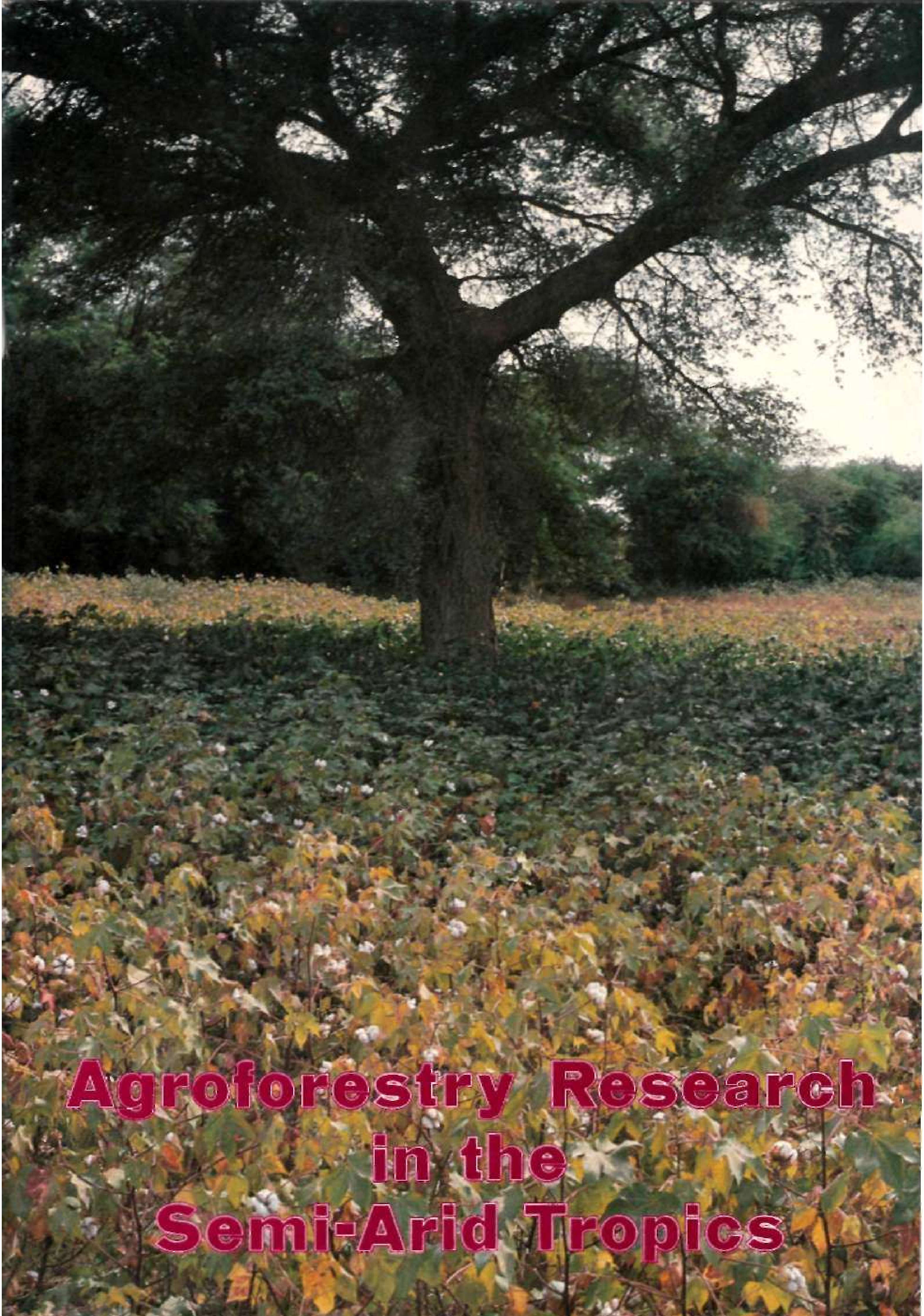

Agroforestry Research in the Semi-Arid Tropics

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Cover: Acacia albida, an important tree usually grown with millet in cropped areas in sub-Saharan Africa, has been shown to increase crop production through its beneficial site effects. Here, cotton plants near the tree trunk are greener and have more bolls.

Agroforestry Research in the Semi-Arid Tropics

A report on the Working Group Meeting held at ICRISAT Center, India, 5-6 August 1985

ICRISAT

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Workshop Coordinator & Scientific Editor

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Foreword

Agroforestry is a new discipline at ICRISAT. We have always recognized the need for trees in farming systems—in fact, some of our earliest plantings at ICRISAT Center included trees for fruit, and as windbreaks or visual screens. But with growing emphasis on resource management on the farm, the role of agroforestry needs to be more clearly defined.

Though agroforestry field research has already begun at ICRISAT Center, we would like to focus first on a preliminary analysis of the potential of agroforestry in the semi-arid tropics as a whole. Advocating development and extension of a new technology like agroforestry to resource-poor farmers calls for caution. But this caution must be balanced by the sense of urgency to address decisively problems common to the semi-arid tropics: wood and fodder scarcities, unstable crop yields, soil erosion, and the advancing desert.

Agroforestry offers promise in alleviating some of these problems. To explore that potential, we convened a working group meeting at ICRISAT Center on 5-6 August 1985.

We hope that this report on the meeting will help readers to visualize the role of agroforestry in the semi-arid tropics. We acknowledge the contributions already made by the All India Coordinated Research Program on Agroforestry, and we look forward to learning from this experience and working with them in the future. The role of industry and the private voluntary organizations in this workshop reflects their commitment to the development and application of agroforestry.

Such enthusiastic yet well-directed efforts should lead to useful agroforestry systems that can be extended into farmers' fields. We hope we have made the right beginning.

L.D. Swindale
Director General, ICRISAT

Preface

Agroforestry research at ICRISAT has been in progress for about 2 years. With assistance from the Ford Foundation, we commenced in early 1985 an ex ante analysis of the potential of agroforestry in the semi-arid tropics (SAT), which may ultimately lead to the establishment of a formal agroforestry program at ICRISAT. A workshop was held at ICRISAT Center on 5 and 6 August 1985, with discussions designed to assist us in exploring that potential.

The workshop brought together participants from Indian industries, research institutes, universities, and nongovernment organizations (NGOs), as well as representatives from foreign aid missions, ICRISAT, and the International Council for Research on Agroforestry (ICRAF, Nairobi) to share ideas, methodologies, and results on agroforestry research.

The objectives of the workshop were:

- To review agroforestry research under way in India*
- To foster dialogue between the various sectors, in order to facilitate development in the semi-arid tropics.
- To prepare broad guidelines on priorities for agroforestry research in the semi-arid tropics.

Although the workshop was traditionally structured, with topical sessions, discussions, working groups, and plenary sessions, this volume does not closely follow that structure. As such, it is not a proceedings but rather a report on the workshop.

No formal papers as such were presented; rather, summaries of research methodologies and objectives of the various institutions were outlined. In preparing this report, therefore, more emphasis has been placed on the content of the papers rather than on authorship. This is particularly so in the section on the ICRISAT program, synthesized from the contributions of six authors.

The section on Collaboration and Linkages has been prepared based on notes transcribed from a taperecorded session led by Dr. J.S. Kanwar (Director of Research, ICRISAT) and Dr. G.B. Singh (Deputy Director General, Indian Council of Agricultural Research). Finally, the section on research recommendations is based on discussions between all the workshop delegates, although Dr. Peter Huxley (ICRAF) and Dr. Matthias von Oppen (ICRISAT) were instrumental in preparing the written summaries.

On behalf of ICRISAT, I would like to thank all those who participated in the workshop and made it a success. In particular, I would like to thank delegates from institutions in the All India Coordinated Program on Agroforestry Research for their enthusiastic and informative contributions.

Rick J. Van Den Beldt
Principal Agronomist (Agroforestry)
Resource Management Program, ICRISAT

Position Papers

Agroforcstry Research—An Introduction

J.S. Kanwar

One of the objectives of ICRISAT is to develop farming systems that will help increase and stabilize agricultural production through better use of natural and human resources in the seasonally dry semi-arid tropics (SAT). Resource management plans are incomplete without consideration of trees. There are lands where mixes of crops, trees, and grasses are ideal. We must optimize their production and maximize returns to the farmer without detriment to the environment. Unless a system is attractive to a resource-poor farmer, it may not be adopted.

Inappropriate agricultural and forestry production systems and population growth (animal and human) outstripping production lead to land degradation. The problem is severe in the tropics, where the pressure of population is high, ecosystems fragile, and exploitation of forest cover ruthless. The consequence is that wood supplies are dwindling. An FAO study on "Agriculture Towards 2000" estimates that even if crop yield on lands already cultivated were to increase by 72%, another 200 million ha will have to be cleared in the world in the next 15 years for meeting food needs. Most of the prime lands are already cropped. In the Indian SAT, 78-80% of the area is under cultivation as against the mean of 40% for the whole country. With the technology now available or in the pipeline, India may be able to meet its food needs. But there may not be enough fuelwood available to cook it.

That rural people rely on trees for fuel, housing, implements, fodder, and a host of other purposes is indisputable. This need is unalterable, and will grow to become more expensive to India both monetarily and ecologically. Some estimates show that India will consume 200 million cubic meters of wood for fuel alone in 1985. The Fuelwood Committee of the Government of India estimated in 1982 that at least 3 million ha will have to be planted each year under quick-yielding fuelwood trees, up to 2000 AD.

India has 75 million ha of forests of various types, with differing levels of productivity. This amounts to a per capita forest area of only 0.14 ha, against 1.04 ha for the world as a whole. Not only is this a significantly narrow forest land to human ratio, it becomes even more narrow when we consider the animal population, especially goats, camels, cattle, and other herded, browsing animals.

The greed of the rich, the genuine needs of the poor for fuel and fodder, the needs of subsistence farming, and neglect of soil and water conservation principles in these fragile environments have all contributed to the rapid decline of forest cover in India.

Increasing numbers of herded, browsing animals outstrip the ability of the land to support them, leading to barren landscapes in much of the semi-arid tropics. Agroforestry, particularly silvipastoral systems, can help alleviate this situation.

Wood cutting is an important source of off-season income for some farmers. Cut wood (left) is being brought to a central depot (right), which will in turn supply cities, rural industry, and local households.

Expansion of agriculture will necessarily involve marginal and submarginal lands, which are better suited for agroforestry and silvipastoral systems than for traditional crop-based agriculture. Trees and crops grown together in alley cropping systems, aimed at increasing productivity of both the crops and the trees, may offer us an attractive alternate production technology. It calls for development of highly efficient systems of farming, using the land according to its capability and conserving and managing the resources most judiciously.

The effects trees have on crop production calls for intensive scientific studies. The competitive effect for moisture, nutrients, and light in a mixed crop and tree culture, the problems of pests, diseases, and birds, and the effects—long and short term—on soil and water conservation are all important aspects, which assume great importance in agroforestry studies especially under the rainfed conditions of the SAT.

Industries and rapidly changing socioeconomic conditions are stimulating the cultivation of trees like eucalyptus, poplar, casuarina, leucaena, etc., in intercropping and sole-cropping systems, with and without irrigation. The short- and long-term effects of changes in the environment have not been studied. There have been too few studies on specific tree/crop mixes, or on water and nutrient depletion and interactions. Careful research in these areas is needed.

ICRISAT has begun a modest research activity on agroforestry. As early as 1973 our Governing Board stated that fruit and forest trees should be tested and used in the Farming Systems Research Program, with emphasis on those tree species that reduce land-related problems, to generate information on comparative suitability and performance. Our aim is to work closely with the national programs and to investigate only critical aspects of high priority where we can effectively enhance their efforts.

Our emphasis is on establishing principles and methodologies for the development of remunerative systems of agroforestry in Alfisols, Vertisols, and other Vertic-type soils. Our economists and social scientists are studying the problems of management of woodlots in the village common lands, as part of a study on management of common resources.

Agroforestry research should emphasize: (1) increasing productivity of marginal lands in both the dry and wet-dry SAT, wastelands (or wasted lands), and land affected by salinity and alkalinity; (2) monitoring nutrient recycling and nutrient and moisture depletion from soil profiles by agroforestry mixes; and 3) developing systems relevant to farmers and adaptable by them.

At ICRISAT Center we can work on dry SAT soils, especially Alfisols, shallow Vertic types, or Inceptisols. The Indian program can cover the range of environments. The ultimate goal should be to develop efficient systems of soil and water conservation and management, with adequate and sustained economic productivity.

Making Agroforestry Research Relevant to the Needs of Small Farmers

Drake Hocking

Applied research is defined as research whose results are of direct and immediate use to the client. The questions are: applied to what? and for whom?

The answer to the second question is "the small dryland farmer". More than three-fourths of India is dryland and small farmers are numerically strongest. We should strive toward reducing socioeconomic disparities. The first question breaks down into the production objectives and the consequent research problems and needs.

Robert Chambers has pointed out that attempts to identify the need of a particular client group are often thwarted by biases in where and to whom questions are asked. Some of these biases include:

Near-urban	that is,	not rural
Seasonal	that is,	dry weather (not wet)
Roadside	that is,	not inaccessible
Elitist	that is,	leaders, not powerless followers
Male	that is,	not village women
Modern	that is,	not traditional
Lead-farmers	that is,	not nonadapters.

