Potential Technologies for Deep Black Soils in Relatively Dependable Rainfall Regions of India[*]

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INTRODUCTION

The tropical dry climates are characterized by a high incidence of solar radiation, high temperatures and unreliable rainfall. Droughts and floods are both common occurrences. Deficient rainfall years may be followed by similar years of years with excess rainfall in no predictable pattern.

Rainfed farming is risky in such conditions and farmers are reluctant to invest to increase crop production. Traditional agriculture means low but stable yields, low inputs, mixed cropping, low incomes and outmigration of family members on both a seasonal and permanent basis. Traditional agriculture in the dry tropics is designed to reduce the risks of losses in dry years because they can be very severe. The benefits that could accrue in good years are usually lost. Until recently, much of the effort to create new improved technology for the region was designed to remove the risk of loss in dry years so that farmers will invest more in anticipation of good years. Another approach adopted by ICRISAT aims to make use of the potential of good years without increasing production risk. Technology options have been developed which are especially suited to the deep black soil regions of India.

The deep black soils of India cover 73 million hectares ; about 28 million hectares of these are true Vertisols, soils at least 50 cm deep. with more than 35%

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clay, with wide and deep cracks when the soils are dry. About 80% of the Vertisols in India lie in the states of Maharashtra, Madhya Pradesh, Gujarat and Andhra Pradesh, 13% in the states of Karnataka and Tamil Nadu, and the rest in the other states (Murthy et al 1982). Most of these soils lie in the seasonally dry climatic belt in which the rainy seasons is short (with only 2-4.5 wet months) and rainfed farmig is generally practised. In most of the deep black soil areas the land is left fallow during the monsoon and crops are only sown as the rains subside and ripen on residual moisture stored in the soil.

Virmani et al. (1981) have divided the Vertisol region of India into two climatic sub-regions: (1) areas with relatively dependable rainfall—generally with a mean annual rainfall above 750 mm and (2) areas with relatively undependable rainfall—generally with a mean annual rainfall below 750 mm.

In the technology described in this paper dry seeding is an important component and is intended to enable an extra crop to be grown in the rainy season on the lands presently left fallow. For it to be successful the early rains must be reasonably dependable. Hence as a general rule this technology is best suited for the dependable rainfall deep Vertisol sub-region, with mean annual rainfall greater than 750 mm (Fig. 1). Furthermore, the soils must generally be one meter or more deep so that their water holding capacity is sufficient to give two crops in a year without irrigation.

We have not yet estimated accurately the area to which this technology is suited, but it is at the least 5 and may be as much as 12 million hectares. The technology is not yet ready for adoption on all this vast area of land. It is ready for pilot scale, on-farm trials. Government agencies are conducting such trials this year near the villages of Begumganj (Raisen District) and Gehun Kheda (Guna District) in Madhya Pradesh, Farhatabad near Gulbarga in Karnataka, and at Tadanpalle/Sultanpur (Medak District) in Andhra Pradesh. These pilot-scale projects will help identify strengths and weaknesses in the technology and clarify the policy issues that must be resolved before the technology can begin to be transferred more widely.

SOME CHARACTERISTICS OF THE HIGH POTENTIAL REGION

In the three states of Andhra Pradesh, Madhya Pradesh, and Maharashtra where the potential for the technology options is greatest (Fig. 1), operational holdings are significantly larger than the All-India average of 2 hectares (Table 1). The proportion of small farms (less than 2 ha) in these three states is 67, 51 and 46%, respectively, compared to 73% for India. The holdings are smaller in Andhra Pradesh than in the other two states because it has more irrigation (24.4%) than either Madhya Pradesh (7.9%) or Maharashtra (6.8%)[1]. In the particular districts identified in these states as having the largest proportions of the rainy-season fallows, the extent of irrigation is even less than the overall state averages. Ryan and Ghodake (1980) found in six Maharashtra and Andhra Pradesh villages that annual average involuntary unemployment rates were 0.20 and 0.26 for males

