PD-AAX-656
ISN [illegible]36

REPORT

AUGUST 1986

SUBPROJECT PAPER DESIGN REPORT

AGROFORESTRY: GERMPLASM, ECOSYSTEM ANALYSIS AND SCIENCE

June 5 - August 18, 1986

Agricultural Research Project (386-0470)

Delivery Order No.3

Contract No.386-00000-C-00-5039-00

WINROCK INTERNATIONAL
1611 North Kent St.
Arlington, VA 22209

Project No. 386-0470

SUBPROJECT PAPER DESIGN REPORT

Agroforestry: Germplasm, Ecosystem Analysis and Science

Team Members

Dr. John C. Gordon
Dr. Charles R. Hatch
Dr. Lawrence C. Promnitz
Dr. J. S. P. Yadav

USAID/New Delhi, India

August 1986

TABLE OF CONTENTS

		Page
I.	Executive Summary	1
II.	Introduction and Background	3
	A. Introduction	3
	B. Subproject Scope and Objectives	3
III.	Team Visits	5
	A. Structure	5
	B. Findings	5
IV.	Subproject Strategy	6
	A. Major thrust	6
	B. Research priorities	6
	C. Subproject components and timing	8
	D. Subproject outputs	12
V.	Subproject Implementation	13
	A. Implementing organizations and institutions	13
	B. Plan of work	13
	1. Agroforestry model	13
	2. Training and equipment	15
	3. Germplasm program	19
	4. Ecosystem project	20
	5. Postgraduate education	20
	6. Analytical laboratory	21
	7. Expert systems	21
VI.	Monitoring and Evaluation	22
	A. Subproject Management Committee	22
	B. External evaluation	23
VII.	Conditions Precedent to Disbursement	24
VIII.	Financial Plan	26
IX.	Appendices	
	A. AICRPA Overview Report	
	B. Team Visit Report	
	C. Quantitative Methods Report	
	D. Agroforestry Training Report	

EXECUTIVE SUMMARY

Agroforestry Subproject Design Team Report
August 8, 1986

I. The proposed subproject focuses on complementing and strengthening the All India Coordinated Research Project on Agroforestry (AICRPA) through 7 subproject activities:

1. Increasing the number of scientists qualified for agroforestry research through short-term training, continuing education, specialized training and the initiation of postgraduate (M.Sc and PhD) programs in agroforestry at selected universities.

2. Creating a quantitative agroforestry format and model for data accounting, generation of hypotheses and prediction of system behavior.

3. Initiating ecosystem-level studies of agroforestry systems at two AICRPA Regional Centers.

4. Initiating an agroforestry germplasm collection, screening and propagation program at all AICRPA Regional Centers.

5. Involving local centers and a social science team in analyses of the needs and behavior of agroforestry clients (farmers and policy makers), in developing technologies for making results of agroforestry research available and intelligible to scientists, and in developing methodologies for evaluating agroforestry systems which incorporate economic, social and environmental factors into the analysis.

6. Creating an analytical laboratory with capability to do sophisticated analyses of ecosystem components (plant, soil, water and microbes) at the National Center.

7. Creating a computer-based expert system at the National Center that links individuals and institutions needing information about agroforestry systems and their components with the subproject data base and scientists.

The subproject builds on the three-tier design (National, Regional and Local centers) of the AICRPA, and focuses on areas (germplasm, ecosystems, postgraduate education) where India-US collaboration will be particularly fruitful. India's leading position in the recognition and implementation of agroforestry research and development, and US strength in tree genetics and propagation and in tree physiology and ecosystem analysis are particularly complementary, and will lead to a fully collaborative partnership.

Institution to institution ties will be effective in providing mutually acceptable training opportunities, consultancies, facilities and equipment improvement, and germplasm exchange. The subproject will improve the science base of agroforestry and thus help clients (farmers and policy makers) by solving problems more quickly and efficiently through a better understanding of the yield potential and mechanisms of agroforestry systems. The subproject will last five years and will be managed by the Indian Council of Agricultural Research (ICAR) through a Subproject Management Committee (SMC).

II. INTRODUCTION AND BACKGROUND

A. Introduction

In India the national needs for increased forest area to reduce wood product imports and to ameliorate local environments have been clearly expressed. At the same time demand for fodder, fuel, timber and other wood products greatly exceeds the supply and additional markets exist for other agroforestry products such as certain fruits and specialty items. Thus, agroforestry provides an opportunity for additional cash income and capital formation for farmers and could be particularly appropriate for those with small holdings on rainfed and marginal lands.

The above considerations have led to the initiation of the All India Coordinated Research Project on Agroforestry (AICRPA) by the Indian Council of Agricultural Research (ICAR) under the Sixth 5-Year Plan of the Government of India (GOI) and its enhancement under the Seventh 5-Year Plan. AICRPA plans include a three-tier system of centers (a national center for coordination and basic research, regional centers to do applied research and training, and local centers to do adaptive research, development and extension activities).

Presently the AICRPA is operating at 31 centers in ICAR institutes and state agricultural universities. The activities are directed by a project coordinator. Objectives of the AICRPA, its Seventh 5-Year Plan budget, and a description of its centers and staffing patterns are shown in Appendix A.

Although agroforestry is old in practice, it is relatively new as an area of science and as an ICAR activity. Although several ICAR institutes and state agricultural universities trace their involvement in farm forestry back 15 to 25 years, the total quantity of research in the field is not large.

