guish "male" from "female" activities, loss or absence of a spouse occasionally results in compromises with ideal behavior. Where the household labor pool is small as in nuclear families, husband and wife may frequently cooperate in the same tasks or undertake those of the opposite sex. Given sufficient incentives, the society-wide model of sex-typed activities will also change.

Within agrarian societies of specified types, this complementarity results in different patterns of labor allocation. Boserup (1970), for example, differentiates between two patterns of cultivation which she refers to as "male" and "female" farming systems. The former characterize Asian societies, while the latter are *more* typical of African ones. "Male" systems are those in which male labor is predominant, while "female" systems rely primarily on women's labor.

As a number of writers have observed (see Martin and Voorhies 1975), female farming systems are normally associated with hoe cultivation (horticulture) rather than "true" agriculture. The latter, which is characterized by use of the plow and draft animals as well as other intensive cultivation techniques, relies more heavily on male labor since plowing is almost universally defined as a male task. Horticultural productivity varies greatly (Wolf 1966, pp. 21-25), but under conditions of moderate population pressure can provide an adequate living with relatively little male input. In the African context, this has meant that men have been able to migrate in search of wage labor, leaving wives on the land to produce subsistence crops. Watson (1958), for instance, discusses this situation among the Mambwe of central Africa during the 1950s; their cultivation system required only a few men for brush-clearing, with other agricultural tasks handled by women. Among East African cultivators, women often had primary responsibility for subsistence crops (millet, maize, plantains), while men tended cattle and spent their time on politics and warfare; with the introduction of cash crops (tea, coffee, cotton, pyrethrum) during the twentieth century, however, men have become interested in cultivating the new and profitable items. Cleave (1974), in a study of smallholder agriculture in Africa notes that: "It is a consistent feature of survey reports and other sources that the introduction of a new cash crop or a new technique tends increasingly to involve men in agricultural operations, frequently leading to reductions in the traditional division of labor on sex lines".

Designating Asian farming systems as "male," by contrast to most African farming systems, tends to obscure the contribution of female labor to intensive agriculture. Accurate evaluation of female labor input is hampered by the tendency of household heads to under-report women's contribution, and by the difficulties male researchers face in interviewing women. Sinha (1977), for example, notes that 54% of all men and 23% of women were enumerated in the work force in the 1951 Census of India; by 1971, due to definitional changes, this proportion had dropped to 52.5% for men, only 12% for women. He suggests that:

> A close look at the concepts and definitions of workers suggests the possibility of under-enumeration in 1951 as well as 1971. In 1951, the application of the income criterion led to the omission of "unpaid family workers." The 1971 census left the determination of working status to the subjective judgment of the respondents and, since non-working status of women is a mark of social superiority among the lower strata who constitute the bulk of the population, it led to a serious under-enumeration bias and a landslide in the number of female workers from 59 million in 1961 to 31 million in 1971.

In India, the participation of males between 15 and 55 appears to be very high, over 90%; the direct economic contribution of women, however, is considerably lower on the whole and varies widely from region to region (Dasgupta 1977, p. 23; Gulati, 1975). The variation is probably genuine although, as indicated above, under-remuneration presents a problem. Recent research by Ryan et al. (1979) documents the importance of female labor in semi-arid regions of India.

Female labor is vitally important in India, as in many parts of Asia, since women (together with children and the aged) provide a seasonal labor pool to handle bottlenecks in cultivation. Agricultural operations are often sex-specific. In the Telangana region of Andhra Pradesh, for instance, men plow and prepare fields for both wet and dryland crops; women help sow, do the transplanting and weeding of paddy seedlings, cut paddy and sugarcane, and assist with threshing. Often a series of agricultural activities follow each other in rapid succession, and delay means lowered productivity or a late harvest. Consequently, women's input, either in the form of unpaid family labor or hired labor, is of crucial significance at key periods even though participation rates in terms of woman-days per acre per year may be low.

Women are also largely responsible for processing of grain, a lengthy undertaking that involves winnowing, cleaning, drying, and finally husking and grinding (either by hand or machine). Women of merchant households clean and bulk the grain traded to them for resale in wholesale markets elsewhere. Even in households where women do not actively participate in field labor, then, they are involved in important agriculture-related activities. In general, it can be said that the greater the labor requirements of the farming system, the greater the input by both men *and* women (Martin and Voorhies 1975) though this may be in the form of wage rather than family labor, distinguishing those whose women perform manual labor from those whose women do not.

Division of Labor: Age

Routine and seasonal labor requirements in paleotechnic agrarian economies also require inputs from children and the elderly, two sources often overlooked by members of industrial societies where mass education and early retirement are norms. Although statistical data on work inputs by children are usually lacking, numerous anthropological studies note their direct or indirect contribution to production. While some students, considering only directly productive activities, devalue the economic importance of children in peasant societies (Mueller 1977), others (Nag et al. 1978) stress their contribution; this perspective is based on the recognition that peasant societies are characteriszed by occupational multiplicity, and the majority of working time is spent by most people in nonagricultural occupations. In comparing work inputs by age-sex groups in a Javanese and a Nepalese village, Nag et al. found that "Javanese boys and girls of 15-19 years spend as much as 7.9 and 10.2 hours per day in all work activities, while the corresponding figures for the Nepalese village are 9.5 and 11.3 hours" (1978, pp. 294-295). In both villages, the average input of the girls aged 12-14 years in all work is nearly the same as that for males 15 years and over, while the average input of 15- to 19-year-old girls exceeds that of males of the same age. In directly productive work, however, inputs of all children are lower than those of males 15 years and older. The total range of activities included animal care, food preparation, child care, other household maintenance work, reciprocal labor exchange, handicrafts, irrigated rice and garden cultivation, wage labor, and trading.

Children in nonwestern societies are trained in sex-specific tasks as soon as they have the ability to manage them; a child as young as 5 or 6 is often actively contributing to household maintenance or animal care (cf Epstein, 1962, p. 70). Responsibility training begins earliest for girls, who are most commonly taught *to* tend younger siblings and perform domestic tasks. Both boys and girls may be assigned animal-tending duties. Nag et al. found that children in both the Nepalese and Javanese villages spent more time herding than in any other activity, and more than adults; between 4 and 5 hours per day for boys and girls of 9-11 in the Nepalese village where cattle, chickens, goats, and sheep are the important domestic animals. Epstein (1962, p. 70) reports from South India that boys begin work by tending bullocks, girls by caring for buffaloes, milking, and watching chickens. Even very young children may thus indirectly contribute to production by freeing the time of adult women and men for cultivation. By the age of 10 to 15, Indian girls and boys may be earning wages as domestic servants or casual laborers, and can provide a useful input into family agriculture.

Although children's labor is economically most important to medium- and low-income households, where education is not a feasible alternative to this use of time, school attendance need not result in the complete loss of childrens' work if chores can be done after school or if vacations are timed to meet seasonal peaks in agriculture. One of the consequences of increased education is a tendency to send males to school and retain female children to cope with the extra work. Many peasant cultivators, however, are sparing with education — even if they can afford it it — because they fear losing the labor potential of sons who may feel that manual labor is beneath them.

In addition to children, the elderly may also make significant economic contributions to household economies. Data from 130 villages collected by Indian Agro-Economic Research Centres (AERC indicate that 46.5% of those over 59 belong to the workforce; there is little variation by region (Dasgupta 1977, pp 46-47). In addition to cultivation activities, the active elderly attend to many of the same duties as younger adults: tending children, food preparation, grain processing, handicrafts such as carpentry or rope-making, and crop-watching. Unless an individual is seriously disabled or senile he or she can almost always contribute in some way to household maintenance or production; this is particularly true for women, whose sphere of activity does not noticeably narrow. In fact, as women reach menopause they frequently have fewer domestic responsibilities and more freedom to travel, while cultural restrictions on heterosexual interaction also lessen at this point. Occupations such as trading, then, are taken up by mature women in many peasant societies (Chinas, 1973; Mintz, 1967) and offer an alternative source of income to agricultural (family or wage) labor. In East Africa and South Asia such marketing normally consists of petty vegetable-vending due to women's lack of access to capital and specialized skills.

Division of Labor: Class and Caste

In addition to sex and age, other characteristics of social organization affect labor use. As mentioned earlier, many horticultural societies have relatively simple occupational structures with most tasks assigned on the basis of age-sex categories. As far as cultivation is concerned, not until the twentieth century — and even then, most strikingly in cases of extensive commercialization (cotton plantations in Uganda, cocoa in Ghana) — has dependence on extra-familial labor emerged. Among horticultural groups in East Africa, the most important inputs are still from family and reciprocal labor exchange rather than hired labor. This is consistent with a rather egalitarian social structure among early stateless societies and the absence — until recently at least — of true economic classes, even in primitive states (Falters 1964, p 163).

In contrast to the egalitarian social organization of many East African societies, South Asia is characterized by marked social inequality based on unequal access to basic resources, namely land. Prior to the British colonization, land might be seized by a conquering warrior lineage, given as a gift to Brahmins, or settled by a kin-group in a frontier area; members of artisan and service castes would be attracted to the new village to serve the dominant group (see Bailey, 1957). Members of the lowest castes formed a permanent labor pool for paternalistic upper-caste farming households to which they were attached. Although the relationships between households of different castes had ritual aspects, the essence of the *jajmani* or *baluta* system was the formation of production teams in which grain was exchanged for goods and services.[2] Barth (1960) discusses a similar system in Swat, Pakistan, which also operated until quite recently in a nonmonetary subsistence *economy. In areas* where artisans had land, their craft work supplemented agricultural income and mitigated the seasonal ity of agriculture. With growing commercialization of the rural economy, the *jajmani* system has been weakened or eliminated in many areas and contractual relations substituted for paternalistic ones (A. N. Michie 1976, Patrons or brokers: clientelism and the commercialization of argiculture, unpublished paper.)

Another consequence of social stratification for labor is related to the economic contribution of women. Among both Indian Hindus and Muslims in rural areas, high status is indicated by the ability of a household head to excuse his women from labor outside the home, in particular wage labor for other households (see Benson 1978). An increase in household wealth is thus likely to be followed by withdrawal of women from the family labor pool and the hiring of servants and casual laborers to replace them. The same process can be seen in African societies where migrant labor is extensively used for cash-cropping.

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2. See Benson (1976).

Peasant Production and the Household: Implications for Development

As suggested above in discussions of task allocation and labor input by sex and age, the household constitutes the basic productive unit in peasant societies; its members play complementary roles in household maintenance, cultivation, and other work. Smallholders rely heavily on household members, supplemented by relatives and perhaps labor exchange, to form the necessary production team. One important difference between social organization in Africa and South Asia is the prevalence of polygyny *in the former region.* Because women have traditionally been given the major responsibility for cultivation throughout much of Africa, multiple wives increased a man's wealth as well as status. Women themselves often appreciate additions to the household labor force and may even ask a husband to bring in another wife to ease the burden of work.[3] In India, while nuclear-family households are most common, joint families consisting of parents and married sons may emerge where landholding or other labor requirements favor large households. Though the household is a basic production unit in both East Africa and India, then, its structure may be quite different in the two regions under consideration.

The implications of the previous discussion for agricultural innovations are twofold. First, any change in the skills for labor commitment of one sex-role category may effect others within the same household; for example, increased emphasis on education for children may require more work by adults. Second, individuals, including male household heads, should not be regarded as autonomous economic actors. Decision-making is usually done with the input and consent of spouses and other kin, who in many cases are the very people expected to change their labor patterns. Compliance with the head's wishes concerning innovation is not automatic. During the 1960s in Kenya, I found that agricultural extension agents were addressing only men on the subject of clean milk production; yet women were responsible for washing milk cans and proved reluctant to adopt new methods because it would have increased their workload.

Where social stratification is marked, and lower class or caste laborers provide labor to large landowners, other impediments to technological innovation may also occur. Epstein (1962, p. 64) notes, for instance, that in the irrigated village she studied, spacing of paddy transplants (the Japanese method) was not accepted because it would upset the techniques to which female labor was accustomed. Ten to 12 women form a team for transplanting, weeding, and harvesting, and are paid a fixed rate per job. The new techniques were resisted because they took much longer, and farmers were bound by customary rates that they could not increase.

Though the traditional division of labor in Africa and India may result in constraints to production, a much more severe problem is seasonality. The following discussion concerns climatic variation and strategies adopted by farmers to even out labor use.

Seasonality and Labor Use: Africa

Cleave (1974, p. 31) notes that until recently, discussions of labor use in agriculture have centered on the existence or nonexistence of underemployment; now interest has turned to the capacity of agriculture to absorb labor. In the case of both African and Indian agriculture, considerable latitude for increased labor inputs appears to exist. Cleave states, on the basis of his survey material, that in African agriculture typically only about 1000 hours per adult worker is spent in the field, or 4 to 6 hours per day for under 200 days of the year. Additional time may be spent in travel to fields, though this is truer of West than East Africa. The seasonal nature of agriculture imposes limits to labor input:

> On the one hand, if all available labor in an area is fully employed at any period of peak demand, then certainly labor may not be permanently removed without affecting production, and increases in agricultural production would be limited to off-peak periods; on the other hand, if all employment is concentrated in a limited period of the year, the total hours of effective work which can be put into and rewarded for

3. See Ames (1955).

agricultural employment are limited unless the agricultural system is susceptible to change (Cleave 1974, pp 66-67).

Cleave (1974, p 90) estimates that 15 to 50% of the underutilization of labor in Africa is due to seasonality. The options, then, would be to change cropping systems to spread out labor needs or make more efficient use of existing labor at peak seasons. Another alternative is to introduce more agriculture related activities (public works, handicrafts) to absorb labor during non-peak periods.

In the tropics, water supply is the most significant variable affecting seasonality. One group of African farms studied by Cleave are located in semi-arid regions, characterized by a unimodal wet season with only 4 or 5 months per year receiving more than 3 inches (75 mm) of rain, and 4 or 5 months with none at all. The villages are located in northern Rhodesia, where maize and groundnut are the main crops; in the eastern Sekoto Province of Nigeria, where groundnut produces a cash crop and millet and sorghum are grown for subsistence; and Gambia, where groundnut is again a cash crop and rice a staple. While several surveys from East Africa are covered in Cleave's analysis, they unfortunately refer to humid and sub-humid cash-crop areas and *not* to regions of semi-arid farming (Cleave 1974, pp 73-74).

Cleave demonstrates a clear relationship between rainfall patterns and labor use, though this is not the only variable involved. For example, in the Toro District of Uganda, which is close to the Equator, adequate rainfall is available 11 months of the year; farms are highly diversified, and the difference between peak and slack seasons in agricultural employment is small. "Conversely, in Chiweshe, Rhodesia, and Sokoto Province, Nigeria, which approach the polar limits of the area covered, periods occur with no rain when crop activity effectively ceases and agricultural work is confined to a limited range of livestock and maintenance tasks" (Cleave 1974, p 128). Different rainfall pattterns may have a significant effect even within a small geographical area. Cleave (1974, pp 128-9) notes that an additional month of rainy season in northern Uganda, as compared to northern Tanzania, allows' Uganda farmers greater flexibility in avoiding a clash between cotton and foodgrains. Although intense activity follows the first rains throughout areas where a definite dry season exists, he finds that "to a remarkable extent, weeding is a major call on labor in the farming year and the single most important cause of seasonal pressures" (1974, p 129). He finds this to be true of cotton farms in Tanzania, maize farms in Rhodesia, and farms in Masii, Kenya, all due to the use of ox-drawn plows; in this case, the switch from labor-intensive hoeing to plowing results in the need for more weeding later. Weeding is a major problem in the tropics, particularly in monsoon areas with a definite dry season, and weeding rather than harvesting is usually the cause of peak labor demands (Cleave 1974, p 130).

Cleave's surveys do not allow easy generalization concerning the role of cash crops in increasing or decreasing seasonal variations in labor use; he notes, however, that African farming systems are consistently modified in response to labor conflicts by cultivators either changing farm operations or the crop pattern. In northern Uganda, for example, farmers deliberately delay cotton planting in order to give precedence to the staple food, millet. Early millet is necessary both because of high prices just before the main harvest and because it is an important part of payment for communal and hired labor. Simultaneous planting of cotton and millet would lead to a clash of labor demand at the three stages of planting, weeding and harvest. He suggests that early modification of the farming system may result from labor conflict of staple and cash crops, even when commercialization is not at an advanced stage (Cleave 1974, pp 131-132, 144).

In summary, Cleave's analysis of African farming systems stresses their flexibility and growth potential. Farmers have not only added cash crops to subsistence production, but have committed themselves to commercialization to a greater extent than usually assumed; in many areas, family farm output has more than doubled, and Cleave suggests a per capita growth rate of around 2% per annum in real terms. Farmers have, however, increased production simply by cultivating more land and using additional family labor. In most cases only traditional cultivation techniques are used, and though ox-drawn plows have been introduced to several areas, farmers have not adopted other ox-drawn implements such as cultivators (Cleave 1974, pp 188-189).

The predominance of hand methods of production means that labor is a limiting factor; on the one hand, commercialization has resulted in higher inputs of family labor, but on the other hand, hours spent on agricultural field work are still low — only about 1000 hours per adult per year, or 120 to 1604- to 6-hour fieldwork days. Farmers appear to rationally balance cost and return to effort, varying working hours according to seasonal conditions and modifying labor patterns, farming systems, the sexual division of labor, and even food habits to relieve pressure on time and accommodate cash crops. "Low total labor inputs in situations where farm operations are organized to save labor is an apparent contradiction; it can be explained by the highly seasonal nature of agricultural production and by the existence of alternative uses for labor that have a positive value to the farm family" (Cleave 1974, p 189). An inverse relationship exists between time spent on farm and nonfarm activities (if resting is excluded); Cleave notes that even at times of maximum farm activity (20 to 40 hours a week for adults), 3 to 4 hours a day may be spent on nonfarm work. There is no "absolute" surplus of labor, then, that can automatically be allocated to agriculture, but rather time and energy must be gradually reapportioned as farmers' valuation of activities, changes, or labor demands for domestic maintenance can be decreased. Interestingly enough, Cleave finds no evidence that ceremonial occasions or construction work interfere with agricultural activities; rather, major constraints on labor use are food preparation and domestic chores for women (up to 4 hours per day) and school attendance by children at critical periods (Cleave 1974, p 191). Similar constraints are also true of India.

Seasonality and Labor Use: India

In India, as in Africa, what appears to be severe underemployment of labor during slack periods may coexist with labor shortage in peak periods, and seasonality is largely due to climatic conditions. Irregularity of rainfall dramatically affects agricultural labor use and formerly led to widespread famines and epidemics. In Medak District, Andhra Pradesh, where the author carried out field research during 1970-71 and 1976-77, rainfall averages 35 inches per year but the annual range is broad, making drought a constant threat (India, 1961, p 78). In August 1970, for instance, rains were very heavy, causing flooding damage but resulting in a relatively good harvest. During the same *kharif* (rainy) season of the following year, however, the rains fell several months late; farmers prepared paddy seedbeds but were then unable to transplant as village reservoirs had not filled. Only a few of the wealthier landlords who owned field wells and pumps could carry out operations as usual. Most of the district's rice was lost, and the local administration was forced to open ration shops and provide work-relief programs for those normally dependent on income from agricultural labor. Extreme unpredictability of rainfall can thus seriously disrupt the agricultural cycle.

Table 1 summarizes the cycle of agricultural activity for Mallannapale village in Medak District, where the author conducted research during 1970-71. This was a community of 733 people cultivating both wet land and dryland and dependent on village tanks or reservoirs for its irrigation water. The total area of village and village lands was 1223 acres, and 23 *guntas,*[4] but over half was waste and uncultivated. Of the land being farmed, 194.21 acres was wet land; 277.24 acres was dry; and 29.05 consisted of dry converted into wet. Wetland is classified as *abi, tabi* or *do fasla* ("two-season") depending on when it can be cultivated. Farmers sow *abi* land during the rains of June and July, *tabi* during October and November, while *do fasla* land produces two crops a year. The latter is highly prized and scarce, however. Most villagers depend on their dryland crops and small amounts of *abi* land, planted to paddy (Benson 1974, pp 34-5). While variation will occur even between communities in the same area in regard to cropping patterns and seasonal bottlenecks in labor (see Dasgupta 1977, p 48), the sequence described in Table 1 can be used as a starting point for discussion of labor use in a semi-arid region of India.

4. There are 40 *guntas* to 1 acre. Figures after a decimal point indicate *guntas* in local practice; e.g. 194.21 = 194 acres, 21 *guntas.* The above figures are from the notebook of the Village Level Worker (the lowest-level extension agent in the development program).

Table 1. Agricultural cycle for Mallannapalle village, Medak District, Andhra Pradaah. 1970-71.

Month	Activity
June	Plowing, sowing of paddy, maize, millet, pulses, etc., preparation of seedbeds for rice, weeding (*kharif* season).
July	Transplanting paddy seedlings, weeding, guarding of maize.
August	Weeding, guarding of maize.
September	Harvesting of maize and other dryland crops.
October	As above; beginning of paddy harvest.
November	Completion of paddy harvest.
December	Preparation of seedbeds for second paddy crop; start of cane harvest; planting of dryland crops (*rabi* season).
January	Transplanting of paddy seedlings; cane harvest and replanting.
February	Weeding, watering cane and paddy.
March	Weeding.
April	Weeding; second paddy harvest.
May	Plowing for *kharif* crop begins.

First of all, a distinction between dryland and wetland crops should be noted. The former (millets, maize, pulses, broadcast paddy) are relatively less labor-intensive than irrigated crops but rely more heavily on "intermittent" family labor — women, children, the elderly — than the other. In her study of two villages in a ragi-growing region of Karnataka, for example, Epstein (1962, pp 212, 215) found that female labor was much more important in the cultivation of dry than wet crops. In the dry village, Dalena, women weed and harvest millets and do the winnowing, while men have only plowing duties. She states that the average labor requirement for ragi (*Eleusine corocana*) was 20 male labor days and 37 female labor days per acre; for one acre of jowar (*Sorghum vulgare*), 10 male labor days and 14 female labor days. Because dryland crops could be tended with largely female labor, men branched out into other activities, including cultivation of paddy in neighboring villages, when irrigation arrived in the area. A similar pattern occurs in parts of Africa where a high percentage of adult males migrate for work.

One important labor requirement of dryland crops is protection from birds and animals when the grain is ripening. During this period in Mallannapalle (July-September), farm families build huts on stilts out in the maize fields and guard the plots with slingshots day and night. Women, children, and the elderly perform much of this labor and also help with the harvest. Villagers frequently intercrop maize and millet with pulses, eggplant, cucumber, groundnut, and beans, harvesting crops at different times as they ripen.

While dryland crops are largely cultivated with the help of family members, wetland crops — mainly paddy and sugarcane — require different arrangements. Much more land preparation is necessary, timing is crucial in paddy transplantation and weeding, and irrigation requires constant attention. Male labor is needed for maintaining canals and ridges between fields, for plowing and levelling paddy plots, for irrigation, and for threshing. Women's groups play a major role in transplantation, weeding, and harvesting of paddy, while both men and women plant and cut sugarcane. Between June and November demand for labor is high since cultivators are performing the same operations simultaneously. In December, work begins on the second paddy crop, and dryland crops can theoretically be planted; in fact, most farmers do not have water for a second paddy crop, and if dryland cultivation is attempted yields are poor. Many cultivators, then, have relatively little agricultural work between December and May or June, when plowing for the *kharif* crop begins.

Sugarcane, a major cash crop in Mallannapalle and the surrounding villages, complicates the farmer's schedule since it requires constant irrigation and takes 12 to 14 months to mature. The sugarcane harvest and replanting follows the paddy harvest closely, extending the months of heavy labor; if sugar factory prices are not good in a given year, farmers may choose to crush their own cane and make jaggery, part of which is kept for household consumption and the remainder sold to local merchants who market it in Hyderabad. Epstein reports that from Wangala, the irrigated village in her study, average labor needs for cane per acre were 178 male and 30 female workdays; by contrast, paddy required only 97 male and 28 female labor days. Farmers adjusted to the new demands by contributing more family labor, but still had to hire about half of it (Epstein 1962, pp

53, 62). The capital expenses involved in sugarcane production, as well as the necessity of owning sufficient land to produce both a subsistence and a cash crop, are discouraging to many Mallannapalle farmers. By far the largest sugarcane cultivators in 1971 were two well-to-do lanlords with 4 and 30 acres, respectively, and they were major employers of agricultural labor in the village.

One important distinction in labor use between African and Indian farmers has already been mentioned, namely that hired labor is much more common in India. African farmers supplement input by household members with aid from visiting relatives and with communal labor, rewarded in kind, while hiring work for cash is not so common.

In India, smallholders and dryland cultivators depend largely on family labor, while hired labor is needed for larger holdings and cash crops. Commercialization affects labor supply by displacing artisans and poor peasantry, who are drawn to labor opportunities in other villages, while demand for labor rises with increased concentration of land. Greater prosperity also results in withdrawal of women and children from the labor force for reasons of status and education (Dasgupta 1977, pp 10-12; Epstein 1962, p 72).

in Mallannapalle and other Telangana villages, the main categories of labor are coolie or casual labor; *jetham pani* or salaried work (a term also used for government jobs); and *gutha* or job contract. Casual labor is hired by the full or half day and paid in cash or in grain for harvest work. Men plow and thresh, women and boys transplant, weed, and harvest, and both men and women do well cleaning and construction work during the dry season. Almost all households supplement their cultivation by working for others at some time during the year. The importance of wage labor can be seen from the fact that 89% of the population between the ages of 10 and 55 said they either customarily performed coolie activities or were working as salaried laborers. Casual labor may be used by any household that has sufficient land to afford (and require) it, but the larger landlords are obviously the most important employers. During 1970-71 Mallannapalle's largest landlord employed casual laborers on a nearly continual basis, not only for cultivation but also to build a new well, clean out old ones, and lay a stone flooring in his house. He had two servants with the regular duty of calling persons for coolie (Benson 1974, pp 123-124).

Salaried or "permanent" labor *(jetham pani)* involves a longer term contractual relationship between employer and employee, usually for a year at a time. While many households hire casual labor during the height of the main agricultural season, and may have their own members do coolie work in turn, only a few of the wealthier families can afford permanent labor — nine of 139 households in the case of Mallannapalle. The two large landlords mentioned above were the largest employers with 21 and 19 workers, respectively.

Landlords commonly obtain permanent labor by giving loans that must be worked off or repaid; this is often difficult since the laborer may need additional advances from time to time. The work is considered rather demeaning since a servant is subject to constant call by his master and may not leave the village without permission. Women are hired to help with housework or carry manure from the cattle shed every day, while men cultivate, irrigate or care for cattle; men also take turns guarding the landlord's fields at night. While hereditary ties between landlords and lower caste clients have been reported from many parts of India (cf. Epstein 1962, p 73), no evidence of such a system can be found in Mallannapalle. Of the 53 workers employed as of August 1971, only four had worked for the same family for 10 or more years, while most had served for only 1 or 2 years. A look at labor rolls reveals that attendance is sporadic; servants frequently quit or rejoin. A number of villagers who formerly worked for the larger landlords no longer do so. The relationship, then, is a contractual one (Benson 1974, p 126).

Although service is temporary, certain customary elements remain. The landlord usually gives his laborers one meal a day, and buys new clothes for them once a year at the festival of *Dassara;* he is also expected to take responsibility for the general health of his employees, and often supports them in disputes (Benson 1974, pp 127-128). It is in the interests of the large landlord, particularly an entrepreneurial one, to maintain a permanent labor pool; one of the chief means of doing this is by establishing a debtor-creditor relationship. Although by 1977 the Indian government was attempting to abolish "bonded labor" and simultaneously establish rural bank branches that would give credit to small-holders, it is not clear that this innovation will be successful.[5]

The third type of labor, *gutha* or job contract, is a form of piecework; employer and employee bargain over the price for a particular job, e.g., weeding a field. The worker plays an independent role, which makes this a favored type of employment; also, since he or she is being paid by the job and not length of time, there is an incentive to finish more quickly.

Another type of labor, *buthulu,* or "loan," also exists. Smallholders attempt as much as possible to avoid hiring labor by using family members and by resorting to labor exchange in certain circumstances. For example, two farmers may cooperate in alternately plowing each other's fields, or two families may jointly rent a sugarcane crusher and pool their bullocks and labor to make jaggery. Cooperative labor seemed to be of minor importance in Mallannapalle, however, perhaps because of the urgency of agricultural operations during the *kharif* season. Farmers are out plowing as soon as the first rain softens the soil, and since everyone is cultivating simultaneously, oxen cannot be spared; even help to relatives seemed uncommon. Commercialization has probably undercut cooperative arrangements to a certain extent, as it has in Africa, and affects nonfarm activities as well.

In addition to agricultural work carried out at the height of the season — between June and December or January — villagers also spend considerable time on nonfarm activities during the remainder of the year. By March, temperatures are rising as the hot season approaches, and for most farmers agricultural activity is minimal. During this period cultivators repair their houses, construct new ones, clean out field wells and dig others, and do miscellaneous maintenance jobs. Potters produce large numbers of house tiles for construction; these must be purchased on a cash basis and are not as part of the customary exchange between landowning and artisan households. As water levels drop in wells and tanks, some villagers supplement their income or diet by fishing. Also at this time local administration initiates public projects such as the repair of reservoirs and roads, for which casual laborers are needed. The nonfarm activities are complementary to agriculture, as in Africa, and do not compete with cultivation since they take place in a slack season. Weddings, the most time-consuming of all ceremonial obligations in India, are also most frequently held during the hot season (especially May) rather than in winter.

In summary, Indian agriculture faces some of the same ecological constraints as African agriculture, particularly seasonality, and to a certain extent has evolved similar coping mechanisms, such as complementary nonfarm work when cultivation is not possible. During years of adequate rainfall observed by the author in Mallannapalle, the population appeared to be working actively and at a fairly even pace throughout most of the seasonal cycle; in fact, labor was scarce and difficult to hire. Part of this is probably due to the spread of sugarcane as a cash crop and the introduction of new sugar factories in the district, although the entrepreneurial activities of one or two households in Mallannapalle accounted for a large proportion of labor use. Commercialization, monetization, and accompanying changes in the organization of production have proceeded to a much more striking extent in India than in Africa, accentuating an already severe system of social inequality. This major socioeconomic issue will be discussed below.

Commercialization, Labor Use, and Implications for Development

In his survey of rural labor use in India, based on data from 133 Indian Agro-Economic Research Centres, Dasgupta (1977) argues that a close relationship exists between the socioeconomic characteristics of a village and its labor utilization pattern. Landlessness and unequal land distribution negatively influence participation. Participation rates of the old (59+), women, and children (0-14) influence the overall participation rate, and the latter is inversely related to duration. "The larger the proportion of intermittent workers, the higher is the overall participation rate, and the lower the duration of work." (Dasgupta 1977, p. 157) With the introduction of

5. See Barry Michie (1978) for a discussion of the reasons villagers prefer moneylenders to banks as sources of credit.

cash cropping and irrigation, a shift from family labor to hired labor takes place and there is a decrease in overall rate of participation of the village population. Dasgupta constructs two models of community labor use based on this analysis. Type A community is characterized by a lower overall participation rate, sharper class divisions, and a higher proportion of 60% of the households in such villages do not own or operate land at all. Type B (which fits much of the African data better) has a higher participation rate, more emphasis on family labor, and is generally more egalitarian. Demand for *labor power* must thus be distinguished from demand for *laborers.*

The AERC surveys, however, were conducted during the early 1960s, before the high-yielding varieties of crops and their associated technologies had been introduced. Numerous studies since then have pointed out that agricultural modernization, together with commercialization and irrigation, has created socioeconomic problems that prove detrimental to "development" in any real sense. For the purposes of this study I will present a general argument concerning the transformation of traditional patron-client relationships in India, and will then illustrate it with case studies from South India.