1. *Source:* Govt. of India (1976, P. 43). Data refer to 1970-71

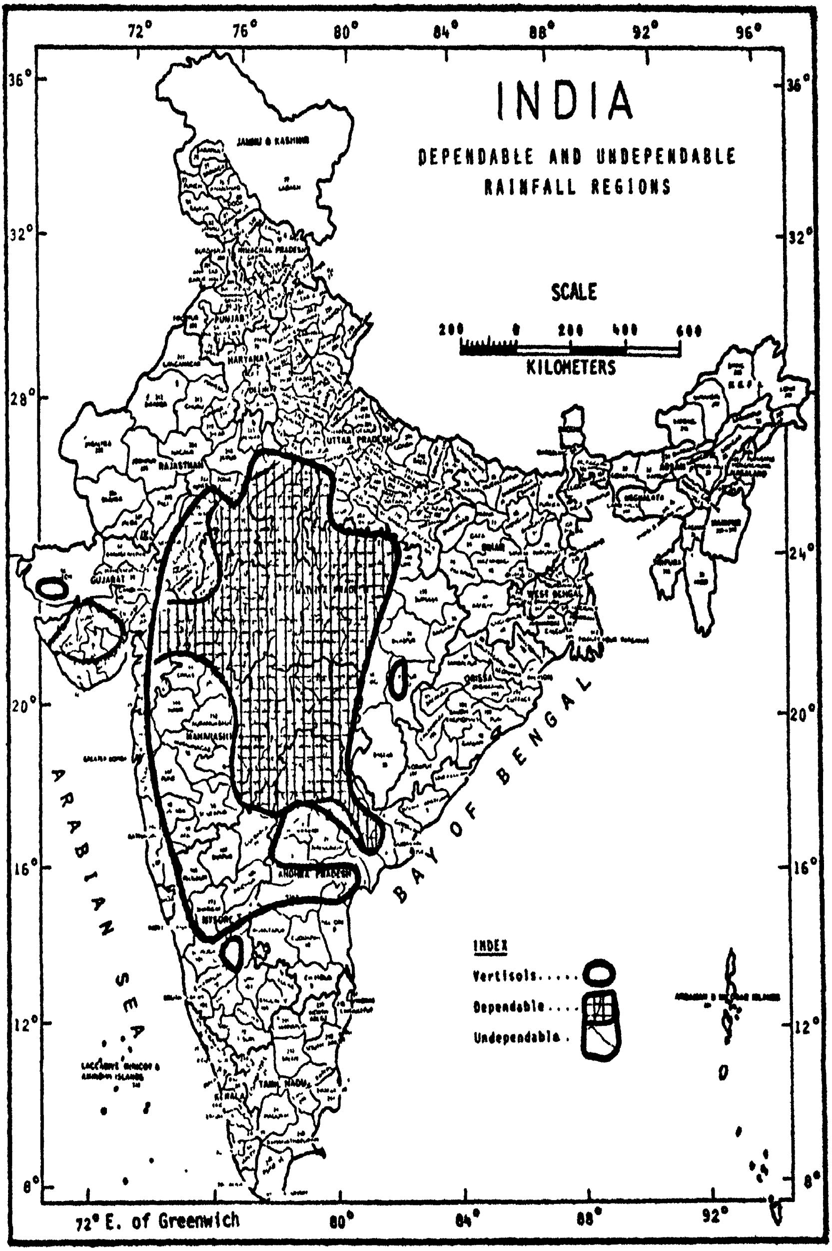

Figure 1 . The Vertisol areas of India where rainfall is dependable and undependable.

and females, respectively. Thus the potential exists to employ underutilized resources of unirrigated land and labor to enhance productivity and incomes of farmers and agricultural laborers. However increasing labor demands in the peak season should be avoided lest farmers fail to adopt technologies due to lack of available labor.

Generally more than 60% of the cropped area is left fallow during the rainy season in these high potential regions. The major crops sown in the postrainy season are wheat, chickpea, sorghum and safflower. Average yields of these crops in the three states are generally quite low (Table 2) and indicate the potential for improvement that exists. Cropping intensities are also low. For example in Vidisha, Raisen, and Sehore Districts of Madhya Pradesh, cropping intensity was only 102% in 1973-75.[1] Adoption of the technology options detailed later will enable cropping intensities to reach 200%.

Where rainy-season crops are grown they include paddy in low lying areas or under irrigation, sorghum, pigeonpea, maize, and minor millets on shallower or less clayey soils. An increasing amount of soybeans are being grown on the deeper black soils in Madhya Pradesh where adequate drainage and access to irrigation ensure that the regular postrainy season wheat crop is not affected by being preceded by soybeans.

Table 1. Proportion of operational holdings in various size classes, 1976-77[a]

Operational holding size (ha)	States			All-India
	Andhra Pradesh	Madhya Pradesh	Maharashtra	
	%			
< 1	46 6	32.6	26.1	54.6
1 < 2	20.4	18.1	19.8	18.0
2 < 4	17.4	20.9	23.2	14.3
4 < 10	12.2	20.9	23.5	10.1
> 10	3.4	7.5	7.4	3.0
Total	100	100	100	100
Average size of operational holdings (ha)	2.34	3.60	3.66	2.00

[a]*Source :* Agricultural Census XXII (1981).

[1]*Source :* Government of Madhya Pradesh (Various years)

Table 2. Average yields (kg/ha) of postrainy season crops in three states, 1975-78[a]

Crop	States		
	Andhra Pradesh	Madhya Pradesh	Maharashtra
Postrainy season sorghum	543	703	455
Wheat	703	821	881
Chickpea	355	543	344
Safflower	229	185	343

a. *Source*. Directorate of Economics and Statistics (various years)

In 1977-78, Madhya Pradesh had 9.62 tractors per 10,000 hectares of net sown area, and Andhra Pradesh had 11.78. There were in addition 0.51 bullocks per hectare of net sown area in Madhya Pradesh and 0.53 in Andhra Pradesh[1] Ryan and Sarin (1981) have estimated that in 1974-75 in six of the high potential districts in Madhya Pradesh where the new technology options should perform well the number of tractors available provided the equivalent of 0.30 bullocks per hectare, whereas for the whole of Madhya Pradesh tractors provided only the equivalent of 0.04 bullocks per hectare. This suggests that draft availability in these regions may be greater than in some of the other semi-arid tropical (SAT) regions of India where we have been working. Figures of only 0.13 bullocks/ha were found in two villages in Sholapur, Maharashtra, 0.25 in two villages in Akola, Maharashtra and 0.38 in Mahbubnagar, Andhra Pradesh. Hence the high potential Vertisol assured rainfall region would seem to have the draft power necessary to implement the technology options being evaluated in the pilot projects.