B. Subproject Scope and Objectives

Although India's agroforestry research program may be the largest and best organized in the world, information needs still vastly exceed the supply. Data are rapidly becoming available from empirical field trials, but the complex interactions of trees, annual crops, weeds, microbes and animals are difficult to understand. Only through a more thorough knowledge of the mechanisms underlying those interactions can better prescriptions for system components and management be made. This knowledge can only come from research that tests mechanistic hypotheses. Thus, the subproject will focus on strengthening the science and supporting the scientists in AICRPA and related activities. The subproject design team's charge was to:

1) formulate a system for identifying, selecting and funding research related to:

   a) the quantification of the interactions between soil moisture, nutrients, light and plant characteristics in agroforestry systems,
   b) the development of mathematical and statistical models to estimate the productivity of integrated tree and agricultural crop production systems, and
   c) the identification and refinement of multiplication methodologies that will enable the large-scale production and establishment of multipurpose trees;

2) identify the type and define the level of resources needed for training, physical facility/laboratory enhancement and research support;

3) develop mechanisms and procedures for ensuring collaboration between India and U.S. scientists and define the type and level of resources needed for this activity; and

4) highlight constraints which could impact the initiation of the subproject activities and identify operational alternatives that might result in timely subproject implementation.

Within this scope, the specific objectives of the subproject design team were to submit to ICAR and USAID a document that:

1) identifies areas of strength and on-going research programs at AICRPA sites based on team visits, reading, discussions and prior knowledge;

2) suggests specific research priorities with country-wide impact;

3) identifies methods (specific training, consultancy and collaboration opportunities) that build on existing strengths within the three-tier system of AICRPA; and

4) describes the major constraints and preconditions that pertain to the strengthening of the agroforestry science base.

III. TEAM VISITS

A. Structure

Before the Team proceeded on tour, it had discussions with Dr. G.B. Singh, Deputy Director General (SAE), ICAR, Dr. Kamla Chowdhry, Chairman, National Wasteland Development Board and USAID officers in Delhi. Dr. G.B. Singh apprised the Team about the background of AICRPA including its objectives, organizational set-up, strengthening in the Seventh 5-Year Plan and indicated its importance in the context of present national economy. Dr. Kamla Chowdhry emphasized that the AICRPA should identify suitable tree species for degraded lands and should develop low cost technology which should at the same time give quick returns to the resource-poor farmers. The Team also visited 2-year old plantations of Eucalyptus hybrid and Leucaena leucocephala under experiments on spacing, time of planting, fertilizer and irrigation application and interaction with agricultural crops undertaken by the Agro-Energy Center of Indian Agricultural Research Institute (IARI) at New Delhi.

Because of time limitations, the Team could not visit all the centers of AICRPA and therefore visited only a few selected places viz. Dehra Dun, Jodhpur, Bangalore, Coimbatore and Hyderabad. These provide a fairly good idea of the ongoing programs on agroforestry in India. The Team discussed the work currently being carried out by scientists at Rahuri and Dharwar with campus representatives. In addition, the Team visited silvipastoral and agri-silvicultural systems at field research centers of the voluntary organization known as Bhartiya Agro-Industries Foundation (BAIF) near Pune and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) near Hyderabad. Detailed results are presented in Appendix B.

B. Findings

The low availability of scientists with degrees or educational background in forestry or agroforestry was apparent at every location visited, as was the relative scarcity of ecosystem-level, team research aimed at understanding why agroforestry systems respond as they do. No basic ecosystem research on extensive (farm size, 1-5 ha) areas was observed. Similarly, while scientists at almost all locations indicated a strong interest in germplasm collection, selection and propagation, little research is underway, although fairly intensive beginnings, have been made at Tamil Nadu Agricultural University (TNAU) and the Central Arid Zone Research Institute (CAZRI).

IV. SUBPROJECT STRATEGY

A. Major Thrust

The team visits and discussions confirmed that the major objective of the subproject should be to strengthen agroforestry science. In the AICRPA context, better science means increased use of mechanistic hypotheses that explain why agroforestry systems behave as they do. Mechanistic hypothesis testing, coupled with accurate field measurements and repeatable techniques will make results of existing trials more interpretable, and will reduce the need for their repetition. Also an acute shortage of scientists, trained and experienced in agroforestry, exists. As this shortage is removed by training, scientific strengthening can also occur. Two clear needs for information emerge:

1) how to collect, screen, propagate and plant the immense number of woody species that could be components of agroforestry systems; and

2) an understanding at the ecosystem level of the functioning of existing agroforestry systems, especially those now practiced over wide areas, particularly with regard to competitive interactions, sustainability, and interactions with animal and human populations.

Both these needs can be used by the subproject to accomplish the strengthening and to assist in training and education of agroforestry research personnel.

B. Research Priorities

More specifically, the team made an attempt to prioritize research needs based on the opinions of Indian scientists and our own deliberations. During this priority setting process, the need for an increased scientific capability in a few technical areas emerged. These essential techniques include:

Essential Techniques

1) Advanced statistical design, analysis and modeling using microcomputers, spreadsheets and statistical software packages.

2) Root system sampling and growth, form and activity (absorption, microbial and soil interactions) measurements.