Advances in agricultural productivity have flowed from effective research and development of the "green revolution" type—but who has benefited? Mostly large farmers on irrigated land. Research is not neutral. The nature of the research does influence who benefits. How can scientists be encouraged to venture out, take the time, and make the effort to listen to the research needs of the small dryland farmer?

Part of the answer lies in the way we manage scientific research. The main rewards of research—promotion, prestige, influence, jobs in main centers with many professional and social facilities—do not recognize the difficulty of tailoring research programs towards the less well-off, less vocal small farmers. The basis of assessment and rewards for scientists' performance need to be changed if we truly want to divert research programs towards our new primary clients.

ICRAF's Diagnostic and Design provides a framework for exhaustive technical and social analysis of production systems. In

1. Chambers, R. 1983. Rural development: putting the last first. New York: Longman.

India the technical aspects of most production systems are reasonably well understood. The main gap lies in the lack of direct contact with the farmers and with their socioeconomic context. This farmer contact needs to be pursued, by scientists themselves, preferably in small multidisciplinary teams that include social scientists.

The Central Research Institute for Dryland Agriculture (CRIDA) has developed a questionnaire and a methodology for sampling and enumeration, which explicitly recognize a number of common biases and are designed to offset them. An example is the specific stratification of a sample into half male and half female subjects.

Other aspects, such as the composition of the field survey team, also have an important bearing on the outcome in terms of research proposals. It may be thus worthwhile to briefly review what may emerge from applied research and how it can be evaluated.

One additional step is to conduct what might be called a "Social Audit" of the proposed research program. It involves an analysis of "who gains and who loses" from the expected results of the research. Chambers gives a simple table of the possible answers:

Possible outcome of research	Rich and powerful	Poor and powerless	Probability of implementation
Scenario 1	gains	loses	high+++
Scenario 2	gains	gains	less high++
Scenario 3	no change	gains	modest+
Scenario 4	loses	gains	none

If our research program is properly designed, the predictable outcomes should fall in scenarios 2 or 3; scenario 1 is undesirable because it reinforces the previous and present tendencies, while scenario 4 is impractical because its implementation would be effectively opposed by the rural elite.

The distributional effects of well-intentioned research may fall into scenario 1 because of a structural defect in the politico-economic context. For example, we may propose to develop technology for growing trees among subsistence crops, which should fall into scenario 2. But only rich and powerful farmers have the knowledge, confidence, and contacts to be able to market the trees upon harvest. So our output falls into scenario 1.

Research scientists cannot escape the politico-economic context of their work. So it is often necessary for scientists to involve themselves in analyses of the context of their technical research, so as to draw attention of policymakers to structural defects or to make policy recommendations.

International Funding Agencies and Agroforestry Research

W.R. Bentley

Growing interest in agroforestry worldwide among international donors is stimulated by three factors, which are discussed below:

- Soil and watershed management;
- Increasing productivity of tree-based crops; and
- Improving social and economic welfare of particular client groups.

Ecological Factors

Serious soil and water conservation problems result in degraded lands with reduced productivity plus huge losses downstream from flooding. India has a total land area of about 329 million ha, of which about 100-175 million ha is degraded land producing only 20% of its potential. This is most spectacular in the Himalayas and western Ghats, but erosion and flood damage are pervasive and enormous throughout the subcontinent. Forests once covered 85% of the subcontinent; therefore, looking towards trees and tree-like plants in agroforestry mixes to undo some of the damage is logical, as they mimic the natural vegetation that once predominated the landscape.

Productivity

In terms of productivity, a primary goal of donor groups is to increase the availability of wood and wood products in countries like India. A major indicator of current production is price. Prices of agricultural commodities are stable or falling; however, prices of tree products–fruit, pulp fiber, timber, lumber, fuelwood, extractives, oils, etc.–are going up about 6% per year (see Fig. 1). A scarcity of trees means a scarcity of commercial and noncommercial tree products. Thus, an investment in trees makes good economic sense. The potential exists for increasing the productivity of tree-based systems. Through breeding and selection, gains of 100-200% in productivity are probably attainable.

Client Groups

A major objective of foreign funding agencies–like the Ford Foundation in countries like India–is to develop projects to assist the rural poor. Poor people are often blamed as the cause

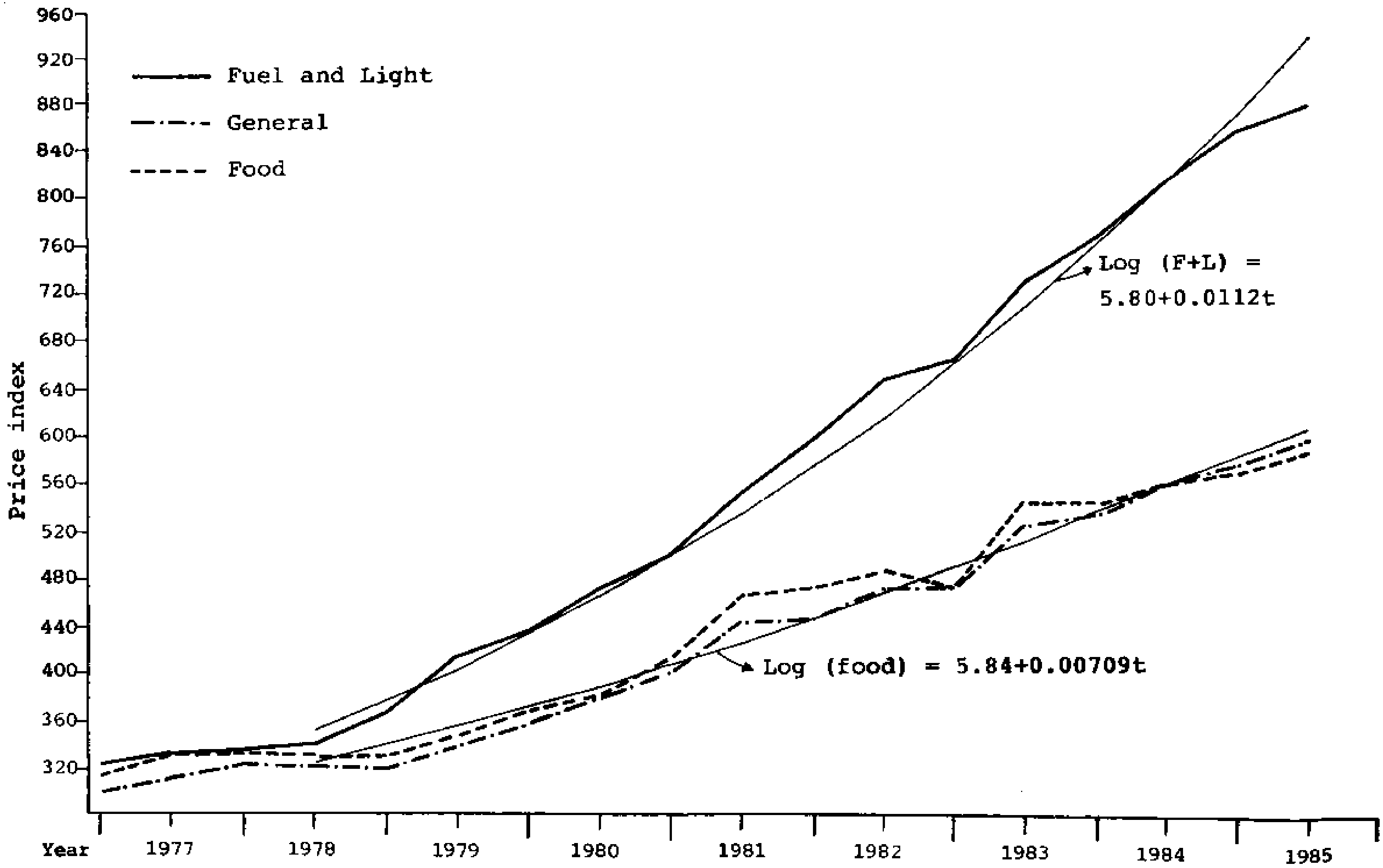


Figure 1. Industrial workers' consumer price index for Hyderabad (Base 1960 = 100). The real index price for fuel and light (in which firewood has a weight of about 50%) is increasing at a rate of 4.5%, while the real food price index is decreasing marginally by 0.5% (courtesy: M. von Oppen and P. Parthasarathy Rao).

of the cycle of environmental degradation, and indeed they are part of the cycle in their role of "marginalized people living on marginal lands." Poor people in India are more dependent on rainfed agriculture, on access to common lands, and on forest-user rights than are their better-off neighbors. Although agro-forestry is not something that the rich cannot benefit from, the measure of success in agroforestery over the next few years will be if the poor benefit more from the efforts now undertaken.

Symptoms and Causes

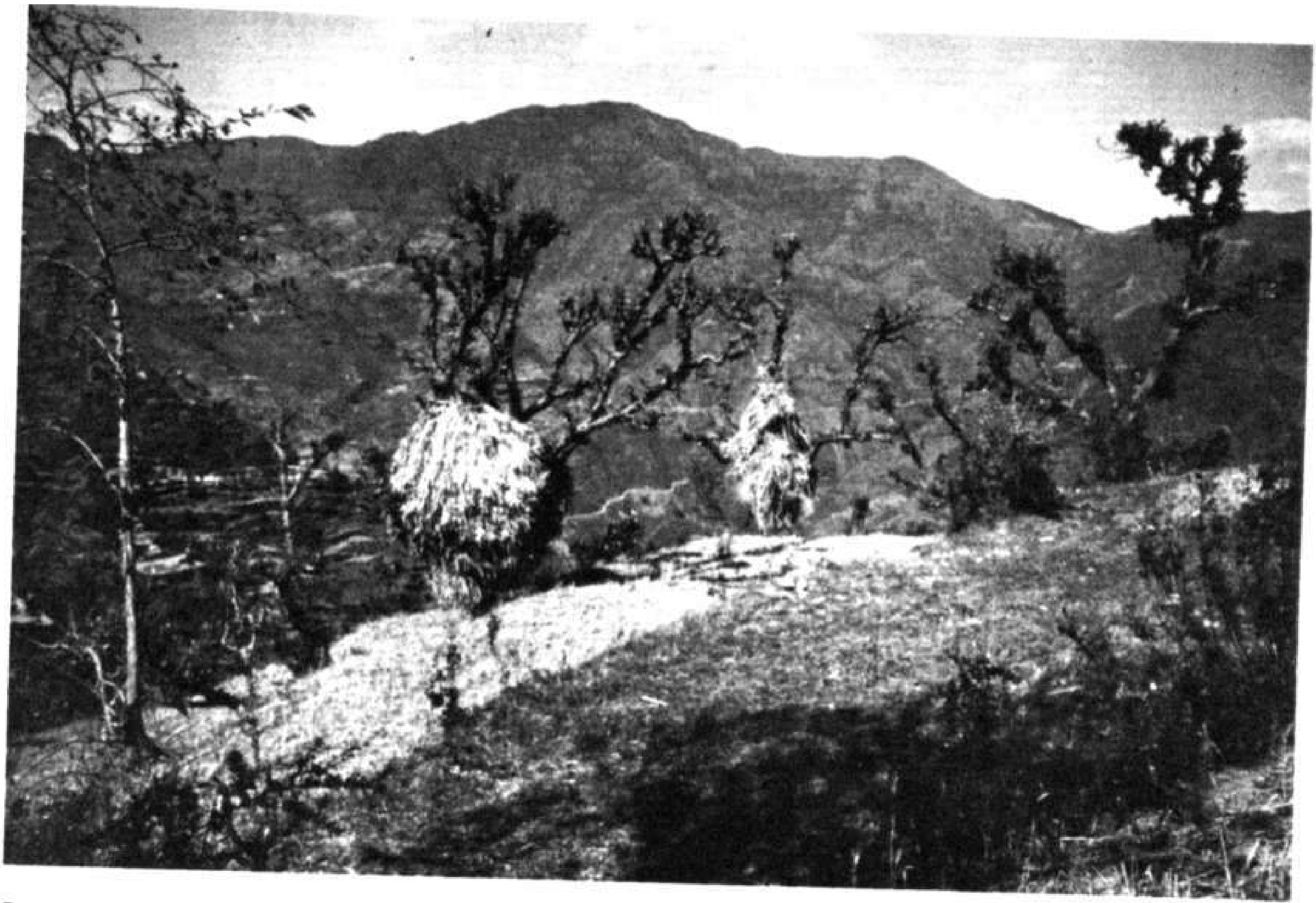
Poverty leads to exploitation of resources. Breaking this cycle requires pulling it apart in some fashion. This could be done by providing poor people the means to utilize resources without overexploitation, or by providing the poor people the means to be no longer poor. Improving the productivity of systems through biotechnological research by itself will probably not do much good. There are needs for advancements along related lines as well.

First, there is a need for a better understanding of intermediate organizations and how they manage resources in the countryside. Good managers are scarce in areas where environmental degradation is taking place. These managers must be provided tools like credit and technical know-how. Also, the comparative advantages of using public, private/profit, and nonprofit voluntary organizations need to be explored.