Average incomes in the SAT regions of India are generally well below those in other areas In the period (1975-78, Singh et al 1982, pp. 3-4) found that in six villages in Maharashtra and Andhra Pradesh annual mean net household incomes ranged between Rs. 1942 and Rs. 3856, with an overall average of Rs. 2842. Per caput the figures varied between Rs. 317 and Rs. 627 per year, and averaged Rs. 483. Singh et al. (1982, p. 4) point out that the average figure represents less than one-half of the All-India per caput income estimate of Rs. 1080 for 1977, and are 70% of the official poverty line of Rs. 700 per caput. The average rates of return to owned farm capital, land and management on farms in these same villages were estimated by the authors at 3.6% per year (p. 23). This is meager by any standards and indicates that even though rainfall is somewhat more dependable in the high potential Vertisol regions, to date this has not been translated into substantial income advantages.

DEVELOPMENT AND PERFORMANCE OF THE TECHNOLOGY AT ICRISAT CENTER

Since 1974 research has been conducted at ICRISAT Center, Patancheru, on operational-scale, deep black Vertisol watersheds and subwatersheds from 1 to 5

1. *Source:* Directorate of Economics and Statistics (Various years)

hectares in size to enable crops to be profitably grown both in the rainy and post-rainy seasons.

The technology options that ICRISAT has developed for the management of deep block soils are of a moderate-input nature based on bullock power and within reach of the small farmer in the rainfed SAT. They are based on the concept of the small watershed as the basic resource management unit. They are technology options that will create employment, and are therefore socially relevant.

The components of the technology are :

- cultivating the land immediately after the previous postrainy season crop when the soil still contains some moisture and is not too hard;
- improved drainage with the aid of field and community channels and the use of graded broadbeds and furrows;
- dry seeding of crops before the monsoon rains arrive;
- the use of improved seeds and moderate amounts of fertilizers;
- improved crop mixtures and row arrangements;
- improved placement of seeds and fertilizers for better crop stands, and finally
- attention to improved plant protection, particularly for the legume crops[1]

Synergistic Effects of Different Components of Technology

The system consists of bringing together several components of improved technology recognizing that the improvement of any one component may have a small effect on production, but the combination of all the components produces spectacular results. For any cropping system, the three components that have produced the most significant synergistic effects are :

1. High-yielding varieties and fertilizers : use of sorghum or maize HYVs in a sequential cropping or intercropping system with legumes such as pigeonpea and chickpea and adequate NPK fertilizers and manures.
2. Land and water management: using improved drainage based on watershed concept and a broadbed and furrow (BBF) system on a 0.4 to 0.6% grade; dry seeding of crops in anticipation of rain.
3. Crop management : good weed and pest control.

Results for a maize/pigeonpea intercrop system using local varieties under rainfed conditions gave maize yields of 600 kg/ha when factors 2 and 3 above were combined together (Table 3). The yield responses were more marked when the fertilizer-, soil-, and crop-management systems were all used with high yielding varieties (3470 kg/ha). Thus, for optimum crop production from Vertisols under rainfed conditions, improvements in land, water, and crop management, use of

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1 For more details about the technical, economic, and policy aspects of the technology the reader is referred to ICRISAT (1981).

Table 3. Synergistic effect of variety, soil management and fertilizer application in a maize/pigeonpea intercropping system on a Vertisol at ICRISAT Center, Patancheru, A.P., India, 1976-77

Treatment	Yields (kg/ha)	
	Maize	Pigeonpea[a]
Maize variety: *Local*		
Traditional inputs and Management	450	320
With improved soil-, and crop-managemet alone	600	614
With fertilizer application alone	1900	452
With improved soil-crop management and fertilizer	2610	837
Maize variety: *improved/hybrid*		
Traditional inputs and management	630	500
With improved soil-, and crop-management alone	960	640
With fertilizer alone	2220	540
With improved soil-crop management and fertilizer	3470	604
C. D. (5%)	470	218

a. Pigeonpea variety was the same in both cases

fertilizers, improved implements to carry out dry seeding and laying out the broadbeds and furrows, should all be combined. However, synergistic effects can be obtained when two or more factors are applied in combination.

The two-crop system described above has performed extremely well at ICRISAT Center. Total crop yields from 1976/77 to 1980/81 from the improved system were 4074, 4131, 3311, and 3886 kg/ha respectively. This means an average yield of over 3.8 tons of foodgrain production per hectare per year was achieved without the use of irrigation. Economic analyses of these experiments have been made by Ryan and Sarin (1981) and the results are shown in Table 4. The improved system generated annual profits averaging Rs. 3650 per hectare, compared with only Rs. 500 per hectare from the simulated traditional system. The ICRISAT Center study suggests that for an extra annual operational cost of Rs. 1200 per hectare, a farmer changing from the traditional to the improved system can earn an additional profit of about Rs. 3100 per hectare. This represents a rate of return on the increasing operating expenditure of 250%—a highly attractive economic proposition.

Risk in an extremely important consideration in designing and recommending new technologies, especially in the rainfed agricultural regions of India. The analysis suggests that the improved technologies increase profit variability, as measured by the standard deviation of gross profits in rupees across both years and fields (Table 4). However, the improved technologies reduce variability of profits when variability is expressed as a percentage of average profits, or the coefficient of variation (CV). The CV of the improved technology was around 27% with the maize/pigeonpea intercrop based on broadbeds and furrows and 55% for the traditional system.[1]

Table 4. Economics of improved technology options on deep Vertisols at ICRISAT Center: annual averages 1976-81