3) Light interception measurements, radiation quantity, crown geometry, leaf area measurement, and phenological description.

4) Plant propagation techniques and seed tecnnology.

5) Animal population sampling and description.

6) Microclimatic measurements, including wind, water, atmospheric composition, and temperature.

The prioritized research needs by subject area are:

Quantitative methods research priorities

1) More efficient experimental designs, particularly minimum land models and more efficient sampling designs.

2) Agroforestry system models that accept mechanistic information and predict system behavior quantitatively.

Germplasm and propagation research priorities

1) Guidelines for seed and vegetative propagule collection, storage and handling of agroforestry species and variants, and nursery and greenhouse techniques for their multiplication and outplanting.

2) Development of species and variant selection systems based on germplasm collections, and rapid propagation and testing techniques.

Physiology and ecosystem analysis research priorities

1) Understanding moisture, nutrient and temperature stress effects, and mechanisms of competitive interaction of crop components, including animals,

2) Detailed understanding of the role of symbiotic associations and soil micro flora and fauna in relation to crop component growth and composition,

3) Landscape level effects of agroforestry practices.

Social science research priorities

1) Development of communication methodologies to transfer scientific information on agroforestry systems to farmers and which allow farmers to directly provide scientists input on research needs and priorities.

2) Development of methodologies for evaluating agroforestry systems in an economic context which includes biomass productivity, social benefits and ecological sustainability factors.

3) Detailed understanding of the impact agroforestry systems could have in the generation or displacement of farm labor in agricultural communities and the role of markets in the selection, establishment and maintenance of agroforestry systems.

Thus, the subproject design addresses these priorities with seven major activities concentrated initially at the AICRPA Regional Centers with active agroforestry research and development programs, but it involves the developing national and local centers as well (Figure 1).

C. Subproject Components and Timing

Major subproject activities are:

1) Increasing the number of scientists qualified for agroforestry research through short-term training, continuing education, specialized training and the initiation of postgraduate (M.Sc and PhD) programs in agroforestry at selected universities.

2) Creating a quantitative agroforestry format and model for data accounting, generation of hypotheses and prediction of system behavior.

3) Initiating ecosystem-level studies of agroforestry systems at two AICRPA Regional Centers.

4) Initiating an agroforestry germplasm collection, screening and propagation program at all AICRPA Regional Centers.

5) Involving local centers and a social science team in analyses of the needs and behavior of agroforestry clients (farmers and policy makers), in developing technologies for making results of agroforestry research available and intelligible to scientists, and in developing methodologies for evaluating agroforestry systems which incorporate economic, social and environmental factors into the analysis.

6) Creating an analytical laboratory with capability to do sophisticated analysis of ecosystem components (plant, soil, water and microbes) at the National Center.

7) Creating a computer-based expert system at the National Center that links individuals and institutions needing information about agroforestry systems and their components with the subproject data base and scientists.

Subproject activities are shown in relation to each other and time in the Subproject Overview (Figure 2). A more detailed description of the duration of specific activities is shown in Figure 3.