Second, understanding of the manpower and land-resource bases with which these institutions have to work is critical to success in any kind of environment-based program. In India, 50 million ha of revenue lands are managed on a common access basis. Off-season grazing on private lands and other traditional rights contribute to the ease with which lands are exploited. It makes very little economic sense to invest in such common properties, either from public or private institutions. The lack of incentive to invest in such common lands is perhaps even more important than their overexploitation. Creating these incentives is a major task.

Third, pricing policies are often counterproductive. Taxes sometimes discourage good forestry and agriculture. Consequently, we must see research in agroforestry from both the biotechnological and socioeconomic angles. We also have to integrate these two disciplines into a pragmatic, problem-solving mode. This challenge requires that we recognize the need to provide researchers, scientists, and applied professionals some incentives toward such integration.

We are witnessing in India one of the great revolutions in forestry and agroforestry in the world. The Indian Council of Agricultural Research (ICAR) and the agricultural universities in various states are developing a major research effort in



Overuse of tree resources in hilly areas (such as severe lopping for fodder of *Grevilla robusta*, above) leads to site depletion, erosion (below), and subsequent lowland flooding.

agroforestry (31 centers by 1986), with 10 professional forestry programs to produce forest scientists for the first time in India. The Forest Research Institute and College at Dehra Dun are shifting their education and research efforts. There is a growth in richness of nongovernment participation, and a leaning towards more technically oriented groups like the Bharatiya Agro Industries Foundation (BAIF), and the Society for Promotion of Wastelands Development, all of which are accomplishing two things: (a) a pragmatic link between biological and social concerns; and (b) providing an alternate avenue for conducting research that did not exist earlier.

What resources will be needed to do this job is a matter for various government and NGO decisionmakers to resolve. It is clear that major donor agencies—bilateral, unilateral, and philanthropic—are available; they can provide resources to help India undergo this marvelous transition that it is experiencing.

Working Group Recommendations

Bioscientific Research

Agroforestry is changing from a descriptive to an experimental activity. The change results from the need to solve the large number of questions that arise when either modifying existing production systems or designing new ones. In some cases, the experimental work required is adaptive and relatively limited in scope; in others, it is more exploratory and requires greater resources. In both sets of circumstances, the complexities of agroforestry systems, which involve plants of different stature and life cycles, are greater than those normally associated with agriculture or plantation forestry.

Research Objectives

Research objectives need to be clearly stated. For example, is the planned experiment on multipurpose trees concerned more with survival or with growth and yield? If the latter, is the study to be on the juvenile or mature phase of tree growth/development, or both? Is it sufficient if the results identify plant growth behavior (e.g., relatively between treatments), or are actual yield data required? What, exactly, are the end uses planned? The answers to questions such as these will markedly affect experimental design, and they must be clarified before research is undertaken.

Site-Specificity and Multiplicity of Agroforestry Systems

Agroforestry systems are usually site-specific. This has two implications for research. First, research programs must be based on a multidisciplinary land-use diagnostic appraisal so that they are logically derived from regional opportunities and constraints. Technical interventions will thus address the key problems that have been identified.

Second, multiplicity requires that some selected areas of research must be undertaken to quickly establish some general guidelines. In some cases, this can be done by assembling and evaluating existing knowledge; in others, it means identifying key research issues and then starting experimental work in those areas. Even where the research is site-specific, the possibilities of designing the experiments so as to permit some extrapolation to other sites should always be borne in mind.

In both cases, there must be a sound categorization of the physical environmental framework within which the experimental work is to be undertaken.

Agroforcstry Research Methodologies

The wealth of experimental methodology (design, assessment, data evaluation) from agriculture, horticulture, and forestry cannot always be directly utilized without some modification. Thus, cost-effective, rapid methods of problem solving have to be derived if development of agroforestry technologies is not to be seriously slowed down.

In this respect, the formulation and initial testing of appropriate agroforestry research methodologies should be undertaken at selected centers that have the resources. However, it is important that the wider testing of such methodologies should be undertaken as rapidly as possible, involving the participation of research teams in national development programs.

Time Scales

Certain aspects of agroforestry research need not take a long time. For example, the formulation of research methodologies could be virtually complete in 5-6 years. The survey of multipurpose tree species/provinences need be only of a few years' duration. Similarly, trials on management techniques (e.g., lopping) can be done over a few seasons for any one species. In all cases, we must look for rapid ways of obtaining the information required about these complicated systems and do this in the simplest experimental way possible.

However, experimental work on woody perennials inescapably involves research programs that can require many years. This will just have to be accepted and accommodated in some aspects of research on multipurpose trees, such as long-term soil changes, flowering/fruiting studies near maturity, etc., and research resources have then to be allocated appropriately.

Specified Subject Areas for Research

There are a great many possible subjects for agroforestry research, and no attempt will be made to list specific areas. Research areas may be broken down into four broad categories: (1) research involving the tree alone; (2) the tree as a crop plant; (3) the tree/crop mix; and (4) the crop alone. Within each of these categories, one must decide on the characters to study, variables to measure, and selection of management treatments. A matrix showing these interactions is presented in Table 1.

A few more research priorities of a broad-based nature can be identified, and these are discussed below.

Germplasm. A major problem holding up both development and research in agroforestry is lack of suitable accredited germplasm. Directories of multipurpose tree seed sources are

Table 1. Priority areas for agroforestry research.

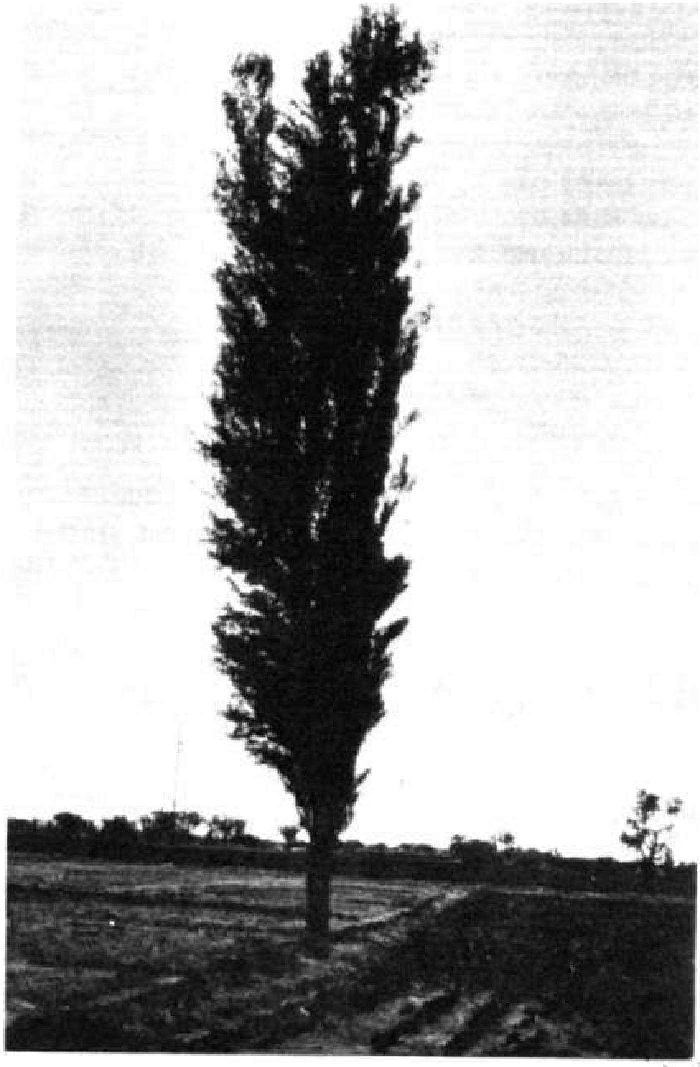
Research focus	Characters to study	Variables to measure	Management treatments
The tree	Tree characters: -morphology -growth characteristics -phenology -source-sink relationships -G x E[1] responses	Attributes of single trees contributing to land sustainability (nutrient accumulation, litter, microsite enrichment	Management of vegetative growth and fruiting.
The tree as crop	Ideotype	Plant density and rectangularity arrangements	Effect of removing part of the crop (thinning/lopping) on sustainable yields.
The tree/crop mix	Space-time considerations Tree/crop interface	Choice of total plant population and degree of intimacy	Woody perennial establishment in relation to crop season Manipulation of plant stresses in tree/crop mixes
The crop	Crop characteristics: sowing time/growth/flowering pattern	(as above)	Plant stress (as above), length of growing season Responses to soil management

1. G x E == genotype x environment.

available (e.g., from the Nitrogen Fixing Tree Association, ICRAF, etc.), but research workers both in national and regional programs often need assistance in obtaining indigenous and exotic tree germplasm in adequate amounts.

An additional undertaking at both regional and national levels would be to compile and maintain an inventory of the available species and provenances, that is, what trees are being imported and used in the region or, better still, in its ecozones.

Nutrients. There is an urgent need to collect information on the potentials of different multipurpose tree species for accumulating nutrients and fixing nitrogen. The ways, rates, and levels of nutrient loss in agroforestry systems need to be characterized. This area of research should include the study of allelo-



Lack of accredited germplasm slows down meaningful agroforestry research. *Acacia nilotica* is a potentially useful species. Two variants—erect (left) and spreading (below)—exist, yet little work has been done on the germplasm collection and evaluation of this species.

pathic effects, as well as the effectiveness of inoculation with rhizobial and mycorrhizal associates.

Tree protection. Tree protection after outplanting is an area of critical importance in agroforestry projects. There is much to be learned about the best procedures for tree protection against environmental hazards and browsing animals. This should mainly be done by on-farm surveys and trials.

Pest management (plant pathogens, birds, insects, mammals, weeds) in agroforestry systems has received little or no study. Experience in both agriculture and forestry suggests that agroforestry development will, inevitably, be seriously impeded by lack of research in this area.

Socioeconomic Research

The group addressed two major issues: 1) identifying research needs in agroforestry; and 2) designing appropriate research approaches, including linkages with national programs, local agencies, and nongovernmental organizations (NGOs).

Research Needs

Research must aim to increase and stabilize the income of the small farmer in the SAT. In order to make agroforestry research relevant for this target group, the following need to be studied.

Identifying production and management objectives at macrolevel and microlevel. At the macrolevel, studies of market demand and market supply of agroforestry products are required. Factors determining demand for fuel, fodder, fruits, and timber need to be identified and trends over time established, so that future demand can be forecast. A knowledge about future demand for agroforestry products will enable policymakers to judge the short-run returns from agroforestry products and to evolve measures that can increase their supply.

There are also the long-run effects of soil and water conservation, which have to be considered when assessing the amount and allocation of investments on agroforestry. Trees can help conserve soil and water and are thus likely to favorably affect productivity of the land in the long run. Research is required to quantify these long-run effects and to differentiate various systems accordingly.

Before experimenting in farmers' fields, ex ante studies at the microlevel are required so that the effects of agroforestry systems on farmers' incomes can be predicted. Mathematical modeling of systems can serve as an ideal tool for such ex ante research, to formulate hypotheses and to design field tests for more specific and effective results. Agroforestry is expected to increase the level of farmers' incomes only to a moderate degree, but its major attraction would be the effect of stabilizing incomes. When identifying and formulating objectives for management of agroforestry, research must also address questions on the infrastructure required to provide market access and market policies conducive to introduction of efficient agroforestry systems into SAT agriculture.

Identifying political and economic constraints and evaluating options for institutional change. With its long-run implications on stability and conservation of resources, agroforestry requires very careful attention by policymakers. The expected social gains justify and require public intervention at various levels. Under existing institutional structures, however, integrated planning is often difficult.

Constraints must be imposed on inefficient marketing of wood and wood products. These can take the form of licensing, or banning in key areas of such destructive activities as tree felling, or removing subsidies on distribution of seedlings free of cost, or establishing tariffs (e.g., for transportation of wood over long distances).

Identifying potentially appropriate agroforestry systems. Existing experiments with agroforestry systems must be studied comparatively to integrate the work under way in many places (e.g., ICAR, industry, NGOs) in an overall framework of location-specific applicability. This research also requires extensive experimentation at research stations and in farmers' fields. Care should be taken to design optimal paths for moving efficiently from components to systems and from research station to farmers' fields (see Fig. 2).

Differentiating between systems for specific regions and locations. Location-specificity is one of the major difficulties researchers face when designing agricultural land-use systems for the SAT. Their task is to identify principles and concepts which apply across wider ranges of soil types, rainfall zones, population densities, and other relevant factors. Based on such principles, region-specific recommendations can be derived and systems identified to suit specific locations and conditions.