Crop	Soil & crop management	Gross returns[a]	Operational costs[b]	Gross profits[c]	Coefficient of variation (CV) of gross profits
		...............Rs/ha	....		%
Maize/pigeonpea intercrop	Broadbeds and furrows, HYVs[d], chemical fertilizers, wheeled tool carrier, plant protection	5380	1730	3650 (975)[c]	27
Maize/pigeonpea intercrop	Flat cultivation, HYVs[d], chemical fertilizers, wheeled tool carrier, plant production	4607	1771	2836 (606)	21
Maize/chickpea sequence	Broadbeds and furrows, HYVs[d], chemical fertilizers, wheeled tool carrier, plant protection	5304	2241	3063 (1527)	50
Maize/chickpea sequence	Flat cultivation, HYVs[d] chemical fertilizers, wheeled tool carrier, plant protection	4811	2254	2557 (1469)	57
Rainy-season fallow postrainy season sorghum and chickpea	Flat cultivation, local varieties, farmyard manure, local implements	1083	589	494 (270)	55

a. Includes value of gram, fodder and other by products.

b. Costs include all materials human and animal labor, and annual costs of implements ICRISAT wage rates were used to value human labor.

c. Gross profit is calculated as gross returns minus operational costs. Overhead costs such as land revenue, depreciation on buildings etc. have not been deducted hence the use of the term gross profits instead of net profits.

d. A variety of cultivars have been used: maize—Decan Hybrid 101, SB23, 51-54, Vitthal pigeonpea Sharada, ICP-1; chickpea-local.

e. Figures in parentheses are the standard deviations of gross profits. They are based on 15 observations for the improved broadbed technologies and 7 for all others.

Of course farmers may perceive risks to be higher with this improved technology simply because of lake of information and experience with it. The fact remains though that objective risks as measured at ICRISAT Center do not seen to be greater with the improved technology. CV's in farmers' fields may be expected to be higher than at ICRISAT Center.

Animal-drawn Wheeled Tool Carriers

Questions are commonly raised about the high cost of the animal-drawn wheeled tool carrier which facilitates the making of broadbeds and furrows improves the accuracy of seed and fertilizer placement, and the efficiency of interrow cultivation and other farm operations. The machine with all necessary tools costs between Rs. 8000-10000. It is designed to provide transportation, in addition to performing agricultural operations. It is able to perform virtually all operations that can be done with a small tractor, thus providing versatility and precision previously available to only a few farmers. Experience has shown that all operations with a wheeled tool carrier can normally be performed using a medium size (300 kg each) pair of bullocks. The equipment offers time saving advantages to farmers. Ryan and Sarin (1981) have examined the economics of this machine and have concluded that the extra profits obtained with the complete new system on four hectares could pay for the costs of a wheeled tool carrier in one year, provided it was utilized along with the other improved technology components.[1]

Animal and Human Labor Requirements

In the first year of introduction of the improved technology options, the bullock requirements could almost double because of the increased use of animal power for land preparation, including smoothing of fields, plowing, forming broad-beds and furrows, effecting drainage improvements, etc. In later years the demands on bullocks may decline, but our experience both at ICRISAT Center and in on-farm trials suggests that the total bullock requirements could remain between 30-70% greater than in the traditional systems with rainy-season fallows. Whether or not the improved systems on average will require a greater use of bullocks per hectare than the traditional systems will depend on how often the beds have to be reformed and the operations of plowing, chiseling, harrowing, and ridging have to be done. Our recent experience suggests that weed control with broadbeds and furrows may need to be more intensive than in traditional systems. If this is true generally it may be necessary to cultivate over the beds every one or two years and reform them in order to control weeds properly. This would, of course, mean that additional bullock power will be required.

The seasonal pattern of bullock power utilization also substantially alters with the intercrop or double-crop system. About three-quarters of the bullock power required for the improved systems occurs between February and May; with the traditional systems only 15% of total bullock labor is required during this period. It is likely therefore, that some additional fodder for animals may be required with the improved systems, particularly in the hot season from March to May. The major problem would occur in the initial year when watersheds are being developed using bullock power before additional fodder is available from the improved systems.

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[1] Research is currently underway to measure the separate contribution of the wheeled tool carrier to the increased productivity and profits of the whole system. It may be that less expensive implements could be utilized without much sacrifice in the performance of the technology options.

The improved technology adds a rainy-season crop and offers the prospect of greatly increased demand for human labor. Our results at ICRISAT Center suggest that human labor employment could increase by more than 250% compared to traditional agriculture. Landless laborers and small farmers who rely on wage earnings for a substantial part of their income can share in the additional income streams that the improved technology will generate.

The operations for which increased labor would be required are threshing, weeding, harvesting and to a lesser extent sowing. Peaks in labor demand will be accentuated with the improved technology options, particularly in the months of July, October-November and January-February. Increased demand for labor results in upward pressure on agricultural wages. This should bring substantial benefits to agricultural laborers, but might encourage selective mechanization such as the use of threshing machines. It is also unlikely that limited cropping patterns would be maintained in villages. In practice, farmers would be likely to grow a range of crops in different cropping patterns, and this would mean a further dampening in projected labor peaks.

ON-FARM VERIFICATION OF PERFORMANCE OF THE TECHNOLOGY OPTIONS

In order to verify whether the experience we had at ICRISAT Center with the technology options we have described could be replicated in farmers' fields, we initiated an on-farm verification experiment in Tadanpalle village, 42 km north-west of ICRISAT, in early 1981. The village was chosen to be representative of the rainy-season fallow, deep Vertisol region with assured rainfall. It is located in Medak District near Sangareddy. A small watershed of 15.42 hectares involving 14 farmers was chosen for the experiment.