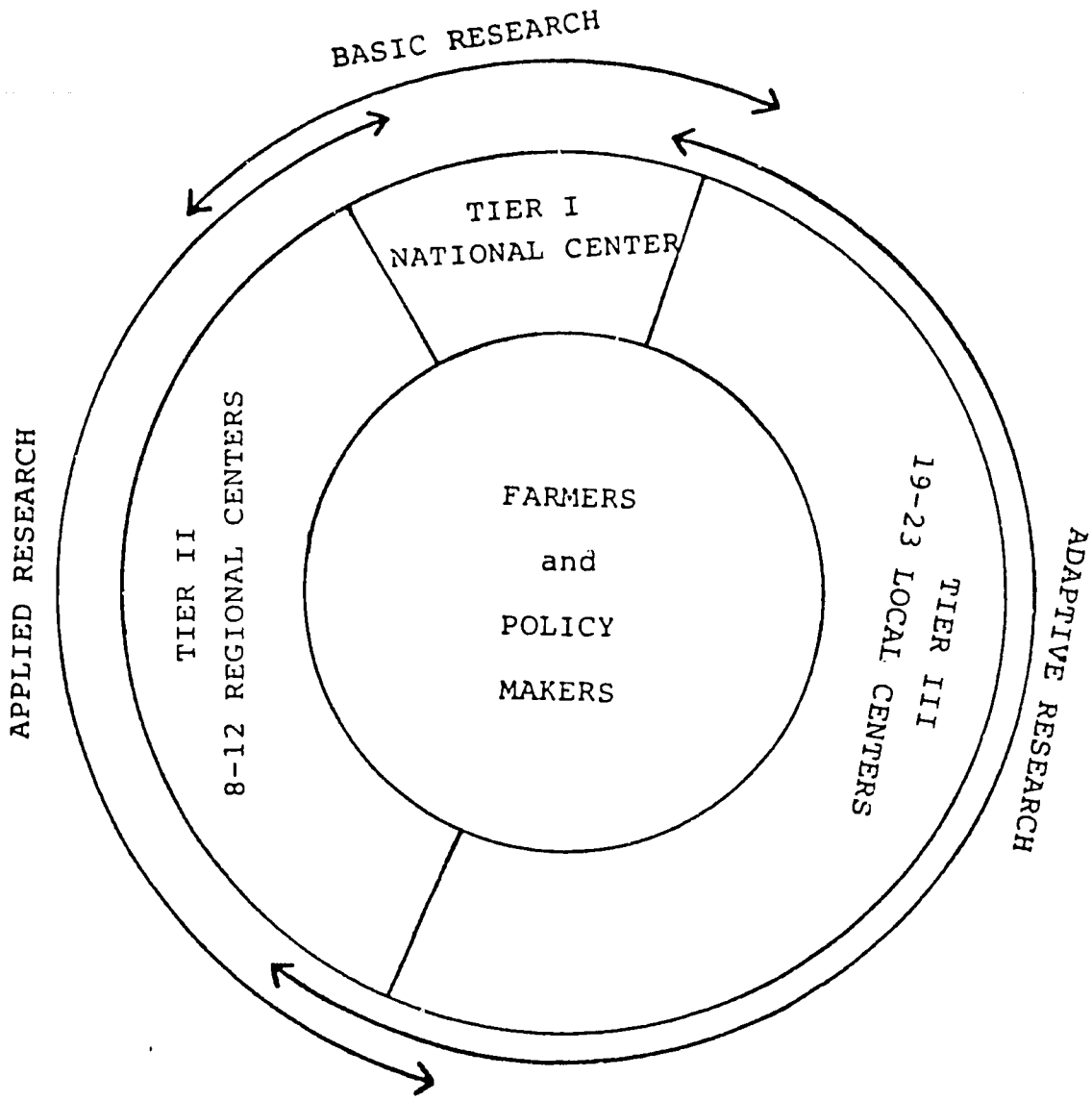


FIGURE 1: Three tier structure of AICRPA.

OBJECTIVES:

Support Better Science - Better use of resources and faster solutions
- Mechanisms
- Measurements

Meet Agroforestry Needs
- Germplasm selection, preservation, improvement and nursery techniques
- Understand competitive interactions (light, water, nutrients) at the ecosystem level

Year	National Center	Regional Centers	Local Centers
1	AF Model - workshop - training - hypotheses	Raise to Common Level - training - facilities, equipment (esp. field)	User Feedback & Markets - Diagnosis and Design - Social Sciences Team
2	Germplasm Coord. Measurement and Quality Control	Establish Research - regional germplasm centers - analysis of ecosystems	Germplasm Deposits Special Expertise
3	Scientific Manpower Collaboration & Coordination - pairing of U.S. institutions	Postgraduate Programs - M.Sc & PhD at SAUs	"Customer" Component in Postgraduate Education - feedback - markets
4	Analytical Lab Expert System	Specialized training	
5	Analytical Lab and Expert System Functional	Germplasm and Ecosystem Projects Underway	Farmer/Scientist Communication Established

FIGURE 2: Subproject overview.