Study of interaction between agroforestry and existing production systems. Agroforestry—wherever applicable—will always have to be incorporated into existing land-use systems. Research will thus be needed on the interactions that will be established between the existing systems and the new component of agroforestry, e.g., establishment of trees in view of grazing pressure on land; milch cattle and fodder from trees; short-term tenancy systems and long-term land use under agroforestry; groundwater

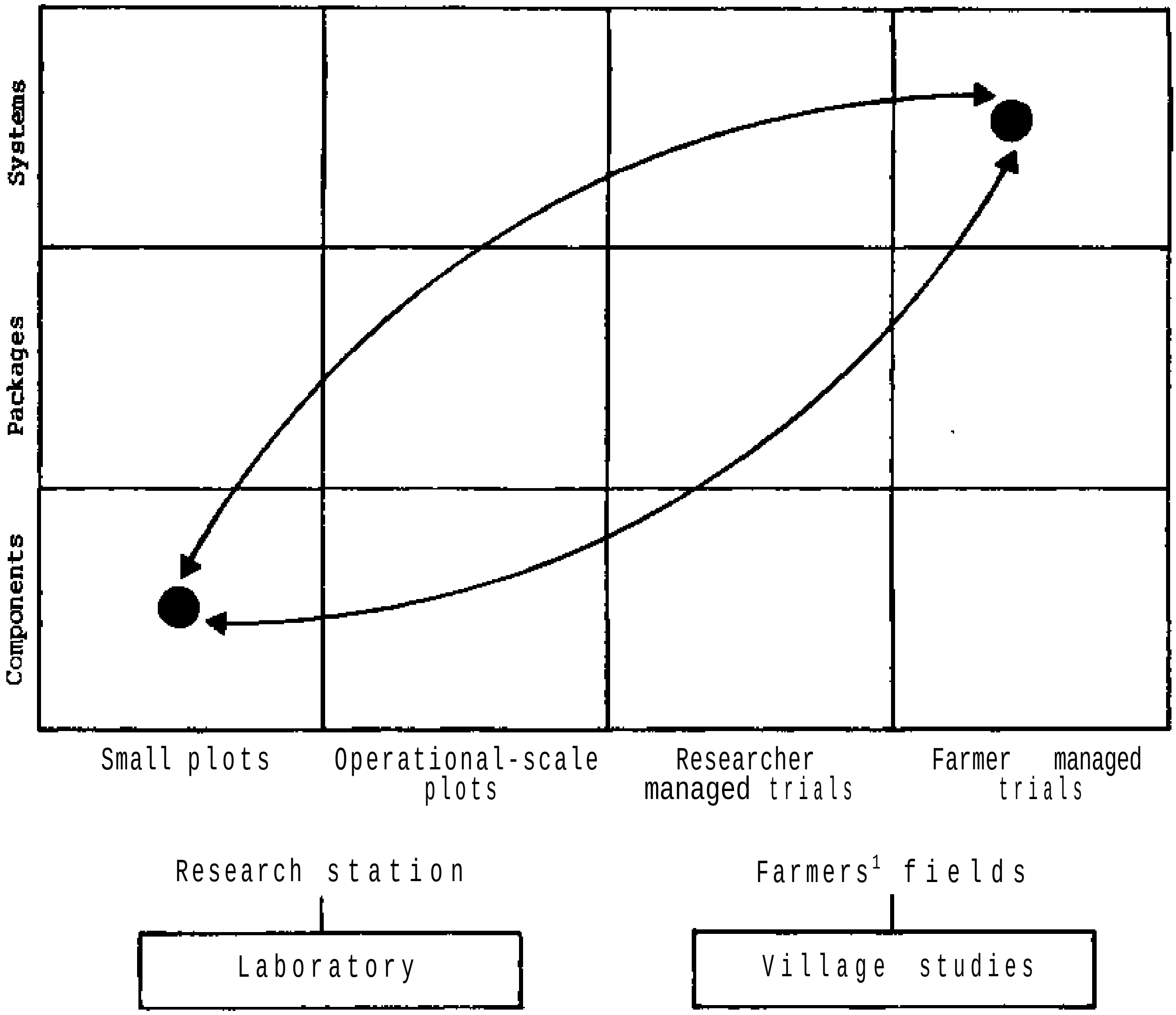


Figure 2. Pathways for agroforestry systems research.

Note: Agroforestry research can be viewed as a process where ideas and knowledge about constraints and components of technologies emanating from laboratory and crop improvement research, as well as from analysis of village surveys and field studies, are translated through experimental research into a farming system that is economically attractive and adopted by farmers. After diagnosis of problems in farmers[1] fields, component research generally begins with generation of principles and solutions in small plots on the experiment station. This is followed by research on packages of these components in operational-scale plots, first at the research station and then in farmers' fields. The latter are done first in researcher-managed trials and later under farmer management. The time required for development of agroforestry systems can be shortened by following the pathway of the lower arrow rather than that of the upper arrow. The lower pathway requires testing components in farmers[1] fields early in the program and developing the next step (packages) with heavy emphasis on farmer participation.

availability and water requirement of agroforestry systems. These studies are needed for better integration of agroforestry into existing land-use production systems.

Identifying research priorities for different areas. Based on the expected demand for specific products and on the long-run needs for soil and water conservation, priority research areas need to be identified and regions delineated where these priorities dictate specific research effort.

Research Approaches

Research approaches should be evolved in accordance with the needs outlined above. The following may be kept in mind:

- Research projects should be planned in such a way that multidisciplinary teams are involved, integrating, for example, social scientists and natural scientists. Incentives and institutional infrastructure should encourage multidisciplinary, target-oriented research.

- An advisory panel should be formed for each project, drawn from various segments including government and NGOs, to counsel on research progress. This produces a two-way flow of communication from practitioners to scientific research and vice versa.

- National agencies and NGOs should be involved in collaborative testing of technology. The access of NGOs to farmers could help in evolving a social laboratory approach to technology design.

Agroforestry is just one aspect of the overall effort needed in management of resources for improving the welfare of the SAT farmer. Because of its long-term nature, it is more likely to be ignored by farmers, who subsist on marginal resources at high risk and who have to satisfy the immediate needs of their families. This puts an additional responsibility on the research sector to design technology with great care, involving farmers and others close to him at all stages of design and testing, so that appropriate solutions are found to enable speedy and efficient transfer.

The Indian Program

The ICAR Program

Introduction

Agroforestry is an age-old practice. In India, woody perennials have long been deliberately grown in conjunction with field crops, vegetable crops, spices, horticultural crops, and pasture with the objective of meeting various requirements of the farmers' home and farm, and also as an insurance against the risk of uncertain weather conditions. Prosopis cineraria and millets in Rajasthan, Alnus nepalensis and Amomum subulatum in NE Himalayas, Grewia optiva along with field crops in W Himalayas, Dalbergia sissoo and field crops in northern Indian plains and Casuarina spp. in coastal areas, are some examples of the traditional agroforestry systems.

In recent years the soil and water conservation role of agroforestry systems has been studied and exploited by the institutes of the Indian Council of Agricultural Research (ICAR), e.g., Central Arid Zone Research Institute (CAZRI), Jodhpur, and Central Soil Water Training and Research Institute, Dehra Dun. The Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, has studied agroforestry systems from the point of view of maximization of fodder production per unit area and time. As a consequence of the International Agroforestry Seminar held at Imphal in 1979, the All India Coordinated Research Project on Agroforestry was launched during 1983 at 20 participating centers in the country (see Fig.3). We intend to expand this network to 31 centers during the Seventh Five-Year Plan, and to establish an Agroforestry Research Center.

The project has been grouped in four agroclimatic zones: hill regions, arid and semi-arid regions, the Gangetic Plain, and tropical regions. With the help of ICRAF, we developed three core projects in 1982. These are:

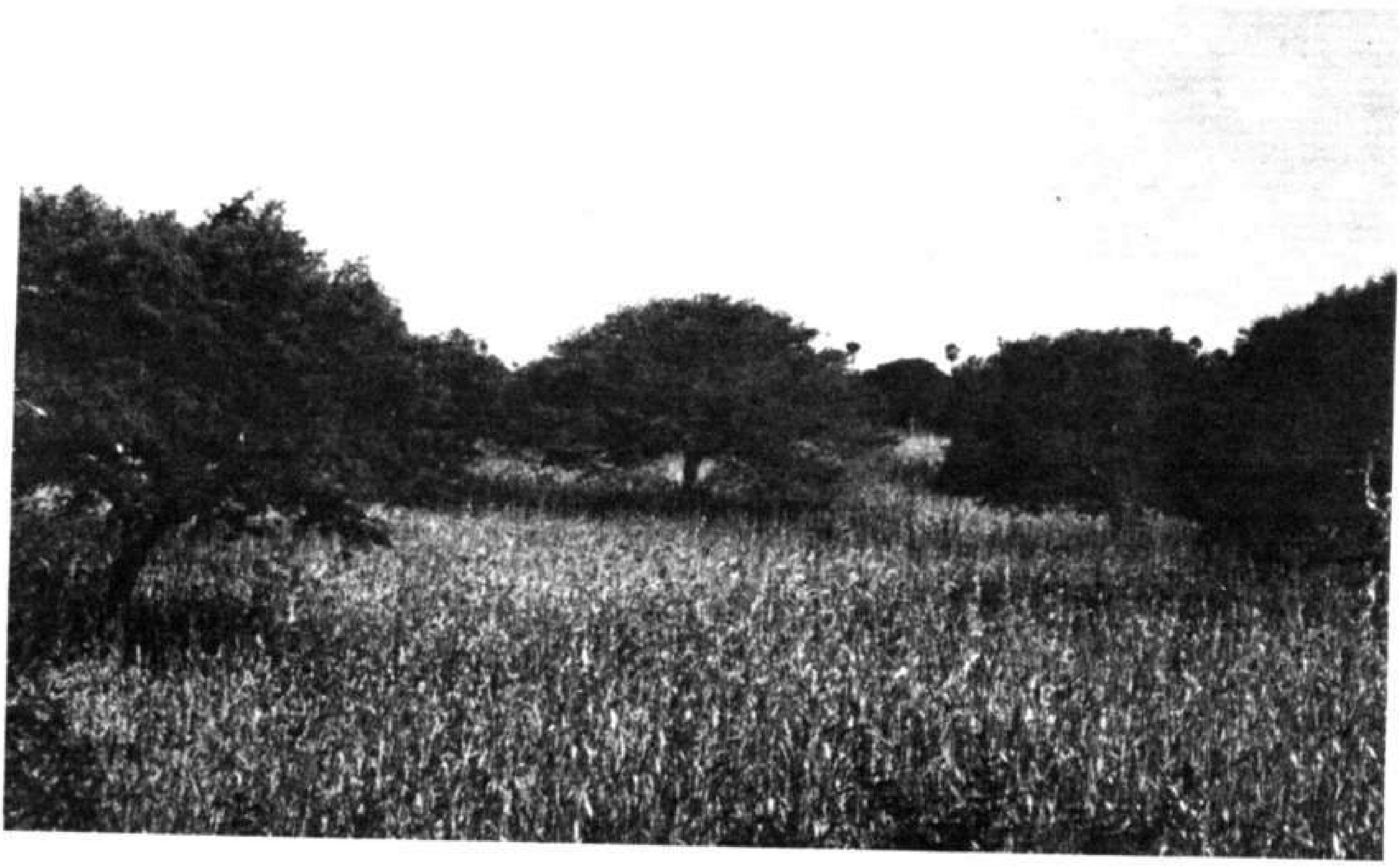
1. Diagnostic exercises and identification of native systems. Nearly all centers are engaged in evaluating native agroforestry systems and determining if these systems are capable of improvement.

2. Collection and evaluation of germplasm of trees most often used in native agroforestry systems.

3. Studies on the management mixes of agroforestry systems to find out the most suitable combination of different components, and to work out the best arrangements of the components to maximize production and sustainability, to find out the economic feasibility of the systems compared to monoculture systems, and to study the microclimatic effect.

G.B. Singh

Agroforestry is an age-old practice, and many traditional examples exist. Above, *Leucaena esculenta* is retained in a farmer's maize field for litterfall and sale of young pods in vegetable market (Oaxaca, Mexico). Below, *Prosopis cineraria* in a millet field (Rajasthan, India), an arrangement believed to benefit the crop through increased fertility under the trees.