The Tadanpalle experiment was as much a test of the ability of the delivery systems to support the demands which the improved technology options will obviosly place upon them, as it was of the technical and economic performance of the options in real-world conditions. Consequently, as far as possible we kept subsidies to the minimum and encouraged farmers to make use of existing sources of credit and input supplies. Officers of the A. P. Department of Agriculture, the All India Coordinated Research Project for Dryland Agriculture, the Andhra Pradesh Agricultural University and ICRISAT were all involved.

The elements that were provided free of cost to the 14 farmers but those which normally they would be expected to pay for in full or in part were :

- use of wheeled tool carriers (2) and the improved implements which accompany them
- construction of a main drainage channel servicing the whole watershed
- use of power sprayers
- surveying the watershed
- rodent control

Fertilizers, seeds, pesticides, petrol, hired labor and bullocks all had to be paid for by the cooperating farmers with either cash or credit. The Department of Agriculture, with the occasional assistance of ICRISAT, ensured their timely availability either in Tadanpalle village itself, or in Sangareddy, some 13 kilometers distant. ICRISAT provided intensive scientific and technical guidance to the project. A senior research technician and a field assistant were assigned virtually full-time to Tadanpalle, plus *ad hoc* input from scientists to the extend of about 1.4 man-years.

Extensive discussions were held with the farmers of Tadanpalle to ensure their cooperation; and they made a number of visits to ICRISAT to familiarize themselves with the technology options. We believe these two factors were key elements in the process of convincing farmers of our bonafides and of the potential of the technology.

A useful device to enlist farmer cooperation was a guarantee from ICRISAT that participant farmers would not earn less than they would expect from crops grown under traditional management. For this purpose, in addition to monitoring inputs/outputs on the watershed plots, we also monitored plots selected to be representative of traditional cropping patterns.

In February of 1981 after the traditional postrainy season crops had been harvested, ICRISAT and A. P. Department of Agriculture soil conservation engineers surveyed the land and planned the watershed, leaving in place existing property boundaries. The farmers did the land smoothing work and made the drainage ways to be within their own plots with their own animals and equipment, but used the wheeled tool carrier behind their bullocks for most other operations. The animals were rather weak, and because the traditional crop was harvested late, the soils were already quite hard. Development operations, excluding the construction of the main drain and the surveying, involved 24 bullock pair hours/ha, plus 31 man-hours/ha. It did not take long for the farmers to get used to the equipment, but the broadbeds and furrows were not well made—although they were no worse than the first ones we put in at ICRISAT. In the very wet year we had in 1981 they have performed remarkably well.

Although the farmers were willing to install small field drains on their own land they were not willing to work collectively to install the necessary community drains to connect the watershed to the existing main drainage system. In consequence in the very heavy rains in the early part of the year the watershed did not work properly and the lower parts of some fields were flooded. When the farmers saw this and realized the potential loss in production to the emerging rainy-season crops, and the fact that drainage problem did not happen at ICRISAT, we were able to persuade them to undertake the construction of the community drains. The A.P. Department of Agriculture paid for the labor to put the community drains in place. Since then, in a year where the rainfall has been 70% above normal, there have been no further problems of waterlogging or drainage.

The total costs of developing the watershed were quite modest at Rs. 254 per hectare. This is somewhat less than our experiences in developing small watersheds in other village situations, where costs ranged from Rs. 300 to Rs. 700 per hectare. The details of development expenditures in Tadanpalle were as follows:

Development cost	*Rs./ha*
Surveying[1]	50
Land smoothing	9
Broadbed and furrow system	92
Private drain construction	8
Rodent control[1]	7
Main drain construction and planting of Soobabul trees[1]	88
Total	254

ICRISAT and the other research agencies recommended what crops would be best, but the farmers made their own choices. In consequence, on this 15.42 hectare watershed with 14 farmers, we had nine different crop combinations including the crops of one farmer who decided not to change his old ways. With one exception, the crops did extremely well and far exceeded anything else in the surrounding area. Not surprisingly, there were some new problems such as *Striga* weed. It must be remembered that usually crops are grown here in the postrainy season only ; the farmers are not used to growing crops during the rainy season. As predicted, threshing—sometimes with unconventional mechanization—and storage were problems, particularly because in this very wet year it was not possible to dry the grain on the head in the field.

Ineffective control measures for pod borer on pigeonpeas led to substantially reduced yields and only 0.5 ton per hectare, instead of 1.3 tons per hectare estimated as the potential at the early podding stage.

However, in spite of these problems the technology options performed extremely well (Table 5). Averaged over the nine cropping systems on improved watershed the profits were Rs. 3059 per hectare, compared with the average profit from the traditional systems (dominated by rainy-season fallow-postrainy season sorghum), of Rs. 1625 per hectare. The improved systems hence generated increased average profits of Rs. 1434 per hectare (88%), and involved an additional operating expenditure of only Rs. 588 per hectare (99%).[2] This implies a rate of return on the added expenditure of 244%, which confirms the experience at ICRISAT Center (250%), and gives us confidence in the viability of these technology options.

The most profitable cropping system was sorghum/pigeonpea intercrop (Rs. 3838/ha), followed by the maize-chickpea sequential crop (Rs. 3266/ha).

1. Borne by the A. P. Department of Agriculture. The other costs were borne by the farmers.

2. Excluding the development costs of Rs. 254 per hectare. Most of the additional operating costs of the improved systems were due to material inputs. Only Rs. 73/ha of the total added expenses (12%) was for human and animal labor.