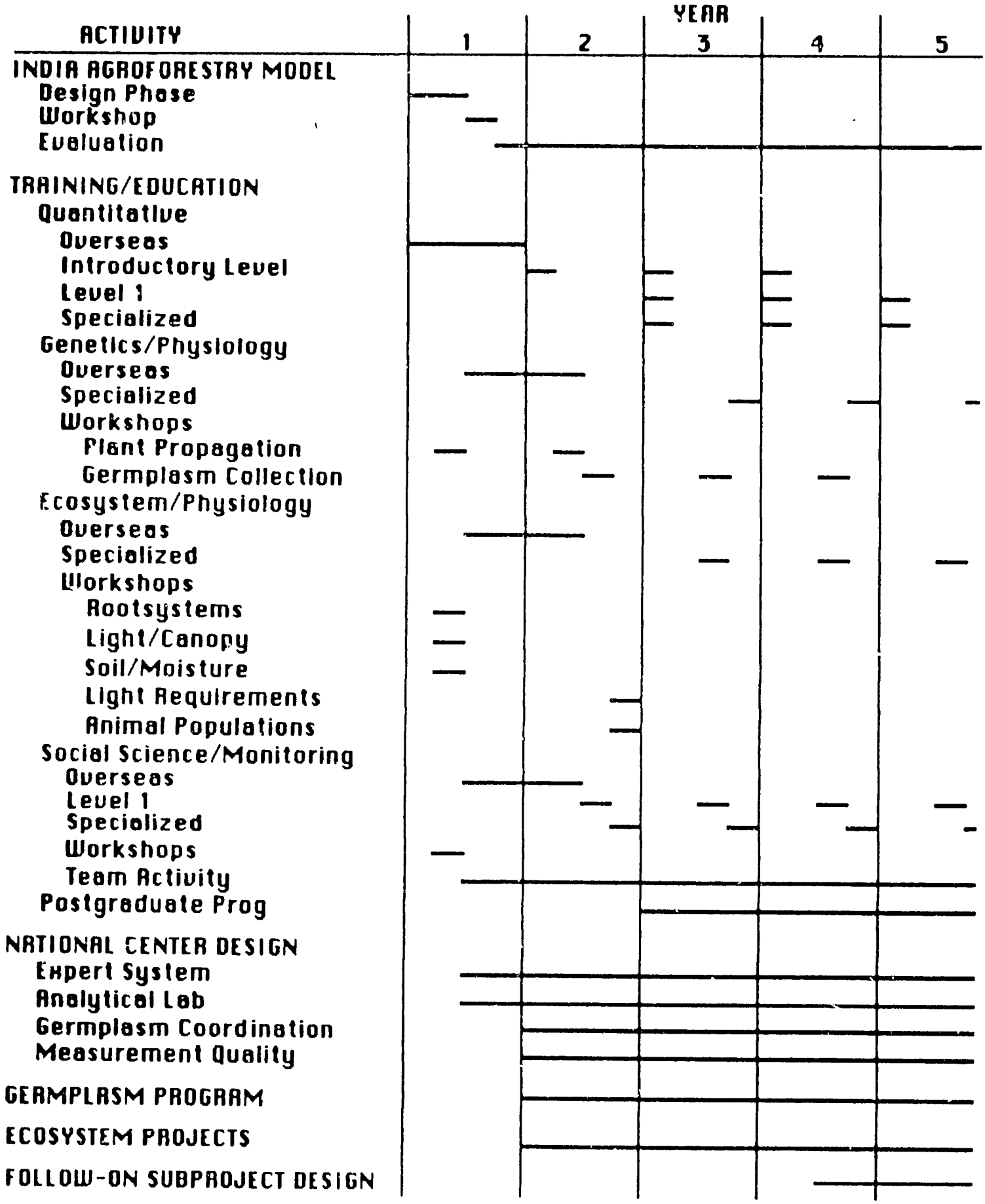


FIGURE 3: Duration of subproject activities.

D. Subproject Outputs

Upon completion of the subproject, agroforestry scientists at all regional centers will have been trained in quantitative science, forest genetics and propagation, tree physiology and ecosystem analysis, and social science methodology to understand user needs. Under the germplasm program a collection will be undertaken at each regional location and screening and propagation of species will be carried out. The ecosystem analysis project will have gathered two years of field data and will have begun using the national analytical center, as well as other AICRPA locations. The computer-based expert system will be in operation and will link all AICRPA sites with the national center. Since subproject activities augment the AICRPA, they could be considered for continuing support by USAID.

Thus at the end of the subproject, AICRPA will have been strengthened by:

1) better use of experimental design and quantitative modeling;

2) greater capability to design and test in large-area field experiments hypotheses concerning the reasons why small plot tests behave as observed;

3) access to a wide range of woody species, and the ability to select, propagate and outplant them;

4) access to state-of-art analytical capability; and

5) use of an agroforestry data base by all AICRPA centers.

These will allow more efficient screening of new agroforestry designs, and will enhance the capability to do research, even of a basic nature, on farmer-managed agroforestry systems. In addition, the Social Science Team will provide techniques to ensure farmer-to-scientist communication and develop methodologies to evaluate agroforestry systems in an economic context which includes biomass productivity, social benefits and ecological sustainability factors.

V. SUBPROJECT IMPLEMENTATION

A. Implementing Organizations and Institutions

The subproject will be implemented by ICAR through its AICRPA Centers for agroforestry research and its new National Center for Agroforestry. Initially, the Regional Centers will receive the maximum subproject emphasis. Guidance and coordination in ICAR with specific reference to subproject activities will be provided by the SMC consisting of ICAR and State Agricultural University (SAU) scientists. In addition, two USAID representatives would serve as observers to the SMC for purposes of subproject coordination (Figure 4). One of the two USAID representatives will be a permanent USAID employee posted in India with responsibility for the project. The other will be an Indian individual contracted by USAID/India to assist the SMC with coordination activities during the life of the project. A facilitating institution (i.e. Winrock International) will contract with four US universities to provide training, consultancies, germplasm exchange, and collaborative research arrangements as they are needed. The four suggested US institutions would draw talent from their own and other faculties and would participate for the life of the subproject activity to create a culture of understanding and exchange with Indian institutions. The Regional Centers of AICRPA and the subproject will pair with one or more US institutions as their specific needs and preferences become apparent.

All operating personnel involved in subproject activities are ICAR and SAU scientists with the exception of the two USAID positions and personnel from US collaborating institutions. Further, all ICAR scientists involved in subproject activities are drawn from positions already sanctioned and filled by the GOI. Thus, at the end of the subproject period, no externally funded positions need be absorbed. All subproject expenditures will be for training, facilities, short-term technical consultancies, US collaborative support, and non-salary research operations and equipment.

B. Plan of Work

1. Agroforestry Model

The first activity of the subproject will be to construct a quantitative, computer-based system capable of accepting data on all components of agroforestry systems. The data will include information on agroforestry species and their combinations and will be maintained and retrievable by region, land form and on-farm system. Furthermore, the model will index knowledge concerning the interactions between agroforestry systems and their environment. Information on interactions will be maintained at both a macro and micro level. Macro level interactions will deal with climatic, edaphic, cultural and management factors. Micro level interactions will reflect plant, soil, microbe, water and nutrient relationships at a physiological level both above and below the ground. Information on these two levels of interactions will