The argument is derived from Aruna Michie (1976), and concerns the transformation of "traditional" socioeconomic forms as they adapt to forces of "modernization." She argues that "while certain behavioral patterns may indeed persist, their *content* and the groups involved are changed substantially." Alterations in production organization, due to agricultural modernization, destroy the traditional reciprocities of patron-client relationships and exclude the poorest as clients. "Insofar as patron-client relationships performed the tasks of at least providing economic survial (thus income distribution) and socio-political mobilization, changes in the client base mean new patterns of both redistribution and mobilization." (Michie 1976, p 1.)

Michie suggests that the process of change in patron-client relations proceeds in the following manner: (1) commercialization of agriculture alters the organization of production and thus traditional interdependencies; (2) reciprocal obligations of patron-client relations are gradually destroyed; (3) the relationship becomes more contractual, less obligatory, and often more coercive; (4) client bases are redefined as government policies and inputs allow new forms of production organization that allow patrons to redefine their role to that of broker; (5) clients are redefined to exclude the poorest, and elites (e.g. government officials) lose a traditional channel of information concerning the poorest economic stratum in rural areas.

The above argument, it should be stressed, applies to specific tenurial conditions, i.e., situations "where land is owned by a few, but is cultivated in small plots by tenants who often till the land in hereditary tenure, and may be landless themselves." It is not applied by Michie to either plantation economies or to fully peasant-owned and operated agriculture (1976, pp. 6-7). In addition to tenant-landlord relations, which required both the payment of crop shares or rents and personal services to the landlord, the need for tools, handicrafts, and ritual services formerly resulted in long-term interdependencies between households of landlords, tenants, and artisan and service castes. Though ultimate control rested in the hands of those who controlled land, economic interdependence gave tenant and artisan households some bargaining power, and a right to subsistence was at least recognized.[6]

Michie argues that agrarian patron-client relationships are grounded in the technology of the production process; if technological inputs result in the erosion of economic reciprocities, then the leverage of the client is broken. For example, mechanization may not only increase the scale of the production unit, but also result in the displacement of labor; large landlords find tractors less of a management problem than tenant families, and in fact this is often one of the explicit intentions behind tractor purchase. As cash crops have become more profitable and new inputs have been provided by government, landlords have illegally displaced tenants who end up as day laborers. They no longer have any right to a crop share, as the landlord does not rely on them in the same way. A breakdown of relations with artisans has also taken place as prestigious machine-made goods compete with local handicrafts and eliminate

6. See also Benson (1976).

this source of supplementary income. Because in most cases there are no alternatives to agricultural labor in rural areas, and it is very difficult for the poor to organize effective resistance, the coercive element in employer-employee relations increases.

Michie further suggests that resources for the modernization of agriculture, introduced by the government, are only useful to farmers (and, I would add, the larger farmers); tenants and laborers become largely irrelevant as clients. There is less emphasis *on* the redistribution of wealth, more on aggrandizement, and patrons are transformed into brokers; i.e. dealers in extra-local goods, between parties not in direct contact — in this case, government agents and other farmers, as opposed to tenants and laborers. Political payoffs to former clients, in the form of land redistribution and other benefits, tend to be symbolic and minimal.

While Michie's analysis stems from her research in Rajasthan, and she applies it to" a single tenurial situation, similar consequences of commercialization and technological change can be seen elsewhere in India. First of all, as she points out, a large proportion of Indian farmers are not in a position to benefit from economies of scale: 87.5% of all farm families are either landless or operate farms of under 10 acres (India 1967; quoted in Michie 1976, p. 7). Second, when tenants are rendered landless, or smallholders lose their land to creditors, it cannot be assumed that their labor will be absorbed elsewhere; often there is no place to go.

In her 1969 restudy of two South Indian villages where she carried out economic research during the 1950s, Epstein (1976, p. 171) argues that increasing economic differentiation has taken in rural Mysore (Karnataka) during the past 10 to 15 years:

> The wealthiest peasant farmers have become considerably richer. The jaggery boom provided the possibility of a windfall profit to all farmers who owned more than two or three wet acres: the greater the cane acreage the greater the benefit a farmer derived from the soaring jaggery prices. This encouraged the wealthier and more enterprising peasants to invest in more and more wet land as well as in cane-crushers to process their crop into jaggery (Epstein 1976, p 171).

Labor inputs for sugarcane have considerably increased: from 52 086 male labor days in Wangala, the irrigated village, during 1955 to 127 113 male labor days in 1969. Male input has more than doubled, with the average number of yearly days per male in agriculture increasing from 174 to 258. Female labor requirements in the same community increased by 50% from 19 296 to 29 565; the annual female per capita workload actually fell, from 73 to 67 days, but Epstein notes that while 50% of male labor is provided by the household, 90% of female labor is hired. Farmers now use more female workers to reduce the costs of labor, since they are paid only half the male rate, while the women of well-to-do households have withdrawn from cultivation.

In spite of this increase in labor input, marked seasonality continues to characterize the agricultural system, and inflation has reduced the real wages of laborers. Epstein (1973, p 172) notes that: "The case studies of the poor A. K. (scheduled caste) households in Wangala and Dalena show that the greater a household's dependence on rural cash wages for meeting necessary expenditure, the greater has been the deterioration in the standard in living." This situation is not unique to Karnataka; National Sample Survey data indicate that the percentage of the national population below the minimum level of expenditure rose by 40% between 1960-61 and 1967-68 (Bardhan 1970, p 1245).

Another example of the consequence of agricultural modernization is taken from my own field work in Andhra Pradesh (Benson 1974). In Mallannapalle and other villages from ex-*Jagir*[7] areas of the former Hyderabad State, most cultivation is by owners and there are relatively few tenants or absentee landlords (cf. Khusro, 1958). Although the majority of villagers possess some land, it may not be sufficient for subsistence needs,[8] and an analysis of land-

7. A revenue assignment of a characteristic Muslim type; the holder of a *jagir* held the right to revenue collection in one or more villages.
8. In 1971 the land records listed 126 owners, of which 111 were owner-cultivators and 15 were tenants according to a 1970-71 agricultural census. A number of deeds have been taken out in the names of sons and daughters, however, to evade land ceiling laws, when actually cultivation is still joint, and many tenancies are held by oral contract.

holdings reveals marked economic differentials between households (Table 2). Six out of 139 households (five of them Reddis, members of a cultivating caste) have more than 20 acres, while 115 households own 5 or less. Reddis own more than 69% of the village wetland (98 acres), several times the amount held by other large caste groups. Two of the largest Reddi landlords were major employers of village labor in 1970-71. One of them, whom I will refer to as the head of household 6-7, shared his budget with another brother, a wholesaler resident in Hyderabad, who played a moneylender role in Mallannapalle and neighboring communities during his frequent visits to the village. During the last few years this household had been expanding its landholding by any means available to it — purchase, taking land as collateral for loans, and forcible occupation (Table 3). As a result of these tactics, by 1971 household 6-7 was in effective control of 34.16 acres, mostly irrigated, in addition to an inheritance of 68.28 acres being disputed with a third brother. In addition, the same household leased another 12 acres during 1970-71, and also controlled approximately 100 acres in another village.

The expansive activities of 6-7 were due to the interest of its head in two cash crops, namely paddy and sugarcane. His wholesaler brother owned a share of a nearby sugar factory to which the cane crop was sold. Since the head of 6-7 had the capital and familiarity with government agents, he was able to take advantage of the new hybrid cane offered by the local

Table 2. Size of holdings by household in Mallannapajle vIllaga, Andhra Pradesh, 1971.

Acreage	Number of households[a]
0-5	115
6-10	11
11-15	5
16-20	2
Over 20	6
Total	139

a. When landholdlngs are joint but a family has split Into separate households, size of holding is estimated to be an equal share for each household.
Source: Benson (1974, pp 113-114)

Table 3. Land acquisitions by Reddi household 6-7 in Mallannapalle village, Andhra Pradesh.[a]

	Wet	Dry	Total
Occupied from other castes	9.19	–	9.19
Occupied Reddi land	11.12	1.20	12.32
Purchases from other castes	6.15	–	6.15
Collateral for loan (Komiti)	*530*	–	5.30
Total	32.36	1.20	34.16

a. Refers to acquisitions for a number of years prior to 1971.
Source: Benson (1974, pp 114-115)

Block Development Office. During the first *kharif* season of my fieldwork (1970), this household put approximately 3 acres into the new hybrid cane; after its harvest, the cane was used to seed a much larger area, giving household 6-7 a total of about 30 acres the following year. Neighbors complained that this household was acquiring all fields adjoining the sugarcane plots, occupying them by force if necessary; by November 1971, the head had plans to trade for or purchase 6 additional acres. The village's water supply was also excessively monopolized for cane-growing by this household. The other large Reddi landlord, 6-7's eldest brother, was also expanding his sugarcane area in Mallannapalle and another village, though not at the same rate.

Because of the lucrative nature of cash crops such as sugarcane, landlords find that it is more profitable to cultivate land, particularly irrigated land, than to lease it to others, and may even let dryland remain idle. It is in their own interest to maintain a potential labor pool with no alternative sources of income. While household 6-7 employed many laborers, it did so at low wages, and eliminated some labor needs entirely by using its tractor to plow dryland crops and sugarcane. On several occasions agricultural laborers attempted to strike against this household, but were out-maneuvered by the head's economic power and his ability, through extra-village contacts with other landlords, to bring in strike-breaking laborers from other communities.[9] As Michie suggests, the poor have little leverage.

9. In one case a Communist leader.

Conclusions and Suggestions for Further Research

As the above discussion indicates, increased demand for labor power tends to adversely affect the lowest socioeconomic segment of society in nonwestern countries. The process is undoubtedly slower in communities where land distribution is relatively egalitarian to begin with (Dasgupta's "Type A" community, which would include tribal areas in India and many East African societies), and more rapid in areas where village land was traditionally monopolized by single castes or ethnic groups (Dasgupta's "Type B" community). This does not imply that economic differentiation has not taken place betwen members of these once-powerful castes, or that middle-level castes have not acquired land in many areas; but entrepreneurial activity is most possible for those who already have resources, and is often at the expense of others. Commercialization probably makes this process inevitable, but planners should be aware of the social costs of their actions. As Cleave notes, development agents must pay close attention to the effects that their technical recommendations and innovations have on labor demand, and should realize that smallholders require complete packages of innovations including credit and marketing facilities. At present, these tend to be monopolized by the well-to-do.

While effective land redistribution in India is politically and economically unrealistic, some of the worst effects of commercialization and agricultural modernization could perhaps be mitigated by discouraging technology that displaces labor, in favor of technology that is more labor-intensive and reduces the seasonality of agriculture. Another tactic would be to investigate the possibility of more cottage industries in rural areas; these could provide income during seasons of agricultural inactivity and would be especially appropriate for women, as well as give laborers somewhat more bargaining power (due to the presence of alternate employment) with landlords.

In order to develop alternative development strategies, further research is essential. Very little information exists concerning labor inputs from family members, especially women and children, although a number of studies suggest that their work is quite important to the household economy. As Dasgupta (1977, p 19) states:

> It is important to know the relative importance of various activities ... how their distribution by age-sex categories varies between villages in response to differences in village environmental conditions. Unfortunately, very few village surveys give such data; and even when they do, their definitions and methods of classification of 'work' vary widely, partly because of social, cultural, and economic differences among the situations studied.

Empirical research is necessary to explain the variation that exists between labor inputs of women and children of different socioeconomic classes and ethnic groups in different ecological settings. As Dasgupta (1977, p. 36) suggests, "To what extent cultural factors promote or hinder women's participation independently of economic and institutional factors is a matter of dispute." He notes that cropping patterns also influence the participation of different age-sex groups in work, but very few Indian village studies document in detail the labor input requirements of different crops.

Since female work-groups handle many of the major agricultural operations in both India and Africa, and at least in India commercial use of irrigated land seems to require lower-class female labor, the organization of these work-groups should be studied. Another problem with time-allocation data is that even where it exists, it does not measure *effort,* which in turn affects duration and productivity. Further research is necessary in all these areas.

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Rural Labor Markets in West Africa with Emphasis on the Semi-Arid Tropics

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Abstract

This paper provides an overview of rural labor markets in West Africa with emphasis on the Semi-arid tropical (SAT) regions. A knowledge and understanding of these labor markets is essential to an understanding of traditional cropping patterns and practices as a basis for the design of new crop technologies appropriate to the farmers of the region. The paper reviews empirical evidence on rural labor markets at a hierarchy of levels beginning with household or family labor utilization, proceeding to the local or village hired labor market, and finishing with the regional labor market integrated by rural-rural and rural-urban migration. On the basis of this review, some generalizations about rural labor markets in the SAT areas are drawn and implications for agricultural research programs noted.

The purpose of this paper is to provide an overview of rural labor markets in West Africa with emphasis on the Semi-Arid Tropical (SAT) regions. There are several characteristics of the SAT region of West Africa that set it apart from other SAT regions and that have important implications in explaining labor market behavior in the area. First, the SAT region of West Africa is generally characterized by a communal land tenure system that ensures each member of the community a right to the use of a piece of land; land cannot usually be sold, although short term access to land is often possible at low "rental" values. In addition, the region as a whole has had a relatively low population density — usually less than 50 persons/sq km — although this is rapidly increasing and pockets of higher population density are now common. These two combine to preclude the existence of a landless laborer class and indeed in many cases result in a relatively equitable distribution of land per capita.

Another factor of importance in analyzing labor markets in the region is the lack of *agricultural* opportunities in the dry season, although *nonfarm* opportunities *are* available *to provide* some dry-season employment. Irrigation development is in its infancy, and bottomlands suitable for dry season cultivation are only locally available. Rainfall for perennial crops is inadequate, and the dry-season clearing of bush characteristic of the humid tropics is not generally necessary in the savanna areas. However, the humid coastal or forest areas of West Africa provide considerable dry season employment in tree crop production, giving rise to opportunities for seasonal migration between the two areas.

The broad emphasis in this paper is on labor markets in the semi-arid tropical or savanna areas of West Africa,[1] but because of my own research experience in the area and access to research of others, evidence is largely drawn from the Anglophone countries of Nigeria, Ghana, and Sierra Leone, including the forest zone. Land tenure and population pressure in the forest areas are usually similar to the savanna areas and the very fragmentary information on rural labor markets in savanna areas

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1. Countries included in the SAT areas of West Africa are the Sahelian countries — Gambia, Senegal, Mali, Mauritania, Upper Volta, Niger, and Chad — and the northern parts of the coastal countries of Guinea, Ivory Coast, Ghana, Benin, Togo, and Nigeria.

can be greatly augmented by cautious inclusion of evidence from the forest zone. Furthermore, as mentioned above, the rural labor markets in the two ecological areas are often closely linked by seasonal and permanent migration streams. Therefore I often refer to a comprehensive study of rural labor markets and migration we conducted inSierra Leone, which, except for the very north, lies in the humid tropics. Here too we gain some useful insights by noting differences in labor use and labor market behavior between the south and the drier north.

This paper reviews empirical evidence on rural labor markets at a hierarchy of levels beginning with household or family labor utilization, proceeding to the local or village hired labor market, and finishing with the regional labor market integrated by rural-rural and rural-urban migration. On the basis of this review some generalizations about rural labor markets in the SAT areas are drawn and implications for agricultural research programs noted.

Family Labor

Most evidence on family labor use in the SAT regions of West Africa comes from multiple visit surveys (usually twice weekly) of rural households to elicit daily labor activities of each family member over the whole year. The most comprehensive of these surveys have been undertaken in the north of Nigeria by Norman (1973) and later by Matlon (1977). Here male adults worked approximately 700 to 1300 hours/year in farm and nonfarm work. These figures are lower than observed in similar surveys in the humid areas of Sierra Leone, where males worked 1400 to 1500 hours/year. Because of Moslem tradition, female participation in agricultural field activities is minimal in northern Nigeria. In northern Sierra Leone females are an important part of the labor force, working 900 hours/year (mostly in farm work) and contributing 39% of all labor inputs. In the southern regions of Sierra Leone females contribute an even higher percentage of total labor. Older children are also an important part of the labor force. Matlon observes that boys 10 to 15 years old contributed 250 hours/year, compared with adult males with 680 hours/year in his study of three villages in Kano State, Nigeria.

A somewhat different approach recently used by Tripp (1978) in the north of Ghana involves visiting a household (selected at random from a given sample of households) at a random point in time and eliciting information on the activities of each household member at that point in time. By continuing this approach over the whole year, Tripp was able to construct a profile of use of time use by family members for the sample of households. Time allocated to work in his sample was 1500 hours for farm work and 560 hours for nonfarm work for men and 1070 hours in farm work and 670 hours for nonfarm work for women. Marketing, food preparation, and household maintenance and other household chores occupied another 1.8 hours/day for men and 4.4 hours/day for women. These figures, based on observation rather than recall, suggest somewhat higher labor inputs than previously estimated and also document the considerable time spent in household activities, particularly for women.

Where female and child labor are important, there is usually some specialization. For example in northern Sierra Leone and Ghana, females are the largest contributors to groundnut and traditional vegetable production and to weeding and processing activities. Young males are important in pest-scaring and labor-selling activities (Gunther 1978, Tripp 1978). Nonetheless, all types of labor participate in all enterprises and most activities, and there seems no reason to assume that sexual or age specialization of labor is rigidly enforced except for particularly strong religious or social reasons, as among the Moslem Hausa of Nigeria. In fact, Tripp notes in northern Ghana an increasing role of women in farm work; partly in response to labor shortages, women now weed millet — traditionally a male activity.

High seasonality of labor use is of course characteristic of this area. In the north of Nigeria 53% of all annual labor inputs occurred in the four busiest months of May to August, while only 15% occur red in the four slack months of January to April (Norman and Pryor 1978). In the peak month, July, adult males worked about 140 hours/month compared with only 51 hours/month in the slack months. In northern Sierra Leone peak month labor inputs, again in July, are as high as 200 hours/month (Spencer and Byerlee 1976) and in northern Ghana, Tripp's data (1978) indicates that males work as much as 250 hours/month in the wet season.

At the peak month there is evidence of an increase in the supply of labor from other members of the family. In Sierra Leone in the peak month of July females contribute 43% of all labor inputs compared with only 29% in the slack season (Gunther 1978). Matlon (1977) and Norman and Pryor found in northern Nigeria, where female agricultural labor is unimportant in all seasons, that similar increases in the relative proportion of labor provided by young males occurred in the peak season.

In addition, in the peak season labor is drawn from nonfarm to farm activities.[2] Over the entire year Matlon (1977) found that 21% of all family labor inputs were in nonfarm activities, largely livestock and traditional manufacturing, trade, and services. However in the peak months of May to July this percentage falls to 10%. In Sierra Leone; 11% of family labor is employed in small-scale industry and trading on an annual basis, but in the peak month only 2 percent of labor is used in this type of nonfarm work compared with 19% in the slack month of February (Spencer and Byerlee). In northern Ghana, the percentage of work time spent on crafts and trade by adult males decreases from 54% in the dry season to 14% in the wet season. In all cases the absolute as well as percentage hours worked in nonfarm activities falls in the peak period.

These figures only document some of the evidence leading to the general conclusion of a peak season labor bottleneck in most areas of West Africa. It is reasonable to hypothesize that the severity of this problem increases as we move north into lower rainfall areas, because the flexibility to stagger plantings is reduced and, as a result, planting and weeding work are more concentrated. There is indeed some evidence to support this. In Nigeria, the coefficient of variation (CV) of monthly labor use (60-70%) in the driest area, Sokoto, was among the highest of the three areas analyzed by Norman and Pryor. Moreover, the adult males worked approximately 30% more in the peak month in this area than in the other two areas. In Sierra Leone, there is a very marked increase in the coefficient of variation of family labor use, moving from 16 to 25% in the south to 40 to 50% in the north. Again the peak season labor inputs increase, moving from an average of 140 to 150 hours/month in the south to about 200 hours/month in the north, although in the dry season, labor inputs in the north are consistently lower than in the south, further increasing seasonal variation in labor use (Spencer and Byerlee 1976). Moreover, there is evidence of greater substitution of farm for nonfarm work in the peak season in the north, again indicating a more severe peak season labor constraint.

Finally, disaggregation of household data reveals that labor use and allocation in the peak season shows substantial variation even within a village. In the north of Nigeria, Matlon found that the peak season for low-income households is less acute with adult males working only 93 hours/month compared with 153 hours and 116 hours/month for the middle and highest income group. Moreover, the lowest income group participated to a greater degree in nonfarm activities in the peak season, when 25% of labor was still utilized in nonfarm work compared with only 3% for higher income households. In part this may reflect a need of low-income food deficit households to continue earning cash incomes through nonfarm work to purchase food. In Sierra Leone, low income households also had the lowest labor inputs during the peak season as well as for the whole year (Gunther 1978).[3] However the largest difference occurs in the slack season where the highest income households worked twice as much as the lowest income households largely because of their participation in relatively capital intensive dry season activities such as fishing, small-scale industry, and tree crops. In contrast to Nigeria, there was a tendency for high income households to spend more time in the peak season on off-farm activities relative to low income households, but these were largely high returns activities such as small-scale industries and fishing, compared with the low returns activities, such as working on nearby farms, that are followed by low-income households in the peak season in Nigeria.

2. The definition of nonfarm labor varies from study to study. In this paper we generally mean all work conducted away from former's fields, e. g. agricultural processing, livestock, local crafts and trading, labor sold out but excluding household work.

3. In both Matlon and Gunther, households were classified into three income terciles for the analysis.

The low labor input of low-income households is clearly an important factor explaining the low income status of these households. Matlon and Newman for example, show that in the north of Nigeria low income households plant and weed basic food crops later than higher income households and also weed less-intensively leading to lower technical efficiency of production. They explain part of this difference in the timing and intensity of labor inputs in terms of a liquidity constraint forcing low income households to work off the farm (see next section) but this does not explain the low total family labor input in the peak seasons, which might result from other factors such as nutrition or disease (Chambers 1978).

Hired Labor

Hired labor in traditional farming situations in SAT West Africa typically accounts for from 10 to 20% of all labor use and is also the largest production expense. In the north of Nigeria, it accounts for 57% of all *cash* expenses (Norman and Pryor); in Sierra Leone, 70% of all expenses.

Three systems of hiring labor are commonly used — the traditional exchange and communal work, daily wage work, and contract work. The importance of traditional exchange and communal work, where young males form groups to work from farm to farm, or engage in individual labor exchanges, varies from area to area and is probably being supplanted by commercial labor hiring. In the north of Nigeria, 55% of labor was hired by the hour, 44% on a contract basis and only 1% *on* exchange (Norman and Pryor). In Sierra Leone, up to half of hired labor is exchange labor and only 13% is contract labor (Spencer and Byerlee). There are also different methods of paying hired labor. In Sierra Leone, 38% of hired labor (largely exchange labor) was paid only meals, 38% meals and cash, 3% cash only and the rest other combinations of cash and kind payments (Spencer and Byerlee). Overall, cash payments were only about 38% of all wage payments since substantial meals were always provided. Cash payments are probably more important and meal payments less important in the north of Nigeria. Wages paid to contract labor are effectively higher than daily wages — over 100% higher in the case of Sierra Leone and 69% higher in Nigeria (Norman and Pryor).

The amount of hired labor varies seasonally and appears to generally follow the seasonal labor profile of family labor. However, in the aggregate there seems to be little tendency for *the proportion* of hired labor to increase in the peak season. To some extent this is to be expected, given the lack of a landless laborer class and the fact that most households experience peak labor demands on their own farm at the same time.

However, disaggregation of households shows some differences in use of hired labor by income group. In the north of Nigeria, Matlon (1977) found that higher income households hire a greater proportion of their labor. In Sierra Leone, this is true to a small extent but, more importantly, Franzel (1978) shows that high income households tend to hire a greater proportion of labor at the peak season of July/August compared with lower income households, who hire in April/May and again at harvest in November — periods of intermediate demands on family labor inputs. This probably reflects the greater cash availability of higher income households in the peak season as well as the fact that exchange labor is not generally used for peak season tasks such as weeding.

It is probably also true that lower income households sell out more of their labor. At least in the north of Nigeria, Matlon found that low income households sell out about 12% of their total labor while middle and higher income households sell out only 1 to 2%. Moreover, in the peak season, low income households sell out relatively the same proportion of their labor and, in terms of hours, actually sell more labor. In Sierra Leone, the amount of labor sold out does not seem to vary much by income level, but this may be because all income groups participate in exchange labor, which is important in this area.

Given the patterns of seasonal labor demands, some seasonal variation in wage rates is expected. In fact, the only evidence available from the savanna areas indicates that this is not the *case,* perhaps because the cash constraint coincides with peak labor demands, preventing high income households from offering higher wages or forcing lower income households to continue seeking off-farm incomes (Norman 1973).

Evidence from Sierra Leone, however, shows some quite important variations in wage rates. Analysis of variance showed that region, sex, and month all had highly significant effects on rural wages. Drier northern regions had the lowest wages and consistently in almost all regions the wage rate for females was 65 to 75% of male wages, and wages for children less than 15 years were only half of adult male wages. However, in the peak seasons there was a tendency for male/female wage differentials to narrow. Peak wages occurred in May to July with a secondary peak in the dry season from January to March, but the differences were not large, with May to July wages only about 25% higher than the low wage period of August to December. The May-July wage peak of course corresponds roughly to the period of peak labor demands. The high wages in the dry season are less easy *to* explain but they might be related to greater cash availability to both labor buyers and sellers. Both payments in cash and the value of meals vary significantly by month. In particular, there is a very clear tendency for the absolute level of *and* proportion of cash payments in wages to increase immediately after harvest in December and remain high until June. In June the value of payments in-kind, particularly meals, increases until the "hungry season" of August/September, when both cash and kind payments (Spencer and Byerlee 1976) are low. Thus the periods of high cash payments correspond very closely to the period of cash availability and vice versa. The high dry-season wage rate could then be due to some households substituting hired labor, for family labor, using available cash to attract workers who, with harvest in hand, would normally consider this a period of relative leisure and reserve a high supply price for their labor.

Matlon (personal communication) also notes a relatively high wage in the dry season in the Kano area of northern Nigeria, which he feels can also be partly explained by the arduous nature of dry season tasks such as deep plowing of lowland fields by hand.

Finally, there is evidence that average wage rates paid are reflected in the marginal value productivity (MVP) of labor. Production function studies in Nigeria by Matlon and by Norman generally show the MVP of labor to be slightly above the wage rate, but not significantly so. There is, however, no evidence available to show that the MVP of labor also varies by sex and season. Matlon did estimate MVPs of labor for households at different income levels and again finds at all levels that the MVP of labor brackets the wage rate. This then is evidence that the labor market is fairly efficient on average in allocating labor. On a seasonal basis there is evidence from linear programming models that the MVP of labor in the peak months with labor inputs set at observed levels is three to four times above the prevailing wage rate (Norman and Pryor). This undoubtedly relates to the seasonal liquidity situation discussed above.

Migration

The most important and widespread migration in the semi-arid areas of West Africa has historically been the seasonal migration to the forest zone during the dry season. The magnitude of this migration is not really known but has been estimated to be as high as 3 million persons per year (Udo 1964). Generally migrants leave their farms in the savanna zone immediately after harvest in November-December and return again for planting in April-May. This is, of course, the dry season of low farm activity in the savanna areas but a peak season for tree crops in the forest areas, particularly coffee, cocoa, and oil palm.

Much of this seasonal migration is international. For example, up to 65 to 70% of the hired farm workers in the Ivory Coast in the dry season are from Upper Volta, Mali and Guinea. A 1960 survey showed that Upper Volta alone had about 7% of its population, *or* 500 000 people working in the Ivory Coast, over half as seasonal migrants (Songre 1973). Seasonal migration within countries is also important. Beats and Menezes (1970) estimate that 200 000 persons from northern Ghana migrate annually to the south to work in cocoa areas. In the high population density area of northern Ghana where Tripp worked, 40% of males migrated to the south in the dry season in which he conducted his survey (1976), and almost all males had migrated at some time in the past. In a farm survey in the Sokoto area of Nigeria, 45% of the off-farm work was accomplished through short-term migration during the dry season (Norman and Pryor).

Typically, seasonal migrants are young males with no education, but much less information is available about the characteristics of the households and regions from which they originate. There is evidence that villages with lowland areas available for cultivation in the dry season produce fewer seasonal migrants (Norman and Pryor). There is also some evidence that high density population areas such as the Moshi area of Upper Volta and the Sokoto area of Nigeria produce more migrants.

Within a region it is tempting to hypothesize that seasonal migrants originate in poorer households with need of additional cash incomes and food. However we have found no available evidence of this linkage.

Seasonal migration has a number of potential implications for farm resource allocation and use in the savanna areas. It will compete with agricultural activities that occur in or overlap with the dry season. Skinner (1965) speculates that the failure to introduce the cash crop, cotton, in the Moshi region of Upper Volta is due to a conflict of cotton harvesting with seasonal migration in December (cotton is typically planted and harvested after the food crops).[4] Capital formation activities using labor in the dry season — such as bush clearing, well-digging and terracing — may also be reduced in areas of high seasonal migration. Skinner argues that in the Moshi areas of Upper Volta new bush land is less frequently cleared, leading to more intensive cropping and perhaps declining fertility.

On the other hand, seasonal migration may add to household resources for farming. Cash returned with migrants could help offset the cash constraint faced in most rural areas, although evidence from more permanent migration streams in Sierra Leone indicates that relatively few cash remittances are used directly in agriculture.[5] Furthermore, households with at least one member absent for 4 to 6 months will experience a decline in home food consumption needs which might either increase the marketable surplus (or reduce the food deficit) or lead to a change in farming systems away from food crops to more profitable cash crops. Unfortunately, no evidence is available on these points.

In addition to seasonal migration, there are important, more permanent migration streams.[6] Rural-rural migration is one means of equilibrating interregional differentials in labor productivity in agriculture. There is evidence that rural-rural migration has indeed partly played this role. Associated with seasonal rural-rural migration has been a tendency for migrants over time to settle in the destination areas where wages and year-long employment opportunities are better. As a result, about one million foreigners, largely from Upper Volta and Mali, now reside in the Ivory Coast (World Bank 1979).

In Sierra Leone, we estimated on the basis of cross-sectional data an elasticity of about 2.5 of the rate of permanent rural-rural migration with respect to interregional rural wage differentials. However, a wage differential of almost 2 to 1 still existed between the highest and lowest wage regions, despite a considerable flow of migrants from the lowest to highest wage regions. It is likely that ethnic and land tenure barriers considerably restrict the amount of permanent rural-rural migration and, as a result, pockets of high population density and declining soil fertility are common. In many areas strangers can still gain access to land through arrangement with local leaders but it is more difficult to obtain permanent user rights and even more so where ethnic differences exist (Eicher et al. 1970).