Table 5. Economics of improved watershed-based technology options on deep black soils in Tadanpalli village, Andhra Pradesh 1981-82[a]

Cropping system	Proportions grown	Gross returns	Operational costs	Gross profits	Yields: Cereals Grain	Yields: Cereals Fodder	Yields: Pulses/oil seeds/vegs Grain	Yields: Pulses/oil seeds/vegs Staks
	%	(Rs/ha)			(Qtl/ha)			
IMPROVED WATERSHED[b]								
Sorghum/pigeonpea intercrop	50	4930	1092	3838	19.5	72	4.6	19
Maize/pigeonpea intercrop	6	4304	1395	2909	16.4	34	6.0	22
Maize-safflower sequence	6	2301	1190	1111	16.2	35	0.5	—
Maize-chickpea sequence	5	5097	1831	3266	22.9	50	4.6	—
Mungbean-sorghum sequence	17	3352	1261	2091	5.9	17	4.7	—
Mungbean-safflower sequence	3	3715	1321	2394	—	—	5.2 (mungbean) 7.3 (safflower)	— —
Mungbean-(sorghum/chickpea) sequence	4	4073	1495	2578	0.8	2	4.8 (mungbean) 5.2 (chickpea)	—
Mungbean-chillies sequence	2	4625	1450	3175	—	—	5.2 (mungbean) 5.0 (chillies)	— —
Fallow chillies	7	2551	734	1817	—	—	4.1 —	—
	100							
Weighted averages		4242	1183	3059	—	—	—	—
TRADITIONAL FARMER's FIELDS								
Fallow-sorghum	90	2194	536	1658	6.7	18	—	—
Fallow-chillies	4	3208	2036	1172	—	—	7.2	—
Mungbean-sorghum sequence	1	3964	1526	2438	9.7	24	3.1	—
Sorghum/pigeonpea intercrop	5	1544	310	1234	5.5	25	1.2	16
Weighted averages		2220	595	1625	—	—	—	—

a. Prices used were based on actual realized or market prices just after harvest. They were as follows:

Grain	Rs/qtl	Grain	Rs/qtl	Fodder	Rs/qtl
Hybrid Sorghum	100	Pigeopea	298	Hybrid sorghum	20.0
Postrainy season sorghum	220	Safflower	300	Postrainy season sorghum	37.5
Maize	112	Chickpea (sold as seed)	450	Maize	10.0
Mungbeam	300	Chillies	618	Pigeonpea stalks	10.0

b. Data refer to 14.48 ha of the 15.42 ha watershed. In three plots data were not available.

Generally the mungbean systems were least attractive. Yields of hybrid rainy-season sorghum grown as an intercrop in the watershed were about 2 tons/ha, those of intercrop maize were 1.6 tons/ha. Sole crop maize yielded 2.3 tons/ha. The traditional postrainy season sorghum yielded only 0.7 ton/ha after a fallow.

The relatively high profits of Rs. 1625/ha from the traditional system in Tadanpalle village compared to the figure of Rs. 500/ha achieved in the traditional system plots at ICRISAT Center in previous years is due to the higher grain prices this year for postrainy season sorghum which were Rs 220 per quintal compared to the average of Rs. 140 per quintal in the years 1975 to 1981.

Pigeonpea prices this year (Rs 298/qtl) were some 28% higher than they have been in the past five years. If we recalculate the figures in Table 5 using the above price relatives between these three crops from 1975-81 the picture which emerges is that profits from the improved watershed amount to Rs 2800/ha, compared to Rs. 1132 for the traditional fields. The improved system under these circumstances would generate a 147% increase in profits per hectare, or a 284% rate of return on the extra operational costs.

SOME POLICY ISSUES AND CHALLENGES

There are a number of policy questions which must be addressed before the promise offered by the new technology can be regarded as a real potential.

1. Bullock power availability

In the first year when the improved drainage and broadbeds and furrows are being introduced, there will be an increased demand for draft power from either animals or tractors, or both, compared with present utilization patterns. Whilst the evidence from village studies suggests that small farmers have about the same average number of bullocks per hectare as do large farmers, the availability of bullocks for small farmers varies much more from year to year than it does for large farmers. Also in most cases small farmers have less sturdy bullocks than large farmers (Ryan and Sarin 1981). If this is true in the high potential region then particular attention will have to be paid to making draft power available to small farmers. If banks presently do not provide loans for the custom hiring of animals or tractors, we suggest that policies may be required to enable this to be done.

2. Drainage improvements

The improved technology options require improvements to drainage of the excess rainwater. When these drains are outside farmers' fiels and/or involve drainage flows of many farmers, farmers can undertake this worked in the off season if funds can be provided from Soil Conservation or Rural Development programs. Food for Work and the National Rural Employment programs could also be utilized, although these are mostly confined to drought-prone and backward areas. Farmers and labor in the high potential regions for the deep Vertisol technology that we have been discussing may not normally quality for these programs. Hence there may be a need to consider some special programs for these high potential regions in order to undertake the community work. In Tadanpalle we had difficulty recruiting casual labor to construct the community drains as the institutional wage rates were often well below the market rates. This suggests a need for flexible wage scales if the work is to be completed in a timely manner.

Small farmers may not be in a position to effect initial land improvements on their own farms, because they need to work for others in the dry season to earn cash income to sustain their families until the next harvest. Consideration may need to be given to payments to such farmers for effecting the land improvements required by this technology as soil conservation loans. Providing crop cover in the rainy-season on traditionally fallowed Vertisols reduces soil erosion by up to 80%.

3. Markets for new crops

To capitalize on the potential of the deep Vertisol technology, it may be necessary to introduce non-traditional crops. Examples are maize and soybeans. Particularly in the initial stages, marketing could be a constraint. We are confident though that in the case of a crop like maize, there is considerable potential for feeding it to animals for both milk and meat production. Soybeans are currently undergoing rapid expansion in Madhya Pradesh as marketing and processing facilities are being developed and suitable varieties released.