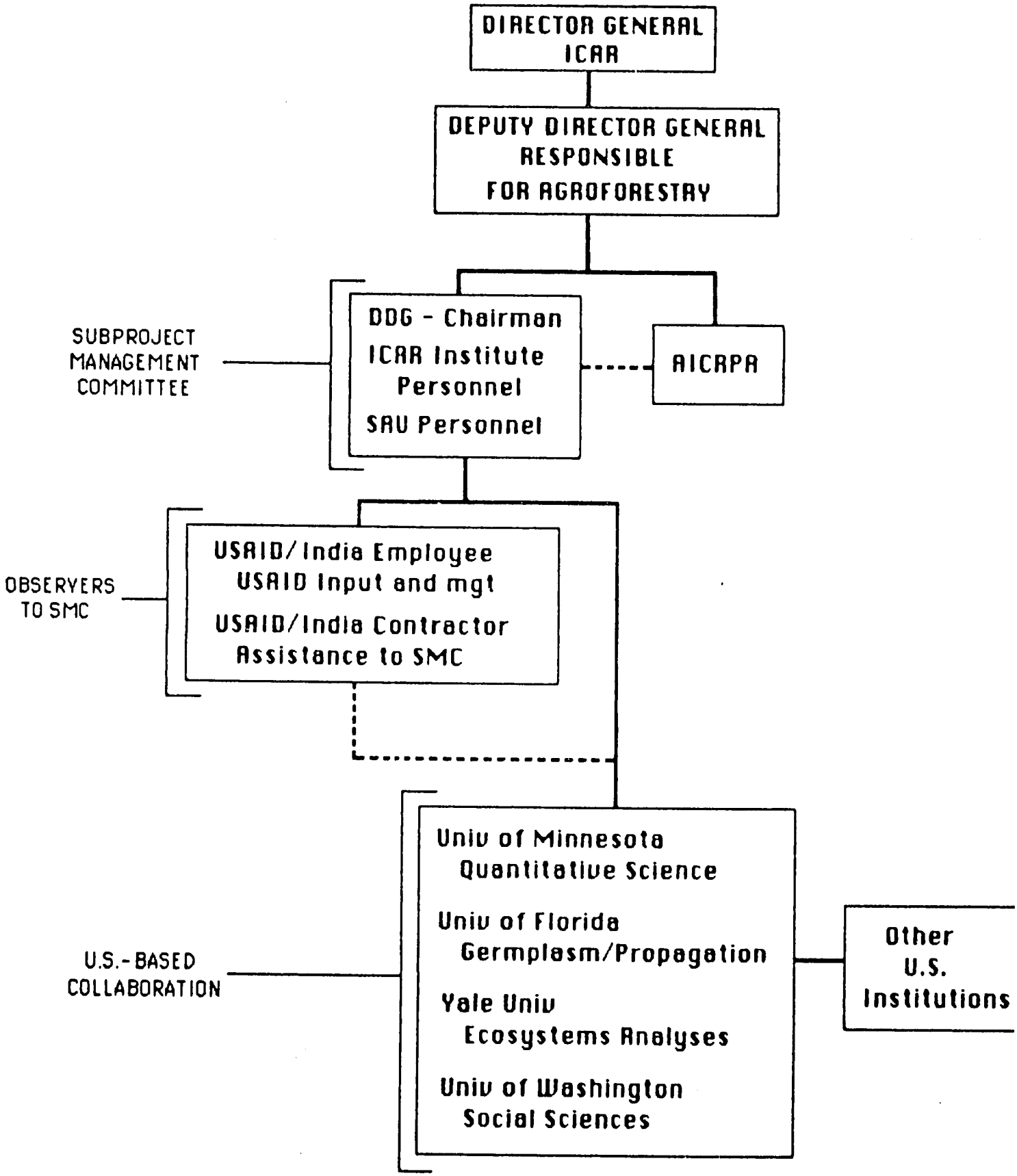


FIGURE 4: Subproject management.

allow scientists to formulate theories on plant/competition relationships in agroforestry systems and test their mechanistic hypotheses. The process of model construction and evaluation will:

1) lay the foundation for the formulation of mechanistic hypotheses and the development of the expert system;

2) generate hypotheses and establish initial thrusts for ecosystem and germplasm studies;

3) set the stage for training in quantitative methods, germplasm/physiology, ecosystem/physiology and social science activities; and

4) involve scientists from all the Regional Centers in subproject activities.

This will be accomplished in a workshop approved by the SMC and facilitated by a consultant. The workshop will consist of three components:

1) Planning Component: To formulate the structure and content of the workshop and identify individuals to participate in the workshop. Senior members of the SMC will confer with the US workshop consultant and collaborating US universities early in the planning process.

2) Execution Component: To conduct a workshop in India of 2 to 3 weeks duration which will construct a model that accomplishes the four objectives listed above.

3) Evaluation Component: To formulate recommendations for the SMC on an implementation plan for the second year of the subproject. Focus will be on application of the model and formulation of boundary conditions for its use.

All three components of the workshop will be completed by the end of the first year of the subproject. A detailed treatment of the quantitative science aspects and prospects of AICRPA is presented in Appendix C.

2. Training and Equipment

The overall objective of the training design is to immediately provide trained personnel to meet continuing training needs in India, to provide basic training in primary areas of research emphasis needed to strengthen research programs, and to provide both a training format and trainers that can be used in existing schemes (e.g. summer institutes) as a continuing basis of strength and refinement. An overview of present agroforestry training is presented in Appendix D.