Rural-urban migration has been growing in importance throughout the region and probably now exceeds rural-rural migration in numbers in most countries.[7] It is also likely that the pattern observed in Sierra Leone is fairly generally applicable in West Africa. There migrants differentiated into two well-demarcated

4. Of course it is implicitly assumed that returns to seasonal migration are higher than for cotton production.
5. However, the cash returned by migrants might indirectly make cash more available for farm investments.
6. In this paper we define permanent migrants as those who move to a new location for a period of over 6 months. This excludes seasonal migrants.
7. For evidence from Ghana, Sierra Leone and Upper Volts see Caldwell (1969), Byerlee et al. (1976), and Gregory (1971), respectively.

streams (Byerlee et al. 1976). On the one side were migrants without formal schooling who originated in poorer households and *poorer* regions of the country. On the other side were migrants with at least primary schooling who came from higher income households and regions of the country.

The large number of rural-urban migrants is considered a serious problem by many governments in the area because *of* the increases in urban unemployment and urban social problems associated with this migration. There has been considerable research on rural-urban migration but it has largely focused on documenting the migration streams and their implications for urban areas. From the perspective of this paper, the impact of this type of migration on farming systems and crop technologies is the critical issue, and here there is little evidence available. Although the rate of rural-urban migration has been high, rural populations in most areas continue to increase. However, because of the selectivity toward young people 15 to 30 years old, the dependency ratio has increased and probably aggravated the seasonal labor bottleneck in many areas.

Conclusions on Rural Labor Market Behavior

Throughout West Africa family labor is the most important resource in household production and hired labor the largest production expense. At the peak season — usually July and August — labor is generally a bottleneck in agricultural production in the sense that there is a relatively high MVP of labor at this time. There is a widespread and competitive labor market to allocate labor within households, villages, regions, and even across international boundaries. At peak seasons additional household labor resources — women and children — often play a relatively more important role. In addition labor from nonfarm activities is drawn into agricultural production. Labor is hired (from local labor markets) at average wage rates that reflect the marginal productivity of labor on an annual basis. Seasonal and permanent rural-rural migration link widely separated labor markets, particularly between the savanna and coastal areas.

However, there are also some factors that lead to inefficiencies in labor allocation. In some areas such as the north of Nigeria, where field work by females is limited, the sexual division of agricultural work may lead to a more serious problem of seasonal labor bottlenecks. Furthermore, there is growing evidence that the buying and selling of labor is intimately linked to the cash flows of rural households, particularly because the peak labor requirements generally coincide with the period of acute cash shortages.[8] To the extent that there are imperfections in the credit market — and there undoubtedly are — these will be translated into imperfections in the labor market. At the peak labor demand period, the demand for hired labor is constrained by lack of available cash while supply remains steady because of the need for some households (particularly lower income households) to obtain cash. As a result, the variation in wage rates is relatively small compared with the likely variation in the MVP of labor.

There is also evidence of considerable variation of patterns of labor use and allocation between households and regions. Lower income households tend to be labor sellers both locally and to other rural regions through seasonal and permanent migration, while higher income households tend to be labor buyers, particularly at the peak period. Across regions, rainfall and population density affect rural labor markets. Drier northern areas have a more pronounced seasonal labor peak and a longer slack period for seasonal migration. More densely populated areas generally have higher rates of both seasonal and permanent rural-rural migration.

Looking to the future, rural population pressure will undoubtedly increase, placing more emphasis on land shortages and declining fertility and further differentiating households into labor sellers and buyers. In areas of low population pressure, the increasing dependency ratio through higher fertility, age-selective out-immigration, and the spread of rural education will probably aggravate the seasonal labor bottleneck. At the same time, seasonal north-

8. Whether wages are paid in cash or kind is not important because this is also the "hungry" period of food shortage for household consumption forcing many households to use cash to purchase food on the market (King and Byerlee 1977).

south migration may decline partly because of increased political problems of international migration (as has already happened to some extent) and more emphasis on food crop versus cash crop production in coastal countries as a result of increasing food deficits (e.g. in Ghana).

Implications for Agricultural Technology

Clearly the seasonal labor bottleneck has important implications for understanding current farming systems and technologies and for introducing new ones. To some extent current systems use enterprise combinations that have complementary seasonal labor needs. For example, Franzel (1978) shows that all major enterprise combinations except one in rural Sierra Leone included enterprises with complementary seasonal labor profiles (i.e. different peak labor requirements). Likewise cotton is planted in the north of Nigeria after food crops to minimize labor competition even though earlier planting dates are recommended (Norman and Pryor). However, the ability to combine enterprises and stagger planting dates undoubtedly declines as rainfall and the length of the growing season decrease. The one enterprise combination in Sierra Leone with highly competitive labor inputs only occurred in the north (Franzel 1978).

The existence of the seasonal labor bottleneck opens the possibility of labor-saving technology at this period. Tractor mechanization of land preparation has proved costly (Byerlee et al. 1976) and in any event does not break the weeding bottleneck. Herbicides offer potential to do this but this imposes a cash expense at the period of acute cash shortage and is also complicated by the widespread interplanting of several crops. Oxen power for both land preparation and weeding may offer the greatest potential without greatly increasing cash costs (Norman and Pryor). Biological-chemical technologies that raise yields of course add labor at harvest time but at the same time usually require some labor at the peak season even if in the form of better manual weed control. There is a danger that only higher-income farmers with cash to hire labor may be able to take advantage of these technologies unless adequate credit or input subsidies are provided to low income farmers (Matlon 1977).

Technologies that utilize labor in the slack season (e. g. capital improvements to the land, irrigation, longer harvest periods for higher yielding technologies) must consider the opportunity cost of labor in off-farm activities and seasonal migration which may provide returns up to three times higher than in agriculture.[9]

Implications for Research on Rural Labor Markets

It is clear from the evidence presented in this paper that there is a wide range of labor market situations in the SAT reg ions of West Africa and that the design of agricultural research programs in the region must take into account the local situation in the labor market. Most evidence presented in this paper was obtained from "cost route" studies to obtain daily data on labor inputs throug hout the year. While this has provided a useful quantification and understanding of the labor allocation process it is doubtful that this methodology can be replicated over a wide area of the SAT regions because of the time and resource costs of implementing it.

Recent experience by Collinson et al. (1978) in areas of East Africa where labor shortages are a critical factor in understanding current farming systems and technologies and introducing new ones suggests that much information can be obtained from well focused one-contact surveys based on a systematic familiarization with farming systems in the area prior to the survey. Information has been successfully obtained on labor force participation, busy seasons, wage rates, labor hiring and migration, and most importantly, farmers' make decisions in the light of these labor market characteristics. Where more detailed labor input information for specific tasks and crops is required, more intensive interviews of a small sample of farmers may be necessary.

9. For example, the agricultural wage rate in Ghana is now reported to be US $5/day compared with US $1/day in the Sahelian countries.

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Labor Use and Labor Markets in Semi-Arid Tropical Rural Villages of Peninsular India

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Abstract

Comparisons of household data from six villages in South India with experimental watersheds show that prospective crop-, land-, and water-management technologies for semi-arid tropical (SAT) India appear to offer considerable scope for increased employment, particularly on Vertisols. Wide seasonal variations in wages, daily labor market participation rates, and probabilities of employment exist for both males and females. Hence there seems good scope for designing technology to capitalize on low opportunity cost periods. Labor opportunity costs are calculated for use in project analyses. Women presently comprise about half the total agricultural labor use in the south Indian SAT villages. Women participate in these daily labor markets more than men, although their wages and chances of obtaining employment are much less. There was little evidence that the "dual labor market" hypothesis operates in these sexually segmented daily labor markets.

Most developing countries of the semi-arid tropics (SAT), particularly in Asia, have a relative abundance of labor resources in propotion to capital and land. Statistics on this apparent abundance are usually only available (if at all) in terms of national or regional annual aggregates, as pointed out recently by McDiarmid (1977, pp 9-10, 18, 29, 54-55), K. Bardhan (1977), Brannon and Jessee (1977, pp 13-15). Even these statistics are often not reliable, particularly for the rural areas, where problems of seasonal unemployment are most acute, as revealed in Rudra's comprehensive study (1973). It is imperative to derive better measures and understanding of the demand and supply parameters of rural labor markets, particularly in India, where 70% of the labor force are classified as agricultural workers.

With a more precise knowledge of seasonal labor markets parameters and behavior, it will be possible to more explicitly design technologies and projects to capitalize on periods when opportunity costs are relatively low. This will enhance the basic economic viability of the technologies and projects, and hence their acceptability, as well as enable incomes of the agricultural labor force to be increased during seasons when it is constrained.

This paper is an attempt to bridge some of the gaps in our knowledge by studying the labor utilization patterns and labor market behavior of a sample of 240 labor and cultivator households in Maharashtra and Andhra Pradesh States of SAT peninsular India. This region has largely been neglected in this field of research.

The first section of the paper describes the data on which the analyses are made; the second section examines the labor use pattern of the 180 cultivator households. Included in this is a discussion of regional and farm size differences in labor use, differences between males and females, differences across seasons, and comparisons made with labor use projections under the prospective watershed-based soil and crop management technology being researched at ICRISAT Center. The third part of the paper discusses seasonal participation rates, probabilities of employment, wage rates and opportunity costs for male and female labor in rural labor markets and how these vary across regions, farms and between sexes. Some tests of Sen's (1966) dual labor market hypothesis are made, as well as McDiarmid's (1977) hypothesis that rural labor markets are

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more "competitive" in peak seasons. A conclusion follows.

Data

The data for this study are drawn from six villages in the SAT of peninsular India in which intensive socioeconomic studies by the Economics Program at ICRISAT have been under way continuously since May 1975. Since that time resident investigators have been interviewing at 2 to 4 week intervals, a stratified random sample of 30 cultivator (small, medium and large size) and 10 labor households. Details of labor utilization of each family member and of hired personnel were obtained. These data related to both on-farms and off-farm activities as well as to household use.[1]

The six villages were purposefully selected to represent three broad agroclimatic zones of SAT peninsular India. Aurepalle and Dokur villages in Mahbubnagar District of Andhra Pradesh were selected to represent the Alfisol low (713 mm) and uncertain rainfall areas in Andhra Pradesh, Karnataka and Tamil Nadu. Shirapur and Kalman villages in Sholapur District of Maharashtra represent the deep and medium-deep Vertisol, low (691 mm) and uncertain rainfall areas of Maharashtra, Karnataka and Madhya Pradesh. The villages of Kanzara and Kinkheda in Akola District of Maharashtra were chosen as typical of the relatively high (819 mm) and more assured rainfall areas of northern Maharashtra and Madhya Pradesh having medium-deep Vertisols.[2]

The present analysis of farm labor utilization and rural labor markets in these six villages apply to the agricultural year 1975-76. Data for subsequent years is presently being analyzed.

Labor use data from the watershed-based research being conducted by the ICRISAT Farming Systems Research Program since 1974 has been used as a basis of comparison with the current village situation. The basic concept in the prospective technology involves management of the soil and water on a small catchment or watershed basis ranging in size from 1 to 50 ha. High-yielding varieties (HYVs) of crops are shown with improved fertilizers and crop management on broadbeds which are established between furrows. The broadbeds and furrows are established with improved animal-drawn implements on a graded slope between 0.4 and 1.0%. This is to enable excess runoff from heavy rainfall storms during the rainy season to be guided slowly across the natural grade (usually 1.5 to 2%). In this way rainfall penetration into the root profile of crops is increased and soil conservation improved.

We have selected several of the experimental treatments which have been found promising by the scientists of ICRISAT's Farming Systems Program to compare with the village data. The experimental treatments have been matched with villages having similar soil types in the manner shown in Ghodake et al. (1978, Table 9).

Farm Labor Utilization

In this section we will discuss the patterns of labor use under the technologies and cropping patterns presently employed in these six villages. These results are presented in much greater detail in the paper by Ghodake et al. (1978).

In these comparisons we confine ourselves to labor used in crop-related activities. We exclude labor used for domestic work, animal husbandry, marketing, handicrafts, etc.

Regional and Village Comparisons

We observe a wide variability across the six villages in total labor use per hectare of cultivated land, whether expressed on a net or gross cultivated area basis (Table 1).[3] The Alfisol

1. The on-farm and off-farm activities were collected on a 2-to-3 week full recall basis. Household time allocation of each household member was collected only for the day immediately preceding each interview.
2. For a detailed description of the methodology, villages, and the complete range of information see Binswanger et al. (1977), Jodha et al. (1977) and Binswanger and Jodha (1976).

3. Paired t-tests of the differences in fortnightly labor use in each village for 1975-76 compared with 1976-77 showed that only in Mahbubnagar did labor use significantly increase in 1976-77. The ranking of villages in terms of labor use per hectare in the 2 years was also the same.

Table 1. Human labor use in man-equivalent hours by farm aiza groups in six SAT villages of peninsular India (1976-76).

District/ Village	Farm size group	Per hectare of net cultivated land	Per hectare of gross cultivated land
Mahbubnagar			
Aurepalle	Small	242	242
	Medium	320	313
	Large[a]	650***	551***
	All Farms[b]	540	479
Dokur	Small	2093	1566
	Medium	1252	989
	Large	1022**	920**
	All Farms	1156***	994***
Sholapur			
Shirapur	Small	613	550
	Medium	426	370
	Large	309*	278*
	All Farms	380	338
Kalman	Small	222	211
	Medium	266	241
	Large	169*	158*
	All Farms	211***	195***
Akola			
Kanzara	Small	475	448
	Medium	472	441
	Large	406	389
	All Farms	425	404
Kinkheda	Small	562	540
	Medium	449	438
	Large	484	447
	All Farms	483	453

a. Asterisks used for the "large farm" category Indicate large farm figures are significantly different from the respective small farm figures.
b. Asterisks used for the "all farm" category Indicate values for the concerned village are significantly different from the respective values of the other village In the same region.
***, ** and * represent significant differences at the 1, 5, and 10% levels, respectively.

villages in Mahbubnagar District — with paddy, groundnut, castor, sorghum, pearl millet and pigeonpeas predominating — use two to three times more labor per hectare than the villages in Sholapur and Akola Districts. The primary reason for this seems to be greater use of irrigation in Mahbubnagar, particularly in Dokur village, where 45% of its net cultivated land is irrigated from tanks and wells.

Although the two Sholapur villages have more irrigation than those in Akola, (10 vs 2%), they use about one-third less labor per hectare. According to Jodha (1977), some 60% of the cropped land in the Sholapur villages is left fallow in the rainy season and cropped in the postrainy season only, compared with less than 5% left fallow in Akola in the rainy season. Postrainy season crops require less labor than rainy-season crops. In the Akola villages, mixed cropping predominates (70 to 84%) whereas in Sholapur it is primarily sole cropping (57 to 86%). Sole crops have a lower labor requirement per hectare. Another factor leading to more labor use in Akola is the dominant role cotton plays in the cropping pattern. In Sholapur, sorghum is the dominant crop, followed by chickpea and safflower.

The ranking of villages with respect to labor use is similar whether expressed on a net or gross cultivated ha basis. This suggests that the intensity of cropping either does not contribute substantially to differences in labor use intensity in these six villages or other factors such as cropping patterns and resource endowment differences must offset the effects of cropping intensity differences as postulated by Vyas (1964).

The cotton-growing villages in Akola used much more hired labor as a proportion of their total requirements (73 to 82%) compared with the other villages, where foodgrains generally predominate (42 to 58%).

Farm Size Differences

In three of the six villages (Dokur, Shirapur, and Kalman) small farms used significantly more labor per hectare than large farms (Table 1). This is in line with previous work by Rudra (1973), Bharadwaj (1974) and Bardhan (1973). However, in the two cotton-growing Vertisol villages in Akola there were no significant differences in labor use per ha on the small and large farms. In Aurepalle village large farmers used significantly more labor per hectare than small farmers, mainly because of more irrigation (10% vs 0%), bullocks, and implements on the large farms.

Are these differences between small and large farm labor use due to a differential in the opportunity costs of labor between these two categories, as postulated by Agarwal (1964), Mazumdar (1963 and 1965) and Sen (1966)? Opportunity costs are defined here as the current wage rate times probability of employment in the daily labor market. In a subsequent section on rural labor markets in this paper an attempt will be made to test this hypothesis.

Small farmers in general hired less labor as a proportion of their total labor use than did large farmers. Hired labor small farms ranged from 29% in Aurepalle to 68% in Kanzara; for large farms it ranged from 45% in Shirapur to 91% in Kinkheda. Hence, although large farmers relied more heavily on hired labor than small farmers, the use of hired labor by the latter was by no means insignificant. The larger the farm size, the higher the proportion of hired female labor in total labor use. Large farmers employed 36% of all hired labor in Kalman village and 92% in Aurepalle; these represent the minimum and maximum values.

Labor

In Dokur, Shirapur, Kanzara, and Kinkheda villages, the total female labor use on crops exceeded total male labor. In Aurepalle and Kalman there was slightly more total male labor used. These high proportions of female labor use on agricultural land far exceed the 20% figure cited for Asia by Boserup (1970). Little work on crop activities is performed by children. Increasing amounts of cotton and irrigation seem to imply increasing employment potentials for women in these villages. In all six villages, the proportion of female labor hired is much higher than the proportion of male labor which is hired. In the Mahbubnagar and Akola villages 80 to 90% of total female labor is hired. In Sholapur the figure is somewhat less (60 to 70%). In the Mahbubnagar villages and in Shirapur village in the Sholapur area, less than 30% of total male labor is hired. In Kalman village, also in the Sholapur region, the figure is 50%, whereas in the Akola villages more than 66% of male labor is hired.

The work of Binswanger and Shetty (1977) showed that new technologies such as use of herbicides in the SAT can have adverse consequences on the demand for female labor required for handweeding. Almost all handweeding is done by hired females, the most disadvantaged of all the labor categories in SAT India. The present analysis of the overall picture of female labor use in these villages suggests that any changes that affect female labor will largely affect hired females, particularly in irrigated and/or cash crop situations.

Of the total hired labor used in the Aurepalle, Dokur and Shirapur villages, 63 to 88% consisted of females. In the Akola villages the males and females shared almost equally in total hired labor use. Males always represented the largest proportion (ranging from 64 to 90%) of the total family labor utilization, especially in the Mahbubnagar villages. The range was from 64 to 90 percent amongst the villages.

Seasonality

In all six villages the intraseasonal variability of total labor use per hectare, as measured by the fortnightly coefficients of variation, was significantly higher on small farms than on large farms (Table 2). The variability of per hectare labor use seemed to be negatively related to the number of different crops and/or crop mixtures grown on farms as an increase in the number of crops helps in evening out labor demands and results in lower CVs. In all cases small farmers grew significantly fewer crops than did large farmers (Table 2), even though in most cases the former have been shown by Jodha (1977) to have a higher proportion of their cultivated area sown to mixed or intercrops.

The higher CVs on small farms occurred in spite of the higher mean level of labor use they have in Dokur village and the two Sholapur villages. Hence small farm intraseasonal variability is quite large in comparison to that of large farms. The reason for this could be that they choose cropping patterns that free them for wage employment off their own farms at irregular intervals. We will show later that they participate in the daily labor market in and around these villages in a significant manner.

The correlation coefficients between total fortnightly labor use per hectare on large farms in each village and the amount of hired labor per hectare in the corresponding fortnight were all around 0.90 or greater, and they were significantly different from zero at the 0.1 percent level.[4] This suggests that hired labor demand changes at least in proportion to total seasonal

4. The correlations for small farms were lower than those for large farms, but still significantly different from zero and greater than 0.80 in three of the six villages. The correlation coefficients between fortnightly total and family labor use for all farms were also significantly positive in all villages except in Kinkheda, but these values were always lower than the corresponding values between total and hired labor use.

Table 2. Coefficient of variation (%) in fortnightly labor use in six SAT villages of peninsular India (1975-76).

District/ Village	Farm size			
	Small	Medium	Large[b]	All farms[c]
Mahbubnagar				
Aurepalle	154	150	97***	133
	(1.8)[a]	(2.5)	(7.1)***	(3.9)
Dokur	151	175	142*	156
	(1.6)	(3.2)	(4.0)***	(2.9)
Sholapur				
Shirapur	213	157	139***	170
	(4.2)	(7.4)	(8.7)*	(6.8)
Kalman	147	113	95**	121***
	(4.9)	(11.0)	(11.1)***	(8.9)*
Akola				
Kanzara	146	122	94***	121
	(2.1)	(3.2)	(7.1)***	(4.1)
Kinkheda	137	120	95***	117
	(2.4)	(2.5)	(5.6)**	(3.5)

a. Figures in parentheses are the average number of different sole crops and/or different crop mixtures on these farms.
b. Asterisks here Indicate "large term" figures are significantly different from the respective "small farm" figures.
c. Asterisks here indicate significant differences exist between villages In the same District.
***, ** and * represent significance at the 1, 5, and 10% levels, respectively.

labor demand. The correlation between total fortnightly labor use and the percentage of hired labor used in the same fortnight was not nearly as high as that mentioned above. In four out of six villages the range in r values for all farms was 0.34 to 0.46, with three significant at 5 percent and one at 10 percent. In Kalman and Kanzara there was no significant correlation. Hence in four villages, whenever seasonal labor demand rises, hired labor's share in this also rises. Contrary to this, in five out of six villages, correlation coefficients between total labor and proportion of family labor to total labor use were significantly negative while in one village there was insignificant negative correlation.

Existing and Prospective Technologies

The labor used per hectare of net cropped land under the prospective broadbed and furrow, improved crop and watershed management technologies researched at ICRISAT Center was 100 to 500% greater than the existing labor use observed in five of the six villages (Table 3).[5] (The exception was the highly irrigated Dokur village where existing average labor use exceeded projected requirements of the new technology under Alfisol conditions.) This was not the case in Aurepalle which has much less irrigation. The new technology doubles the present village labor requirement.

On the Vertisols the potential for increased labor demand under the new technology seems greater than on Alfisols, particularly in Sholapur district where labor use could increase by more than four times.[6] In the Akola Vertisol region there is scope for almost triple labor demand with the new technology. These increased demands apparently will occur without substantially affecting the CVs of fortnightly labor use per hectare throughout the year, providing, as was the case here, that it is based on more than one cropping system (Table 3).[7]

The extent of apparent surplus labor available after attending to farm crop activities is an indication of the degree to which labor bottlenecks are likely to arise under different situations. These apparent surpluses have been calculated for both the existing village and the prospective technology scenarios (Table 3). They are computed as the sum of the fortnightly difference between the apparent supply of able-bodied man-equivalents per hectare in the village (including cultivator and labor households) and the fortnightly requirements for crop activities. Apparent supplies have been calculated assuming 14 days of work a fortnight at 7 hours per day.

Considering other labor commitments, the pressures on available annual village labor from the prospective technologies would appear to be greatest in the Vertisol villages of Akola and Sholapur. In the former region, the apparent surplus would drop from 82 to 45% with the prospective technology and in the latter from 90 to 53%. The fall in the case of the Mahbubnagar villages would only be from 83 to 75%.

When we focus on the three peak fortnights with the apparent surplus calculation we obtain a picture of the effects of the prospective technologies on seasonal labor bottlenecks (Table 3). These seasonal peaks would appear to be greatest under the prospective technology in the case of the Sholapur and Akola Vertisol regions. From an apparent surplus labor position of 80 and 60% in the existing three peak periods in these Sholapur and Akola villages, we would move to deficit situations of approximately 120 and 80%, respectively. The surplus would fall from around 60% to zero in the case of the Mahbubnagar villages.

5. When labor use was expressed per gross cropped ha the prospective technologies generated between 10 and 140% more than existing village technology (excluding Dokur village, which had more labor use per gross cropped ha due to the predominance of irrigated paddy).
6. The Sholapur village comparison with the new technology at ICRISAT Center Hyderabad should be viewed with some caution, however. As Virmani et al. (1978, pp 2-7) show, the probability of successfully growing rainy season crops at Hyderabad is significantly higher than in Sholapur. As the new technology primarily depends for its superiority on rainy season cropping followed by postrainy season cropping, it is not clear that in Sholapur this will be possible without considerable risk.
7. The CVs of the individual cropping systems labor requirements under the new technology were mostly much higher than those presently existing in the villages (Ghodake et al. 1978, Tables 9 and 10).

Table 3. Comparison of labor requirements in six traditional villages of SAT peninsular India (1975–76) with prospective new watershed-based technology at ICRISAT Center, Hyderabad (1976–77)

District/ Village	Traditional village technology of Maharashtra and Andhra Pradesh				Improved technology on watersheds at ICRISAT Center			
	Annual labor use per ha of net cropped land (ME/ha)[a]	CVs of fortnightly labor use/ha (%)	Apparent labor surplus under present technology[c]		Annual labor use/ha of net cropped land[d] (ME/ha)	CVs of fortnightly labor use/ha (%)	Apparent labor surplus under improved technology[e]	
			Average for the year(%)	For three peak periods (%)			Average for the year (%)	For three peak periods (%)
Mahbubnagar								
Aurepalle	540	133	87	71	n.a.[e]	n.a.	n.a.	n.a.
Dokur	1156***[b]	156	77	49	n.a.	n.a.	n.a.	n.a.
Average	726	146	83	63	1048[f]	135	75	0
Sholapur								
Shirapur	380	170	90	78	n.a.	n.a.	n.a.	n.a.
Kalman	211***	121***	91	81	n.a.	n.a.	n.a.	n.a.
Average	268	146	90	79	1287[g]	153	53	19
Akola								
Kanzara	425	121	83	62	n.a.	n.a.	n.a.	n.a.
Kinkheda	483	117	81	61	n.a.	n.a.	n.a.	n.a.
Average	450	119	82	61	1345[g]	106	45	−78

a. All labor is measured in man-equivalent hours (ME).
b. *** denotes significant difference between villages of the same district, at the 1 percent level.
c. Calculated as the sum over all fortnights of the difference between the apparent supply of able-bodied village workers (adults and children, males and females) in 1975–76 and the requirements for farm labor during the year expressed as a percentage of apparent supply. It is the area between the top horizontal line in Figures 1, 2 and 3 and the labor use lines expressed as a proportion of the total area enclosed by the top horizontal line.
d. These are the average of two cropping patterns tried on each soil and water management system.
e. Not applicable.
f. The two crops on Alfisols were hybrid sorghum/ratoon sorghum and pigeonpea intercropped with setaria.
g. The two crop systems on Vertisols were hybrid maize followed by sequential chickpea and pigeonpea intercropped with hybrid maize.
CV = Coefficient of Variation

The three major peak periods would shift under the prospective technology in the villages, in Mahbubnagar (Fig 1) they would move from July, August, and November to August, October, January, and November. In the case of Sholapur (Fig 2) the move would be from October, January, and February at present to September, October, and January. In Akola (Fig 3) the existing peaks in August, October, and November would change to September, November, and January.

The major bottleneck under the new technology would appear to be at harvest and threshing time of the first crop in either the sequential crop or the intercrop system. In addition, there would be bottlenecks at weeding time after the initial sowing. The scope for spreading out the harvesting/threshing period to alleviate the strain on labor at that time would appear to be greatest under an intercrop system, where there is less pressure to harvest the first crop promptly than with a sequential crop system, where the first crop must be removed before the second can be sown.[8] If, as Ryan et al. (1978) show for ICRISAT Center, intercropping is more profitable and less risky than sequential cropping, then the superiority of a new soil, water and crop management technology based on an intercrop system seems evident.

Rural Labor Markets

In this section we discussed the functioning of daily rural labor markets in the six villages, particularly attention is given to the extent to which able-bodied people attempt to participate in the daily labor market throughout the year, what wages they receive, and with what probability they obtain employment. This will be examined separately for males and females from the four

8. Relay cropping is a possibility but there is a risk of damage to seedlings if harvesting of the first crop occurs after sowing of the second crop.

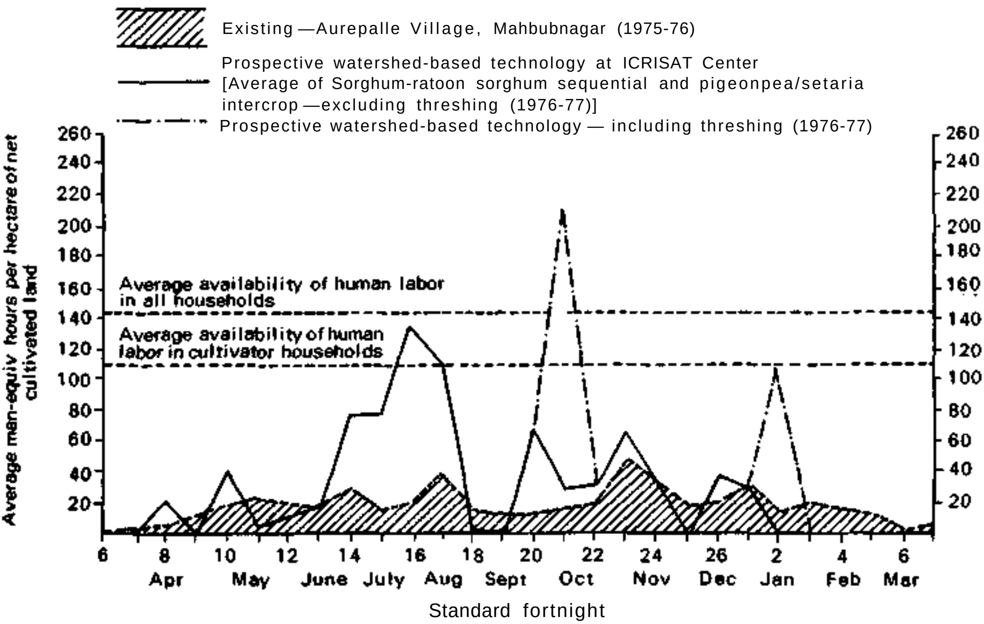

Figure 1. Average seasonal human labor availability and use with existing and prospective watershed-based technology on Alfisols.

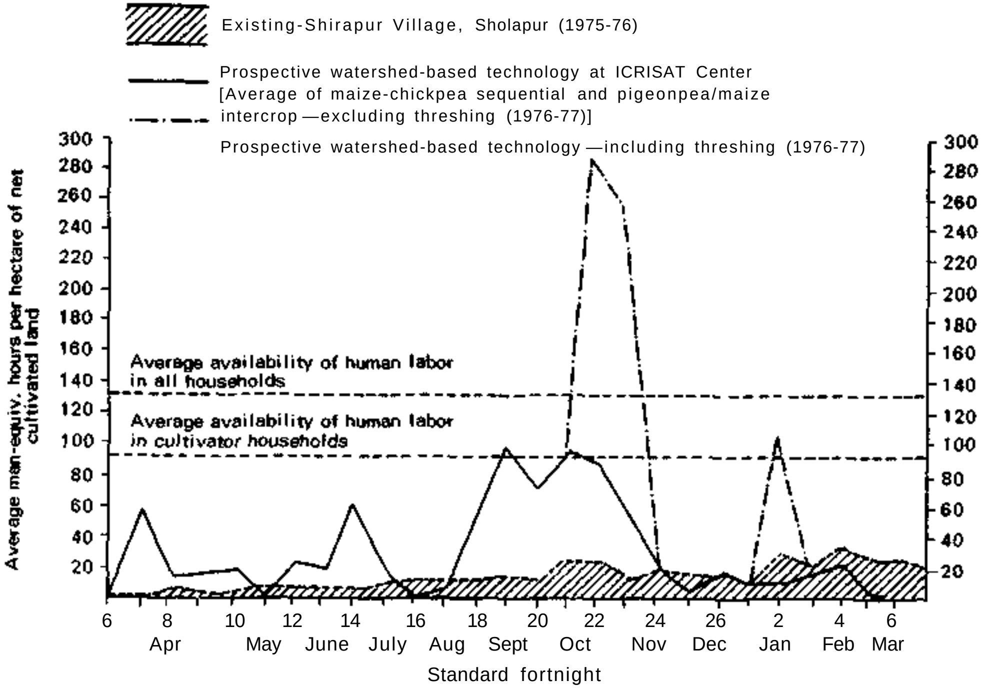

Figure 2. Average seasonal human labor availability and use with existing and prospective watershed-based technology on deep Vertisols.

categories — labor, small, medium, and large farmers — using data collected on a 2- to 4-week recall basis throughout the 1975-76 year.[9]

One key measure to be derived from the above statistics is the seasonal opportunity cost of labor, measured as OC_t where:

(1) $OC_t = W_t \quad P(Et)$

and W_t = actual equilibrium wage rate in fortnight t.