4. Credit requirements

The purchase of a wheeled tool carrier costing between Rs. 8000-10000 is probably beyond the reach of individual small farmers. Programs may be required to enable entrepreneurs to purchase these implements for custom hiring out to farmers on a daily basis Perhaps educated unemployment programs could be utilized for this purpose with the assistance of banking institutions At the same time, more on-farm research is needed to determine whether modified traditional implements could do the job in place of wheeled tool carriers. Credit programs would also be needed to allow small farmers to hire wheeled tool carriers from such entrepreneurs. At present such custom hiring is not easy to arrange through credit programs.

Farmers in the improved watershed in Tadanpalle spent an average of Rs. 660/ha on material and inputs such as fertilizers, seeds, manures, and pesticides. This represented 56% of total operational costs. The average loan from the Department of Agriculture was Rs. 707 per hectare of the watershed.[1] Farmers with rainy-season crops on 11.7 hectares of the 15.42 hectare watershed negotiated rainy-season loans to the extent of Rs. 811/ha of their plots. Only 2.85 hectares of the postrainy season crops had loans negotiated by their operators, and the average loan on this area was Rs. 496/ha.

1 The difference between the costs of materials and the loan taken is probably due to the fact that farmers used some of the loans for purposes other than financing the purchase of materials for the watershed plots.

Table 6. Some aspects of credit usage and facilities in selected states of India

State	Debt per ha of owned land under cultivation at 30-6-1971[a]	Proportion of cash debt of cultivators due to institutions at 30-6-1971[b]	Density of bank offices at March 1981[c]	Proportion of cash debt of cultivators for "production purposes" at 30-6-1971[d]	Density of fertilizer sale points at 31-5-1980[e]
	(Rs/ha)	(%)	(No/1000 km²)	(%)	(No/1000 km²)
Andhra Pradesh	452	15.3	8.1	53.4	28.1
Madhya Pradesh	158	33.4	4.1	56.1	10.3
Maharashtra	247	70.7	9.9	80.6	23.6
Kerala	860	45.2	29.9	44.3	126.6
Punjab	628	43.9	29.4	63.4	70.0
Tamil Nadu	979	24.3	15.1	65.0	105.0
All India	324	31.7	9.0	54.0	38.0

a. *Source* : Reserve Bank of India (1977, p. 26).

b. *Source* : Reserve Bank of India (1977, p. 35). Institutional sources refer to banks, cooperatives, provident funds and life insurance companies.

c. *Source* : Government of India (1982, p. 116).

d. *Source* : Reserve Bank of India (1977, pp. 85-86) and Directorate of Economics and Statistics (various issues).

e. *Source* : Fertilizer Association of India (1980, p. 1-73) and Directorate of Economics and Statistics (various issues).

The average total debt of cultivators in Madhya Pradesh in 1971 was only, Rs. 158 per hectare of owned land under cultivation (Table 6). Just over half of this debt was for so called "productive purposes", involving capital (33%) and current (19%) expenditures on the farm business.[1] The Reserve Bank of India (1976, p. 306) notes that the Working Group on Cooperative Credit for the Fifth Plan adopted an ad hoc scale of Rs. 250/ha for irrigated land and Rs. 125/ha for unirrigated land as the credit requirements for agricultural production. Using these figures the Working Group estimated that in December 1974, there were the following gaps between credit requirements and institutional credit supplies:

State	*% Credit gap*
Andhra Pradesh	45
Haryana	32
Karnataka	27
Madhya Pradesh	53
Uttar Pradesh	27

Of the five states analyzed, Madhya Pradesh had by for the largest credit gap of 53%. If we assume that all the material input costs of Rs. 660 per hectare in Tadanpalle were to be financed on credit, we can calculate the gap between potential demand for credit in the unirrigated deep black soil areas of Madhya Pradesh, Andhra Pradesh and available credit supplies. For both Andhra Pradesh and Madhya Pradesh this potential gap would be in excess of 90%, although precise figures are not available. Much of this gap should probably be filled by institutional credit sources. It is here that the challenge lies for the banking community.

It is time that credit facilities in the dryland areas of states like Andhra Pradesh, Madhya Pradesh and Maharashtra catch up to those in states like Kerala, Punjab and Tamil Nadu, where credit per hectare is two to three times higher and where the density of bank offices is more than three times higher (Table 6). The investments required to reap the sizeable increases in profits achieved in Tadanpalle village make it imperative that the banking industry mobilize the resources to set up the required infrastructure and make the necessary credit available. For 5 million hectares of Vertisols where the technology options could have a major impact the additional crop season credit required could be in the vicinity of Rs. 500 crores. In addition, medium-term credit would be required to assist in purchase of wheeled tool carriers, plus long-term credit for land development. As of June 1978, the Multipurpose Cooperatives and Primary Agricultural Credit Societies in Andhra Pradesh, Madhya Pradesh and Maharashtra had loans advanced to the value of Rs. 322 crores (Fertilizer Association of India 1980, pp. 11:71-72). This places the size of the task in perspective.

The practice of negotiating rainy-season crop loans. Separately to postrainy season crop loans can be a constraint to the adoption of these technology options.

1. Almost 40% of the total debt was for household expenditures in Madhya Pradesh. The All-India figure for this item was 38% in 1971.