Overseas Training

A program of overseas training will begin shortly after the implementation of the subproject design. Training would be non-degree of 12-month duration in the priority areas listed below. On completion of the overseas training, personnel should provide immediate support to in-country training programs plus strengthen research efforts. Training would include:

Area of Emphasis	No. of Persons	Suggested Institutions	Alternative Institutions
Quantitative Methods	2	U. Minnesota	Virginia Polytechnic Institute, U. Georgia
Germplasm/Physiology	2	U. Florida	U Cal Berkeley, North Carolina State
Ecosystem/Physiology	2	Yale	U. Missouri, Michigan State
Socio-Economics/ Marketing	2	U. Washington	U Cal Berkeley, U. Idaho, Yale
TOTAL	8		

University selection criteria were:

a) strengths within specific disciplines and overall university strength;
b) potential for future collaborative research efforts; and
c) university commitment to international programs.

Continuing support for overseas training will come from subproject funds, and overseas training, coupled with short-term consultancies, will be used to build collaborative research programs between the institutions and the regional and national centers of AICRPA.

In-country Training

The primary objective of in-country training is to:

a) rapidly develop essential skill areas in agroforestry research, and
b) bring regional centers to a common level of scientific ability.

Later efforts will cover:

a) basic skill areas,
b) primary concepts, and
c) specialized interest areas.

Initially consultants will be used heavily in in-country training programs but they will be reduced over time through the use of returning overseas trainees and internally trained personnel. Training in the use of specialized equipment and measurement principles will be a function of the National Center. Primary and specific interest areas can also be incorporated into the summer institute scheme to strengthen local centers' efforts in specific areas.

Concomitantly with the beginning of in-country training, equipment and facilities will be upgraded at Regional Centers (Figure 5). Workshops will include techniques and an overview of the current state-of-the-art in specific areas. Workshops will be in a "summer institute" format. Thus, scientists at all regional centers will quickly be brought to a common level in the techniques most critical to progress in agroforestry research. Continuing training in the primary areas (quantitative methods, germplasm/physiology, ecosystem/physiology and social science/marketing) and specialized training in areas of need that arise will be handled primarily by those trained overseas. The timing of training events is shown in Figure 3. A training plan outline for quantitative methods is presented at the end of Appendix C. Similar outlines would be developed for the other three primary areas.

Social Science Training

Social Science training will build on the Diagnosis and Design experience of the centers, and will explore alternative models for:

1) fostering interaction between agroforestry researchers and clients (farmers) to include the role of demonstration in the transfer of agroforestry technology;

2) assessing and increasing market potential for products of agroforestry systems including the identification of unique processing requirements and opportunities associated with agroforestry products;

3) predicting and understanding employment effects of agroforestry systems; and

4) evaluating agroforestry systems which incorporate productivity, economic, social and environmental factors into the analysis.

Research Area	Regional Center 1/	National Center
Quantitative Methods	Microcomputers with Printers and Software	Minicomputer with Printers and Software
	Tree Measurement Set 2/ height, diameter, land survey	Tree Measurement Set height, diameter, land survey
Germplasm	Basic Laboratory Set mass, pH, temperature basic plant chemistry	Basic Laboratory Set mass, pH, temperature basic plant chemistry
	Controlled Environment greenhouse, mist benches, cold storage	Controlled Environment greenhouse, mist benches, cold storage
	Seed Technology Set	Seed Technology Set
		Growth Chambers, Incubators, Transfer Hoods
Ecosystem /Physiology	Soil Science Set field sampling, neutron probe, conductivity bridge pressure plate, muffle furnaces, Kjeldahl N	Soil Science Set field sampling, neutron probe, conductivity bridge pressure plate, muffle furnaces, Kjeldahl N
	Gas Chromatograph	Gas Chromatograph
	Radiation Measurement Set	Radiation Measurement Set
	Plant Moisture Stress Set	Plant Moisture Stress Set
	Forced-air Drying Ovens	Forced-air Drying Ovens
	Spectrophotometer	Mass Spectrometer
		Atomic Absorption spectrophotometer
		High Pressure Liquid Chromatograph
		Radio Isotope Set
		Autoanalyzer
		CN analyzer

1/ Items indicated: 1 for each Regional Center unless otherwise noted.
2/ Items labelled "Set" will be specified in detail by consultants.

FIGURE 5: National and Regional Center equipment needs.

Incorporation of the above points into an agroforestry extension system methodology will address, in a comprehensive manner, the biological and social factors which should be considered by farmers when they adopt agroforestry systems. These include:

a) What amount of biomass will be produced and in what form will it be obtained?
b) What will be the net financial returns and when will they be obtained?
c) What will be the longer-term effects on site productivity and future resource inputs?

To do this, a Social Science Team will be constituted by the subproject to develop and transmit information on the above topics over the life of the subproject. The team will include four social scientists and two natural scientists from regional centers and two consultants from collaborating US institutions.

3. Germplasm Program

The Regional Centers are expected to perform lead functions for their respective regions in a nationally coordinated agroforestry germplasm collection and screening program. Emphasis will be on the collection of woody species. The initial activity will be a workshop to produce a detailed design for the program. At a minimum, this will include:

1) major and most promising species by region;

2) directions for collecting, depositing, verifying, preserving, multiplying and distributing seed and vegetative propagules;

3) identification of special collection and collaboration needs;

4) identification of priorities for research in propagation, nursery operations and seeding and planting; and

5) development of species selection systems.

The program would focus on the collection of a broad array of species, and the development of rapid selection and multiplication procedures for promising species, varieties and individuals. Particular emphasis will be placed on nursery and outplanting research.