P(Et) = probability of obtaining daily wage employment in period t.

It is important to know the opportunity cost of labor in different seasons as some of the prospective technologies for rainfed areas, such as watershed-based land and water management technologies that are under investigation at ICRISAT and in the All India Coordinated Research Project for Dryland Agriculture, require *engaging labor* in capital-creating activities such as building tanks, wells, bunds, levelling land, etc. For these it is necessary to know the seasonal opportunity cost of labor in order to determine the appropriate time for carrying out such activities. More importantly seasonal opportunity cost data are required to enable proper benefit-cost analyses of these types of technologies.

9. For details see Subrahmanyam and Ryan (1976, pp, 11-16). Most estimates reported here are annual averages. However the comparisons across farm size groups, villages, and sexes were also made separately for "peak" and "slack" labor seasons. In almost all cases results for the slack seasons were consistent with the annual average.

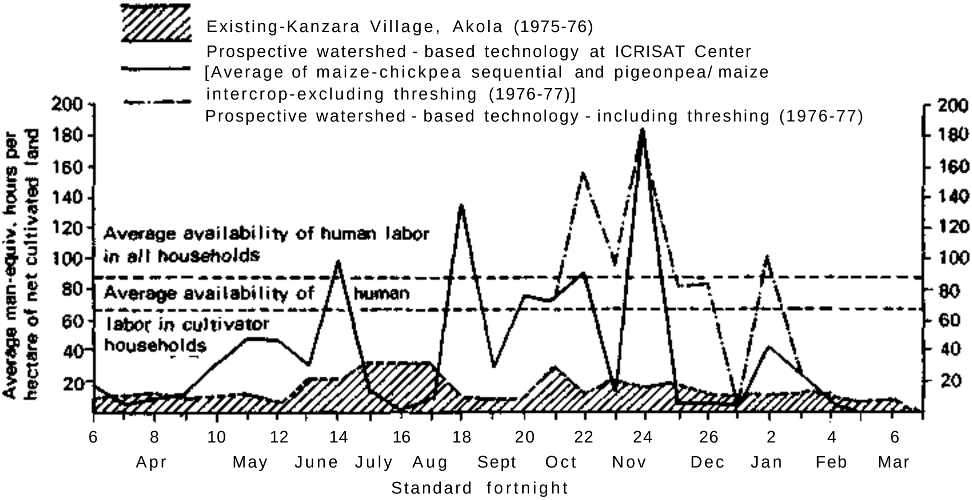

Figure 3. Average seasonal human labor availability and use with existing and prospective watershed-based technology on medium-deep Vertisols.

In many instances data can be obtained on seasonal rural market wage rates, but there is no way of knowing how close these are to the seasonal opportunity costs of labor, which are at the heart of questions related to labor supply analysis and the value of household production and time. McDiarmid (1977, pp 9-10, 18, 29, 54-55), refers to the necessity of local or regional measures of seasonal opportunity costs (as opposed to the countrywide single measures he derives) under conditions where minimum wage laws and religious and language constraints prevent free labor mobility. These circumstances generally prevail in the parts of the Indian SAT studied here. The opportunity cost equation (1) above is equivalent *to* the first of the three elements of McDiarmid's shadow wage rate — namely the "immediate cost" or the alternative production that would have occurred in the optimum available alternative employment. Subrahmanyam and Ryan (1976, pp 9-10) felt the opportunity cost measure in (1) is preferable to other alternatives such as wages of attached servants, marginal values productivities (MVPs) derived from production function, or linear programming studies.

The interval between interview rounds varied from village to village and from household to household. In addition, it was not possible to date the days of employment and involuntary unemployment.[10] For these reasons a smoothing procedure was used whereby the fractions of participation rate, employment and involuntary unemployment during the round interval were assigned to each day in the round and then summed up over standard fortnights. Details of this can be found in Subrahmanyam and Ryan (1976, pp 11-16).

Participation Rates

The participation rate is defined as the proportion of days in the period in which a person attempted to find a job *on* the daily labor market in and around the village. The numerator includes the days the person was successful in

10. Investigators asked each household member how many days they obtained wage employment since the last interview and how many days they tried but were unsuccessful. The latter represented days of involuntary unemployment. Wage rates referred to the average of the wages received by all respondents in each category during the round.

finding wage employment plus the days he was not. The latter are subsequently referred to as involuntary unemployment days. The participation rate does not include days of work on their own farm.

Participation rates for males were significantly lowest in the two Mahbubnagar villages and generally highest in the two Akola villages (Table 4). From Appendix Table 1, it can be seen that interdistrict participation rates were all significantly different for males as well as females. For only 7% of the time in Aurepalle did males endeavor to find a job on the daily labor market. In Kanzara, on the other hand, the males participated almost 50% of the time. The whole-sample participation rates for all villages are reduced by the meager participation by large farmers and, to a lesser extent, by medium farmers. Participation by labor and small-farm households is generally much higher. For males the highest average participation rate during 1975-76 for both the labor and small farm groups was in Kanzara at 0.87 and 0.70 respectively, while the lowest was in Aurepalle at 0.18 and 0.14.

Females participated substantially more (always significant at 0.1% level) than males in Mahbubnagar villages and in Kinkheda while in other villages males participated significantly more than females. Dokur registered the highest participation on the average for females at 0.61. In this village even females from large farms participated 36% of the time, whereas in both labor and small-farm households females participated 82% of the time, the highest of all villages. This indicates the influence of paddy irrigation on demand for female labor. It is such as to lead to substantial labor market participation by females, even those from the large-farm group.

The lowest female participation came in the Sholapur villages at around 0.25. The range within these two villages, in which foodgrain crops predominate, was a high of around 0.47 for females from labor households to a low of 0.08 for those from the large-farm group.

There was a significant amount of seasonal variation in participation of males and females, particularly in Aurepalle (Table 4). The CVs of fortnightly male participation ranged from a high of 48% in Aurepalle to a low of 14% in Dokur and Kanzara. For females the range was from 61% in Aurepalle to 10% in Dokur. Again the effect of extensive paddy irrigation in Dokur is reflected in a much more steady labor force participation throughout the year.

The mean fortnightly participation rates of males and females from labor households were always greater than those from the small-farm households. The differences were significant at the 1 % level using paired t-tests in five out of six villages for males and two of six for females (Appendix Tables 2 and 3). The labor group also had higher participation rates than medium-farm households for males and females. These differences were statistically significant at the 1% level in five of six villages for males and in all villages for females. Except for Shirapur, males and females from small-farm households participated significantly more than those from medium-farm households.

The simple correlation between the participation rates of males from labor and from small-farm households was positive and significant in four of the six villages (Appendix Table 4). Aurepalle and Kalman had negative correlations, the latter not being statistically significant. In five of six villages there was no correlation between the participation of the male members of the labor households in the market and that of those from medium farm households. For females (Appendix Table 5) the correlations were significantly positive in three cases between participation of those from the labor and small-farm categories. The other three village correlations were not significant. Only two correlations were significantly positive between labor and medium-farm female participation rates; one was significantly negative and the others were not significant.

These results suggest, as expected, that males and females from labor households participate more in the labor market than those from cultivator households. Those from the labor group tend to enter the labor market at a similar time to those from the small-farm group. However, there does not seem to be as much competition between participants from the labor group and those from medium-sized farms, especially among males.

Probabilities of Employment

The probability of employment was calculated as the number of days a person was successful in obtaining wage employment as a proportion

Table 4. Average participation rates, employment probabilities, opportunity costs and wage rates for adults in rural daily tabor markets in six SAT villages of peninsular India, 1975-76.

District/ Village/ Sex	Participation rates		Probability of employment		Daily opportunity cost		Daily wage rates	
	Mean	CV (%)	Mean	CV (%)	Mean Rs	CV (%)	Mean Rs	CV (%)
Mahbubnager								
Aurepalle								
Male	0.07***[a]	48	0.71	23	1.77***	25	2.50***	33
Female	0.27	61	0.69	20	1.03	26	1.49	16
Dokur								
Male	0.25***	14	0.76***	30	1.97***	35	2.59***	17
Female	0.61	10	0.82	20	1.58	30	1.93	15
Sholapur								
Shirapur								
Male	0.38***	29	0.70***	12	1.80***	12	2.57***	13
Female	0.25	22	0.49	37	0.68	47	1.39	18
Kalman								
Male	0.29***	19	0.92***	11	2.50***	31	2.72***	19
Female	0.22	17	0.77	18	1.08	28	1.40	14
Akola								
Kanzara								
Male	0.48***	14	0.82**	12	2.05***	15	3.72***	11
Female	0.39	22	0.77	30	1.41	35	1.83	12
Kinkheda								
Male	0.30***	22	0.88***	12	2.52***	19	2.86***	11
Female	0.36	20	0.91	7	1.41	22	1.55	19

a. Asterisks indicate significant differences between male end female figures of the same village:
** Significant at 1% level
*** Significant at 0.1% level.

of the number of days in the period he tried.[11] In the two drought-prone, predominantly foodgrain producing villages of Sholapur region and in Kanzara village which has relatively assured rainfall with a predominance of cotton, males have a significantly better chance of obtaining daily wage employment than females. In Aurepalle village there is no significant difference. On the other hand, in Dokur and Kinkheda females had a significantly higher probability of employment than males (Table 4). In Shirapur village females succeed in finding employment only 50% of the time, compared with males, who are successful 70% of the time. In Shirapur not only are average female probabilities of employment low but their fluctuation throughout the season is particularly high also, with a CV of 37%, whereas for males it is much less (12%). The range in employment probabilities for females was from a low of 0.2 in October 1976 to a high of 0.7 in November 1975. The range for males was from 0.5 in October 1976 to 0.8 in June 1976. In Kalman village of the same region, employment probabilities for both males and females were substantially better at 0.92 and 0.77, respectively, than in nearby Shirapur. Seasonal variations were also less.

11. In calculating the probability of employment we have not differentiated between employment on other farms, in nearby urban areas, for private or government employers.

This illustrates the difficulties of generalizing results from individual villages to the region in which they are located.

The most buoyant daily labor markets appear to be in the two cotton-growing Akola villages (Appendix Table 1). In Kanzara both males and females succeed about eight times out of 10 in finding a job, while in Kinkheda they succeed nine times in 10. Seasonal fluctuations are not substantial except for Kanzara females, whose CV is 30%.

Males in Mahbubnagar are successful in finding off-farm employment about three times in four attempts; Dokur females are successful eight times out of 10, but in Aurepalle females succeed only seven times out of 10. The seasonal variation in job probabilities also seems higher for males than for females in these two villages, where irrigated paddy is important. The range for males is from a low of 0.3 to a high of near 1.0, whereas for females the comparable figures are 0.5 to 1.0.

Paired t-tests showed that for males there was a mixed picture with respect to the relationship between probabilities of employment for the labor group and the small- and medium-farm groups (Appendix Table 2). In three villages there was no significant difference between the mean probability of employment for the labor and small-farm groups. In two villages the probability for small-farm males was significantly greater than for males from the labor group, but in one village the reverse was true. In three villages the probability of employment for males from the medium-size category was significantly less than that of the labor group, and in the other three there was no significant difference. In four villages the small-farm males had a significantly better chance of finding a job than medium-farm males. In the remaining two villages there was no significant difference.

Females from small farms in three of the villages had significantly better employment probabilities than those from labor households. In one village the reverse was true but in the other two there was no significant difference (Appendix Table 3). Females from the medium farm group in three villages also had significantly better chances of finding a job than those from the labor households. There was no significant difference in the other three villages. Females from the small and medium farm group did not differ statistically in their employment probabilities in four out of the six villages. In Dokur the latter had a better chance while in Shirapur the former did.

What the above pattern suggests is that in general males from labor households have a better chance of being successful in finding daily wage employment vis-a-vis their counterparts in the cultivator households than do their spouses. Hence it is not only true that females generally are no better off, and often worse off, than males in terms of daily labor market employment opportunities, but in addition females from the poorest houeseholds, namely the labor group, are often the worst off of all.

It seems that probabilities of employment throughout 1975-76 for females from the labor, small-, and medium-farm group in each village tended to move more together than those of the males. This is suggested by the fact that all 12 correlations were positive and significant for females while for males only six were (Appendix Tables 4 and 5). This suggests that females from the different socioeconomic groups within these villages tend to be competing for similar jobs more so than males.

The overall average probability of involuntary unemployment[12] for males in these six villages during 1975-76 averaged around 0.20, while for females the average was about 0.26.[13] These estimates of the extent of unemployment are far in excess of the rates derived in the 1961 census in India of 0.005 and 0.001 for males and females, respectively. They are also much higher than in the twenty first round of the National Sample Survey in 1966-67 of 0.018 for rural males and 0.045 as reported in Sen (1975, pp 115-134). Our average involuntary unemployment rates compare with Mehra's figure for disguised unemployment in the total ag-

12. The probability of involuntary unemployment is calculated as 1 minus the probability of employment.
13. The average probabilities of involuntary unemployment for males were 0.12 and 0.39 during peak and slack periods, respectively, while for females, the corresponding figures were 0.11 and 0.50. These indicate that during peak periods the probabilities of involuntary unemployment for males and females become almost equal while during slack periods the difference increases, affecting female labor employment more adversely.

ricultural labor force in India of 0.17 as reported in Sen (1975, p 130), but are about double those derived by Krishna (1973) using NSS data on rural workers who are idle but willing to work more. Krishna points out that his figures are minimum estimates.[14]

A number of models of rural-urban migration, such as those by Harris and Todaro (1970) and McDiarmid (1977, pp. 75-76), assume the probability of employment in rural areas to be 1. Lal (1974) reports a value of 1 as the ratio of the market to the "social wage rate" in a number of states in India. These are often used as implicit weights in social benefit-cost analysis of projects. The results from these six villages and the above studies suggest that calculations of opportunity costs of rural labor based on probabilities of employment of 1 may be overestimated. This may explain the paradox of increasing rural-urban migration in India in spite of apparently increasing amounts of urban unemployment. Ignoring rural unemployment in such models may be the villain of the piece.

Wage Rates and Opportunity Costs

Average female daily wage rates in these six villages in 1975-76 were about 56 percent of those for males and also were significantly different at the 0.1% level. Male wages averaged Rs 2.83 per day and females Rs 1.60 (Table 4). Male wages were generally highest in the two cotton-growing Akola villages. Kanzara had the highest of Rs 3.72 and Aurepalle the lowest at Rs 2.50.[15] Females from Dokur had the highest average wage rate of Rs 1.93 per day. The lowest female wages were in the Sholapur villages, where they averaged only Rs 1.40 per day.

Rodgers (1975) contended that the degree of seasonal wage variability is less than that of employment variability; we find more evidence to support this in the case of females than we do for males. Rodgers contends that wages are more "sticky" than employment due to provision of meals by employers and interseasonal "guarantees." We find in five of the six villages CVs of wages are less than the CVs of the employment probabilities for females. For males it is true in three villages but not in the other three. Similar to Raj (1959) though, we did find a general tendency for lower average employment probabilities to be associated with higher CVs of wages. In line with Sethuraman (1972) and McDiarmid (1977, pp 48-49), we found that whenever there was a statistically significant correlation between fortnightly daily wages and probabilities of employment for the labor and small-farm households, it was in most cases positive (Table 5). However, this was true in only one of the 12 cases for males and in four of 12 for females. On the other hand there was at least one case of small farm males in Aurepalle wherein the correlation coefficient value was significant and negative which is in line with Rodgers (1975). Hence the evidence on this relationship is still quite weak.[16]

Males from the labor households have significantly lower average wage rates in four of six villages compared to those of small farmers, and in one of six compared to medium farmers. In one village wages of male workers from medium farms were significantly less than those from the labor category (Appendix Table 2). There seems to be no significant differences in the average wages of males from the small- and medium-farm categories.

Except in Aurepalle, there does not seem to be any major difference between average wages earned by females from the labor and small-farm households (Appendix Table 3). In Aurepalle the latter have significantly higher wages than the former. In Kalman village females from the labor group have significantly higher average wages than those from the medium-farm group. In the other five villages there are no significant differences. In Aurepalle and Kinkheda females from the small-farm

14. The various studies cited don't always use similar definitions of unemployment and this is one explanation for discrepancies. They are also aggregate measures involving counts of people unemployed on their survey day or week. The measures in this study are taken over the whole year for the same people.

15. These are expressed in nominal terms only. Deflating by a foodgrain price index in the two states would no doubt bring these wages closer together.

16. Bardhan (1977) provides an excellent review of the available Indian literature on the relationships between labor supply, demand and wage determination.

Table 5. Simple correlation coefficients between fortnightly daily wages and probabilities of employment in six SAT villages of peninsular India, 1975-76.

District/ Village	Labor households		Small-farm households	
	Males	Females	Males	Females
Mahbubnagar				
Aurepalle	0.07	0.21	-0.62**	-0.16
Dokur	-0.01	0.46**	0.02	0.38*
Sholapur				
Shirapur	-0.17	0.17	-0.17	0.39*
Kalman	0.20	0.11	0.19	0.23
Akola				
Kanzara	0.00	0.07	0.00	0.50**
Kinkheda	0.39**[a]	0.27	-0.09	0.10

a. ** and * indicate significance at the 1 and 5% levels, respectively.

group average significantly higher wages than those from medium farms.

From these results it also seems that males from the labor group, though they generally participate more in the rural daily labor market, do not tend to receive higher wages as a result of their being more continuously availability throughout the year. In fact, there is evidence from these villages to the contrary. Hence it seems that small-farm males in these villages can hire daily workers from labor households at the same time that they hire themselves out, and be better off for it. The same is not true for females. This no doubt helps explain the relatively high levels of labor hiring observed on the small farms by Ghodake et al. (1978 pp 17-20).

There were significant positive correlations between male participation rates and probabilities of employment in four of the six villages. For females this was true in only two villages, and in two others the correlation was significantly negative. This suggests that males there have a better chance of obtaining a job the more they participate in the labor market. This is not so for females. Hence in these villages it would seem there are no strong "discouraged-worker" effects operating for males as they tend to withdraw from the labor market when employment probabilities are low.

Opportunity cost of labor for males averaged Rs. 2.26 per day during 1975-76, which was 90% higher than that for females (Rs 1.20). In spite of the mixed picture for employment probability in these villages, the opportunity wage figures showed consistency, males having significantly higher opportunity wages than females (Table 4). The CVs of opportunity costs were in general higher than for both daily wages and probabilities of employment. There would therefore seem to be considerable scope for designing technologies that specifically aim at capitalizing upon periods when labor opportunity costs are low. This would enhance the profitability of the technology as well as create employment in slack/unremunerative periods, with consequent redistributive benefits. The periods of the year when opportunity costs are at their maxima and minima are shown in Table 6. Peak periods are generally associated with operations such as harvesting; transplanting, preparatory tillage, sowing, and weeding.

To test the labor market dualism hypothesis of Sen (1966), that the imputed price of labor to small farmers is lower than the actual price of labor to large farmers, paired t-tests were performed on the fortnightly wage rates of the labor category (by sex) compared to the fortnightly opportunity costs of labor from the small-, medium-, and large-sized farms.[17] Medium and large farmers employ more than 80% of all hired labor in these villages. Presumably then the best measure of their cost of labor is the wage rate received by the labor households. If we find that these wage rates are significantly higher than the opportunity costs of labor from the smaller farm categories, this lends support to the dual labor market hypothesis.

In three of the six villages the differences between wage rates of males from labor households and small-farm male opportunity costs are significantly positive. In two, the differences are *not* significant and in *one* the difference is significantly negative (Table 7). In

17. For details about this hypothesis, see Ghodake et al. (1978).

Table 6. Peek and slack labor periods for adults in six SAT villages of peninsular India, 1976-76.

District/ Village	Category	Peak period: Months	Peak period: Major operations	Slack period months
Mahbubnagar				
Aurepalle	Males & Females	Dec-Jan	Harvesting and threshing sorghum, pearl millet, castor	Feb-April
Dokur	Males & Females	Nov-Jan	Harvesting and threshing sorghum, nursery bed preparation paddy, paddy transplanting	Feb -June
Sholapur				
Shirapur	Males	April-May July-Aug	Preparatory tillage, ploughing, sowing pearl millet, mesta, mungbean	Dec, Feb - March
	Females	Sept	Harvesting and threshing pearl millet, mesta, mungbean	Apr -Aug
		Dec-Feb	Sowing & harvesting wheat, sorghum, chickpea, safflower	
Kalman	Males	Jan-Mar	Harvesting & threshing wheat, sorghum, chickpea, safflower	Aug -Oct
		May	Preparatory tillage, ploughing	
	Females	Mar-Apr	Harvesting 81 threshing wheat, sorghum, chickpea, safflower	Oct - Dec - Jan
		Nov	Harvesting & threshing pearl millet, mesta	
Akola				
Kanzara	Males	Mar	Harvesting cotton; harvest - ing & threshing pigeonpea	Apr.-Sept,
		Aug-Sept Nov	Preparatory tillage, sowing wheat, chickpea, harvesting sorghum, groundnut	
	Females	Oct-Dec	Harvesting & threshing sorghum, groundnut, cotton	Apr -June
		March	Harvesting cotton	
Kinkheda	Males	April June-July	Preparatory tillage Sowing, interculturing cotton, sorghum, pigeonpea, mungbean.	Aug-Oct May

Continued

Table 6 ***Continued***

District/ Village	Category	Peak period		Slack period months
		Months	Major operations	
		Nov-Dec	Harvesting & threshing, sorghum, groundnut; sowing wheat and chickpea.	
	Females	May	Field cleaning	Feb-Mar
		Sept-Dec	Harvesting & threshing sorghum, groundnut; weeding cotton.	

Table 7. Paired t-tests of differences between fortnightly wage rates of labor households and opportunity labor costs of small, medium and large farms in six SAT villages of peninsular India, 1975-76.

District/ Village	Males			Females		
	Small farms	Medium farms	Large farms	Small farms	Medium farms	barge farms
Mahbubnagar						
Aurepalle						
Mean differences (Rs/day)	0.05	0.21	a	0.32	0.15	-0.08
Paired t-values	0.34	0.73		5.15**	1.94	-1.09
Dokur						
Mean differences (Rs/day)	0.69	0.23	0.33	0.31	0.25	0.26
Paired t-values	5.87**	2.08*	1.68	5.34**	4.82**	3.28**
Sholapur						
Shirapur						
Mean differences (Rs/day)	0.39	0.90	0.66	0.62	0.69	0.68
Paired t-values	3.64**	6.18**	2.63*	6.74**	6.74**	5.12**
Kalman						
Mean differences (Rs/day)	-0.32	0.13	-0.40	0.35	0.42	0.28
Paired t-values	-2.72*	0.53	-4.15**	5.85**	7.41**	6.36**
Akola						
Kanzara						
Mean differences (Rs/day)	0.02	0.33	0.60	0.57	0.45	0.32
Paired t-values	0.19	2.52*	3.32**	5.54**	4.65**	3.12**
Kinkheda						
Mean differences (Rs/day)	0.38	0.91	1.37	0.11	0.004	0.12
Paired t-values	2.58*	8.30**	8.12**	2.99**	0.07	2.89**

** significant at 1% level
* significant at 5% level
a. No participation by large farm members.

the case of females, in all six villages the wage rates of the labor group significantly exceed the opportunity costs of family female labor from the small-farm households. It thus appears that for these villages the dual labor market hypothesis receives only partial support in the case of males and full support in the case of females.

A paradox remains, however, in the case of large farmers who participate in the labor market. Table 7 shows that in three out of six villages the fortnightly wage rates of male labor from the labor group are significantly higher than the opportunity labor costs of male labor from large farms. In the case of females, five out of six villages showed positive, significant differences between labor wage rates and opportunity labor costs of females from large farms. Hence for those large farms whose members enter the labor market the dual labor market hypothesis holds equally well. That is, wage rates paid by large farmers for hired labor exceeds the opportunity costs of their own family labor. It seems clear the hypothesis is at best an oversimplification of the operation of the labor market in these villages.

Judging by the generally low and/or nonsignificant correlations of males and female wage rates, there would appear to be considerable segmentation in the male and female labor markets in five of the six villages studied here (Table 8). The notable exception is the highly irrigated village of Dokur.

Males and females tend to participate at similar times, particularly in Aurepalle and in the Sholapur villages. They also experience similar movements in their chances of obtaining a job throughout the year (Table 8). In theory, then, one would expect wage rates of males and females to also move together if females were able to shift in and out of tasks similar to those done by males as their respective wage rates begin to move apart. The extent to which this does not occur in five of these six villages is an indication of the degree of apparent segregation of their male and female labor markets.

Conclusions

We found no overriding consistent evidence in these six villages that the small farms use more labor per hectare than the large farms. Small farms did employ a surprisingly large amount of hired labor (29 to 68%), but it was less than that employed by large farms (41 to 91%).

Female labor represented more than half the total labor employed in most of the six villages, and was more significant where cotton and irrigation were prevalent. Up to 90% of total female labor was hired in. Hence technologies

Table 8. Simple correlation coefficients between mala and female participation rates, probabilities of employment and wage rates in six SAT villages of paninsular India, 1975-76.[a]

District; Village	Participation rates	Probabilities of employment	Wage rates
Mahbubnagar			
Aurepalle	0.47*[b]	0.76**	-0.16
Dokur	0.22	0.95**	0.76**
Sholapur			
Shirapur	0.40*	0.70**	-0.24
Kalman	0.56**	0.68**	0.30
Akola			
Kanzara	0.21	0.82**	0.10
Klnkheda	0.26	0.59**	0.46**

a. Data for all respondents *has* been pooled here, including that from large farm households who do not participate much in the labor market

b. ** and * indicate significance at the 1 and 6% levels, respectively.

that affect demand for female labor in these villages will largely affect the most disadvantaged of all females — those entering the daily labor market. Females represented 50 to 90% of the total hired labor force used. Males dominated the family labor used on these farms (64 to 90%).

Small farms had much higher CVs of fortnightly labor use than large farms and this seemed to be inversely related to the number of different crops grown, with small farms having fewer. This may allow the small farmers to have more scope for off (own) farm work, as they were found to participate significantly in the daily labor market.

In comparisons of the labor requirements of the prospective watershed-based technology being researched at ICRISAT and current labor use in these villages, it was found that, except in the highly irrigated village of Dokur, the new technology had a potential for increasing labor requirements by 100 to 500% with little alteration of the intraseasonal CVs of labor, provided it is based on more than one cropping system. The new technology would generate such vastly increased labor demands in a number of peak periods, particularly in the Vertisols, that apparent supplies of labor existing in these villages would be exceeded. The periods of harvesting, threshing and, to a lesser extent, sowing and weeding of the first crop would entail the largest potential labor bottlenecks. Intercrop systems offer better scope for spreading the harvesting/threshing peaks, as they have more flexible timeliness demands.

There is a wide degree of variability in daily labor market participation rates both among and within villages. Dokur village, with extensive irrigation, has high and stable participation rates compared the others. Males and females from labor households participate more than those from cultivator households. Those from labor and small-farm households tend to enter the daily labor market at similar times during the year. Those from labor and medium-sized farms do not.

Average probabilities of involuntary unemployment for these six villages in 1975-76 were 0.20 and 0.26 for males and females, respectively. These were highest in the drought-prone, predominantly foodgrain-producing village of Shirapur in the Sholapur region. There was large seasonal variation in employment probabilities, especially in that village. The Akola cotton-growing villages had the most buoyant labor markets. Peak periods for employment varied from village to village.

The males from labor households have a better chance than the females of obtaining a job compared with their counterparts in cultivator households. Thus females from the poorest socioeconomic group are the most disadvantaged in terms of employment opportunities. Females from all households tend to compete in the labor market at the same time during the year.

Female wage rates were some 56% those of males on an average (Rs 2.83 vs Rs 1.60 per day). There was no evidence that wage rates and employment probabilities were negatively related. In some villages there was evidence of a significant positive relationship, while in only one village was it significantly negative, hence giving weak support to McDiarmid's (1977, pp 48-49) hypothesis that labor markets are more "competitive" in peak wage periods.

There was no evidence to support the contention that those males who participated more in the daily labor market had significantly greater wages than those who participated less; in fact, in several villages the reverse was true. This suggests that there may be factors such as differences in education, skill, and nutrition that affect wages. More research on this aspect is required, embracing recent advances in the literature on the economics of human capital applied to the developing country situation. No doubt the fact that many times small farmers can hire labor at less than their own opportunity wage influences their decisions to be both buyers and sellers of labor at the same time.

Average opportunity costs of male labor (Rs 2.26 per day) were some 90% greater than those of female labor (Rs. 1.20) in these villages. CVs of opportunity cost were quite large throughout the season (12 to 47%). Hence there seems to be good scope for design of technology that strategically uses low opportunity cost periods to enhance the economic viability of the technology and generate additional incomes for disadvantaged groups at times when job opportunities and/or wages are low.

What is the appropriate cost of labor to use in benefit-cost analyses where this apparent excess labor pool would be called upon at strategic times of the year? According to Sen

(1975, pp 89-91), the social cost of labor is zero in a surplus labor economy if there is no sub-optimality of savings. On the other hand if all weight is on investment as opposed to immediate consumption, and there are no savings out of wages, the social cost of labor is given by the market wage rate. As the actual position with respect to Sen's conditions lies somewhere in between these extremes, it is probable that the true opportunity cost of labor lies between zero and the market wage. The calculated opportunity costs of wages in this paper make the adjustment in the right direction, although as Sen (1975, p 102) points out, this is a planned arbitrary adjustment. It is certainly preferable to the unplanned arbitrary guesswork involved in alternative methods of calculating shadow prices, which involve mathematical programming models and the determination of competitive equilibria.

This probability adjustment to market wages, in fact, moves us towards the equilibrium wage and towards Sen's concept of the social cost of labor. Whether the adjustment overshoots *or* undershoots the mark requires knowledge of the elasticity parameters of demand and supply of labor. There is a dearth of such estimates available, particularly of supply parameters and seasonal estimates. Until we have these it seems the probability-adjusted wage rates are the best measure we have of the social cost of labor. However, assuming the elasticity of labor supply is not zero then when wages are adjusted downwards by the probabilities (if < 1) in this way, the amount of surplus labor or involuntary unemployment available does not stay constant. Hence if one uses the probability-adjusted opportunity wages as the social cost of labor, one *should not* at the same time assume the available surplus labor pool to be the same as that at the prevailing (full) market wage rates.