We found in Tadanpalle that the farmers required postrainy season loans to be made available quickly to enable them to buy seeds, fertilizers, and pesticides for the postrainy season crops. Under present banking practice it appears that until farmers repay any rainy-season loans they cannot be given a postrainy season loan. It generally takes at least 6 weeks after the harvest of the rainy-season crops before farmers have dried, threshed, winnowed, and marketed the grains. Only then would they have the cash to repay the rainy-season loans. By that time it is too late for negotiating a postrainy season loan. To alleviate this constraint we suggest that an annual crop loan system be instituted for these dryland areas embracing rainy and postrainy season crops as one loan instead of two. Two disbursements of cash credit could be effected but without the requirement of repayment of the rainy season portion prior to the disbursement of the second loan.

5. Infrastructure and fertilizer supplies

One of the key elements in the improved technology options is increased use of fertilizers on unirrigated crops. Currently the bulk of fertilizer consumption in India is concentrated in irrigated areas. Our calculations from Jha and Sarin's (1980) original data show that those areas with the largest extent of rainy-season fallow in the states of Madhya Pradesh, Maharashtra and Andhra Pradesh have levels of fertiltzer use much below the national average of 28 kg/gross cropped ha/year (Table 7). Madhya Pradesh and Maharashtra have little irrigation and their consumption figures are well below the 18.5 kg/ha for the less irrigated SAT districts.

All this suggests that there seems to be considerable potential for increasing the use of fertilizers in these high potential Vertisol areas. This will require investments in improving fertilizer distribution networks. Experience shows that unless fertilizer of the desired type is physically available and accessible to dryland farmers, they will not use it. A substantial increase in the number of fertilizer distribution points would obviously be required to effect a significant increase in fertilizer use in black soil areas having assured rainfall. Presently the density of fertilizer sale points in the three black soil states of Madhya Pradesh, Andhra Pradesh and Maharashtra ranges between 10 and 28 per 1000 km^2. In Kerala, Punjab, and Tamil Nadu there are 70-127 fertilizer sale points per 100 km^2 (Table 6).

6. Availability of wheeled tool carriers

The indroduction of wheeled tool carriers could facilitate not only the introduction of the technology but also make it viable and economically attractive. However the availability of these machines in large numbers in the near future is a serious question. Currently the manufacture of agricultural machines is within the small-scale industrial sector in India. There are three such units with a capacity to produce about 300 machines per annum. Considering that a wheeled tool carrier can effectively service about 10 hectares of land it will take a very long time to cover even 10% of the area for which the technology is suitable. Two approaches are possible: a large number of small-scale industrial units may be encouraged to take up manufacture of wheeled tool carriers or one or two large industrial houses may manufacture these machines. The questions of cost and quality control will assume importance. We have generally noted that small-scale industrial units are not well equipped to effectively carry out rigorous quality control, and the price also may be higher.

Table 7. Average annual fertilizer use per gross cropped hectare in three states of India, 1975-77, in kg/ha

State	% of rainy-season fallow[a]		
	< 15	15.1-45	>45
Madhya Pradesh	6.2	5.3	7.0
Maharashtra	21.7	13.2	12.1
Andhra Pradesh	28.1	31.0	21.2

a. Districts in each of the three states were classified according to the three ranges of fallow extent and their fertilizer consumption averaged.

7. Skill development in farmers/extensions officers

The Vertisol technology options involve the application of high-technology principles to small farms. While it utilizes known elements, these have been put to ..ier to give them a new meaning and value. This will require that agricultural extension workers and farmers fully comprehend and appreciate the value of each of the components of the technology options. It will be necessary to guide the farmer at every step in the initial phases. It is our observation that dryland farmers are keen to learn new techniques, and appreciate the advice given to them in time and sincerity. Refresher in-service training programs for agricultural officers at various levels in the black soil states will be necessary. Some adaptation of the Intensive Agricultural Development Programs (IADP) model will be necessary.

Other Issues

- staff in Department of Agriculture should be exclusively assigned to such projects.
- separation of responsibilities and administration of soil conservation and agriculture staff creates coordination problems.
- fiscal year does not correspond to the period when budgets can be well planned
- delays in sanctions for expenditures hampers development activities
- some difficulty with timely availability of fertilizers and pesticides in the villages

- extreme labour bottlenecks at times of threshing, drying, transporting, and storing of rainy-season cereal crops and sowing of post-rainy season crops, as predicted from our on-center research; tractors and all-crop threshing machines may have a key role to play in alleviating these bottlenecks

- lack of adequate knowledge of cropping systems options and their rotational requirements in these types of agroclimates suggests a need for further research

- the need for more research on the technical and economic potential of collecting excess runoff in small upland ponds on watersheds in these high potential areas for use on postrainy season crops such as wheat, sorghum, and chickpea, such ponds could help ensure that cropping intensities of 200% are achieved in these regions

- more extensive analysis of rainfall probabilities is required to define optimum dry sowing dates in various regions

- more research required on improved methods of weed control in the early rainy-season.

CONCLUSION

The technology components outlined in this paper have shown considerable promise in experimental station research and in the first year of on-farm testing. Before this promise can be regarded as a real potential more extensive regional adaptive research and on-farm verification tests are required. Changes in agroclimatic and socioeconomic characteristics across the relatively dependable rainfall regions having deep black soils may require modifications to be made before the technology options can be transferred more widely to farmers.

A foundation has been laid for such a regional program with the initiation of pilot projects in Raisen District of Madhya Pradesh, Gulbarga District of Karnataka, and Medak District of Andhra Pradesh. Much more needs to be done and in this there are key roles for central and state agricultural research and extension institutions, in concert with banks and development agencies.

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