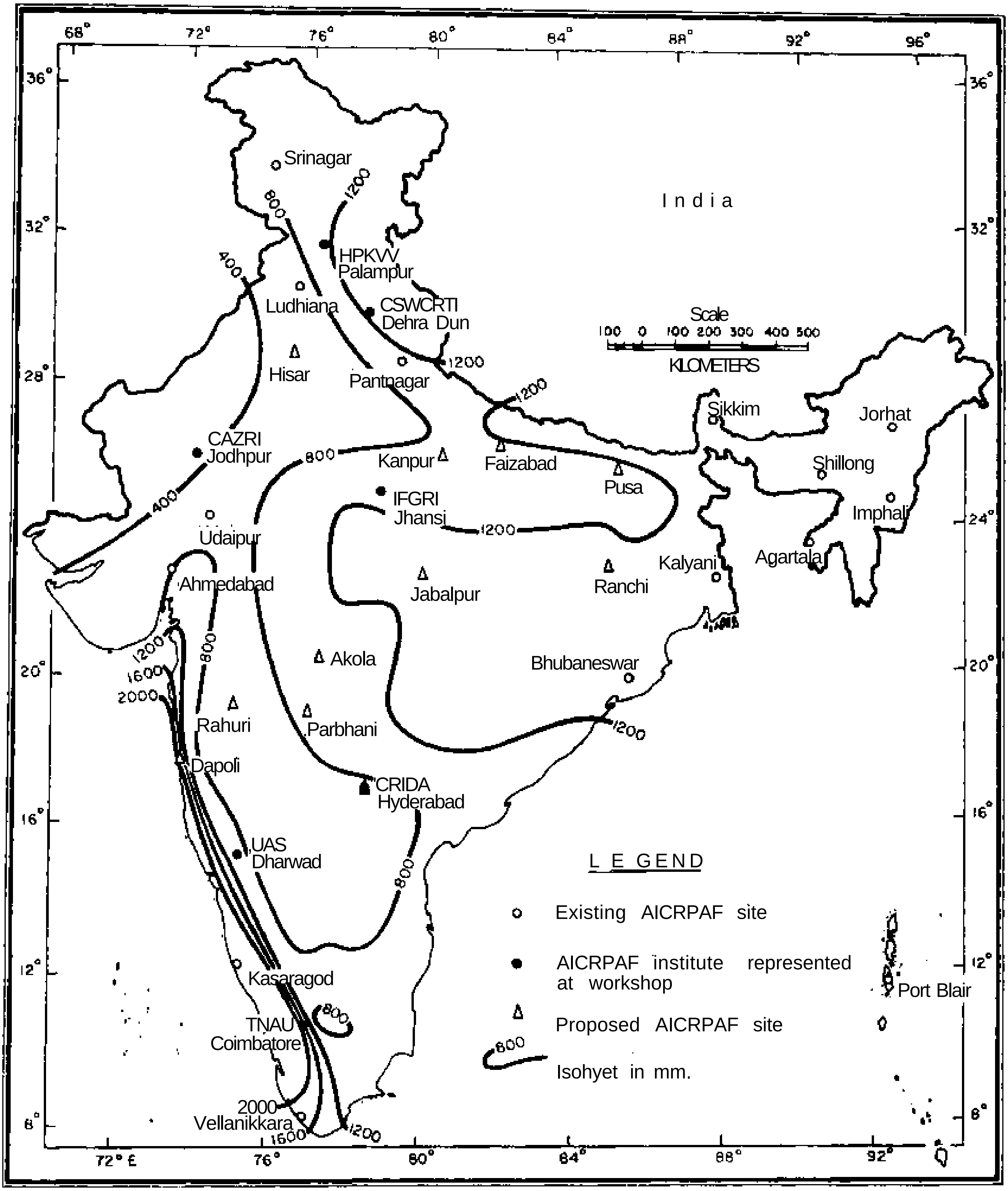


Figure 3. Location of centers by rainfall zone in the All India Coordinated Research Project on Agroforestry.

Indian Grasslands and Fodder Research Institute (IGFRI), Jhansi

The IGFRI has the following trials under way.

Silvipastoral systems for wasted lands. Research on these systems were initiated as early as 1970, to meet the twin needs of firewood and forage, including grazing, for animals on wastelands. The silvipasture system is the practice of simultaneously growing grasses and legumes in association with trees and shrubs on the same land. We advocate the use of multipurpose trees in this context. There are three approaches to this subject:

1. Use of trees primarily for direct environmental benefits–erosion control, climate amelioration, etc., in addition to secondary economic uses.

2. Use of trees as managed browse in grass/legume pastures. These schemes have been shown to be extremely productive, with annual grass yields of 7-10 t/ha in our test plots.

3. Occasional production of cash crops. For example, we have shown that crops sown under trees after clearing grass pasture produce more than the control areas.

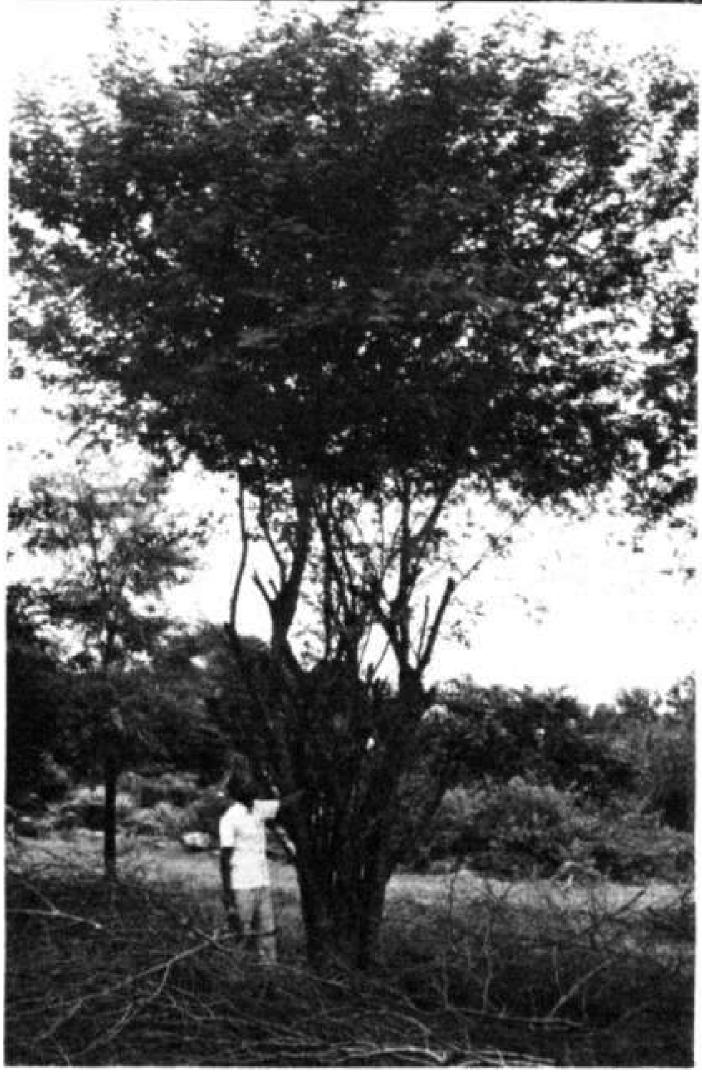
Coppice farming. Coppice farming involves the establishment of tree species with the ability to regenerate by shoots or root suckers at close spacings and under intense management. We have developed schemes that have doubled productivity over silvipastoral schemes, and we advocate them in areas with a high demand for tree products (firewood, fodder, etc.), low ability for capital investment, and a large share of marginal lands. These schemes have several notable features: they are simple to establish and manage; regeneration is more certain; and initial fast growth of the trees eliminates weeds.

Strip cropping. We have demonstrated yield increases of 63% for pearl millet grain and 19% for straw when the crop was grown between 10m strips of fast-growing trees in semi-arid and arid locations. The trees also produce sizable amounts of forage and wood.

Farm forestry. Trees planted on farm boundaries, irrigation channels, roadsides, and other such vacant areas grow well and produce sizable quantities of wood and forage. Over a 4-year period, our boundary planting trials yielded nearly 40 t/row km of firewood and more than 3 t/row km of forage. Poplars are especially suited for cooler areas and leucaena for drier areas.

Agrisilviculture. Our studies of Seebania grandiflora and Leucaena leucocephala with several crops have indicated positive gains in crop production, in addition to the forage and fuel benefits from the tree crops. Green manure from these trees has been shown to increase cereal yields. When grown in rotation with leucaena, millet yields increased by 10% over the control.

B.D. Patil



Work at the Indian Grasslands and Fodder Research Institute emphasizes the management of multipurpose trees in silvi-pastoral systems. Above/ the useful fodder tree *Alibizia amara* in open-grown form. At left, nearby tree of same species/ lopped. The treatment allows more trees per hectare and greater grass production under the tree.

University of Agricultural Sciences (UAS), Dharwad

Karnataka has 9 different agroclimatic zones, with varied problems of land use. Agricultural zones range from coastal, high-rainfall areas (annual mean rainfall 3800 to 4700 mm) to areas receiving scanty rainfall (630 to 810 mm). The middle, dry zone is the largest, covering about 65% of the total land area. There is fairly good scope for agroforestry in each of the zones. In the uplands, forest removal for agricultural purposes is a major problem. In the dry lowlands, trees are cut for firewood, producing a barren landscape.

Agroforestry work at Dharwad (northern transition zone) and the nearby hilly areas of Prabhunagar started almost a decade ago. We have 15 trials under way at Prabhunagar and 5 at Dharwad, covering land-use systems, siliviculture, crop nutrition, and crop introduction. Beginning next year, we will be establishing trials at Hagari, Gangavati, and Raichur.

Our research thrusts are three-fold:

1. to determine the spatial arrangements of trees and crops;

2. to determine the long-term sustainability of agroforestry systems; and

3. to follow up studies on research stations with studies on farmers' fields.

We have also begun an inventory of traditional agroforestry systems in the area, and have documented a few of these. For example, *Acacia fervuginea* is largely found in the northern dry zone where black clayey soils predominate. *A. fervuginea* is useful for fodder, fuel, and household timber and has a complementary effect on crop growth.

B.S. Nadagaudar

Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehra Dun

Dehra Dun, with annual average rainfall of 1705mm, is in the temperate subhumid agroclimatic zone. A diagnostic survey of 240 farmers in the valley has shown their first preference to agri-horticultural systems followed by agri-silvicultural systems. About 10-12 important agroforestry species have been identified for agroforestry work at the institute. These species are: *Eucalyptus* sp., *Bauhinia* sp., *Morus alba*, *Grewia optiva*, *Leucaena Ieucocephala*, *Albizia* sp., *Dalbergia sissoo*. *Terminalia* sp., *Oegenia oojensis*, *Anogeissus latifolia*, *Emblica officinalis*, and

Wheat yields diminished 20-25% at a distance of 5m from the trunks of mature eucalyptus trees in Dehra Dun, mostly from competition for nutrients and water. The effect is more pronounced in postrainy-season crops. Trenching (left) has effectively improved crop yield in this situation.

Work at Tamil Nadu Agricultural University includes a study of crops grown under three species of trees. Crop yields have decreased systematically with time as the trees mature and compete for light, water, and soil nutrients. Thinning the trees or establishing them at wider initial spacings (right) may help.

Moringa ptygoeperma. Over the last 30 years, the institute has done considerable work on silvipastoral systems suited for degraded soils. Some important combinations are Eulaliopeie binnata with fuel fodder trees and eucalyptus + Crysopogon fulvue.

Our agroforestry experiments have shown that under Dehra Dun conditions, postrainy-season crops are more affected by trees than rainy-season crops. Wheat is especially affected by trees, with reductions in yield of 20-25% at a 5m distance from tree trunks. The reduction was more with eucalyptus hybrids and Morus alba than with Grewia optiva combinations. Further studies at Kota (semi-arid region) have shown that eucalyptus reduced the yield of legumes more than that of sorghum in the rainy season. Trenching (0.5m wide and 1.0m deep) around trees has effectively improved postrainy-season crops at Dehradun.

An experiment on nutrient and water budgeting was started in 1983 on 90m x 15m plots at 4% slopes with Crysopogon fulvus grass, maize-wheat crops, and using eucalyptus hybrid and leucaena as an intercrop for fuel and fodder. The trees had little effect on crops in the first rainy season; however, substantial reductions were noted under the leucaena (from 2.1 to 1.8 t/ha) and the eucalyptus (from 2.1 to 1.7 t/ha). Maize yield in the second year was reduced from 3.2 t/ha to 2.4 t/ha under leucaena and 2.1 t/ha under eucalyptus. Runoff and soil losses were greatly reduced under the agroforestry mixes. Pure stands of trees (4444 stems/ha) had very little runoff and soil loss.

Pratap Narain

Tamil Nadu Agricultural University (TNAU), Mettupalayam

The Mettupalayam station is located about 30 km from Coimbatore at 300m elevation, with 800mm rainfall. Native vegetation is scrub jungle, and the soil is of a red gravelly type.

Experiments on agroforestry were initiated at the University as early as 1979. With the inception of the ICAR program, the work was further intensified. Our agroforestry work centers on the effects of different tree species on growth and yield of crops. In one trial, we compare economic and site benefits of four different forms of farming;

1. Agriculture: Sesame-groundnut-maize.

2. Silviculture: Monoculture of eucalyptus and casuarina.

3. Agroforestry: Sesame-groundnut-maize with eucalyptus and leucaena.

4. Silvipasture: Leucaena + Stylosanthus hamata.

Another trial utilizes three perennials (eucalyptus, casuarina, and kapok) intercropped with maize, sorghum, millet, cotton, sesame, black gram, cowpea, mung bean, sunflower, lablab, soybean, groundnut, and turmeric. Initial results show that crop yields decrease as the trees become larger and more competitive. There was no yield reduction in the crops the first year, while overall yields were reduced 20% in the second and 60% in the third year. In a related trial, we are investigating the optimum rectangularity of trees. We monitor air temperature, relative humidity, and light intensity in these trials.

We have begun a project to study the allelopathic effects of casuarina and leucaena on the germination of agricultural crops such as maize, sorghum, and millet.