We found weak support in these six villages for Sen's (1966) dual labor market hypothesis. It would seem to be an oversimplification of the operation of the labor markets in these villages. We also found evidence of significant amounts of segmentation between the male and female labor markets in these villages.

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Appendix Table 1. Paired t-tests of differences in participation rates and probabilities of employment in daily labor *market tor* adults in different SAT districts.[a]

Sex	Mean difference		
	Mahbubnagar-Sholapur	Mahbubnagar-Akola	Sholapur-Akola
Participation rate			
Male	-0.19***[a]	-0.23***	-0.06**
	[21.63][b]	[16.431	[3.61]
Female	0.22***	0.11***	-0.14***
	[16.92]	[10.58]	[9.731
Probability of employment			
Male	-0.16**	-0.16***	-0.05*
	[3.43]	[4.95]	[2.67]
Female	0.07	-0.07**	-0.19***
	[2.07]	[3.62]	[6.30]

a. *** Significant at 0.1% level
** Significant at 1% level
* Significant at 5% level
b. Bracketed figures are 't' values.

Appendix Table 2. Paired t-tests of differences between participation rates, probabilities of employment and wage rates for *males* from different households in six SAT villages.

Village	Labor – Small			Labor – Medium			Small – Medium		
	Participation rate	Probability of employment	Wage rate	Participation rate	Probability of employment	Wage rate	Participation rate	Probability of employment	Wage rate
Aurepalle	1.01	−0.23	−2.16*	4.47**	2.05	−0.58	6.02**	2.87**	1.13
Dokur	15.88**a	0.33	0.60	20.40**	−0.64	1.59	10.18**	−0.76	1.44
Shirapur	3.11**	−2.42*	−2.18*	0.19	2.14*	−0.98	−4.94**	6.86**	1.85
Kalman	4.98**	2.97**	−5.79**	9.96**	2.85**	−1.46	12.04**	2.35*	1.52
Kanzara	6.81**	0.41	−6.33**	17.94**	1.61	−4.13**	6.98**	1.45	1.19
Kinkheda	16.70**	−6.79**	1.52	22.10**	4.01**	3.04**	4.27**	6.21**	0.88

a. ** Significant at 1% level; * Significant at 5% level.

Appendix Table 3. Paired t-tests of differences between participation rates, probabilities of employment and wage rates for *females* from different households in six SAT villages.

Village	Labor – Small			Labor – Medium			Small – Medium		
	Participation rate	Probability of employment	Wage rate	Participation rate	Probability of employment	Wage rate	Participation rate	Probability of employment	Wage rate
Aurepalle	0.55	0.49	−4.21**	7.33**	0.64	−1.12	7.30**	0.10	6.09**
Dokur	0.33	1.45	−0.93	12.80**	−3.17**	0.48	19.19**	−4.62**	1.67
Shirapur	4.79**a	−8.21**	−0.09	2.84**	−3.95**	−1.99	−2.05	3.93**	−1.75
Kalman	1.59	−3.35**	0.51	14.50**	−5.57**	3.87**	10.62**	−0.73	1.78
Kanzara	0.94	2.06*	1.89	9.67**	1.22	−0.14	7.65**	−1.23	−1.64
Kinkheda	8.64**	−2.15*	1.68	27.95**	0.03	−1.46	17.13**	1.28	2.52**

a. ** Significant at 1% level; * Significant at 5% level.

Appendix Table 4. Simple correlation coefficiants of participation rates, probabilities of employmant, and wage rates for males from dtfferent households in six SAT villages).

	Labor-Small farm			Labor-Medium farm		
Village	Participation rate	Probability of employment	Wage rate	Participation rate	Probability of employment	Wage rate
Aurepalle	-0.48*[a]	0.30	-0.41	-0.41	0.02	-0.69**
Dokur	0.44**	0.89**	0.75**	0.10	0.80**	0.23
Shirapur	0.40*	0.29	0.49**	0.15	0.11	0.24
Kalman	-0.31	0.35	0.67**	-0.40*	-0.08	-0.07
Kanzara	0.44*	**0.58**	0.35	0.34	0.46**	0.41*
Kinkheda	0.43*	0.78**	-0.11	0.15	0.78**	-0.003

[a]** Significant at 1% level; * Significant at 5% level.

Appendix Table 5. Simple correlation coefficients of participation rates, probabilities of employment, and wage rates for females from different households in six SAT villages.

	Labor-Small farm			Labor-Medium farm		
Village	Participation rate	Probability of employment	Wage rate	Participation rate	Probability of employment	Wage rate
Aurepalle	0.83**[a]	0.62	0.53**	0.88**	0.82**	0.38
Dokur	-0.24	0.97**	0.77**	0.05	0.92**	0.85*
Shirapur	0.33	0.73**	0.25	-0.60**	0.64**	0.28
Kalman	-0.22	0.40*	0.12	0.12	0.74**	0.64**
Kanzara	0.39*	0.79**	0.59**	0.18	0.77**	0.19
Kinkheda	0.42*	0.83"	0.77**	0.61**	0.72**	0.72**

[a]** Significant at 1% level; * Significant at 5% level.

Discussant's Comments

V. N. Misra*

My observations on these papers are in no way to detract from the quality of the papers. They are well written and encompass several disciplines such as economics, sociology, and anthropology. However, I want to raise some issues discussed in the papers, in relation to methodology as well as with regard to the implications of the findings for policy purposes.

The paper by Benson is a good review of different issues relating to labor use based on studies conducted by several authors. However, the statement that "commercialization of agriculture displaces labor" is too general. In fact, there is evidence to show that commercialization of agriculture has increased the demand for labor.

Benson's conclusion about the role of cottage industries in providing alternative or supplementary employment is now well-recognized. However, the basic problem is the competitiveness of cottage industries vis-a-vis manufacturing industries. Despite our emphasis on cottage industries in several five-year plans, they have not evolved as a viable alternative.

Two observations can be made on Byerlee's paper. One is related to methodology while the other has some bearing on the functioning of the labor market.

Byerlee observes that in West Africa "the labor market is fairly efficient in allocating labor". This finding is based on the comparison of marginal value productivities (MVPs) of labor estimated through production function analysis. This value is slightly higher than prevalent wages, but there is no significant difference between the two. Thus, his conclusion drawn, that the labor market functions efficiently appears to be correct. However, the author then proceeds to make estimates of the MVP of labor based on a linear programing model. In this case the values are found to be three to four times higher than the prevailing rates. Hence one obtains the impression that the labor market is efficient when the MVP calculation is based on the production function but that it is inefficient when the MVP of labor is based on a linear programing model. How can we reconcile this? The estimates of MVP of labor based on production function analysis should not be compared with those derived from a linear programing model because the former is positive, whereas the latter is normative in the sense that it gives an estimate of MVP at an optimum level. The estimates of MVP of labor based on a linear programing model should only be compared with wages that would exist at an equilibrium or optimum position in order to judge the efficiency of labor market.

Another finding by Byerlee is that wage differentials of almost two to one still exist between the highest and lowest wage regions, despite a considerable flow of migrants from the lowest to the highest wage regions. This is difficult to explain. It would be expected that when sufficient labor migrates to the highest wage regions, and is available in the job market, that the wages in these areas would become lower. There are however, two necessary conditions for making wages a function of the supply of labor: free mobility of labor among employers and also the availability of alternative employment. There is no information on these two aspects in the paper. Thus, it becomes difficult to explain wages and the persistance of differentials under conditions of considerable migration. Byerlee has tried to explain the wage differentials by considering the demand side of the labor market. In addition to this, there are other factors such as the financial capacity of cultivators, size of holding, cropping pattern and extent of irrigation, which supposedly influence the demand for labor and hence wages. If Byerlee would have taken these factors into consideration also, he would have been able to better explain the wage differentials.

Ryan and his colleagues have presented an excellent paper. It covers all the important

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aspects of the labor market. It is so comprehensive that it raises many debatable issues. The findings are very important for research as well as with regard to policy implications.

It is observed by Ryan et al. that intensity of cropping does not contribute substantially to differences in labor use intensity in the six villages. This finding is quite different from the results of the study of Shakuntala Nehru. In her paper, which is based on farm management data, it was found that intensity of cropping contributes to differences in labor use. Since the finding of Ryan et al. is quite different from what one would expect, it seems worthwhile to compare the per hectare use of labor given in Table 1 of their paper with the intensity of cropping for the six villages. These latter data are taken from another paper by Ghodake et al. (1978, p 7) cited by the authors. There does not appear to be much difference in the cropping intensity in the Sholapur and Akola villages. In the former, the range is from 105 to 115, whereas in the latter, the variation in the cropping intensity is very low, being in the range 103 to 108. The result is that in the villages of these two districts, intensity of *cropping has not really been the important* factor accounting for the differences in labor use. However, the position is entirely different in the villages of Mahbubnagar district. In Aurepalle, per hectare labor use increases with increases in farm size. A similar trend exists with increasing intensity of cropping. In the case of Dokur village, the position is reversed in the sense that the per hectare labor use decreases with increases in farm size. However, in this case, intensity of cropping also decreases with increases in farm size, again resulting in a positive relationship between labor use per hectare and intensity of cropping. From this comparison it seems that wherever there is sufficient variation in the intensity of cropping, it does account for differences in labor use. On the other hand, wherever there are only small variations the intensity of cropping cannot account for differences in labor use.

Another point is related to segmentation of male and female labor markets. Based on low and nonsignificant correlations of wage rates of male and female labor, it has been observed by Ryan et al. that there appears to be segmentation in the male and female labor markets. Female labor is a non-competing group with males for the obvious reason that certain types of agricultural operations are generally done by males only. However, having proved the segmentation of labor markets for males and females, it is difficult to understand what has prompted the authors to compare the probability of employment for females with that of males.

Ryan et al. found that hired labor demand changes at least in proportion to total seasonal labor. This observation is based on the correlation coefficients between total labor use and the absolute amount of hired labor. The coefficients between total labor and proportion of family labor to total labor have been found significantly negative. Based on this it is concluded that if disadvantaged groups such as landless laborers and small farmers are to benefit from additional employment created by the new technology in these villages, then this evidence suggests one should not necessarily design them to have stable seasonal labor use patterns. This conclusion contradicts the inference drawn earlier in the paper that there would seem to be considerable scope for designing technologies that specifically aim at capitalizing upon periods when labor opportunity costs *are* low. This would enhance the profitability of the technology as well as create employment in slack/unremunerative periods with consequent redistributive benefits. The stabilization in demand for labor need not mean a stabilization at a low level, which seems to be proposed by the authors in suggesting technology development to take advantage of low opportunity costs. If these opportunity costs are to be used as a basis for designing new technology then such, technology may turn out to be very profitable because of the low opportunity costs. However, how is providing employment at such low opportunity costs going to benefit agricultural laborers? It seems that employment would be created per se, rather than to really improve the income level of agricultural laborers.

Chairman's Summary

J. Kampen*

In the discussion of Benson's paper, a question was raised on how relief projects to provide jobs during non-peak periods can be financed without taxing or otherwise obtaining the necessary resources from agriculture. It was pointed out that in India resources for such purposes are not raised directly from the agricultural sector but are obtained from general resources.

Issue was taken with Benson's generalization regarding women's specialization in maintaining subsistence crops, and it was pointed out that in the Sudan these activities are executed as cooperative activities between men and women. It was agreed that while this may be true the division of tasks still exists (e.g. men clearing brush and women weeding).

The generalization of migration aspects in Byerlee's paper without considering relationships between migration, off-farm activities and on-farm activities, particularly in the context of the African countries where migration occurs from dryer to less dry areas was questioned. The author pointed out that the considerable literature on migration flows does not clearly identify such relationships. He said that rural-rural migration is most important to low-income food-deficit households and is more important than rural-urban migration in the context of new agricultural technologies and the implementation of innovations in West Africa.

Labor bottlenecks and constraints aspects of new technology were discussed at length. The optimistic view was expressed that after a lapse of 5 to 10 years when new technologies would actually be implemented on farmers' fields, such constraints would have disappeared because of increasing populations. Therefore, the need for ICRISAT's research strategy to be output oriented and to give less attention to issues such as labor bottlenecks was stressed.

In the Sudan in areas with extensive mechanized agriculture, lean period wages are only 20% of peak period wages. There is a danger that if one tries to smooth out the seasonal peaks, migrant and landless laborer would be adversely affected.

A question was raised about the policy conclusion in the paper by Ryan et al. regarding the design and transfer of new technologies during low opportunity cost periods, and implications thereof on wage rates. This is an area where more research is needed. Furthermore, because few operations are done separately by males and females on a piece wage rate basis, it is difficult to measure the productivity differentials between them and hence attempt to explain why their wages really differ.

The use of village survey research findings in terms of feedback to ICRISAT's overall research strategy was discussed. It was pointed out that this is a continuous process; for example labor use information in relation to possible solutions for anticipated bottlenecks has been assembled as well as the application of village opportunity cost measures in the assessment of new technologies. This information in turn is being utilized by the Farming Systems Research Program scientists in developing technologies.

The necessity to do operational participation analysis in order to understand participation differences according to sex and/or operation was emphasized. It was suggested that the substantial contribution of female labor can be partly explained by male migration in many instances.

A discussion ensued about ICRISAT's interdisciplinary teamwork to generate technology that will meet the requirement of efficient use of seasonally available labor at low opportunity cost. It was pointed out that at present watershed-based research in collaboration with other physical and biological scientists is underway in villages. This activity helps to ascertain the potential constraints related to labor or other factors; it will also provide opportunities to verify the low opportunity wage periods.

Caution was suggested with regard to the use of opportunity wages in evaluating new

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technology. There is a need to take into account the possibility of enforcement of minimum wages. Peak period differentials in case of males and females, if relevant and significant, should also be considered. It was suggested that minimum wage laws, if effective, would probably have the effect of increasing unemployment and the net effect on real opportunity cost may well be neutral. However, actual effects depend on demand and supply elasticities of labor, and little is known about these.

It was felt that the health-nutrition-pregnancy relationship was not adequately discussed in the papers. Additional information in this area would help explain which people do not work and why, and if ICRISAT should explore the possibility of attracting the attention and involvement of those responsible for public health programs. The linkages between these health aspects with labor employment should be clearly established. It was noted in response that the ICRISAT Economics Program's village-level studies involved a diet, nutrition and health evaluation project in collaboration with the Home Science College of Andhra Pradesh Agricultural University and the National Institute of Nutrition in India. These studies were started in late 1976 and the data have been collected; the final findings, implications and their interpretation in explaining labor employment patterns have not yet been published.

In response to lively discussion, it was stated that there is no conflict between a research focus on agricultural production or productivity of the natural resource base and an Institute charter emphasizing benefits to small farmers and the rural landless poor. Appropriate technologies that do not displace rural labor must be designed for agricultural development; if increased and more stable production are to be achieved and the quality of life enhanced for the less affluent people of the SAT.

In relation to the objectives of the workshop it appears that the papers presented emphasized the need for further socioeconomic research and surveys, as well as guidelines and methodologies for such studies in national programs and by ICRISAT. Unfortunately, there were few suggestions with regard to the design of improved technology and agricultural policy, particularly in the African setting. This conclusion would seem to be relevant to the focus and orientation of future socioeconomic research and surveys.

Appendix 1

French Abstracts and Texts (Resumes et Textes en Franqais)

Résumés des Communications

Chapitre 1 : Analyse Socio-économique des Systèmes et des Pratiques de Culture Actuels

Analyse Socio-économique des Systèmes et des Techniques de Culture Pratiqués au Nord-Nigeria

G. O. I. Abalu et B. D'Silva

L'objet de cette communication est l'étude des caractéristiques principales des systèmes de culture du Nord-Nigeria, et l'évaluation, d'un point de vue économique, des assolements et des pratiques culturales existants. Les auteurs s'appuient sur les recherches menées depuis les dix dernières années, au niveau micro-économique, par le Département d'Economie et de Sociologie Rurales de l'Université Ahmadu Bello, au Nigeria.

Quelques Caractéristiques des Systèmes de Culture Traditionnels des Zones Tropicales Semi-arides de l'Inde

N. S. Jodha

Cette communication rassemble quelques résultats des études menées depuis 1975, par l'ICRISAT dans les six villages des trois zones agroclimatiques de l'Inde péninsulaire. L'auteur commente les résultats intéressants des recherches qui visent à la mise au point d'une nouvelle technologie dans les zones tropicales semi-arides. L'analyse met en lumière la rationalité de deux pratiques culturales: la jachère de mousson en Vertisols (sols noirs) profonds, et les associations de cultures en agriculture pluviale. Les contraintes à la diffusion d'une technologie prospective des bassins versants sont également abordées. L'auteur conclut que, puisque les petites exploitations pratiquent davantage la jachère de mousson et les associations de culture, tout progrès dans la mise au point d'une technologie peu coûteuse en ces deux domaines servira davantage les intérêts des paysans les plus défavorisés. Il est probable que, dans le mode actuel de répartition et d'utilisation des terres, la technologie prospective des bassins versants se heurte à de sévères contraintes institutionnelles.

Assolements, Pratiques d'Exploitation et Economie des Principales Cultures de Quelques Régions Indiennes sous Système de Cultures Sèches

B. K. Rastogi

Cette communication traite du niveau technique actuel des systèmes de cultures sèches pratiqués par le paysan indien, à travers l'étude des assolements, des pratiques d'exploitation et de l'économie des principales cultures de quelques régions indiennes sous système de cultures sèches. Elle s'appuie sur les données collectées dans le cadre du projet de Recherche Agro-Economique du Programme pour les Régions Prédisposées à la Sécheresse (D.P.A.P.), volet du Projet Indien de Recherche Coordonnée pour l'Agriculture Sèche (A.I.C.R.P.D.A.). L'information provient des résultats obtenus en 1976–77 par huit centres situés dans les régions arides et semi-arides de l'Inde. Il apparaît que les paysans de ces régions travaillent à un très bas niveau de technologie. En de nombreux endroits, le travail de préparation du sol n'est que facultatif, et souvent inadéquat. L'emploi de semences améliorées, d'engrais et de produits phytosanitaires se fait à très faibles doses. Tracteurs et batteurs ne sont utilisés que ponctuellement. Les fumures d'origine animale sont maigres; les cultures de rente en ont la priorité. Pour l'auteur, bien que les nouvelles technologies pour cultures sèches mises au point dans les centres de recherche s'avèrent applicables et viables, dès lors qu'on met en pratique les techniques préconisées, et bien que ces technologies soient dites neutres par rapport à la taille de l'exploitation, elles n'ont pas encore reçu un accueil enthousiaste de la part des paysans des régions arides et semi-arides du pays.

Chapitre 2 : Aspects Socio-économiques des Techniques Prospectives

Analyse Socio-économique de l'Introduction de Techniques Nouvelles en Milieu Rural Sénégalais

Moussa Fall

Cette communication aborde les contraintes physiques et les facteurs humains liés à l'introduction de la nouvelle technologie dans le milieu rural sénégalais particulièrement dans la zone sahélienne où les enquêtes ont été menées depuis trois ans. Si la rentabilité de certaines techniques est démontrée, il reste encore à motiver le paysan au changement. Cette motivation a pour support essentiel l'accroissement du revenu monétaire et le surplus des produits. D'où la nécessité d'intensifier les systèmes de production, de bien organiser la commercialisation, de permettre aux coopératives d'exercer leur rôle véritable et d'assouplir le système de crédit. L'analphabétisation reste un problème crucial dans le processus de la modernisation.

Evaluation de Technologies Prospectives d'Aménagement des Ressources en Sol et en Eau et des Techniques Culturales pour les Zones Tropicales Semi-arides de l'Inde Péninsulaire

J. G. Ryan, R. Sarin et M. Pereira

Cette communication rassemble les analyses économiques des expériences menées dans le cadre du Programme de Recherche sur les Systèmes de Culture par l'ICRISAT, de 1975 à 1978, pour l'amélioration des méthodes d'aménagement des ressources en sol et en eau, et des techniques culturales. Sur les Vertisols (sols noirs) profonds du Centre ICRISAT, le système de planches larges et de sillons d'aménagement de l'eau et du sol, s'est révélé extrêmement avantageux; ce qui n'a pas été démontré pour les Vertisols semi-profonds. Dans les expériences à différents degrés de technologie menées sur les Alfisols (sols rouges), les profits obtenus par le système de planches larges et de sillons ont été de 60% inférieurs à ceux obtenus sur Vertisols, mais ils demeurent néanmoins appréciables. Le système de planches larges et de sillons s'est révélé cependant moins avantageux que la culture à plat dans les expériences à plus grande échelle menées sur les bassins versants en Alfisols. L'ensemble des technologies améliorées (variétés culturales, fertilisation, aménagement du sol) a permis d'obtenir au Centre ICRISAT, sur Vertisols comme sur Alfisols, des profits maximums à l'hectare, les risques mis en jeu étant compatibles avec ceux qu'acceptent généralement de courir les payans indiens des zones tropicales semi-arides. Dans les bassins versants sur Vertisols du Centre ICRISAT, l'association de cultures maïs-pois d'Angole a donné des profits nettement plus élevés, et plus réguliers, que la succession de cultures maïs-pois chiche, surtout en Vertisols semi-profonds. Au Centre ICRISAT, les Alfisols semblent plus aptes que les Vertisols à accueillir une technologie de collecte de l'eau et d'irrigation complémentaire, parce qu'ils favorisent davantage le ruissellement de l'eau, et que le rendement des cultures sur Alfisols répond bien à l'irrigation. Il est peu probable qu'une telle technologie soit applicable dans les Vertisols de Sholapur. Les dimensions optimales des bassins versants se situent entre 8 et 16 ha.

La Nouvelle Technologie Agricole dans le Sertão Brésilien

John M. Sanders

Cette communication décrit quelques caractéristiques du Sertão brésilien en rapport avec la nouvelle technologie agricole. Elle passe ensuite en revue les travaux de recherche d'une nouvelle technologie — l'introduction du sorgho — et en tire les leçons. Dans la région considérée, la main-d' œuvre n'est pas simplement un facteur limitant, saisonnier, de la production; elle souffre également, et de façon chronique, de problèmes nutritionnels. C'est pourquoi il faut juger les effets de l'introduction de la nouvelle technologie sur des revenus des producteurs en termes d'équité, aussi bien que d'efficacité. L'augmentation des rendements des cultures vivrières de base dépend de la réponse de celles-ci aux engrais, et des conditions de sol, deux facteurs qui tendent à être peu favorables à l'heure actuelle. Il convient d'abord d'identifier les espèces végétales susceptibles de bien supporter la sécheresse, puis de sélectionner les variétés et d'entreprendre une recherche agronomique de base. Les résultats agronomiques ayant montré la supériorité du sorgho sur le maïs, en termes de rendements, et les essais au niveau expérimental, puis a l'échelle de l'exploitation, prouvant que la culture du sorgho est compatible avec les autres activités du paysan, et peut être source de profits, une politique d'intervention en faveur du sorgho grain s'avère justifiée. Plusieurs étapes sont proposées pour cette intervention.

Chapitre 3 : Evaluation Socio-économique sur le Terrain des Techniques Prospectives

Evaluation Socio-économique sur le Terrain, des Techniques de Cultures Sèches Mises en Oeuvre par le Projet Indo-Britannique d'Indore (Inde)

A. K. Chaudhari

Cette communication décrit les effets de l'introduction d'une technologie améliorée d'aménagement des ressources en sol, eau, espèces cultivables, et bétail sur Vertisols (sols noirs) dans le cadre du Projet Indo-Britannique d'Indore dans l'Etat de Madhya Pradesh (Inde). Depuis 1974, date de lancement du Projet, les paysans sur les 2.000 ha de la zone ont adopté de façon croissante les variétés à haut rendement de sorgho, blé et pois chiche et se sont mis pour la première fois à cultiver du soja et du maïs. La superficie consacrée aux cultures de saison des pluies a sensiblement augmenté depuis les quatre dernières années, passant de 32% de la surface totale cultivée à 54%; de plus la surface sous double récolte a été multipliée par dix. Ces changements alliés à un usage croissant des engrais et de l'irrigation ont permis une augmentation de rendements de 30 à 500% et du revenu net à l'hectare en moyenne de plus de 170%. La technologie consistait en un emploi intensif de la main-d'œuvre et des bœufs, ce qui a favorisé les petits paysans dont les rapports homme/terre et bœuf/terre sont plus élevés que ceux des gros exploitants.

Nature Humaine et Elaboration de Technologie Agricole

V. S. Doherty

Des résultats des recherches sur la taille et la fonction de divers groupes sociaux, on peut tirer des stratégies d'organisation destinées à promouvoir à grande échelle, l'amélioration des techniques *d'aménagement des terres et à permettre le développement d'une irrigation complémentaire*. L'amélioration des techniques d'aménagement des terres sera très rapide si les outils peuvent devenir la propriété individuelle, même des plus petits paysans et des petits entrepreneurs. Le développement de l'irrigation complémentaire sera très rapide si les sources d'irrigation sont la *propriété de particuliers ou sont assez importantes pour justifier l'assistance du gouvernement pour* leur usage et leur entretien.

Participation Paysanne et Prise en Compte des Besoins des Catégories les plus Défavorisées (Quelques Idées sur les Conditions de la Participation Paysanne à partir d'un Programme de Recherche)

Jacques Faye

Cette communication présente quelques idées sur la participation paysanne aux programmes de recherche les concernant. Cette réflexion porte sur un programme de recherche mené dans les Unités Expérimentales du Sine-Saloum au Sénégal de 1974 à 1976. L'auteur observe que dans tout projet concernant l'ensemble d'une population rurale il est indispensable de partir d'une analyse des structures et de la stratification sociale. On doit s'attendre à ce que les gro upes et les catégrories les plus favorisés développent des stratégies visant à ce que ces change ments maintiennent ou renforcent leurs positions dans la hiérarchie sociale. Le chercheur ou le développeur ne saurait se désintéresser du fait que les innovations peuvent toujours être confisquées ou contournées par un groupe ou une catégorie sociale au détriment des autres. Il faut avoir en tête que les couches les plus pauvres ne le sont pas par suite de retards technologiques, mais parce qu'elles se trouvent dans une série de relations inégales. L'auteur constate que cette analyse au niveau des collectivités rurales peut facilement être élargie aux ensembles nationaux et internationaux.

Evaluation Socio-économique sur le Terrain des Technologies Prospectives dans les Zones Tropicales Semi-arides du Mali: Etude d'un Cas dans la Zone OACV*

B. Traore

Cette communication présente un modèle de l'économie du ménage paysan, à partir de l'étude d'un cas dans la zone OACV, au Mali, en résumant ses caractéristiques de base dans un algorithme de programmation linéaire. Ce modèle sert ensuite à une simulation de l'impact des diverses stratégies

* L'Opération Arachide et Cultures Vivrières (OACV) est un projet de vulgarisation pour le développement de l'arachide et des céréales dans une zone spécifique, sous l'autorité du Gouvernement malien, de la Banque Mondiale et du Fonds d'Aide et de Coopération (FAC).

gouvernementales de développement rural sur les petits exploitants. Des résultats de l'étude, on déduit les effets des politiques appliquées: (1) la technologie moderne intermédiaire actuellement introduite, bien que considérée comme peu coûteuse, reste néanmoins trop chère pour le paysan pratiquant une agriculture de subsistance, et une technologie encore moins chère s'avère nécessaire; (2) l'augmentation des crédits destinés aux paysans et des prix des productions agricoles, jouant comme aiguillon, serait sans doute l'outil le plus efficace pour l'adoption de la nouvelle technologie par les paysans, dans la région; (3) les structures de vulgarisation, qui jouent un rôle important, devraient être bien organisées et rendues véritablement opérationnelles; (4) toutes les conséquences possibles doivent être envisagées et les mesures préconisées doivent s'insérer dans un plan global et cohérent de développement agricole. L'auteur définit enfin le champ de validité de son étude et fait quelques suggestions pour de nouvelles recherches.

Approche Socio-économique des Exploitations Agricoles

M. Benoit-Cattin

Cette communication fait un certain nombre de propositions méthodologiques pour une recherche sur les exploitations agricoles. La méthode repose sur un choix raisonné de situations caractéristiques. Elle privilégie l'exploitation agricole comme lieu où se prennent les décisions par rapport avec la production agricole. Ces décisions résultent, d'une part, des relations dialectiques entre une formation économique et sociale et un écosystème et d'autre part, d'un contexte historique donné. Parmi les thèmes abordés sont: le choix des lieux d'investigations; les investigations au niveau du village; l'unité de résidence comme unité d'investigation; l'identification et l'analyse de l'exploitation agricole; la parcelle cultivée comme lieu d'observation; l'étude des élevages; la méthode d'analyse des observations; le travail interdisciplinaire; et l'intégration de la recherche et l'action.

Chapitre 4 : Questions de la Commercialisation des Grains Alimentaires

Réforme des Systèmes de Commercialisation des Grains en Afrique de l'Ouest : le Cas du Mali

Elliot Berg

Cette communication examine les problèmes de la commercialisation des grains alimentaires dans la République du Mali, en Afrique de l'Ouest, et analyse pourquoi les nombreuses propositions de réforme se sont avérées inapplicables ou trop difficiles à mettre en œuvre. Parmi les principales observations, citons: (1) les possibilités d'action du Gouvernement malien sont fortement limitées par des facteurs d'ordre physique, financier, et d'organisation; (2) le système actuel de commercialisation mixte (gouvernement et secteur privé), ne peut être facilement amélioré, comme certaines études le recommandent; (3) l'incertitude sur les prix et la désorganisation générale du marché détourne l'effort des paysans vers les cultures de rente, et risque de décourager leurs efforts ou leurs initiatives dans la production des grains; (4) les coopératives en place, étant des instruments du gouvernement, utilisés essentiellement pour la réquisition des grains, les paysans sont peu enclins à créer de véritables coopératives, qui pourraient mieux défendre leurs intérêts; (4) l'assistance étrangère, comprenant aide alimentaire et ouverture d'un crédit sur les livres des Comptes d'Opération, à Paris, a atténué l'impact des politiques de commercialisation des grains, et permis au Gouvernement malien de maintenir des politiques sans avoir à en supporter pleinement les consequences; (6) jusqu'à très récemment, le Gouvernement malien ne s'est pas vu présenter de propositions bien élaborées. L'auteur conclut qu'une réforme ne peut réussir que si une agence d'Etat pour le grain y joue un rôle majeur — même avec les présupposés "minimalistes" sur le rôle de l'Etat quant à la co mercialisation des grains — et que le progrès résultera surtout de mesures indirectes, telles que l'amélioration et l'extension du réseau de transport, une meilleure information sur les cultures et la commercialisation, et une meilleure diffusion de cette information, une plus grande attention portée à l'allègement des contraintes sur la production de grains alimentaires, et une meilleure analyse des politiques par le gouvernement. De tels changements, indirects, élargiront le champ des options s'offrant à la réforme, et augmenteront les chances de leur adoption.

Commercialisation des Grains Alimentaires et Développement Agricole en Inde

M. von Oppen, V. T. Raju et S. L. Bapna

Cette communication traite de la commercialisation des grains en Inde et de son impact sur le développement agricole, à travers les approches et les résultats des quatre principaux thèmes de recherche étudiés à l'ICRISAT, sur la commercialisation en agriculture. Les voies de commercialisation agricole, en Inde, sont concurrentielles, et les mécanismes de formation des prix, en général, jouent bien. Les préférences du consommateur (aspect extérieur et qualités intrinsèques) pour le sorgho et le mil, ont un effet mesurable sur les prix de marché, et un index de préférence à la qualité permettant de choisir un grain de "bonne qualité," peut être déduit des mesures de préférence. Les grains alimentaires étudiés à l'ICRISAT sont, en Inde, essentiellement produits pour l'auto-consommation. Cependant, l'élasticité-prix de l'offre, pour l'arachide et le pois d'Angole, dans l'Etat d'Andhra Pradesh, est positive et mesurable. Bien que la formation des prix, sur les marchés, se passe généralement bien, elle varie d'un marché à l'autre. La formation des prix est déterminée par un ensemble de facteurs qui mènent à conclure qu'un plus grand nombre de marchés, avec un nombre plus réduit de commercants par marché, équipés de téléphones également répartis, et supervisés par un secrétaire de marché, fréquemment remplacé, favoriserait une meilleure formation des prix. Les investissements destinés à améliorer les échanges commerciaux agricoles permettent des gains mesurables. L'élimination des restrictions au commerce inter régional, on l'a montré, entraine une augmentation de la production globale des grains alimentaires, avec des changements relativement mineurs dans les assolements.

Chapitre 5 : Aspects Socio-économiques du Matériel Amélioré à Traction Animale et de la Mécanisation

Observations sur l'Economie des Tracteurs, des Bœufs et des Multiculteurs dans les Zones Tropicales Semi-arides de l'Inde

H. P. Binswanger, R. D. Ghodake et G. E. Thierstein

Cette communication passe en revue les résultats des enquêtes sur l'économie de la culture motorisée dans les zones tropicales semi-arides de l'Inde (S.A.T.). Il apparait que la culture motorisée, telle qu'elle est généralement pratiquée, n'augmente ni l'intensification des cultures, ni leurs rendements, et se substitue à la main-d' œuvre. Cette constatation justifie l'accent mis sur la traction bovine par le Programme de Recherche sur les Systemes de Culture (F.S.R.P.) à l'ICRISAT.

On examine ensuite les données disponibles à l'ICRISAT sur l'économie des multiculteurs. Même dans les circonstances les plus favorables, ces machines ne peuvent soutenir la différence de coût avec le matériel traditionnel, en agriculture traditionnelle. Elles devraient permettre, pour justifier leur coût supérieur, une augmentation de rendement de l'ordre de 200 à 400 kg à l'hectare. Les données obtenues en station d'expérimentation indiquent qu'une augmentation de rendement encore supérieure à ces quantités peut être atteinte avec les techniques améliorées d'aménagement du sol, rendues possibles par l'emploi du multiculteur dans les Alfisols (sols rouges) et les Vertisols profonds (sols noirs profonds). Un tel résultat n'a cependant pas encore été démontré au niveau de l'exploitation paysanne.

Culture Attelée en Afrique Francophone

M. Le Moigne

Cette communication examine le développement et l'utilisation de la culture attelée dans l'agriculture de l'Afrique francophone. Bien que de nombreux équipements utiles soient mis au point et soient introduits avec succés dans quelques régions, l'auteur n'est pas optimiste sur leur usage répandu dans l'avenir prochain. Il constate que la culture attelée tout en présentant un ensemble de solutions techniques, reste de toutes façons limitée. Il faut donc la concevoir, associée à d'autres solutions techniques. Les exploitations agricoles sont des systèmes de production diversifiés à l'infini et dynamiques. Ceci est incompatible avec les idées de standardisation ou de conformité à des modèles mathématiques préétablis. Pour aider une exploitation à se développer, il faut analyser ses problèmes dans l'état où elle se trouve et lui conseiller progressivement les solutions qui lui sont propres. L'avenir de la culture attelée est conditionné par la recherche en tous genres et par la vulgarisation portant sur un travail plus rapproché de l'exploitation individuelle plutôt que servant d'organe de diffusion d'intrants.

Aspects Socio-économiques du Matériel Amélioré à Traction Animale et de la Mécanisation dans les Zones Semi-arides de l'Afrique de l'Est

Bruce F. Johnston

Cette communication examine les principaux facteurs socio-économiques déterminant l'importance du rôle des outils à traction animale dans les régions agricoles semi-arides du Kenya, de la Tanzanie et de l'Ouganda. Les caractéristiques structurales et démographiques qui doivent être prises en considération pour élaborer des politiques de développement agricole et industriel, doivent également être prises en compte pour déterminer les priorités de la recherche agricole et des stratégies de développement pour ces zones semi-arides. Ces relations sont particulièrement évidentes au Kenya où la migration d'un milieu rural à un autre a été, pour une bonne part, responsable de la croissance extrêmement rapide de la population dans les principales zones de culture semi-arides, surtout dans les districts de Machakos et de Kitui. Un accent particulier est mis dans cette étude, sur la situation actuelle et les perspectives d'avenir au Kenya, qui illustrent notamment le fait que les problèmes techniques de définition de systèmes de culture plus productifs et plus stables, doivent être étudiés en relation avec les problèmes, plus larges, de transformation économique et de modernisation sociale.

Chapitre 6 : Examen Analytique de la Documentation sur les Zones Tropicales Semi-arides de l'Afrique de l'Ouest

L'Etude au Niveau de l'Exploitation dans les Zones Tropicales Semi-arides de l'Afrique de l'Ouest

M. Newman, I. Ouedraogo et D. Norman

Cette communication présente un bref aperçu analytique des études réalisées antérieurement sur les problèmes socio-économiques des systèmes de production, au niveau de l'exploitation et du village, dans les zones tropicales semi-arides de l'Afrique de l'Ouest. Cela doit permettre d'identifier les régions devant bénéficier en priorité des recherches de l'ICRISAT, et de fournir à ce dernier une ligne directrice des techniques de culture devant être développées dans ces régions. Les auteurs insistent sur un point: l'emploi d'une nouvelle technologie risquant d'augmenter les inégalités de répartition des revenus au niveau du village, le développement de cette technologie doit prendre en compte l'hétérogénéité des exploitations pour définir les systèmes d'infrastructure, de telle sorte que les petits exploitants défavorisés ne soient pas laissés pour compte et que la croissance s'accompagne d'équité. La connaissance limitée des techniques de collecte et d'analyse des données, associée au manque de collaboration des différentes disciplines, ont abouti, dans le passé, à une ignorance des problèmes d'équité, mais un travail interdisciplinaire peut aujourd'hui être accompli par des techniciens, des scientifiques, des anthropologues, des sociologues et des agro-économistes. Cette interdisciplinarité doit permettre de définir des stratégies adéquates pour l'avenir. C'est dans cette perspective que se situe le rôle de l'ICRISAT. Dans le cas de l'Afrique de l'Ouest, les auteurs proposent que l'ICRISAT concentre son intervention, pendant plusieurs années, en un ou deux emplacements, et étudie davantage de cultures que les cinq faisant l'objet de son mandat, de telle sorte que l'ensemble du système d'exploitation (y compris l'élevage) soit comme un tout unifié, et puisse être amélioré en étroite collaboration avec les institutions nationales.

Grains : Un Développement à Rebours

Barbara Harriss

Cette communication étudie, à travers un examen critique de la documentation, les relations existant entre la politique interventioniste, les systèmes de commercialisation privés du grain et la production des grains, dans les zones tropicales semi-arides de l'Afrique de l'Ouest. Elle examine comment le système de commercialisation local peut contribuer à l'inégalité rurale et avoir un effet dépressif sur la production des grains; comment les interventions de l'Etat exacerbent ce processus, sans parvenir à atteindre les objectifs déclarés, et contribuent, par d'autres voies, à la stagnation de la production des grains; comment, enfin, la production et le système de commercialisation indigènes, à leur tour, influencent les formes d'intervention de l'Etat et contribuent à "une crise structurale insoluble de la commercialisation." L'auteur conclut que les possibilités de changement — soit réformistes, soit radicales — dans le cadre actuel des structures économiques des zones tropicales semi-arides de l'Afrique de l'Ouest, semblent extrêmement limitées.

Chapitre 7 : Nature et Signification du Risque

Nature et Signification du Risque dans l'Exploitation d'une Nouvelle Technologie

Jock R. Anderson

Cette communication se veut plus une *réflexion* qu'une *tentative d'examen empirique des questions* abordées. Des questions, cependant, sont soulevées — parfois sous forme d'hypothèses susceptibles de subir une analyse empirique. Si l'objet des préoccupations demeure, manifestement, l'agriculture des zones tropicales semi-arides, l'auteur espère que les réflexions rasemblées ici peuvent être appliquées à des sujets relatifs au risque en agriculture, dans les autres régions du monde.

Nature et Signification du Risque dans les Zones Tropicales Semi-arides

Hans P. Binswanger, N. S. Jodha et B. C. Barah

Cette communication rassemble un certain nombre de projets de recherche sur le rôle du risque dans l'agriculture des zones tropicales semi-arides (S.A.T.) de l'Inde. Ces projets s'appuient sur: (1) des données macro-économiques sur les variations de rendements, de prix et de revenus; (2) des données micro-économiques sur les niveaux de revenus et de dépenses de ménages ruraux, pendant les périodes de sécheresse; (3) un ensemble d'expériences psychologiques sur les attitudes face au risque. La recherche a permis, jusqu'à présent, d'aboutir aux conclusions suivantes:

1. *Le niveau des risques affectant le revenu dans les zones tropicales semi-arides de l'Inde, est élevé* et provient essentiellement de la production, plus que des incertitudes de prix.
2. Pratiquement tous les paysans des zones S.A.T. échantillonnées s'avouent défavorables au risque, sans toutefois le rejeter entièrement.
3. Les paysans ne parviennent pas à s'assurer à moindre coût en diversifiant les risques — ce qui leur permettrait, confrontés à l'incertitude de la production, de pourvoir aux dépenses de consommation.

Nous sommes donc obligés de conclure que le risque, et son aversion, conduisent à un sous-investissement dans l'agriculture des zones S.A.T.

Le Risque et l'Incertitude dans la Prise de Décision par les Paysans

Frank Cancian

Cette communication fournit un cadre théorique à l'étude du rôle du risque et de l'incertitude dans le processus de prise de décision par les paysans. L'auteur souligne que la distinction entre économie normative et économie descriptive, notions parfois confondues, doit être maintenue. Sa réflexion suggère que les paysans les plus défavorisés peuvent jouer, dans le changement technologique, un rôle plus grand que celui qui leur a été souvent accordé; et que l'hésitation, dans le passé, des paysans relativement plus aisés, est due sans doute davantage au souci de conservation d'un statut social, qu'à un refus catégorique. Les actes d'un individu sont en effet largement influencés par sa position sociale dans la communauté.

Chapitre 8 : Less Marchés du Travail en Milieu Rural

Emploi de Main-d'œuvre Rurale et Stratégies de Développement en Afrique de l'Est et en Inde

Janet Benson

Cette communication traite de la division du travail en Afrique de l'Est et en Inde, et de ses conséquences sur l'élaboration d'une nouvelle technologie agricole. L'accent a été mis, en premier lieu, davantage sur la production des petites exploitations que sur celle des grandes, et l'auteur a essayé, dans la mesure du possible, de concentrer son étude sur l'utilisation de la main-d'œuvre dans les systèmes de cultures sèches. Cependant, des données importantes sur des sujets comme le caractère saisonnier de la main-d'œuvre et la répartition des temps de travaux (en particulier par sexe et par âge) n'étant pas souvent disponibles, l'information provenant d'autres régions géographiques a été introduite, lorsqu'elle était pertinente. Des problèmes méthodologiques sont également discutés.

Les Marchés du Travail en Milieu Rural Ouest-Africain, Particulièrement dans les Zones Tropicales Semi-arides

Derek Byerlee

Cette communication présente une vue d'ensemble des marchés du travail en milieu rural ouest-africain, et particulièrement dans les zones tropicales semi-arides (S.A.T.). La connaissance et la compréhension de ces marchés du travail, en milieu rural, sont essentielles pour la compréhension des pratiques culturales et des assolements, et doivent servir de base à l'élaboration de nouvelles technologies agricoles appropriées aux exploitations de la région. L'auteur passe en revue les données empiriques sur ces marchés de travail, selon une hiérarchie de niveaux commençant par l'utilisation du travail du ménage ou de la famille, à laquelle fait suite le marché du travail local, ou au niveau du village, pour finir enfin par le marché du travail à l'échelle régionale, où interviennent les migrations d'un milieu rural á un autre, et du milieu rural au milieu urbain. Cette étude permet de tirer quelques conclusions générales sur les marchés du travail en milieu rural des zones S.A.T., et les conséquences qui en résultent pour les programmes de recherche agricole.

Emploi de la Main-d'œuvre et Marchés du Travail dans les Villages de la Zone Tropicale Semi-aride de l'Inde Péninsulaire

James G. Ryan, R. D. Ghodake et R. Sarin

Cette communication examine les modalités d'utilisation de la main-d'œuvre, et le comportement des marchés du travail, d'un échantillon de 240 ménages d'ouvriers agricoles et de paysans dans les Etats du Maharashtra et de l'Andhra Pradesh, en zones tropicales semi-arides (S.A.T.) de l'Inde péninsulaire. Les six villages étudiés représentent trois grandes zones agro-climatiques et ont fait l'objet d'études socio-économiques approfondies, depuis le milieu de l'année 1975, dans le cadre du Programme d'Economie de l'ICRISAT. Les technologies prospectives d'aménagement de l'eau, du sol et des techniques culturales, pour les zones S.A.T. de l'Inde, semblent largement favoriser une augmentation de l'emploi, surtout sur Vertisols (sols noirs). L'importance de la contribution des femmes, dans la main-d'œuvre des villages, est légèrement supérieure à celle des hommes, alors qu'elles bénéficient de taux de salaires et de possibilités d'emploi en général largement inférieurs. La séparation des marchés du travail "hommes" et "femmes" n'est qu'apparente, et ces marchés ne semblent pas se faire davantage concurrence lors des périodes de hauts salaires. L'hypothèse de la dualité du marché du travail ne semble guère opérante dans ces villages. Une participation continue au marché du travail n'augmente pas nécessairement le taux des salaires, ce qui suggère que d'autres facteurs liés aux qualités du capital humain interviennent peut-être dans les variations de salaire. La grande variabilité saisonnière des coûts d'opportunité de travail laisse penser qu'il existe de grandes possibilités d'élaboration d'une technologie permettant de capitaliser les périodes de bas coûts d'opportunité, augmentant ainsi la viabilité économique et les revenus du travail. Les coûts moyens d'opportunité de travail utilisés dans les analyses de projet, sont calculés.

Analyse Socio-économique de l'Introduction de Techniques Nouvelles en Milieu Rural Sénégalais

Moussa Fall*

La production du secteur primaire représente environ un tiers de la production intérieure brute du Sénégal. Mais près de 70% de la population active est employée dans le secteur.

Les divers plans de développement se sont donc donnés comme priorité la modernisation de l'agriculture et l'amélioration des revenus des ruraux, par des investissements importants dans le secteur, l'introduction d'innovations techniques et l'intensification des systèmes techniques de culture.

Dans cette présente communication nous tenterons de cerner les quelques aspects liés à l'introduction de techniques nouvelles en milieu rural sénégalais, particulièrement dans la zone centre-Nord (donc sahélienne) où nous avons mené des enquêtes depuis trois ans.

En ne choisissant qu'une seule zone, nous avons conscience de ne pouvoir donner que des résultats partiels. Cependant, ceux-ci pourront être utilement comparés aux résultats des études similaires entreprises dans d'autres pays, et être vérifiés pour d'autres régions du Sénégal.

Nous aborderons brièvement les problèmes liés à l'interaction entre les techniques de production et le milieu, avant de nous consacrer à l'évaluation économique de quelques innovations.

Les Techniques de Production Agricole et leur Insertion dans le Milieu Physique et Humain

Technique de Production et le Milieu Physique

L'une des caractéristiques essentielles de l'agriculture est l'importance de l'influencé du milieu physique sur le processus de production. Ce phénomène est particulièrement visible dans nos milieux ruraux, où la capacité d'une superficie donnée de terre d'absorber les apports de capital et de travail dépend, dans une large mesure, de la quantité de facteurs limitants associés au sol. Cette remarque parait évidente, mais il semble utile de la répéter, car de fréquentes erreurs ont été commises sur ce point, et de nombreux échecs sont encore dûs à une insuffisante adaptation aux conditions physiques locales.

Technique de Production et Milieu Humain

Les relations qui unissent les techniques au milieu humain sont évidentes, mais souvent négligées. On a longtemps cru en effet, qu'il suffisait, pour diffuser des procédés et des équipements nouveaux, d'en prouver l'efficacité aux futurs utilisateurs et de leur faire des facilités; on s'aperçoit aujourd'hui, que de telles mesures sont insuffisantes. La lenteur de la diffusion des innovations et les difficultés rencontrées pour transformer les techniques d'exploitation montrent la nécessité d'adopter une démarche nouvelle intégrant l'agriculteur, ses traditions et son milieu social.

Deux postulats sous-tendent cette démarche:

- Le premier est que pour connaître un système il faut y introduire des changements pour appréhender son fonctionnement, ainsi que les motivations et les besoins des agents qui le composent.
- Le deuxième est que la modernisation des exploitations familiales ne peut être qu'un processus de longue durée, car il ne s'agit pas seulement d'adopter des innovations mais de changer les mentalités et les comportements.

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Interédependance des Techniques

En milieu traditionnel sénégalais, du fait du sous-emploi des facteurs et de leur faible combinaison, la perception de l'interdépendance des techniques est faible. Cependant, le système d'exploitation constitue un ensemble complexe où s'opèrent des échanges diverses (équipement, main-d'œuvre, usage de la terre, etc...), et dont la modification d'un des éléments peut entraîner des bouleversements.

L'introduction de certaines innovations et l'intensification agricole ont mis en évidence la liaison entre techniques:

- L'efficience de l'engrais nécessite un entretien des cultures et l'application de certains thèmes (ex. démariage pour le mil).
- L'introduction de la traction animale implique une meilleure alimentation des animaux, l'augmentation des ressources en eau et en fourrage.
- L'utilisation du semoir a permis l'augmentation des superficies, une modification des assolements, et la nécessité d'accroître la productivité du travail.

Ainsi il est apparu qu'une bonne vulgarisation doit se faire sous forme de "paquets techniques" cohérents et pratiquement réalisables et s'insérant dans le système de production.

Problèmes de Transfert de Technologie dans un Milieu Rural Sénégalais

Le Milieu Physique et Humain

Il s'agit de la zone centre-Nord, entièrement située dans la bande sahélienne. Le climat est donc sec durant 8 à 9 mois de l'année; la pluviométrie moyenne est environ 500 mm/an. Les sols sont à dominance dior (faible en argile). La population rurale, très importante, connait un mouvement intense particulièrement chez les jeunes.

Le carré, qui est l'unité de production, peut comporter un certain nombre de ménages indépendants constituant des sous-exploitations. Le chef de carré, propriétaire des principaux moyens de production, détient généralement le pouvoir de décision.

Les principales cultures sont le mil et l'arachide; les jachères tendent à disparaître et la progression des surfaces réservées aux cultures de diversification se fait de façon assez lente.

Les Innovations Proposées

Ces innovations ont pour but essentiel d'améliorer les rendements et d'augmenter la productivité du. travail. Elle concernent: les variétés, les techniques culturales, l'équipement, la diversification des spéculations et le système de production.

1. Les variétés proposées par la recherche sont des variétés amélioriées s'adaptant assez correctement au milieu.
2. Les principales techniques en vulgarisation sont les suivantes:
   — la préparation adéquate du sol (labour début de cycle avant céréale);
   — l'utilisation de la fumure minérale forte (150 kg/ha) et un phosphatage de fond, en système intensif;
   — le semis en bonne date;
   — le désherbage chimique de l'arachide et le démariage précoce (à trois pieds) du mil;
   — la restitution de la matière organique par le biais soit du fumier, soit de l'enfouissement des tiges de mil après récolte.
3. L'équipement proposé permet au paysan d'avoir une capacité de travail plus importante et de mieux entretenir les cultures.
4. La diversification des spéculations devra permetrre aux paysans de "minimiser" les risques et de diversifier leur source de revenus. A ce titre, il a été proposé l'intégration de l'élevage dans l'agriculture, par l'intermédiaire de l'embouche animale et l'augmentation des surfaces en cultures diverses. verses.

Des modèles simples et économiquement viables sont à l'étude.

Les Conditions de Diffusion des Innovations

L'encadrement des paysans et la vulgarisation des techniques sont assurés par une société autonome (SO.DE.VA.[1]), à côté d'autres services de l'agriculture.

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1. SO.DE.VA.: Société de Développement et de Vulgarisation Agricole.

Cette société intervient de plus en plus aussi bien au niveau de la distribution des facteurs de production, qu'au niveau de leur utilisation par les paysans.

Cependant des freins à l'adoption des thèmes techniques proposés existent, et une analyse approfondie de la situation a permis de déceler les principales contraintes.

Contraintes Techniques

Ces contraintes se situent à tous les niveaux:

- La formulation des propositions techniques de la recherche n'est pas toujours parfaite et les références technico-économiques sont parfois insuffisantes.
- La société de développement devient une machine lourde et l'information technique ne circule pas toujours du sommet à la base. Les relations avec la recherche sont ponctuelles et peu suivies, sauf en cas de projets spécifiques.
- Le travail et la technicité demandés aux paysans dépassent parfois leurs possibilités réelles et les limites d'un calendrier cultural très étroit (démariage précoce, labour de fin de cycle, fabrication de fumier, etc . . .).
- A tout cela il faut ajouter les contraintes écologiques qui augmentent les risques et diminuent l'efficacité de certaines innovations. Ainsi, plus on va vers le Nord, plus on constate une baisse de la productivité des engrais liée au climat et au sol.

Contraintes Humaines

Dans le cadre des méthodes de diffusion adoptées dans la région, l'organisation sociale de l'exploitation familiale, sans être un frein insurmontable à l'amélioration technique des systèmes de culture, ne permet pas de réaliser des investissements suffisants ni de stabiliser la main-d'œuvre qui est devenue une ressource rare à certaines périodes critiques.

Il faut, par ailleurs, noter que les objectifs des paysans ne sont pas toujours déterminés, et vont souvent à l'encontre des thèmes proposés.

Contraintes Economiques

La rapide monétarisation de l'agriculture sénégalaise et l'existence d'un circuit de commercialisation relativement satisfaisant de l'arachide ont conduit les paysans à pratiquer l'extensification en l'absence d'un progrès technique substantiel.

Ainsi, avec l'augmentation des populations, la rémunération du travail se déprécie, étant uniquement déterminée par la surface cultivée par actif. Les terres encore disponibles deviennent de plus en plus rares et les droits de jouissance individuelle s'opposent à la concentration des exploitations par absorption.

Les grandes exploitations qui de ce fait possèdent les revenus les plus élevés, adoptent plus facilement certaines techniques (herbicides, labour à façon, main-d'œuvre rétribuées pour certains travaux, etc . . .) et s'écartent des petites qui, endettées, acceptent difficilement des innovations chères ou non rentables immédiatement.

D'autre part, le système d'approvisionnement en facteur de production, les circuits de commercialisation de certains produits ne fonctionnent pas toujours sans présenter quelques défauts.

Les coopératives sont, par ailleurs, souvent bloquées par leur "taux d'endettement" alors que les paysans attendent le matériel commandé.

Dans tous les cas il est certain que la réussite d'actions de vulgarisation, même bien étudiées, reste pour l'instant essentiellement subordonnée à une bonne organisation de l'environnement économique des producteurs.

Evaluation de l'Impact des Techniques Vulgarisées

Les multiples contraintes citées plus haut ont conduit la recherche à se pencher sur l'étude des systèmes réels de production, et sur l'evaluation de l'effet des thèmes techniques en milieu paysan.

Il ne s'agit donc pas ici de "mesurer" le progrès technique des exploitations, mais surtout d'apprécier leur dynamique interne et de voir leur capacité de réaliser les innovations préconisées.

Méthode d'Approche

Deux types d'approche peuvent être considérés dans la zone; l'approche de la recherche au niveau de quelques exploitations particulièrement "suivies" et l'approche de la vulgarisation plus globale et plus lâche, s'étendant sur un échantillonnage plus vaste.

Pour le premier cas les enquêtes sont conçues pour la détermination des taux de pénétration des thèmes techniques, pour la deuxième il s'agit surtout de mesurer les différences entre les catégories d'exploitation selon leur degré d'intensification.

Les Types d'Enquêtes

Trois types d'enquêtes sont à distinguer :

- Les enquêtes sur la démographie, l'équipement en matériel agricole et les surfaces exploitées,
- Les enquêtes à caractère agronomique,
- Les enquêtes socio-économiques.

Méthodes d'Analyse

Les données du premier type d'enquêtes font l'objet d'un dépouillement synthétique permettant de caractériser les exploitations. Tandis que les autres enquêtes fournissent les éléments pour l'évaluation du degré de pénétration des thèmes et leur efficacité. A cet égard sont utilisés : l'analyse comparative, l'analyse factorielle, les régressions, et les comptes d'exploitations.

Analyse comparative (tableaux croisés). Le programme employé permet d'avoir quatre types de sorties présentant diverses combinaisons entre variables avec leurs caractéristiques statistiques.

Cette analyse nous a permis, entre autres, de juger de l'importance du statut social dans l'adoption des techniques au niveau de trois terroirs-test de la zone.

Ainsi l'arachide y est cultivée par tous les membres actifs de l'exploitation : chef de carré, chef de ménage, "sourga,"[2] "navétanes,"[3] femmes.

Les chefs de carré ne cultivent que 38% de la surface avec une moyenne de deux parcelles par chef de carré. Les parcelles cultivées par les femmes sont de dimensions beaucoup plus faibles que celles des autres membres de l'exploitation; 0,39 ha de moyenne, soit le quart de celles des chefs de carré.

Les rendements sont décroissants des chefs de carré aux femmes; les écarts types étant élevés, les différences ne sont pas significatives mais il est remarquable, cependant, qu'elles soient dans le même ordre pour les trois villages et concordent avec d'autres observations (Tableau 1).

Dans l'ensemble, il a été constaté que les techniques ne sont pas très différentes d'un statut à l'autre. Les plus grandes variations sont enregistrées au détriment des femmes et, dans une moindre mesure, des sourgas (Tableau 2).

Toutefois il ressort de l'étude des caractéristiques des parcelles par statut, la prééminence des chefs de carré par rapport aux autres membres de l'exploitation; ils ont un plus grand nombre de parcelles avec engrais et emploient les plus fortes doses (Tableau 3).

Analyse factorielle. Les variables de cette

2. "sourga": travailleur familial.
3. "navétane": travailleur saisonnier.

Tableau 1. Répartition par statut (terroirs test 1976).

Statut de l'exploitant	Nombre de parcelles	Surface moyenne des parcelles (ha)	Surface totale d'arachide (ha)	Surface (%)	Rendement (kg/ha)	Engrais (kg/ha)
Chef de carré	50	1,54	77,07	37,9	1309	60
Chef de ménage	17	1,27	21,58	10,6	1273	39
Sourga	78	0,74	57,91	28,5	1005	15
Navétane	15	0,89	13,37	6,6	1103	50
Femme	86	0,39	33,47	16,4	847	19
Ensemble	246	0,83	203,40	100	1077	31

Tableau 2. Techniques culturales par statut.

Statut de l'exploitant	Nombre de parcelles	Numero de pluie de semis	Parcelles binees 2 fois de plus (%)	Nombre moyen de binages	Nombre moyen de desherbages	Parcelles avec engrais (%)
Chef de carre	50	1,28	78	2,34	1,80	62
Chef de menage	17	1,18	76	2,59	1,41	41
Sourga	78	1.37	94	2,46	1,78	15
Navetane	15	1,00	66	2,07	1,67	53
Femme	86	1,69	58	1,91	1,86	21
Ensemble	246	1,43	75	2,23	1,78	29

Tableau 3. Utilisation da l'angrals par statut.

Statut de l'exploitant	Parcelles avec engrais (%)	Dose moyenne d'engrais (kg/ha)	Dose sur parcelle avec engrais (kg/ha)
Chef de carre	32	60	116
Chef de menage	41	39	95
Sourga	15	15	94
Navetane	53	50	94
Femme	21	19	89

étude ont été choisies en fonction des buts de l'analyse:

- Déterminer l'importance de l'action des principaux critères sur les résultats économiques des exploitations;
- Déterminer les effets de variation de dimension;
- Déterminer les niveaux d'intensification des exploitations concernées.

Quatre facteurs indépendants ont été mis en évidence pour expliquer la variance de l'ensemble des variables: la dimension (physique et économique), l'utilisation des facteurs de production, la productivité du sol et la productivité du travail.

L'analyse a permis de noter les faits suivants:

- Le système d'exploitation est purement extensif, la dimension étant un facteur très important pour la formation des revenus.
- Le sous-équipement apparaît surtout dans les exploitations de grande taille et les paysans les mieux équipés utilisent le mieux les autres inputs.
- La productivité du sol est peu importante, car les intrants ne sont pas employés à l'optimum; aussi la rémunération du travail se déprécie.

ANALYSE DE REGRESSIONS MULTIPLES. Cette méthode est utilisée en complément de la précédente. Comme on devrait s'y attendre, les variables explicatives du revenu sont essentiellement la surface cultivée par actif et la production en arachide.

Actuellement dans une grande partie de la zone, l'extensification présente un avantage certain sur l'intensification. Remarquons cependant que ces deux notions ne sont pas antagonistes; en cas de pénurie de terre l'intensification est nécessaire.

Bien que comptabilisé dans les mêmes conditions que l'arachide, la production de mil a peu d'effet sur la formation du revenu, le rendement étant faible au cours de l'année d'enquête.

Comptes d'exploitations. La méthode d'évaluation utilisée a pour objet essentiel de cerner la formation des revenus. Par souci de conseils individuels, elle exclut les problèmes de commercialisation et d'interférence avec les activités extra-agricoles.

Les productions céréalières (mil, sorgho) se trouvent incluses dans les calculs parce que les activités de production sont étroitement liées au sein de l'exploitation, et qu'elles font l'objet de transactions au niveau des villages.

Les paramètres quantitatifs (prix, charges, unités, travailleurs, etc . . .) sont appliqués dans tous les cas, afin d'obtenir des résultats permettant une comparaison, et éviter la prise en compte des multiples cas particuliers existant dans le milieu.

Deux aspects sont considérés: les comptes calculés et les comptes monétaires. Dans l'analyse des performances de systèmes de production on utilise souvent la première méthode, tandis que dans l'étude de la capacité d'accumulation, pouvant expliquer les progrès plus ou moins rapides d'un système, c'est la seconde qui est employée.

Pour comparer les systèmes de production, notamment quant à leurs productivités, on se sert des marges (brutes ou nettes) ou des valeurs ajoutées (brutes ou nettes).