G.M. Dasthagir

Himachal Pradesh Krishi Vishva Vidyalaya (HPKW), Solan

Himachal Pradesh, a northwestern hill state of India, encompasses a wide variety of climates, ranging from subtropical to wet temperate and dry temperate, culminating in alpine. About 92% of the total 4.2 million people are rural. There are 4.8 million head of livestock. About 11% of the State is under agriculture and 38% is forested. The land holdings are small (0.2-0.5 ha) and widely scattered. Generally, the people are dependent on the surrounding forests for 90% of their basic needs like fuel, fodder, constructional timber, and fruit packing cases. About 60-70% of the firewood demand is met from forests. On the average, per capita consumption of firewood is 0.6-0.8 t/yr.

Decreasing forest areas are straining the traditional relationship between forests and people. Soil erosion and reduced land productivity have emerged as a result of this forest clearing. There is an acute shortage of fuel, fodder, and increasingly important, of raw material for fruit packing cases. Presently about 0.2-0.3 million m3 of wood is being cut per year for this purpose alone. The problem is exacerbated by subsidies to the fruit industry for packing cases, which eliminate the incentives to grow trees for this purpose.

We started our research work during May 1983, with the following three broad objectives:

Diagnosis and design. Farmers with small, medium, and large holdings were selected. Data pertaining to their land holding, fuel and fodder resources, number of cattle, agricultural income, and existing agroforestry systems were collected. The studies confirmed acute shortages of fuel, fodder, and wood for packing cases. The existing agroforestry systems in the state need to be improved for both bioproductivity and ecological stability.

Germplasm bank. We have emphasized suitable fodder species in multilocational trials. The purpose is to evaluate their growth pattern, genotype x site interaction, and to standardize lopping practices for fodder production, a major use of trees in the State.

Development of agroforestry systems. Trials have been established to develop productive and transferable agroforestry systems. Trials include poplar/crop mixes in areas of intensive agriculture, poplar/fruit tree mixes (i.e., plum, *Prunus salicina*) in temperate fruit-growing zones where wood for packaging cases is in short supply, and leucaena/citrus (*Citrus reticulatia*) mixes in the citrus belt where fuel and fodder are the main constraints. Silvipastoral studies have been started in areas with a large amount of unused land. For small farmers, the hegderow planting concept is being evolved, incorporating fuel and fodder species with coppicing ability.

V.K. Mishra

About 90% of the fodder, fuel, and wood needs of hill dwellers in Himachal Pradesh comes from forests. Trees are usually lopped rather than felled, but this can lead to decline and eventual death of mature trees.

Central Arid Zone Research Institute (CAZRI), Jodhpur

The retaining of multipurpose trees in agricultural fields of arid areas as an insurance against the failure of the monsoon and subsequent drought is an age-old practice. The commonly observed multipurpose trees in fields are: Prosopis cineraria, Acacia nilotica var. cupressiformis, Zizyphus rotundifolia and Tecomella undulata. However, no systematic study was made to identify the systems and to improve them for higher productivity and better economic returns.

In the early 1970s some work on agroforestry was started at the Central Arid Zone Research Institute with the following objectives:

1. To determine the suitability of intercropping within tree belts, using different arrangements of plant geometry.

2. To select optimum combinations of tree shelterbelts for maximized production of intercrops.

3. To study the economics of different agroforestry systems, working out the comparative economics of trees versus crops.

In earlier studies, crops were sown under trees aged 8-15 years. These studies have shown a definite effect of shading in crops such as mung bean and guar. Grain yield of mung bean and guar under Holoptelia integrifolia trees was reduced under unlopped trees, but reductions were less when the trees were pruned.

Several studies have been under way to examine the effect of tree cover on production of forage grasses. This work has been documented in recent station bulletins and other publications originating from CAZRI. Generally, it was observed that trees have shown little adverse effect on grass production.

More recent studies have shown that at early stages (less than 3 years), the growth of trees (such as Acacia tortilie) was severely supressed when grown with grasses, but after the 4th year there was a positive effect on tree growth. Economic analysis of silvipastoral systems revealed that income from plots of grass alone were between a half and a third of the income from plots with tree/grass mixes, depending on spacing.

L.N. Harsh

Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad

Agroforestry work at this Institute may be divided into three parts: a) agroforestry, b) silvipastoral studies, and c) diagnosis and design (D&D) and evaluation of systems . Each of these will be discussed briefly in turn.

Agroforestry. These studies focus on the long-term ability of a site to support tree/crop systems. Four major trials are installed. The first examines the role of leucaena at different row widths in an alley cropping situation with sorghum, castor, pearl millet, and pigeonpea. The second compares various tree species (leucaena, calliandra, Desmanthus virgatus, Sesbania sesban, and gliricidia) as hedgerows set 7.2m apart. Various cutting and mulching schemes are among the variables. The third trial involves cropping underneath a leucaena canopy, with lopping of the canopy as the major variable. The fourth study is cropping under Acacia tortilis.

Besides examining the yield potentials of these systems, we are also quantifying their physiological and site effects. We are especially interested in the degree of competition by the tree and crop components for important microclimatic factors limiting the productivity of the systems. We monitor radiation intensity and spectral quality of light, soil moisture (at 20 and 40cm depth), relative humidity, and soil temperature, all as a function of distance from the tree component. Field observations of crop photosynthetic rates, diffusive resistance, leaf to air temperature difference, spectral properties of leaves, and other crop physiological and growth observations are being carried out on both tree and crop species.

Silvipastoral studies. These trials are designed to determine the relative efficiency of two silvipastoral management systems on marginal red soils of drylands, and to study their soil fertility changes over time. One trial consists of leucaena planted at a 6 x 2m spacing with Cenchrus ciliavis planted underneath, while the other uses leucaena at the same spacing with Stylosanthus hamata sown as an understory. Observations include height and diameter breast height (4.3m above ground) of leucaena, fodder yield of leucaena and forage, and microclimate and soil fertility changes from the two systems.

Diagnosis and Design (D&D) and System Evaluation. We are making use of our trials to determine the costs of land preparation by manpower and machinery. Careful records are kept to determine costs of field establishment and maintenance. We are also utilizing our trials to assist in the determination of suitable statistical methodology for experimentation by specifying techniques for design of plot size and shape, field layouts, and data analysis.

We are also conducting a diagnostic survey of rural knowledge and attitudes toward tree planting. The survey is being carried out in zones varying in agroclimatic conditions, labor availability, sociocultural conditions, and wood availability.

G.R. Korvvar

Role of Industry

Ion Exchange India—A Philosophical Perspective

Ion Exchange India is in water treatment, employing several unit operations like reverse osmosis, ion exchange, electrodialysis, and various other means to purify water for industrial use. Not entirely facetiously, it could be stated that our common link with agroforestry is water. More to the point, we are interested in agroforestry because we see the potential for profit and the twin opportunities of creating employment for the rural poor and making productive use of our nation's wastelands.

We have been trying for 5 years to obtain a lease from the Maharashtra government to begin our own agroforestry project on a 180 ha degraded hilly tract and are optimistically awaiting approval of our plans. The main production will be fodder, fuelwood, and poles. Fruit trees will be planted and aquaculture undertaken in the water storage created for irrigation. The objectives would be to provide employment and training at all levels from management to field workers, sustainable through a reasonable rate of return. An important objective is to serve as a marketing backup for the produce of the area surrounding the project. I should note that we have spent the last 5 years in R & D activities supporting this project and are convinced of its potential.

The three essential inputs for the success of agroforestry or any other project are management, motivation, and training. I think we can all agree that the main task is to get agroforestry projects started on a much wider front. The most practical way of doing this is to combine the best available management with the best technology. The best management is with the corporate sector. What is lacking is an awareness of the tremendous opportunity that exists in the productive management of the country's wastelands.

Agroforestry undertaken on common lands or public property will not show the results of similar work done on private or leasehold lands, because no one relates common lands to himself except as an opportunity to plunder and to plunder before others do so. Protection of newly planted trees, which is vital, is difficult to provide.

Not surprisingly, successful tree plantations are commercial ones connected with wood-based industry looking for a continuous supply of raw material—for paper, matches, and rayon. The secret of this success is management, built on a foundation of training, leavened by experience, and motivated by profit, which includes every incentive ranging from money to a halo.

Degraded land with the forest and revenue departments and panchayats should be offered on long lease at a nominal annual fee to companies for the purpose of raising commercial tree crops. Companies with good management would be able to make such unproductive land productive quickly. The profit from such ventures would not only attract many more to take to such activity/ generating employment and wealth, but also improve the environment and increase agricultural production by creating more water storage and minimizing erosion. An important effect of such activity would be to make the urban market freely accessible to rural poor and develop a strong link between rural and urban India which is missing today and is one major cause of our problems,

A large part of the blame for rural poverty is the existing marketing set-up of rural produce, which fetches the producer hardly a tenth of the urban sale price. This sale price could easily be halved and the producer's income doubled if modern marketing ideas could be applied. These would fix an annual rate contract with the producers and by means of a well-planned infrastructure of collection, transport, storage, and distribution, permit their sale at a stable price. Current high prices are based on shortages, which would not exist if production could be increased. The charge for such a marketing service could be reasonable and yet provide an acceptable return on investment.

There is much excitement over importing technology to make cars and computers, but technology to increase rural production and provide modern marketing backup for rural produce would bring about a much more rapid transformation of our economy by benefiting many more millions. It should receive priority.

Shankar Ranganathan

Mysore Paper Mills—Research from Necessity

Mysore Paper Mills in Bhadravati is one of the biggest industries in Karnataka State, producing over 100,000 tonnes of paper annually, out of which 75,000 tonnes is newsprint. We have recently established a sugar plant capable of processing 2500 tonnes/day. The bagasse is used for paper manufacture, while coal fires the boiler for power and steam. The use of bagasse for pulping, instead of its more conventional use as a captive fuel, is by necessity rather than choice. Our mills use bamboo and eucalyptus primarily, but production of these raw materials has been dwindling in the past few years. Although we can produce 120,000 tonnes of bagasse annually, this is not sufficient to feed the paper mill.

The reason for our interest in agroforestry is evident—we want to evaluate these systems for the possibility of producing more biomass for the mills. We have started a collaborative agroforestry research program with the the University of Agricultural Sciences, Bangalore. Our program is an integrated strategy of growing several plants–annuals, perennials, woody, and nonwoody, preferably nonedible–with one industrial end use, fiber for pulp.

The study mostly involves the intercropping of trees with sugarcane. We have screened sugarcane for varieties tolerant to partial shading. Trials involving spatial arrangement with species such as casuarina, acacia, leucaena, acrocarpus, etc., leaving an open canopy, have been attempted in sugarcane with no adverse effect on cane yield and quality. As boundary trees, these species have helped to reduce lodging of cane, besides providing fodder and fuel to the farmer. A trial has been initiated with strip cropping of these trees in sugarcane.

It is widely argued that eucalyptus is allelopathic and negatively affects soil moisture and fertility. Hence, a study has been inititated of sugarcane intercropped with eucalyptus, to find out the allelopathic effects. Preliminary studies in irrigated Vertisols show no ill effects of eucalyptus on sugarcane.

Kenaf, popularly known in India as mesta (*Hibiscus cannabinus*) and roselle (*H. sabdariffa*, L.) are excellent raw materials for pulping and paper manufacture. In Andhra Pradesh they are grown both as sole crops and as intercrops with millet. In the USA, 25% blends of kenaf pulp in newspaper manufacture have proved satisfactory. We believe that kenaf could substitute totally for bamboo; we are screening varieties for biomass production and examining the feasibility of growing it as an intercrop with sugarcane.

Gururaj Hunsigi

Intercropping of kenaf and sugarcane is studied in the Mysore Paper Mills agroforestry program. The kenaf will be used to replace bamboo in manufacturing paper.

Role of Nongovernment Organizations (NGOs)

A Brief History of NGOs in India

The Indian movement with nongovernment organizations (NGOs) was started by Mahatma Gandhi for the socioeconomic upliftment of the rural poor. During the 1930s and 1940s, many Gandhian disciples operated ashrams and voluntary organizations at the village level throughout India, providing skill-oriented training and stressing eradication of untouchability and illiteracy. Schools and hostels were established by these NGOS, with funding borne by the industrial and other well-to-do sections of society. Gandhi stressed appropriate, decentralized, labor-intensive technology, as symbolized by the popular khadi (homespun) cloth industry, which provided job opportunities to villagers in their homes.

After independence, NGOs continued their activities in these limited fields, working independently of government programs, with enthusiastic participation of local leaders and social workers concerned with the development of their communities. NGO projects of this postindependence era were successful because the programs were flexible enough to suit the local conditions and because activities were planned in consultation with the client group—the rural poor. On the other hand, the government's community development programs during this time were less successful because they were planned at the top without consulting client groups and without providing sufficient flexibility at the implementing level.

As a result, the government encouraged the participation of NGOs in rural development programs during the Fifth and Sixth Five Year Plans. Tax concessions were introduced to benefit private industries who contributed to nongovernment agencies for research and development activities.