Les résultats obtenus en 1975 et 1976 ont confirmé les remarques faites plus haut.

Malgré les meilleurs rendements en arachide, des petites exploitations et les doses d'engrais plus importantes épandues, leur produit brut reste faible.

Un examen des classes d'exploitations dans l'échantillon montre que les carrés varient de 3 à 27 ha (l'échantillon n'est pas représentatif de toute la zone si l'on considère les champs des marabouts).

La marge nette/actif est plus grande dans les carrés de 27 ha et la marge nette/ha est plus grande dans les carrés de 15 à 18 ha.

Les résultats des catégories d'exploitations en traction bovine ont montré que si la traction bovine est un élément favorable à l'augmentation de la dimension, elle doit, pour être rentable, s'intégrer dans un ensemble où tous les facteurs de production sont employés de façon rationnelle.

Résultats de Suivie d'Exploitations par la Vulgarisation (SO.DE.VA)

Dans le cadre de l'évaluation du programme agricole, la SO.DE.VA a suivi 162 exploitations de la zone.

Les critères de choix étaient les suivants:
- exploitations suivies par le système d'encadrement,
- facilité d'accès en toute saison,
- paysans favorables.

L'enquête a permis de mesurer les différences entre les catégories d'exploitations:

TL: thèmes légers
TB: traction bovine
TBFF: traction bovine, fumure forte

Deux faits importants peuvent être soulignés:

1. La supériorité des TBFF (au cours de l'année considérée, 1977) dans la production du mil[4] grâce à un meilleur équipement en houes et l'utilisation plus intensive de l'engrais. Ces critères techniques expliquent une supériorité des TBFF de 90 kg/ha.
2. Les équations de régression ont permis de calculer l'intérêt de l'extensification.

Dans les conditions de l'étude, le paysan moyen aurait intérêt à augmenter ses surfaces/actif jusqu'à 2, 2 ha pour le mil (moyenne 1, 0 ha) et jusqu'à 3,5 ha pour l'archide (moyenne 1,5 ha). Dans ce cas la production du mil augmenterait de moitié et la marge brute sur arachide s'accroitrait de 36.000 Frs au total.

Comparaison Globale des Résultats Economiques des Exploitations (TL-TB-TBFF)

La comparaison entre les trois types d'exploitation montre une différence nette des marges nettes par actif.

En prenant comme base le niveau TL (thèmes légers) on obtient les indices de marge nette suivants:

TL = 100
TB = 108
TBFF = 128

La différence entre TBFF et TL, provient à la fois des rendements en mil et arachide, de l'assolement et de l'équipement.

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4. 1977 étant une année de sécheresse, l'arachide a particulièrement souffert.

En effet, si l'on décompose la marge nette/actif on obtient les rapports TBFF/TL suivants:

marge brute arachide/actif	1,61
marge brute mil/actif	1,09
marge brute totale/actif	1,29
amortissement/actif	1,38
marge nette/actif	1,28

Conclusions

Nous avons abordé cet aspect tant important pour le développement de notre agriculture, qu'est l'introduction de techniques nouvelles, dans le but de poser le problème de son évaluation et de son impact en milieu paysan.

Cette analyse partielle nous a permis cependant de noter l'importance de l'environnement économique de l'agriculteur dans le processus de la modernisation des exploitations.

Au Sénégal, si la rentabilité de certaines techniques est démontrée, il reste encore à motiver le paysan au changement. Cette motivation a pour support essentiel l'accroissement du revenu monétaire et le surplus de produits.

D'où la nécessité de bien organiser la commercialisation de permettre aux coopératives d'exercer leur rôle véritable et d'assouplir le système de crédit.

L'analphabétisation reste un problème crucial pour une population rurale en croissance.

La pénurie de terre commence à se faire sentir, alors que toutes les méthodes d'approche concordent sur les caractéristiques suivantes:

- Le système d'exploitation des terres est purement extensif et le revenu est déterminé par la dimension.
- Les exploitations sont relativement sous-équipées.
- La productivité du sol est faible par le fait de la sous-utilisation des facteurs productifs.

Il s'agit donc de modifier les systèmes de production et de créer les conditions économiques pour la rentabilité de l'intensification.

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Participation Paysanne et Prise en Compte des Besoins des Catégories les plus Défavorisées (Quelques Ideés sur les Conditions de la Participation Paysanne à partir d'un Programme de Recherche)

Jacques Faye*

Le texte ci-dessus est provisoire. Nous avons saisi l'occasion que constitue le séminaire de l'ICRISAT sur le thème "les entraves socio-économiques au développement agricole dans les zones tropicales semi-arides" pour mettre sur papier quelques idées sur la participation paysanne.

Cette réflexion ne porte pour l'instant que sur un programme de recherche que nous avons mené dans les Unités Expérimentales du Sine-Saloum[1] au Sénégal de février 1974 à juillet 1976.[2] Nous comptons l'élargir progressivement à d'autres programmes internes et externes au Projet Unités Expérimentales. On nous excusera donc de l'aspect peu structuré du texte et du caractère sommaire de nos énoncés. Les exemples que nous donnons à l'appui servent plus à les illustrer qu'à faire une démonstration.

Le programme de recherche qui sert de prétexte à cette réflexion intitulé Programme Régime Foncier, avait les objectifs suivants:

- Faire une étude du droit foncier traditionnel et surtout de son évolution à la suite de la législation foncière votée en 1964 au Sénégal mais non appliquée, et cela dans les villages constituant les Unités Expérimentales et ceux environnants.
- Définir et expérimenter une meéthodologie d'aménagement et de remembrement des terroirs villageois utilisant des techniques et des méthodes peu coûteuses, à la portée des paysans et faisant appel à une large participation paysanne.
- Enfin, proposer les modalités pratiques d'application de la législation foncière, compte tenu des implications foncières des innovations techniques vulgarisées et du droit foncier traditionnel.

On peut dire qu'ils s'agissait de recherche-action ou de recherche-développement. On ne s'est pas contenté d'étudier le régime foncier d'une collectivité paysanne donnée mais on a, avec son accord et sa participation, introduit des modifications profondes dans ses manières d'utiliser l'espace et dans ses rapports avec le sol.[3]

Pour comprendre le caractère recherche-action du Programme Régime Foncier, il faut savoir qu'il est né de préoccupations essentiellement techniques qu'on peut résumer de la façon suivante:

— Dans le cadre d'une expérimentation de nouvelles techniques et façons culturales, les agronomes ont identifié, entre autres freins à l'adoption par les paysans des pratiques culturales nouvelles, le morcellement et la dispersion des parcelles de

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1. Les communications rédigées pour ce séminaire par MM. Moussa FALL et Michel BENOIT-CATTIN présentent le Projet Unités Expérimentales, nous y renvoyons les lecteurs.
2. Un chercheur géographe, M. Madické NIANG, a mené ce programme avec nous et divers chercheurs de l'Institut Sénégalais de Recherches Agricoles y ont plus ou moins participé. Pour une présentation globale du programme de recherche voir Faye et Niang (1977).

3. Trois terroirs villageois ont été aménagés et remembrés: un la première année, deux la deuxième année, soit au total 3.000 ha concernant 250 maîtres de terre.

culture, leurs formes inadaptées à la traction bovine, le caractère précaire des droits fonciers d'une proportion non négligeable de paysans.

C'est en cours d'élaboration d'un programme de recherches destiné à les étudier et à les lever que l'approche essentiellement technique a été élargie pour devenir une approche de type réforme foncière.

La Participation des Paysans dans le cadre du Programme de Recherche

Le programme posait donc doublement le problème de la participation des paysans:

- D'abord explicitement, puisqu'un des objectifs essentiels était de recourir à des techniques d'aménagement et de remembrement simples et peu coûteuses qui permettent la participation des paysans et qui, éventuellement, soient maîtrisables par eux. De même dans les propositions d'application de la loi foncière, le mode de gestion des terres et les structures de gestion devaient être confiés aux paysans.
- Ensuite implicitement, une intervention aussi importante au niveau foncier ne pouvait, de toutes façons, laisser les paysans indifférents.

Sans doute leur engagement pouvait aller de l'hostilité déclarée avec des actions ou des réactions violentes à la collaboration. Le non-engagement, l'indifférence, quelles qu'en soient les raisons, ne leur étaient pas permis.

Définition

Le sens étymologique du mot participer signifie "prendre part à quelque chose" et le dictionnaire Le Robert définit le mot participation comme l'adhésion, la collaboration, la contribution.

On peut certes soutenir que l'attitude du paysan, qui reste indifférent aux propositions techniques qui lui sont faites, n'est pas neutre, qu'elle est aussi une certaine façon de participer.

Dans une première étape au moins, nous préférons adopter la définition ci-dessus et nous essayerons maintenant, à la lumière du Programme Régime Foncier, d'examiner quelles sont les conditions qui permettent la participation des paysans à un programme de recherche les concernant.

Les Conditions de la Participation

Tenir Compte des Besoins et des Priorités des Paysans

Aujourd'hui cette condition est unanimement admise, les projets de développement et les programmes de recherche élaborés ces dernières années vont même plus loin puisqu'ils visent à "répondre aux besoins des paysans les plus pauvres."

Au démarrage du programme on pouvait s'attendre plutôt à une attitude négative des paysans dont l'opposition à la nouvelle législation foncière était générale.

La loi sur le domaine national votée depuis 10 ans (1964–1974) n'était appliqué que de façon occasionnelle.[4] De l'ensemble des textes législatifs, les populations rurales avaient retenu les idées suivantes: l'Etat s'appropriait les terres et reconnaissait un droit de culture à ceux qui les mettaient effectivement en valeur; les terres que leurs anciens maîtres ne pouvaient pas mettre en valeur, pouvaient être reprises et attribuées à d'autres cultivateurs. Ainsi, pour eux, non seulement l'Etat les dépossédait mais encore interdisait les prêts de terre, transférait les anciens prêts aux bénéficiaires qui étaient pour la plupart des "étrangers" qu'ils avaient accueillis et installés. Enfin, l'Etat voulait redistribuer leurs terres les empêchant ainsi de les transmettre à leurs descendants.

Pourtant ces aspects de la législation foncière ne touchaient que peu de paysans de cette région et presqu'uniquement quelques grands maîtres de terres et quelques groupes d'éleveurs peulhs.[5] Par contre, cette loi qui prevoyait aussi le regroupement des terres avait des aspects positifs pour la majorité.

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4. Les paysans continuaient et continuent à appliquer le droit coutumier, ce n'est qu'en cas de conflit grave ou quand une des parties en cause décidait de faire appel aux autorités administratives que la loi servait de référence pour le règlement du conflit.
5. Les peulhs constituent une ethnie qui se consacre essentiellement à l'élevage.

La première phase du travail de recherche a donc été de leur présenter les buts de notre programme pour obtenir leur adhésion. Au cours des assemblées de paysans que nous avons alors organisées quartier par quartier, leurs attitudes ont été pour la plupart hostiles au programme allant de la méfiance sourde à une hostilité ouverte: une des réunions s'étant même terminée par quelques injures. Les paysans semblaient se prononcer unanimement pour un rejet de la législation foncière et donc, pour un refus de toute recherche visant à son application. A partir de ces réactions nous avons essayé d'analyser et de comprendre les motivations et les préoccupations des populations.

Nous avons heureusement pu disposer dans cette analyse des études menées pendant deux ans par un anthropologue L. B. VENEMA et qui avaient porté entre autres, sur les structures sociales et la stratification du milieu rural, et aussi de la connaissance très approfondie que les vulgarisateurs avaient des quartiers où ils intervenaient.

Des entretiens collectifs et individuels ont été systématiquement menés de façon à cerner les attitudes des paysans et à les rapporter systématiquement aux catégories et groupes sociaux que L. B. VENEMA avait dégagé dans son étude.

Plutôt que de formuler tout de suite et de présenter aux paysans des propositions d'aménagement et de remembrement de leur terroir, nous leur avons proposé un accord contractuel:

- La recherche serait divisée en plusieurs étapes, chaque phase étant précédée de réunions collectives quartier par quartier, l'équipe de recherche présentant le travail accompli qui serait alors discuté. Les actions envisagées dans la phase suivante feraient l'objet d'une présentation et de discussion. Après chaque phase l'équipe s'engageait à ne poursuivre le programme que si les paysans approuvaient le travail fait dans l'étape précédente et donnaient leur accord pour la suivante.
- La première devait consister en dehors des études sur le droit foncier en l'établissement d'un cadastre du terroir. Les paysans devaient nous guider sur le terrain et régler les litiges suivant la législation foncière ou le droit coutumier.

Pendant cette première phase nous avons progressivement, compte tenu des préoccupations et des intérêts manifestés par les différents groups, élaboré des propositions d'aménagement et de remembrement du terroir. Les propositions étaient au fur et à mesure présentées aux paysans individuellement et en petits groupes de façon à étudier leurs réactions.

Une fois dissipée leur méfiance à l'égard de l'équipe de recherche, nous avons réussi à nous appuyer sur un certain nombre de paysans leaders de leurs groupes ou ayant une certaine influence pour relayer les propositions ou nous faire des contrepropositions.

Ainsi après l'établissement du cadastre, nous avons pu présenter et obtenir l'accord de la majorité des paysans de tous les quartiers sauf le quartier habité par l'ethnie peulh, sur un ensemble de propositions cohérentes de remembrement et d'aménagement du terroir et pour lesquelles les paysans s'engageaient à participer à leur réalisation sur le terrain.

La conclusion provisoire que nous tirons de cette partie du Programme Régime Foncier est que, dans un projet qui concerne l'ensemble d'une population rurale, il est indispensable de partir d'une analyse des structures et de la stratification sociale du milieu rural auquel on s'adresse. Les besoins et les priorités qu'on décèle dans le milieu doivent être référés aux catégories sociales et aux groupes sociaux qui composent la population rurale.

Ce n'est qu'à partir de cette analyse qu'on peut bâtir un programme et fixer des objectifs qui visent à satisfaire les besoins des catégories les plus pauvres.

Une fois cette analyse faite et une fois repérée les catégories les plus pauvres qui constituent en général la majorité dans les paysanneries du tiers-monde (des catégories étant situées dans leurs rapports avec les autres catégories sociales avec qui elles entretiennent des relations de dépendance et de domination), on peut bâtir un programme et fixer des objectifs qui visent à satisfaire leurs besoins. Cette condition nous paraît un préalable si on veut que les paysans participent et non subissent le projet. Ainsi la participation n'est pas une notion abstraite, c'est l'adhésion, la collaboration des groupes, dont le projet veut satisfaire les besoins.

Aider les Paysans les Plus Pauvres à Satisfaire Leurs Besoins

Dans une population, toute modification du système foncier concerne la totalité des gens: ceux qui ne cultivent plus parce qu'ils tiennent à transmettre la terre à leurs descendants, ceux qui cultivent, ceux qui ne cultivent pas encore parce qu'ils sont les futurs utilisateurs de cette terre.

Dans la mesure où le programme vise à aider les catégories les plus défavorisées, il a pour conséquence de modifier les rapports que les différents groupes et catégories sociaux entretiennent entre eux.

On doit donc s'attendre à ce que les groupes et les catégories les plus favorisés développent des stratégies visant à ce que des changements maintiennent ou renforcent leurs positions dans la hiérarchie sociale ou familiale et, dans le cas contraire, à refuser ces changements. Notamment les hommes par rapport aux femmes, les aînés par rapport aux cadets, les adultes par rapport aux jeunes, les paysans riches (paysans-commerçants, paysans-transporteurs) par rapport aux paysans pauvres, les membres du lignage fondateur du village par rapport aux lignages ou familles "étrangers," sont, grâce aux relations d'autorité, de clientèle, de domination et de dépendance qui les lient, mieux placés pour défendre leurs intérêts ou même utiliser le projet à leur profit. On peut donner quelques exemples:

- Des informations sur des conflits ayant éclaté à l'intérieur de certains carrés prouvent que des chefs d'exploitation ou des chefs de carré ont essayé, avec le remembrement, de déplacer des femmes ou des jeunes gens sur des parcelles de mauvaise qualité ou de réduire la taille de leurs parcelles; d'autres ont voulu s'approprier des champs gérés et cultivés par eux mais appartenant à des neveux ou des cadets encore sous leur dépendance. A l'inverse, certains cadets ont voulu en profiter pour imposer aux ainés qui géraient leur terres, un partage des terres familiales en parts égales contrairement au droit traditionnel qui privilégiaces derniers.
- Des maitres de terre ont essayé pendant les levées cadastraux, de récupérer des terres qu'ils avaient prêtées à des familles venues s'installer dans le village et parfois depuis plus de cinq ans et qui avec le temps seraient certainement devenues des dons.
- Les populations des quartiers voisins de celui des peulhs bien qu'opposées à toute idée de redistribution des terres pour ce qui les concernait, nous ont régulièrement incité e procéder à une redistribution des champs que les peulhs possédaient mais ne mettaient pas en culture.
- Dans les deux villages de l'Unité Expérimentale, nous nous sommes heurtés à cha qu e fois à la catégorie des paysans riches.[6] Sans s'opposer ouvertement au remembrement et aux aménagements proposés, ils ont systématiquement refusé les échanges de champs arguant que les leurs avaient déjà bonnes dimensions ou étaient plus fertiles. A trois reprises au moins, ils sont arrivés, en jouant sur les liens de clientèle et les solidarités familiales et lignagéres, à dresser les paysans contre nous, nous obligeant à arrêter les opérations de découpage des champs sur le terrain pour reprendre les discussions avec la collectivite.[7]

S'il ne s'agit pas pour le chercheur ou le développeur de se substituer aux groupes ou aux catégories sociales dont le projet vise à satisfaire les besoins on ne saurait pour autant se désintéresser de cet aspect et se contenter de proposer des innovations. Celles-ci peuvent toujours être confisquées ou contournées par un groupe ou une catégorie sociale au détriment des autres.

Une des tâches doit donc consister à aider les groupes dont on veut améliorer la situation matérielle en les mettant en situation de développer leurs propres stratégies de façon à modifier leur position sociale.

Nous avons utilisé pour cela plusieurs méthodes:

- D'abord la participation à la vie du village:

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6. Les paysans les désignent sous le vocable de "borom brake" (littéralement "ceux qui ont la barake"). Ils possédent en général de grandes surfaces et grâce à leur troupeaux de bœufs peuvent fumer leurs champs et les cultiver en céréales qui sont prêtées à des taux usuraires aux paysans pauvres en période de soudure. Ils ont en général des activités non agricoles: commerce et transport le plus souvent, et contrôlent les coopératives paysannes.
7. Un d'entre eux a réussi néanmoins à repousser d'un an, le lotissement du village de Thysse Kayemor.

longs séjours, participation aux cérémonies, visites dans les concessions, discussions sur la place du village, repas avec les paysans, menus services. Ainsi délibérément nous créeons des situations de dialogue pour les amener à s'exprimer spontanément.

- Reprendre systématiquement les problèmes soulevés par les groupes et leurs propositions pour les clarifier et les relayer aux autres groupes pour qu'ils se prononcent.
- Préparer les assemblées de quartier par des discussions informelles avec les leaders et les membres des différents groupes. L'expérience nous a montré que sans ces discussions préalables, les groupes et les catégories situées au bas de la hiérarchie sociale sont rarement en mesure de faire valoir leurs intérêts par suite de l'ordre de prise de parole, des relations d'autorité, de l'ordre de naissance, de l'âge, du sexe, etc . . .
- Dans ce travail d'animation pour aider les paysans à clarifier, à traduire leurs besoins en propositions d'actions, l'équipe de recherche doit veiller non pas à rester neutre, mais à n'être l'instrument d'aucun groupe. Cette attitude est d'autant plus difficile que les paysans pauvres ont tendance à adapter une attitude passive et à laisser l'équipe du projet s'opposer aux autres paysans dès l'instant qu'une proposition remet en cause les intérêts de ces derniers. Il peut paraître a priori surprenant de voir des paysans nous inciter à recourir aux autorités administratives ou pour contraindre un des leurs à accepter un échange de terre ou une rectification des limites de son champ, alors qu'eux-mêmes refusent de prendre publiquement position ou d'exercer une pression sur lui. Dans un cas, par exemple, où un riche chef de carré refusait une rectification de limite sous prétexte d'être lésé, il a fallu plus de deux heures de vives discussions pour que les villageois acceptent de désigner une commission chargée de vérifier sur le terrain, le bien fondé des arguments du chef de carré. Sans l'intervention des jeunes présents nous n'aurions pas eu gain de cause. En fait, il s'agissait d'un des usuriers du village.

Conclusion

Nous avons, en nous basant sur notre expérience, dégagé deux conditions essentielles à la participation paysanne:

- La première est de savoir qui on veut aider: quels groupes de paysans (les hommes et/ou les femmes et/ou les jeunes), quelles catégories (les paysans pauvres et/ou les paysans moyens et/ou les paysans riches), de façon à fixer au programme des objectifs qui correspondent aux besoins de ceux-ci. Pour cela nous avons dit qu'il fallait nécessairement partir d'une analyse de la structuration du milieu rural afin d'en identifier les différents groupes et les rapports qu'ils entretiennent.
- La deuxième est qu'il ne suffit pas que le programme repose sur une analyse de ce type; il faut, si on décide d'aider les couches les plus pauvres de la population rurale, avoir en tête que celles-ci ne sont pas pauvres par suite de retards technologiques mais parce qu elles se trouvent aussi, et surtout, dans toute une série de relations inégales qui les empêchent d'adopter les innovations proposées ou, quand elles les adoptent, d'en tirer bénéfice.

La recherche-action si elle veut obtenir l'adhésion et la collaboration des couches défavorisées, doit les aider à agir sur ses relations inégalitaires pour les changer.

On peut nous reprocher de raisonner comme si les collectivités rurales étaient isolées, alors qu'elles sont insérées dans tout un système de relations nationales et internationales qui, plus que leur structuration interne, sont facteurs d'inégalités.

Mais on voit bien que l'analyse peut facilement être élargie aux ensembles nationaux et internationaux. Simplement les analyses des systèmes politiques nationaux et internationaux sont souvent faites, alors qu'elles sont rarement au niveau des collectivités rurales même quand on se réfère aux groupes et aux couches pauvres ou défavorisées.

Référence Bibliographique

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Approche Socio-économique des Exploitations Agricoles

M. Benoît-Cattin*

La présente communication fait un certain nombre de propositions méthodologiques pour une recherche sur les exploitations agricoles conduite au sein d'une structure de recherche agronomique.

Ces propositions reposent essentiellement sur l'expérience de l'auteur, expérience acquise au Sénégal dans le cadre du projet "Unités Expérimentales" et antérieurement en Côte d'Ivoire (étude interdisciplinaire d'un terroir de la zone forestière).

L'objectif général de cette recherche est de comprendre la dynamique des exploitations agricoles, ceci afin d'expliquer leurs situations actuelles et de mieux saisir leurs devenirs potentiels. Il ne s'agit donc pas du suivi d'un projet de développement ni d'une enquête statistique.

La dynamique des exploitations agricoles est mise en relation avec l'innovation technique, les propositions techniques mises au point par la recherche agronomique. Cette recherche est donc un relais utile entre la recherche et le développement, mais elle est également utile aux recherches techniques dans l'identification, le choix et la manière d'étudier les problèmes (feed-back).

La méthode repose sur un choix raisonné de situations caractéristiques, en nombre limité pour être bien appréhendées. Elle privilégie l'exploitation agricole comme lieu où se prennent les décisions en rapport avec la production agricole. Ces décisions résultent, d'une part, des relations dialectiques entre une formation économique et sociale et un écosystème et, d'autre part, d'un contexte historique donné.

Ecosystème × Formation économique et sociale × Histoire

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Première Préoccupation du Chercheur

Le premier travail du chercheur sera une bibliographie générale. A travers les thèses et autres travaux sur la région concernée, il se documentera, entre autres, sur le processus de peuplement, sur les grands épisodes en relation avec la production agricole: guerres, conquêtes coloniales, économie de traite, etc...

A travers les projets de développement et leurs évaluations il s'informera sur les actions de développement passées, en cours, et projetées.

Le Choix des Lieux d'Investigation

Le lieu d'investigation du chercheur sera "le village." En pratique un chercheur peut intervenir au niveau de trois ou quatre villages en utilisant un ou deux enquêteurs par village. Au-delà il aura du mal à maîtriser son information surtout au début de ses travaux.

En général, le village est une entité administrative définie, mais dans la pratique on pourra s'intéresser à un village composé de plusieurs quartiers dispersés ou non dans l'espace ou à plusieurs villages entretenant entre eux certaines relations au sein d'une même coopérative ou d'un même terroir. Ces quartiers ou ces villages peuvent correspondre à des lignages, des ethnies, des castes différents.

Le choix de ces villages est très important et devra être fait en concertation avec toutes les personnes "connaissant" la région: administrateurs, chercheurs, développeurs, etc... (L'accord avec les développeurs évitera une contestation ultérieure de la "représentativité" des résultats.)

Les critères de choix seront relatifs à l'écosystème (pluie, sol, végétation, etc...) et à la formation économique et sociale: ancienneté et densité d'occupation (saturation foncière), ethnies différentes, proximité d'une ville, etc...

Les Investigations au Niveau du Village

Un certain nombre d'investigations permettent de vérifier et de mieux caractériser la représentativité des villages choisis et de préparer les autres investigations.
Le chercheur s'intéressera à:

- l'histoire du village et de ses quartiers,
- le régime foncier et l'utilisation de l'espace (élevage),
- les équipements collectifs,
- la coopérative,
- les relations avec l'extérieur (la ville voisine, les migrations, les échanges de produits, les transferts de revenus, etc...),
- les blocs de culture et autres aménagements en relation avec des projets de développement.

Les renseignements seront recueillis par entretien avec certaines personnes (chefs de village, notables, agents du développement, etc...).

Après recensement des unités de résidence, un recensement démographique exhaustif pourra être exécuté. Il permet d'obtenir des données plus précises sur les structures familiales, sur les migrations, sur les activités et revenus extra-agricoles, etc...

L'Unité de Résidence comme Unité d'Investigation

Sans préjuger de la correspondance entre exploitation agricole et unité de résidence, on retiendra cette dernière comme première unité d'investigation: elle est visible dans l'espace, socialement reconnue et organisée, relativement stable, etc...

Au Sénégal, c'est le "carré" ("keur" en wolof, "m'bind" en Serere) alors que les enquêtes ultérieures peuvent montrer qu'un carré peut grouper plusieurs exploitations.

Un système d'identification sera établi et repris sur toute feuille d'enquête ou de travail: anné, village, quartier, unité de résidence, ménage.

Compte tenu des investigations faites au niveau du village et de l'ensemble des unités de résidence, et des différentes situations mises en évidence (ethnie, caste, lignage, disponibilités foncières, ancienneté, système de culture et d'élevages, complexité interne, etc...), un choix raisonné pourra être fait pour les investigations de détail. Chaque enquêteur doit pouvoir suivre une dizaine d'unités de résidence.

L'Exploitation Agricole, son Identification, son Analyse

La localisation des analyses sur l'exploitation agricole est nécessaire car c'est, par définition, à son niveau que se matérialisent les relations: formation économique et sociale × écosystème par le biais de pratiques agricoles.

L'exploitation agricole est un système. L'étude de ce système et de son fonctionnement implique l'identification de ses éléments et l'analyse des relations entre ces éléments par rapport aux objectifs de ce système.

Dans une économie agricole en transition (de l'autosubsistance vers l'économie marchande), les objectifs du système agricole sont multiples. Si, comme pour tout système, son premier objectif est sa reproduction, cela correspond à la recherche de l'autosuffisance alimentaire mais aussi à la maîtrise du foncier. La plupart des autres objectifs (différents suivant les individus, leur statut) se résolvent, et de plus en plus, en besoins monétaires.

Les éléments du système peuvent être classés en:

anthropiques, biotiques et abiotiques et entretiennent des relations biunivoques:

é. anthropiques ↙↗ ↖↘
é. abiotiques ⟷ é. biotiques

Les relations entre ces trois catégories d'éléments seront identifiées et analysées, d'une part, au sein des unités de résidence choisies et, d'autre part, entre unités de résidence:

- relations entre éléments anthropiques: structures parentales, ménage, statuts et hiérarchie sociale, organisation du travail, échanges monétaires, endettement.
- relations entre éléments biotiques: rota-

tions, assolements, composition des troupeaux, élevages.

- relations entre éléments abiotiques: chaînes de matériel de culture.
- relations entre éléments anthropiques et biotiques: répartition des cultures et des animaux suivant les personnes et leurs statuts; consommation des produits agricoles.
- relations entre éléments anthropiques et abiotiques: répartition des terres, des outils, etc... suivant les personnes, leurs statuts, et le mode d'acquisition.
- relations entre éléments biotiques et abiotiques: les facteurs du rendement, la traction animale.

L'essentiel de ces relations se combinent au sein de l'organisation du travail agricole (au sens large): qui fait quoi, avec qui, sur la parcelle de qui... C'est précisément cette interdépendance complexe dans l'organisation du travail agricole qui permet d'identifier l'exploitation agricole.

La Parcelle Cultivée comme Lieu d'Observation

C'est au niveau de la parcelle cultivée que l'on peut observer la plupart des éléments énumérés ci-dessus et surtout leurs relations: appartenance de la parcelle, organisation du travail, utilisation du matériel et du cheptel de trait, pratiques culturales, etc...

Ces observations doivent être complétées par des observations au niveau de l'unité de résidence, puis des exploitations (une fois identifiées): démographie, migrations, activités et revenus extra agricoles, recensement des chaînes de culture (matériel et cheptel de trait), dépenses monétaires (endettement, consommation...), consommation des produits agricoles, etc...

L'Etude des Elevages

Celle-ci est tributaire de la même démarche générale. Les animaux sont des éléments biotiques à mettre en relation avec des éléments anthropiques (propriétaires, gestionnaires...), des éléments abiotiques (parcours, sous produits de récolte, fumures organiques de parcelles), que ce soit au sein des unités de résidence, au sein des villages et éventuellement entre villages (transhumances).

Il est important d'identifier les interférences entre systèmes d'élevages et systèmes d'exploitation agricole qui entretiennent des relations de complémentarité et/ou de concurrence determinantes pour le devenir de chacun d'eux.

Méthode d'Analyse des Observations

La quantification des observations n'est pas une fin en soi mais un moyen pour mieux qualifier les relations entre éléments. Ainsi, étudier des temps de travaux a peu d'intérêt en soi et, qui plus est, est très fastidieux et souvent décevant. Par contre, une fois connue l'organisation du travail, il peut être intéressant de préciser la nature de certains échanges (réciprocité, déséquilibre) en évaluant leur importance. Une estimation en demi-journées de travail est en général largement suffisante. Les mêmes observations pourraient être faites sur les enquêtes budgétaires.

On mentionnera pour mémoire les méthodes d'analyses statistiques (analyse factorielle, correspondances, régression, etc...). Celles-ci sont des instruments à la disposition du chercheur. Ils doivent être utilisés pour étudier tel ou tel problème et non l'inverse: collecter des données pour appliquer des méthodes existantes.

La présentation des relations entre éléments, quantifiées ou non, peut se faire de façon très pratique sous forme de matrice et ceci à toutes les étapes du travail (du premier dépouillement à la présentation finale). A partir de tableaux à double entrée de ce type, il est possible de quantifier, d'agréger, de hiérarchiser et de contrôler (recoupements, cases vides...).

La modélisation des exploitations agricoles est une représentation simplifiée d'une certaine catégorie d'exploitation en général pour pouvoir faire des opérations de simulation sur ordinateur.

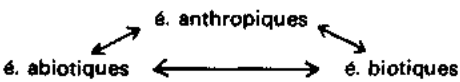
On souligne ici simplement que cette modélisation n'est possible, et en tout cas pertinente, que si les mécanismes de fonctionnement des exploitations agricoles sont bien connus, donc si les analyses évoquées ci-dessus ont été suffisamment poussées notamment en ce qui concerne l'insertion des innovations dans les systèmes de production. La modélisation implique l'utilisation de données normatives dont l'établissement est tributaire d'une méthodologie spécifique.

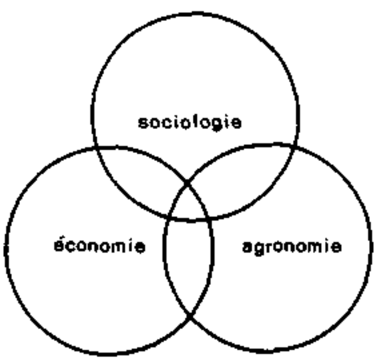
Remarques sur le Travail Interdisciplinaire

La nature des éléments du système d'exploitation et leurs relations est en principe du ressort de plusieurs disciplines scientifiques.

Cependant l'ensemble des analyses évoquées ci-dessus peut être réalisé par un chercheur de formation agronomique ayant acquis une certaine pratique de la socio-économie mais avec le risque de privilégier les éléments biotiques et abiotiques.

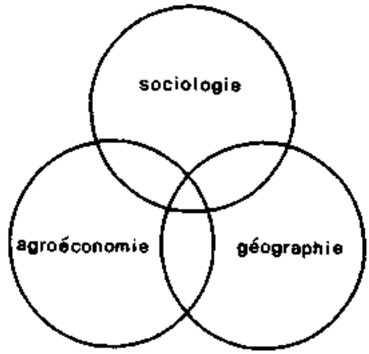
Par contre, une collaboration fructueuse peut s'instaurer entre deux ou trois chercheurs dont les spécialités dominantes seraient la sociologie, l'agronomie et l'économie.





Le recouvrement des sphères de chaque discipline illustre le non cloisonnement, l'interférence des approches.

Agronomie et économie étant souvent associées chez un même chercheur, un élargissement des préoccupations sera acquis par l'intégration de la géographie qui apporte une vue davantage spatiale des phénomènes ainsi que les techniques de représentation cartographiques.



Dans ces deux cas de travail interdisciplinaire, la problématique commune pourra être élargie à la dynamique de la société rurale. Le terrain commun sera les villages sélectionnés comme ci-dessus.

Un tel travail réellement interdisciplinaire semble difficile à plus de trois chercheurs car il implique un travail en commun effectif sur le terrain (et au bureau), des affinités de personnes, une certaine philosophie, etc . . .

Recherche et Action

L'originalité et la fécondité des travaux poursuivis depuis plus de 10 ans dans le cadre du projet Unités Expérimentales au Sénégal viennent de ce que analyses et actions ont toujours été associées. L'analyse des situations et de l'évolution guident les actions alors que les résultats des actions enrichissent les analyses dynamiques.

Au départ, l'objectif premier était de faire diffuser dans le milieu réel, et le plus rapidement possible, les innovations techniques mises au point par la recherche agronomique. Cette diffusion entraînait un certain nombre de corollaires concernant l'élevage, la coopération, la commercialisation des produits, la vulgarisation, le régime foncier, la gestion des exploitations agricoles, etc... Pour tous ces aspects ont été également associées analyses et actions.

Pour ce qui est de la gestion des exploitations agricoles, un grand nombre de travaux ont été conduits dont l'analyse a posteriori a fourni *l'essentiel des propositions méthodologiques* faites ci-dessus.

Pour ce qui est de l'action au niveau des exploitations agricoles, celle-ci a été progressivement organisée, structurée, pour déboucher sur une méthode de conseil de gestion d'exploitation. Cette méthode s'est améliorée parallèlement aux progrès des connaissances sur la dynamique des exploitations agricoles.

A l'heure actuelle le conseil de gestion plurlannuel focalise les actions de vulgarisation technique (tant pour l'agriculture que pour l'élevage) et fournit la matière première pour la poursuite des analyses sur la dynamique des exploitations agricoles.

Les recherches sur la dynamique des exploitations agricoles seront d'autant plus pertinentes qu'elles auront un minimum de durée et qu'il s'est passé et qu'il se passe quelque chose au sein de ces exploitations: on ne fait pas un film avec une photo.

Culture Attelée en Afrique Francophone

M. Le Moigne*

La culture attelée est assez ancienne. On s'accorde pour la dater de 1930. Mais, dans les stations et dans les secteurs administratifs, on la trouve dès 1926. A Madagascar on la fait même remonter à 1900. Donc phase de sensibilisation très longue et très diffuse.

Le démarrage de l'action de vulgarisation est beaucoup plus récente, postérieure à l'indépendance des Etats le plus souvent (1960–1962).

Elle se développe dans le cadre "d'opérations" ou de "projets," d'abord de production, plus tard de développement. Ceci est une caractéristique qui différentie profondément les actions francophones et anglophones. L'initiative, en début de projet relève plus de l'opération que de l'agriculteur lui-même. Le crédit lorsqu'il existe, la commercialisation des cultures uniquement monétaires, sont encadrés; dès lors l'agriculteur est très dépendant de cet environnement opérationnel.

Raccourci Historique

Initialement, tous les équipements introduits sont d'origine française : des charrues brabants à Madagascar (technique extrapolée directement à partir de l'agriculture européene), des charrues Bajac à versoir long, ou BOURGUIGNON à versoir court en Afrique de l'Ouest. Le matériel EBRA, plus hélicoidal dans ses formes est présent, HUARD également.

Mais il s'agit de petits marchés, passés à l'initiative d'administrations ou de centres de recherches.

Dans la plupart des cas, on prédétermine les techniques culturales en choisissant des outils de labour, car les cultivateurs et bineuses, lorsqu'ils existent (MANGA, GARD, PUZENAT, houe occidentale FABRE, etc . . .) sont rarissimes sur le terrain. Plus tard viendront des matériels d'origine yougoslave, japonaise ou soviétique.

Après l'indépendance des pays, la vulgarisation assurée par les services traditionnels de l'agriculture n'a qu'un impact limité car ses moyens matériels et en personnel sont faibles. De plus le travail est freiné par les difficultés d'approvisionnement. Les délais sont longs, les matériels commencent à disparaître des fabrications européennes et ceux qui restent ne sont pas nécessairement adaptés (généralement trop lourds pour la puissance disponible des attelages).

Plusieurs facteurs créent les conditions d'une implantation importante de la culture attelée, entre 1960 et 1965 approximativement.

Des industriels acceptent de poursuivre des fabrications pour la culture attelée (MOUZON, HUARD, BAJAC/CODAMM, etc . . .) en utilisant des brevets plus adaptés (rôle éminent d'inventeurs comme MM. NOLLE et BARIANI) et répondant aux cahiers des charges des centres d'études et de recherches, puis de les "transférer" en soutenant la première usine africaine (SISCOMA au Sénégal). Beaucoup plus tard, viendront celles du Cameroun (TROPIC), du Mali (SMECMA) . . .

La recherche agronomique, très puissante au Sénégal et à Madagascar, après des essais de techniques culturales et d'équipements, est en mesure de préconiser des systèmes techniques de production centrés sur le travail du sol (culture attelée lourde).

Un renforcement de la vulgarisation par le lancement d'opérations dites de "productivité" (riz, coton, arachide, etc . . .) financées par l'aide internationale dans les Etats permet de toucher des populations complètes.

Les Equipements Actuels

Les essais et adaptations ont été très nombreux durant près de 18 ans. On peut désormais les

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classer de façon quasi définitive en fonction de leur pénétration en vulgarisation.

Les Materiels Plutôt Spécifiques

- Les semoirs SISCOMA (ou SMECMA) simples ou jumelés, pour semis de l'arachide, des mils et sorgho, du maïs et du riz pluvial (moins utilisé). Ils dérivent des semoirs Super Eco FABRE. Une trémie est théoriquement réservée au coton.
- Les charrues de type Huard ou Codamm fabriquées par les différentes usines, de 10'', à corps cylindro-hélicoïdal le plus souvent.
- Les houes à traction asine ou équine SISCOMA et SMECMA (ex-Occidentale FABRE) pouvant être jumelées derrière une paire de bœufs. Leur fonction première est le sarclage; des "pointes griffon" peuvent leur donner plus d'aggressivité dans le travail.
- Les houes Manga, ayant plus une fonction de binage ou de travail du sol (genre cultivateur) que de sarclage.
- Les charrettes asines de 400 kg C.U., équines chargeant jusqu'à 1.000 kg, bovines de 1.500 kg, moins vulgarisées.

Les Matériels pour Travaux du Sol, Polyvalents ("Multiculteurs")

- Les séries basées sur brevets MOUZON/NOLLE, dont les plus connues sont les houes Sine 7 puis 9 (à des adaptations locales près) fabriquées dans toutes les usines pratiquement, et Ariana qui connaît un début d'expansion. Un bâti supporte les outils de sarclo-binage, les dents de cultivateur, la charrue, le(s) crops billonneur(s), la souleveuse d'arachide.
- La série basée sur brevets ARARA/BARIANI également fabriquée par l'ensemble des usines. Les définitions précédentes restent valables; ce matériel, souvent utilisé dans les opérations cotonnières, est considéré comme plus lourd que les Sine bien que les poids, fonction des équipements, soient assez proches les uns des autres.
- Les nouveaux "triangles" voltaïques dont les bâtis diffèrent de ceux des Sine, mais dont les définitions culturales sont proches.

Les Matériels de Grande Emprise

- Le polyculteur NOLLE qui n'a pas connu un grand développement bien qu'il soit muni d'un plateau charrette.
- Le Tropiculteur NOLLE, très peu vulgarisé.
- Le polyculteur à grand rendement Bambey-SISCOMA dont l'aire d'extension est limitée à une région du Sénégal. Il est équipé de semoirs classiques (type Super Eco).
- Le Tropisem LE LOUS actuellement expérimenté dans une autre région du Sénégal. Equipé de trois semoirs à rouleaux plastiques.

D'autres équipements ont été essayés, des variantes existent dans la liste précédente qu'il n'est pas utile de développer davantage.

Les limites techniques de la culture attelée actuelle apparaissent de fait:

- On peut labourer de l'ordre de 12 à 15 cm de profondeur.
- On peut semer la plupart des plantes annuelles (excepté le coton non délinté sans pralinage). Les plantations ne sont pas nécessaires.
- On peut sarcler ou biner suivant le cas, l'ensemble des cultures, et butter dans le cas du cotonnier.
- La récolte partielle de l'arachide (soulevage) est assurée.

Enfin le transport (eau et matériaux) peut être assuré, dans tous les cas, avec des charrettes fiables.

Les Recherches en Cours

- Semoir à coton non délinté.
- Forme spéciale de dent (Jumbo buster) permettant un travail en conditions plus sèches (donc l'allongement des temps disponibles).
- Matériel d'appoint herbicide qui ne relève déjà plus vraiment de la culture attelée.

Malgré cette diversité, des contraintes apparaissent dans les systèmes techniques basés sur la culture attelée:

- de temps, pour effectuer la préparation des sols en bonnes conditions;
- techniques, pour assurer des enfouissements de matière organique si nécessaire;
- de main-d'œuvre, pour compléter les sarclages mécaniques;

– de temps et de main-d'œuvre, lors de la récolte, du conditionnement ou de la transformation des produits.

Importance Relative de la Culture Attelée

Des chiffres souvent flatteurs sont cités pour caractériser l'implantation de la culture attelée en zone francophone d'Afrique de l'Ouest. On essaiera ci-dessous de les replacer dans leur contexte en les comparant aux superficies cultivées. La précision des recensements (notamment des surfaces cultivées en céréales ou en plantes à tubercules) est rarement de grande qualité. Il faut donc seulement voir dans la présentation de ces données une tentative pour multiplier les indicateurs et non une photographie exacte de la situation en 1977.

En Nord Côte d'Ivoire, 6.000 planteurs sont censés utiliser la culture attelée en 1977–78 (multiculteur) mais celle-ci marque un temps d'arrêt après un début d'expansion.

Au Togo la culture attelée est pratiquement inexistante; le chiffre de 800 attelées dans le Nord est fortement contesté.

Matériels de Culture Attelée et Exploitation

Le tableau suivant doit être aussi interprété prudemment. En effet, la notion même d'exploitation donne lieu à discussions et est difficile à traduire de façon générale. Nous ne retiendrons pas ici les distinctions basées sur l'organisation de la société (ex. patriarche, famille élargie, ménage) qui, si elle est étudiée, n'est pas

Tableau 1. Parc de matériels.

Matériel	Haute-Volta	Mali	Mauritanie	Niger	Sénégal	Tchad	Bénin
Charrues traction bovine	12 050						
Charrues asines	4 470						
Total charrues	16 520	106 700	2400 (?)	3000	8 000	58 056	7450
Multiculteurs	2 500	40 555		4300			185
					204 000	1 727	
Houes (traction asine, équine)	21 000	14 058		900			
Herses		10 739					
Semoirs		9 707	100 (?)	900	220 000		
Charrettes		52 204		3300	89 600	14 606	
Butteurs (butteurs, sarcleurs)				1500	5 000	(3 883)	
Souleveuses				3300	88 000		

Tableau 2. Matériels de culture attelée et superficies cultivées: densité "moyenne" (ha/unité de matériel).

Matériel	Haute-Volta	Mali	Niger	Sénégal	Tchad
Charrue	190	12	900	278	19
Multiculteur ou houe	160	31	690	11	199
Butteur				445	199
Herse		116			
Semoir	8800	129	3020	10	
Souleveuse			820	25	
Charrette	325	24	820	25	76

Tableau 3. Matériels de culture et superficie cultivée: densité particulière (zones encadrées de façon plus intensive) en cultures exondées (ha/unité de matériel).

Matériel	Zone cotonnière du Mali	Zone arachidière du Mali	Zone cotonnière du Sénégal	Zone arachidère du Sénégal	Zone de Maradi, Niger
Charrue	6		13	227	833
Multiculteur ou houe	15,4	64	25	6,5– 8,1	90
Butteur			13,4		111
Herse	386				
Semoir	373	71		3,9– 4,5	268
Souleveuse d'arachide				5,6– 6,7	310
Charrette	18	117		10,3–12,9	146
Paire de bœufs	15				
Ane	29				
Pulvérisateur à pression entretenue	4		3,6		

Tableau 4. Matériels de culture et superficie cultivée: Densité particulière sur aménagements (ha/unité de matériel)*.

Matériel	Opération Ségou, Mali (riz)	Office du Niger, Mali (riz)	Plaine de Kou, Haute-Volta (riz)	Ibohamane, Niger (sorgho/coton)
Charrue	3,6	6	1	6,8
Herse	14	10		
Corps butteur				6,8
Outil sarclage			1	
Faucille			1	
Batteuse à pédale			3	
Charrette	8,4	15		
Pulvérisateur			1	7,5

*Exemples très limités dans chaque pays.

vraiment recensée. Plus prosaïquement nous raisonnerons en terme de producteur d'une culture de rente, le seul qui soit connu dans les opérations car c'est celui qui vient vendre son produit et qui a un compte auprès de celles-ci (crédit) etc. Ce peut être le chef d'une grande famille, mais aussi un ménage. Les chiffres risquent donc d'être entachés d'une erreur par défaut: Malheureusement nous ne disposons pas de statistiques agricoles beaucoup plus précises.

Le développement de la culture attelée n'a pas été uniforme dans les pays; des régions

Tableau 5. Les matériels de culture attelée et exploitation (nombre d'exploitations/unité de matériel).

Matériel	Haute-Volta (ensemble du secteur agricole)	Mali	Niger	Sénégal
Charrue	55	2,8	160	38
Matériel de binage	46	7,4	42	1,5
Semoir	2500	31	500	1,4
Charrette	92	5,7	136	3

sont mieux équipées que d'autres. Néanmoins on peut être étonné qu'après d'aussi nombreuses années de sensibilisation et de vulgarisation, la situation "moyenne" ne soit pas meilleure. Ce qui nous conduit aux reflexions suivantes.

Données Conditionnant le Développement de la Culture Attelée

L'environnement agro-socio-économique et la conception de la vulgarisation en matière de culture attelée présentent des aspects positifs et négatifs qui peuvent expliquer l'expansion très lente de cette dernière, voire son ralentissement dans le développement des paysannats.

L'Augmentation Escomptable des Rendements

La recherche agronomique, très puissante par les moyens dont elle disposait (notamment au Sénégal, en Côte d'Ivoire, à Madagascar, etc . . .) a obtenu des résultats importants dans les domaines mettant l'équipement en jeu. S'il est permis de dissocier les facteurs du rendement, on peut dire que:

- La rapidité du semis peut entraîner des gains de 50% sur arachide et sorgho; le mil hâtif est moins sensible mais peut accuser des écarts de 20%. Le coton est particulièrement sensible à la date de semis. (Ces résultats apparaissent dans la fourchette suivante: semis à la date optimum/semis avec un mois de retard par rapport à cette date.)
- Les façons mécanisées d'entretien des cultures, correctement répétées, entraînent des gains de 50% sur arachide et jusqu'à 175% sur mil.
- Les travaux de préparation du sol ont donné lieu à des recherches multiples. R.
- NICOU (Institut de Recherches Agronomiques Tropicales) résume les résultats du Sénégal dans le tableau suivant.

Tableau 6. L'influence du labour sur les rendements des cultures au Sénégal.

Matériel	Effet du labour seul	Effet du labour d'enfouissement
Mil grain	+ 19%	+ 23%
Sorgho grain	+ 24%	+ 24%
Maïs grain	+ 50%	+ 73%
Riz pluvial	+103%	+112%
Cotonnier	+ 17%	+ 31%
Arachide	+ 24%	+ 9%

L'utilisation des pièces travaillantes de cultivateur est moins spectaculaire. Lorsqu'on prépare un sol sec, l'effet sur cotonnier est égal à la moitié de l'effet labour, il est faible sur arachide, mil, sorgho et maïs. En préparation de sol humide, l'effet est plus marqué puisqu'il égale 2/3 du labour sur cotonnier, 1/2 sur maïs, entre 1/4 et 1/5 sur arachide et sorgho.

On ne fait état ici que de résultats déjà publiés, ce qui ne veut pas dire, évidemment, que de telles façons culturales sont exclusives des autres. Nous ne disposons pas, malheureusement, de données aussi précises en matière de no-tillage ou de minimum tillage (par exemple).

Ces effets positifs des techniques culturales ne sont pas cumulatifs (on ne peut pas faire la somme des pourcentages précédents pour chiffrer le résultat global). Mais on peut, au moins, miser sur les résultants du travail du sol; en effet les essais réalisés associent des semis faits à une date correcte, des sarclages normaux, etc . . .

Il faut, en tous cas, retenir que l'application simultanée de telles techniques, permises par la culture attelée, entraine un accroissement de la production très significatif.

La "Dérive" Possible

On désigne par ce terme la différence inévitable entre résultats obtenus en station et application dans les exploitations réelles. Cette dérive n'est pas le seul fait des agriculteurs dont certains obtiennent d'excellents résultats.

Dans le chapitre précédent, la nécessité d'une application simultanée des facteurs de rendement a été soulignée. Or, la vulgarisation peut difficilement suivre cette démarche car elle s'adresse à une population hétérogène du point de vue technicité et réceptivité; par ailleurs, elle dispose rarement des moyens financiers et en personnel nécessités par une action technique tous azymuths. En conséquence, elle procède au coup par coup, thème par thème (ex. semis, puis sarclage, puis travail du sol). Les résultats obtenus sont inférieurs à la cible visée et il faut du temps pour que l'ensemble des techniques soit intégré par le paysan.

Enfin certains de ces thèmes sont imposés par des considérations agronomiques (ex. sole de régénération; assolement comportant des plantes non commercialisées) dont l'intérêt n'apparaît pas évident à l'agriculteur.

Aussi les aspects positifs de la culture attelée, liés aux rendements, sont pondérés dans leur application pratique; ce qui diminue d'autant la "motivation" de l'exploitant.

Les Contraintes du Système de Production

Elles constituent un point fondamental du développement de toute technologie nouvelle. Il est absolument nécessaire de déterminer les contraintes devant lesquelles se trouve un producteur, avant de lui proposer un ensemble de techniques, et de veiller à ce que celles-ci les fasse disparaître. Lorsque les contraintes sont masquées plus ou moins artificiellement, ou déplacées dans le système, on n'a pas résolu le problème et on peut s'attendre à des blocages. L'exemple suivant illustre ce propos pour la culture attelée.

Considérons des paysannats traditionnels ne pratiquant que la culture manuelle. Les chiffres suivants sont hétérogènes car ils caractérisent des pays différents donc des variantes dans les techniques. Mais ils situent le déroulement du travail.

Mettons en parallèle les données dans l'établissement du "modèle 4 S" par J. F. RICHARD et M. FALL (ISRA, Sénégal); ces données constituent le bilan le plus récent et le plus complet en matière de temps de travaux — au Sénégal — pour la culture attelée.

Tableau 8. Nombre d'heures/ha d'intervention manuelle nécessaires pour compléter le travail dans une exploitation complètement mécanisée en traction équine ou bovine.

Travail cultural	Arachide	Maïs	Mil	Coton
Rayonnage			24	6
Fumure	5	5	5	5
Semis			18	80
Désherbage	80			
Désherbage-démariage		80	100	100
Récolte		115	170	600

On peut discuter, bien sûr, la valeur exacte des chiffres présentés. Mais les ordres de grandeur subsistent. On en tire la comparaison suivante (Tableau 9).

En outre, il ne faut pas oublier que le bloc de travail en culture attelée comporte, de plus, des

Tableau 7. Temps de travaux exprimés en jours/ha pour les cultures conduites entièrement à la main par des hommes et des femmes.

	Arachide			Maïs	Mil		Coton	
	Côte d'Ivoire	Sénégal	Tchad	Côte d'Ivoire	Sénégal	Bénin	Côte d'Ivoire	Cameroun, RCA
Préparation du sol	40	15–20	10	40		13	8	15/20
Billonnage							20	
Fumure	10			2			5	
Semis	5	10	9	6	4	7	8	5/10
Resemis			1	1			2	
Sarclage	30	15	20	24	12	31	60	30
Démariage				5	2		5	3/4
Récolte	25	19		6	16	29	50	40/50

Tableau 9. Nombre de journées de travail nécessaire pour faire un bloc de travail (semis, sarclage, démariage) en culture manuelle et en culture attelée.

Culture	Culture manuelle pure (nombre de journées de travail nécessaire/ha)	Culture attelée élaborée (nombre de journées de travail manuel complémentaires nécessaires/ha)
Arachide	25–35	10–14
Maïs	36	10–14
Mil	18–38	18–24
Coton	38–75	24–32

journées de travail pour la conduite des attelages.

En culture manuelle, on le sait, les exploitations sont réduites en superficies; ces dernières correspondant à la capacité de travail des exploitations. Le principal problème posé y est celui de la mise en place et de l'entretien des cultures. En introduisant la culture attelée on a donné aux agriculteurs le moyen d'étendre les surfaces, sans supprimer la contrainte précédente qui demeure extrêmement forte à l'unité de surface.

On a en quelque sorte masqué le problème. Car les chiffres précédents montrent que seules les exploitations disposant d'une réserve de main-d'œuvre peuvent étendre leur superficie et utiliser avec profit leur culture attelée.

En matière de travail du sol, on a bien augmenté la productivité du travail par l'introduction de la charrue et du canadien, mais pour résoudre un problème créé par l'utilisation de ces nouvelles techniques.

Enfin (et heureusement) on a fait croître les rendements, augmentant ainsi l'appel à la main-d'œuvre pour la récolte. Ce problème n'a pas été résolu: on l'a déplacé dans le temps.

Les Normes d'Equipement

La nécessité de faire "cadrer" les différents moyens de production dans l'exploitation est bien apparue au Sénégal à partir de 1967. Les études menées sur "modèles" théoriques à Bambey, puis sur modèles pratiquement installés sur le terrain, enfin dans le cadre de paysannats particulièrement suivis par la recherche agronomique (Unités Expérimentales du Sénégal), ont permis de préciser les limites à ne pas dépasser pour l'utilisation des unités de culture attelée. Ces normes constituent de bons indicateurs pour la zone sahélo-soudanienne à une saison des pluies et pour des cultures équilibrées dans l'assolement, de type mil, sorgho, arachide, coton, maïs, voire riz pluvial.

M. BENOIT-CATTIN les résume ainsi in 1977:

- 1 semoir pour 4 ha
- 1 houe Sine pour 3,5 à 4 ha (suivant le modèle choisi)
- 1 houe occidentale pour 3 ha
- 1 charrue pour 1,5 ha à labourer
- 1 *souleveuse d'arachide pour 4 ha* d'arachide et par paire de bœufs
- 1 corps butteur pour 2 ha (et par paire), en maïs/coton
- 1 multiculteur Arara pour 4 ha et par paire de bœufs
- 1 multiculteur Ariana pour 6 ha et par paire de bœufs
- 1 Ariana + 1 houe Sine pour 6 + 4 ha
- 1 Polyculteur à grand rendement pour 8–10 ha

En capacité de traction rapportée à la surface et pour des systèmes techniques de production semblables:

- 1 âne pour 2,5 ha
- 1 cheval pour 2,5–3,5 ha (selon l'âge)
- 1 paire de bœufs pour 3–6 ha (selon l'âge)
- 1 paire de vaches pour 4 ha
- 1 paire de bœufs très forts pour # 8 ha

Ces normes se trouvent d'ailleurs assez bien approchées dans les différentes zones africaines où la culture attelée est soigneusement encadrée.

Mais, par prudence et pour éliminer le "piège" main d'-œuvre illustré précédemment, nous ajouterons la recommandation suivante: dans la définition actuelle de la culture attelée, la constitution des familles concernées par ces mises en place doit être telle que l'on approche le nombre de 1 actif/ha.

La Conjoncture Economique Défavorable

Elle s'est répercutée directement sur la culture attelée freinant son expansion. On soulignera les aspects suivants:

- L'augmentation des prix du matériel face à une relative stagnation des prix aux producteurs ,(excepté peut-être en Côte d'Ivoire). Ainsi au Mali, en 3 ans les multiculteurs ont vu leur prix augmenter de 177%, les charrues de 101%, les charrettes de 86%.
- L'augmentation du prix des animaux de trait liée à la diminution des troupeaux du Nord (sécheresse) et à la concurrence de la boucherie. Il n'est pas rare désormais de voir des paires de bœufs atteindre 150.000 F CFA et des ânes coûter 18.000 à 20.000 F CFA, le premier représentant la récolte de 3 ha de céréales, le second près de 1/2 ha.
- L'encadrement du crédit, lorsqu'il existe, qui reste sélectif. Tous les matériels ne peuvent pas en bénéficier (cas de la charrette en particulier) et les animaux de traction sont rarement concernés.
- La commercialisation officielle centrée uniquement sur les cultures dites monétaires (coton, arachide). Le riz bénéficie d'une situation particulière dans les zones spécifiques mais ceci ne suffit pas. Dans les régions d'expansion de la culture attelée on ne peut pas vraiment tabler sur un revenu procuré par les céréales traditionnelles. Il faut alors payer les intrants sur le coton ou l'arachide.

Conclusions

Nous ne souhaitons pas paraître pessimistes sur l'avenir de la culture attelée en Afrique, en exposant ainsi des problèmes qui se posent actuellement. Lorsqu'on constate que la courbe d'équipement du Mali (rigoureusement engagé dans l'option culture attelée) s'infléchit, que la jeune expérience ivoirienne stagne, il est nécessaire de prendre le temps de la réflexion.

Et ceci d'autant plus que la situation des bonnes exploitations mécanisées est saine. Il n'est pas rare d'observer des marges brutes/ha (valorisées aux prix du marché ou monétarisées dans les opérations) comprises entre 60.000 et 100.000 F CFA/ha, et une production de vivriers sur 50% des surfaces assurant autoconsommation et stocks.

Parmi les facteurs négatifs, certains sont d'ordre politique (prix, commercialisation . . .) et le technicien ne peut les infléchir. D'autres, par contre, sont liés au système de production sur lequel il peut agir. Pour ce faire, il convient de raisonner à partir de deux idées simples:

- La culture attelée présente un ensemble de solutions techniques mais reste de toutes façons limitée: certains secteurs d'activité agricole ne seront jamais assurés par elle. Il faut donc la concevoir, associée d'entrée de jeu à d'autres solutions techniques. Ainsi les sarclages nous obligent à penser aux herbicides. Les solutions sectorielles motorisées pour la récolte et le traitement des produits apparaissent nécessaires, entraînant à leur suite un renforcement des moyens de transport. Les problèmes ainsi soulevés ne sont pas vraiment techniques. Ils sont liés au milieu qu'il faut d'abord connaître, et dans lequel il faut rechercher les structures possibles d'accueil (paysan entrepreneur, petits groupements, etc . . . pour les solutions mécanisées. Et il va de soi qu'il faut abandonner certaines attitudes technocratiques tendant à faire adopter systématiquement par les agriculteurs, des solutions utilisées en pays industrialisés. Si le Mali voit ses forgerons développer leur implantation, c'est bien parce que leur "définition" et leur mode d'action ont été décidés par les villages eux-mêmes.
- Les exploitations agricoles sont des systèmes de production diversifiés à l'infini et dynamiques. Ceci est incompatible avec les idées de standardisation ou de conformité à des modèles mathématiques préétablis. Ces derniers sont bien utiles, comme outils de travail, pour envisager diverses variantes dans le jeu des facteurs de production, mais leur rôle doit s'arrêter là.

Pour aider une exploitation à se développer, il faut analyser ses problèmes dans l'état où elle se trouve et lui conseiller progressivement les solutions qui lui sont propres.

Ceci atténue l'attrait des "chaines" complètes de culture attelée. En phase de démarrage il peut être plus intéressant pour un producteur d'acheter seulement une bineuse et non la totalité de l'équipement; mais il est aussi possible que la bonne solution réside dans une poursuite provisoire de la culture avec utilisation des herbicides. Enfin, paradoxalement, il est fort possible que le développement de la culture attelée dans certaines zones, passe d'abord par l'introduction de matériels motorisés au niveau de la récolte ou du traitement des produits.

En conclusion, il nous semble nécessaire que les options soient parfois infléchies dans deux activités clefs qui conditionnent l'avenir de la culture attelée:

- La recherche en tous genres: diversification dans la prospection des problèmes, donc dans des solutions, plutôt que construction complète de quelques systèmes de production; ces derniers, à terme, apparaîtront comme des placages artificiels entraînant des phénomènes de rejet, ou seront modifiés par l'exploitant (hypothèse la meilleure mais faisant perdre du temps).
- La vulgarisation: travail plus rapproché de l'exploitation individuelle et véritable conseil de gestion, plutôt qu'organe de diffusion d'intrants agricoles.

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Appendix 2

List of Country Papers

List of Country Papers

Appendix 3

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