The BAIF Experience

The Bharatiya Agro-Industries Foundation (BAIF) was founded by Dr. Manibhai Desai, a Gandhi disciple, in 1967. Deviating from other Gandhian groups, Manibhai assessed the various rural industries and determined that khadi weaving alone could not provide gainful employment. Past experience with crossbred cattle showed that their husbandry for milk production could provide remunerative employment to rural families. But the facilities provided by state animal husbandry departments were inadequate and not easily available to poor people. Hence, BAIF developed a cattle development program to benefit poor rural families.

The specific objective of the BAIF program was to motivate farm families to maintain 2-3 crossbred cows to raise their earnings above the poverty line, without major interference to their normal routine, investments, and risk. The program included breeding of local nondescript cows, with superior quality exotic breed bull semen made available at the doorstep of the farmers, providing superior quality vaccines to protect against diseases, promoting fodder cultivation on wastelands, demonstration and training of dairy management practices, which motivated many farmers to take up dairy farming in Maharashtra. BAIF has played a major role in increasing the milk sales of Bombay from 100,000 to 2,100,000 liters/day during the last 10 years.

Soon after the initiation of this project, BAIF initiated a fodder production program, introducing leucaena from Hawaii in 1972 in addition to grasses. Afforestation as a source of additional fodder production was incorporated later. In a short period of 6-8 years, leucaena has today become popular in many of the rural areas where we work, mainly because of the favorable results of our problem-oriented research, availability of necessary data on cultivation and economics, assured supply of quality seeds, and motivation through extension and demonstration.

It has been well-established by BAIF that biomass production through leucaena cultivation is highly profitable. However, we do not advocate converting productive agricultural lands into forests. Therefore, agroforestry was introduced at BAIF, with the goal to provide farmers with fodder and wood in their field with minimal reductions in grain yield.

Agroforestry is not a new practice to Indian farmers. One can see trees in almost every field. Farmers cut them whenever they need wood for implements, timber, or fuelwood. The tree population per unit area has, however, stayed small mainly because of the market factor. Trees like acacia and neem can be sold for timber, but the rotation age of 25-30 years is too long to motivate farmers to grow trees.

The Role of NGOs

Although agroforestry has numerous economic and ecological benefits, poor and marginal farmers are not interested in a new technology unless it ensures additional direct benefits, preferably in cash. This may ultimately be the most limiting factor to acceptance of agroforestry in the rural areas. Our experience is that farmers have a difficult time getting a fair price for nonagricultural biomass like wood. Market development, distribution networks, and product processing are required to increase profitability and thus people's participation. Additional needs are training and the establishment of an inputs supply program. It is also necessary to intensify research and to test new models in the field to closely examine their feasibility and social acceptance.

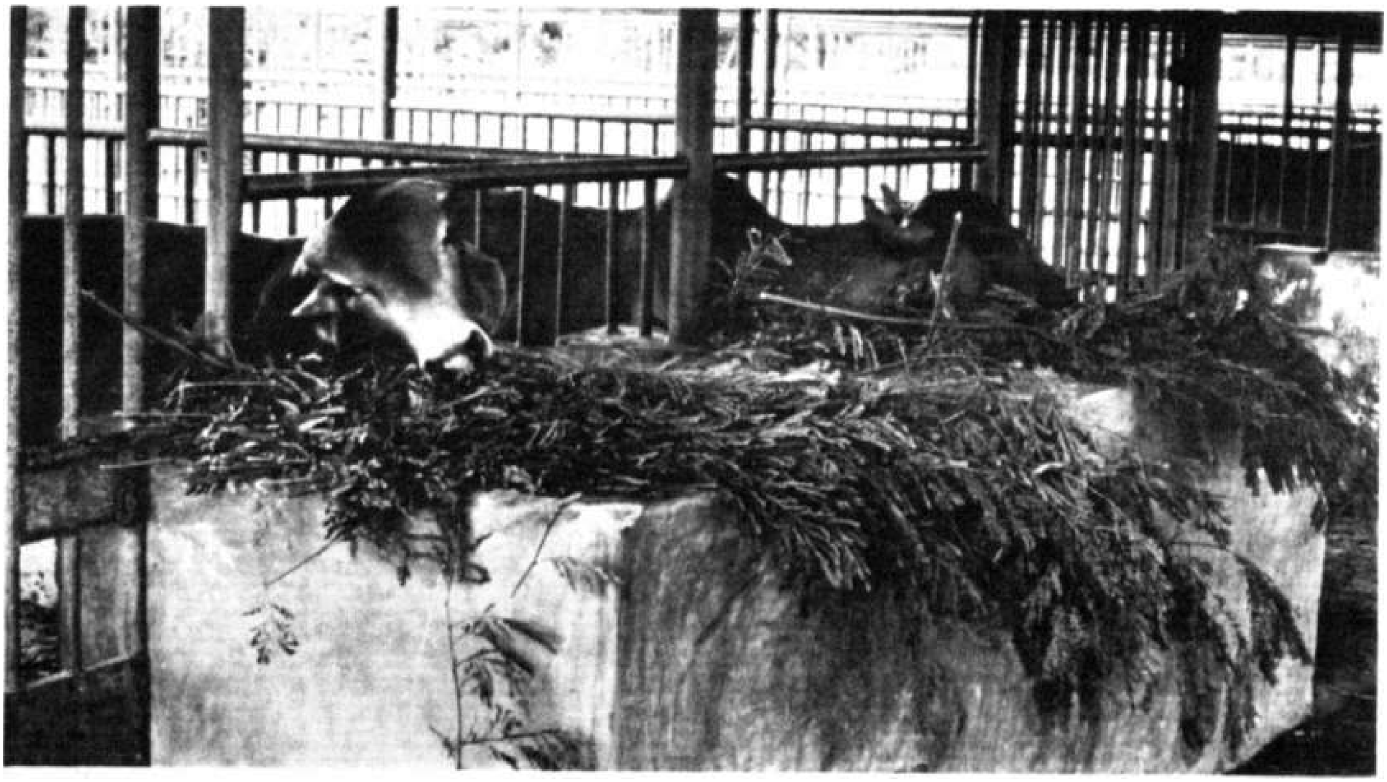
During the last few years, other NGOs have started agroforestry research programs. Unfortunately, it is extremely difficult for NGOs to engage in basic research unless a commercial or industrial interest is involved and financial assistance is provided.

Excepting a few NGOs who have attained the status of research institutions, the best way of involving them is in the testing of research results in field conditions. NGOs have the advantage of close interaction with farm families, and they can suggest modifications to improve the acceptability of different models. NGOs can also assist in establishing marketing networks through their involvement with marketing associations and cooperative societies. Extension is another area where NGOs should be involved in program promotion, as government agencies have generally been less effective in motivating the farmer.

At the very least, dialogue between scientists and NGOs may be useful before new technologies are released. This not only gives the scientist an opportunity to understand the relevant conditions in the field but also provides an opportunity for the NGOs to obtain current research findings that may be useful to them in their work. This can only improve the credibility of NGOs in the field.

However, despite this usefulness in extension and verification of research findings, NGOs should be screened carefully before they are used in promoting agroforestry in the field. The primary considerations should be technical competence, a record of successful rural intervention, and nonaffiliation with political groups.

Narayan Hegde



Agroforestry research at the Bharatiya Agro Industries Foundation emphasizes fodder production through silvipastoral systems. High-protein fodder from such mixes (here, leucaena loppings) is fed to crossbred cows to improve milk production.

ICRISAT's Program

ICRISAT's Program

Introduction

Farming systems research at ICRISAT aims to develop improved production systems that give the small subsistence farmer of the SAT higher yields not only in the short term but also into the forseeable future. Improved systems are urgently needed because crop yields are low—about 800 kg/ha for the two staple cereals, sorghum and millet—and traditional systems give little protection against erosion.

The approach used in our farming systems research involves a range of activities conducted in a logical order. In sequence, these include:

1. base-data analysis to define the various agroecological environments in the SAT;

2. diagnostic research on farms and research centers to determine the constraints in existing systems;

3. detailed research on constraints;

4. operational research to fit the various components into an overall farming system that is practical for the small subsistence farmer; and

5. testing of these systems in farmers' fields to determine their practicability.

This approach has been used in the development of the improved system for double cropping on deep Vertisols in the assured rainfall areas in India. We feel that the same procedure can be used for developing alternate technologies for harsher sites like ICRISAT's Sahelian Center, where the rainfall is low and the sandy soils have a low water-holding capacity and are of low inherent fertility.

Research Objectives

Agroforestry provides much promise for marginal environments, not only because it could provide fodder for animals and wood for fuel, but also because it could provide a better environment for food crops.

The major thrust of recent agroforestry research has been on the biological productivity of various tree/crop mixes. There is an urgent need to provide some basic principles for a better understanding of agroforestry systems in general. Given the complexity of agroforestry systems, a multidisciplinary approach is required to examine their sustainability in different ecozones of the semi-arid tropics. The most crucial test of viability in introducing a perennial species into annual cropping systems is the degree of long-term economic improvement achieved by the new system over the old. While the introduction of trees in cropping systems may influence crop yields beneficially, long-term environmental stability must also be considered.

We view agroforestry research as a logical extension of our work on intercropping over the last 10 years. Intercropping has been shown to have a higher economic productivity than traditional sole-cropping systems because it makes more efficient use of physical resources. Our goal is to determine whether or not this is true for agroforestry systems as well, utilizing ICRISAT's five mandate crops in carefully managed mixes with multipurpose trees.

Our work will emphasize the development of principles and methodologies that may be applied in other locations (particularly our Sahelian Center at Niamey), rather than site-specific observations of effect of agroforestry treeatments on yield of crops. We will utilize our expertise with instrumentation to focus on the crop physiology implications of agroforestry.

An example of such basic research is the question of how trees and crops interact in their competition for light/ water, and nutrients, and how the tree can provide advantages—in the form of microclimate amelioration, erosion control, and nutrient inputs—that offset the disadvantages caused by light, water, and nutrient competition and by allelopathic effects. Studies along these lines can lead to the development of basic concepts.

In addition, our work will emphasize the development of appropriate methodologies. New methodologies will have to be designed in research to determine the effects of trees on nutrient distributions. In addition to the normal random heterogeneity in the distribution of nutrients in soil, agroforestry is likely to cause considerable systematic heterogeneity—both with distance away from plants and with soil depth.

Systematic designs (see Fig. 4) are valuable in agroforestry research. They can be set up to examine a wide range of treatments, using comparatively fewer experimental resources, such as land and labor, than the usual agricultural designs. They are particularly important in agroforestry research because little preliminary information is available, and the perennial nature of trees demands large plots in conventional layouts.

ICRISAT will look at agroforestry research as an exercise in farm resource management and conservation, recognizing that the needs, abilities, and incomes of farmers are of major importance in guiding us in the design of station research.

Field Studies

Our program of field trials was started in 1984 with experiments on Alfisols and Vertic Inceptisols involving cereal and legume

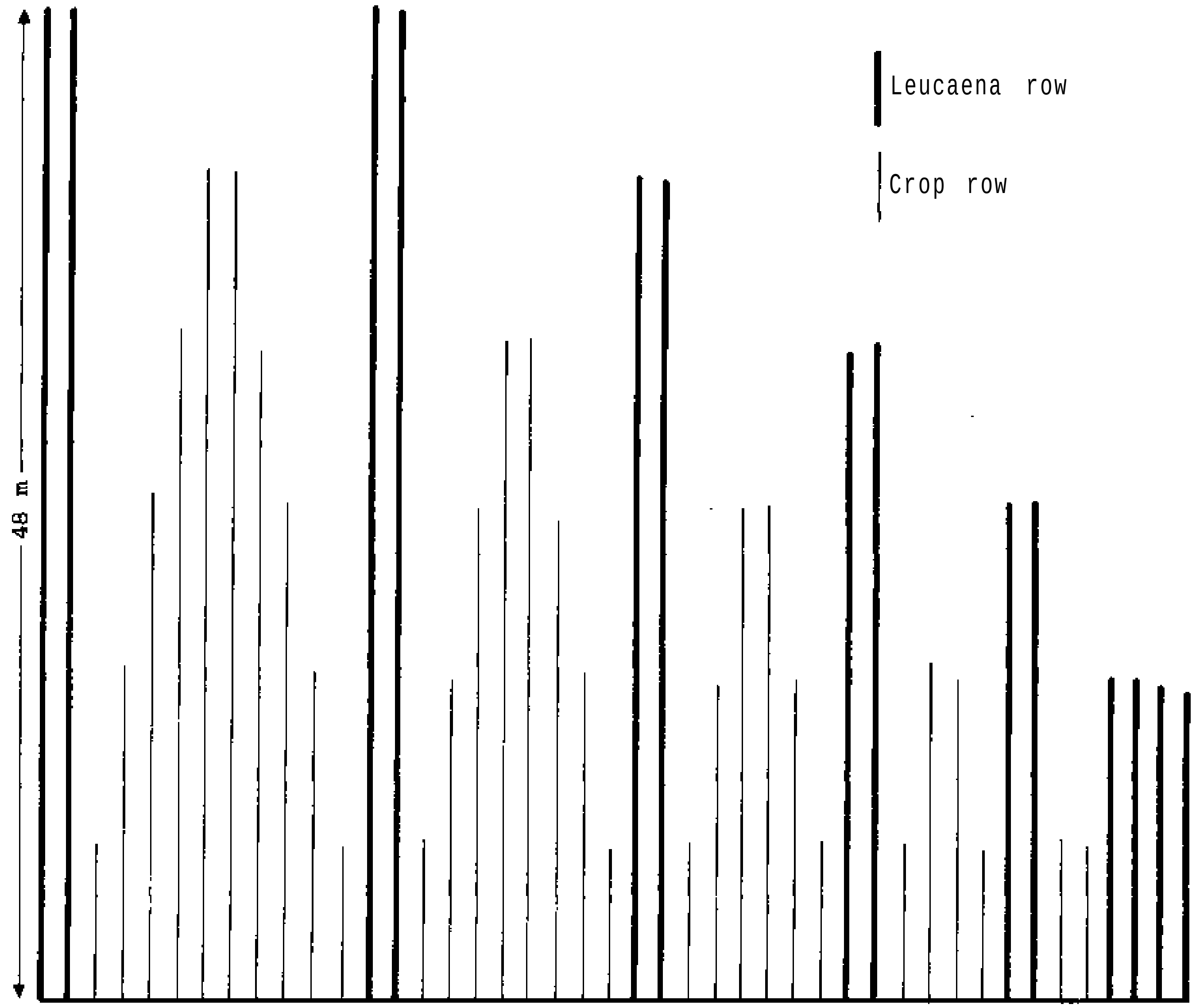
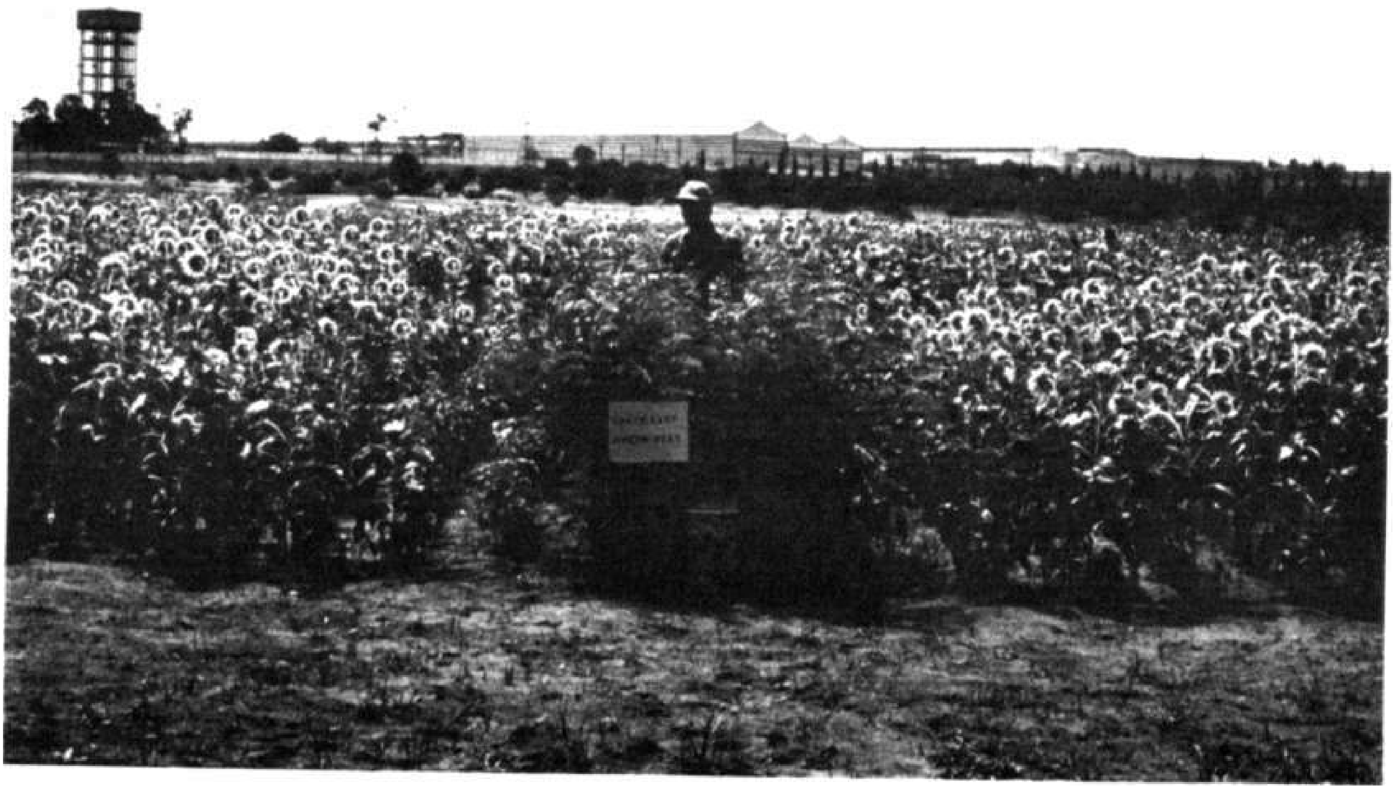


Figure 4. A schematic representation of a 2-way systematic design used in ICRISAT's agroforestry research.

Note: In this design, paired rows of leucaena are direct seeded vertically, decreasing distance between rows. Annual crops such as millet, sorghum, or a cereal/pigeonpea intercrop, are then sown between the tree rows in the patterns shown. With each succeeding closer-spaced leucaena "alley", two rows of crop are dropped. Additionally, within an alley, crop rows vary in length. Near the leucaena hedgerows, blank spaces between the crop and the hedge increase as one proceeds into the alley. The entire block is replicated 3-4 times. Such designs are highly suited to regression analysis, and ideal for screening a large number of treatments. In this trial, effects of row width of leucaena hedges, effects of different spacings between the crop and the hedge, and competitive effects of the crop/hedge mix can be observed.

Seasonal rainfall in the Hyderabad area was <400 mm in about 40% below average. This seriously affected leucaena-based alley cropping trials. Growth and subsequent yield of sunflower (below) was greatly diminished near the hedgerows. The effect was not so noticeable in sorghum (above). Increasing the distance between hedgerows and severely pruning them closer to the ground would lessen this negative impact.



grain crops (millet, sorghum,, and pigeonpea) associated with *Leucaena leucocephala*. Experiments were designed to study interface effects between leucaena and the crops and to monitor resource utilization in the mixes.

Leucaena is utilized not because of its potential in agroforestry per se, but rather because it is fast-growing in the Hyderabad region, and because of the urgent need to produce basic principles of agroforestry that can be tested with different mixes in other locations. Fodder production from the hedge is emphasized, as this is a valuable coproduct in semi-arid environments and is often a constraint in livestock production.

Summarized, the projects now under way at ICRISAT include:

Alley cropping. Three trials have been established to study the various effects of a pruned, perennial hedgerow (*Leucaena leucocephala*) on performance of various crops (millet, sorghum, and pigeonpea). Of particular interest is the physiology of the tree/crop interface, and the rooting habit of the tree hedge.

Cropping under standing trees. Established just this year, this trial examines the effect of spacing of standing trees on crops (millet) grown underneath. Emphasis will be placed on competition and use of light and water.

Pigeonpea in agroforestry systems. These trials examine the wood, food, and fodder biomass potential of perennial, late-maturing, nondeterminate, disease resistant pigeonpea lines screened at ICRISAT. This information will be used to develop agroforestry cropping patterns based on the arboreal pigeonpeas.

Land management systems. This study evaluates land management systems for efficient soil and water conservation on shallow black soils, utilizing perennial species. Changes in soil nutrient status and distribution, and effect on soil losses and water runoff, are emphasized.

Observational tree plantings. This incrementally planted small trial is designed to observe the growth of trees recommended by foresters and to determine their potential role in SAT agroforestry systems. There is a need for such simple observational plantings at all institutions with an agroforestry program.

ICRISATs West African Program

In the southern Sahelian and the Sudanian bioclimatic zones of West Africa, natural resource management and conservation are poorly known and practiced. Recent studies by the World Bank have suggested that the population carrying capacity, in terms of fuel and food, will steadily decrease over the coming years, with fuel shortages rapidly becoming more critical than food.

ICRISAT has assembled a group of 8 principal scientists based in Niger who, with their separate but converging interests, form a team to develop resource management solutions for millet-based agriculture in the Sahel. We anticipate that agroforestry research will be incorporated in their efforts from 1986.

Our interests are to provide guidance, based on research, to West African farmers with limited resources, so that they can integrate trees, shrubs, and herbaceous plants into cropping systems based primarily on pearl millet and cowpea. This is not a novel idea. Farmers have traditionally conserved trees and some shrubs in their cultivated areas. But such plants must now be deliberately planted to perpetuate their presence in cultivated fields, with the prospect of improving food crop production. Additionally, the indigenous species, which "nature" plants in cultivated areas, are not necessarily the most advantageous taxa that can be found.

Previous research results on the agroforestry aspects of farming systems in the drier zones of West Africa have not been voluminous, but they are sufficient to suggest that trees and shrubs improve agricultural conditions by controlling wind and water erosion, improving soil structure and fertility, and providing shade and animal feed; they have the added virtue of producing a portion of the fuel needed by the farming family.

We anticipate that trees and shrubs, when deliberately incorporated into the farming milieu, may have some negative effects: moisture competition, shading, and perhaps unanticipated toxic effects on food crops. Our initial concern will be pragmatic: to develop tree-shrub-crop systems that are more productive than present practices and within the capabilities of farmers.

Perennial pigeonpea may obtain truly arboreal dimensions. The crop here is 4 months old. Some lines grow 4-5m tall with basal diameters of 8-10 cm, in 1.5 years. ICRISAT has begun studying the wood yield of these varieties to examine their potential use in agroforestry systems.

Collaboration and Linkages

Collaboration and Linkages

Agroforestry as a development package is unique in that the urgency with which it should be extended to farmers' fields is offset by the length of time research in the area is expected to take. In the SAT, this time factor is important because the sustainability of agroforestry systems is an important constraint in their long-term acceptance by small farmers. Quantification of this sustainability should be a key part of agroforestry research in the SAT.

The procedure can be shortened by incorporating basic research components into ongoing applied research efforts. For example, simple yield, mixture, and species trials now in place at many institutes and universities could increase in value if the trials were expanded to include some subjects of more basic research, such as light and water use and nutrient recycling, which will assist in determining the sustainability of the system.

Most institutions have personnel well-trained in methodologies of applied research, but they lack trained personnel and the sophisticated equipment necessary to perform the precise and repetitive measurements necessary for basic research. Thus, it is important that institutions performing agroforestry research pool their efforts to achieve a reasonable balance between applied and basic research on a regional basis. This approach has the following advantages:

1. It is cost effective, in that it does not require each institute to develop its own skills and/or programs in both the applied and basic fields.

2. It prevents the duplication of research effort, eliminating waste of resources and time.

3. Networking and information sharing is enhanced and, therefore, results with wide applicability are produced.

The ICAR agroforestry program is a network of both ICAR institutes and state agricultural universities. The major goals of the program are twofold: a) evaluation of agroforestry systems; and b) dissemination of agroforestry practices to the field. A link with ICRAF was formalized in August 1985. ICAR intends to build a capability in basic agroforestry research, and has proposed as part of the Seventh Five Year Plan the establishment of an Agroforestry Research Center in 1986.

This conference was preceded by deliberations between ICAR and ICRISAT regarding possible collaboration in agroforestry research. ICRISAT is placing its emphasis on basic research of agroforestry systems, particularly in the area of physiology and sustainability of crop/tree mixes. ICRISAT's comparative advantage lies in handling concepts and developing methodologies of research, instead of developing location-specific technologies. However, it must be realized that agroforestry is just one small part of a range of farm resource and conservation disciplines that ICRISAT maintains. Thus, ICRISAT's ability to support agroforestry research is limited at present.

The nature and extent of collaborative research between ICRISAT and ICAR is an issue that will have to be worked out in the months following this workshop; however, certain broad areas were agreed upon. Firstly, it would be most advantageous if collaborative research links could be developed between ICRISAT and those ICAR agroforestry institutions working on a similar semi-arid environment, with closely matching research priorities. Secondly, common experiments should be installed so that 'mini networks' could be developed to insure that generated information is widely adapted. Species, experimental designs, data collection methodology, etc., should be as uniform as possible. Thirdly, all collaborative research should be preceded by a database of information regarding the areas wherein experiments are established—climate, soil parameters, etc.

Appendix: Participants

Seated (left to right): C.R. Jackson, B.S. Nadagaudar, L.N. Harsh, B.D. Patil, W.R. Bentley, J.S. Kanwar, G.B. Singh, R.J. Van Den Beldt, Narayan Hegde, Shankar Ranganathan, Radha Ranganathan.

Middle row (left to right): : Gururaj Hunsigi, Piara Singh, P.T.C. Nambiar, G.M. Dasthagir, C. Renard, M.R. Rao, M. Natarajan, D. Gangadhar Rao, Pratap Narain, V.K. Mishra.

Back row (left to right): C.K. Ong, J.R. Burford, K.L. Sahrawat, Sardar Singh, P. Pathak, Peter Huxley, M. von Oppen, G.R. Korwar, Drake Hocking.

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