4. Ecosystem Project

Two Regional Centers will establish long-term ecosystem studies on existing agroforestry sites. Ideally, as far as possible, these would be in farmers' fields, where the farmer was subsidized to allow the presence of researchers and the manipulation of the site and vegetation. The objectives of the ecosystem projects are to:

1) understand root zone interactions, light distribution and effects, carbon allocation, and nutrient and water cycling in established agroforestry systems;

2) provide instrumentation experience and training for agroforestry scientists; and

3) establish interdisciplinary research training focused on understanding mechanisms in agroforestry.

An initial workshop of AICRPA administrators, scientists and consultants would recommend sites and participating centers, and design experiments to test hypotheses generated by the agroforestry model. Indepth work at the ecosystem sites would suggest additional studies to be conducted at other AICRPA locations. The Social Science Team would use the models of agroforestry systems developed through these ecosystem studies to estimate biomass productivity and ecological sustainability factors that are needed for the development of methodologies to evaluate the economic return of alternative agroforestry systems. Furthermore, the ecosystem project builds on and augments the training program.

5. Postgraduate Education

Selected agricultural universities that also may be Regional Centers will be strengthened and the development of postgraduate (M.Sc, PhD) programs in forestry, including agroforestry, will be accelerated. The location of training activities in the four areas (Quantitative Methods, Germplasm, Ecosystem, Social Science) and the germplasm and ecosystem research will support postgraduate education by:

1) upgrading faculty skills;

2) providing research opportunities for postgraduate students; and

3) making agroforestry research attractive to faculty and students.

Those universities will collaborate with the four U.S. universities, and may develop joint graduate programs with them. ICAR institutes that have regional centers will also provide research opportunities to postgraduate students and faculty.

6. Analytical Laboratory

In addition to its other coordination and research functions, the National Center will include a state-of-the-art analytical laboratory with the capability to support all AICRPA sites with plant, water, soil and microbial analyses (chemical, physical and biological). Figure 5 suggests minimum equipment needs for the laboratory. The analytical laboratory will analyze specialized samples received from the Regional Centers and those generated by its own basic research. It will also perform analytical quality control for all AICRPA centers doing field and laboratory analyses.

7. Expert System

In addition to its other coordination and research functions, the National Center will include a minicomputer capable of storing the entire AICRPA data base and maintaining an expert system that links agroforestry information to scientists, farmers and management agencies.

VI. MONITORING AND EVALUATION

A. Subproject Management Committee

The subproject has outlined four areas of activity, namely:

1) development of manpower through strengthening postgraduate teaching programs;

2) improvement in professional competence of the scientists working in the AICRPA;

3) conduct of efficient research on selected priority areas to find suitable solution to the practical problems; and

4) provision of appropriate additional physical facilities for achieving these objectives.

To facilitate successful implementation of these subproject activity areas it is suggested that a management committee be constituted which may have the following broadly defined functions:

1) reviewing and monitoring the progress of work defined in the subproject through regular meetings to be held at least two times every year - preferably one in December and other in June;

2) identifying the constraints/deficiences/bottlenecks in the implementation of the program and taking suitable steps to remedy the same;

3) suggesting future lines of work within the proposed outline of the subproject and taking appropriate decisions for their efficient implementation; and

4) making any other recommendations relevant to the overall implementation of the subproject.

It is proposed that the management committee may function under the chairmanship of the Deputy Director General, ICAR in-charge of the agroforestry program and it may have a possible configuration that would include:

Deputy Director General in-charge of
Agroforestry research - Chairman

Project Director, National Center - Secretary

Three Directors of ICAR Institutes having programs
related to agroforestry

Two Directors of Research at SAUs having programs
related to agroforestry

Two Deans of Colleges of Agriculture at SAUs having programs
related to agroforestry

In addition, for purposes of subproject coordination, individuals holding the following positions may serve as observers to the committee.

USAID/India employee with project responsibility
USAID/India contract employee assisting the SMC

B. External Evaluation

The SMC should receive annual, written progress reports from each subproject location on each subproject activity. These reports will be supplemented by semi-annual ICAR/USAID collaborative visits to subproject locations in India.

The SMC, in conjunction with individuals from one or more U.S. collaborative institutions, will annually review the germplasm and ecosystem research program activities. A significant portion of the review will emphasize the extent and quality of progress, and identify challenges and propose solutions to activities associated with the development of the expert system and agroforestry postgraduate programs. This review should be immediately followed by a national symposium on key project activities.

Near the end of the third year of the subproject an international symposium on agroforestry germplasm and ecosystems studies would be undertaken. The symposium would report on subproject findings and would initiate planning activities associated with the formulation of follow-on subproject activities.

VII. CONDITIONS PRECEDENT TO DISBURSEMENT

Prior to the disbursement of any funds for research, training, technical assistance or equipment the ICAR will ensure that it has:

1) Officially designated the location of the National Research Center for Agroforestry. Criteria in order of importance for the selection of the location may include:

   a) accessibility
      daily air and rail service
   b) attractiveness to ICAR personnel
      housing, medical facilities and hospitals, schools
   c) infrastructure
      communication services, equipment development and maintenance services, continuous supply of water and electricity
   d) existence of a state agricultural university
   e) existence of scientific research and development institutions
   f) centrally located within India in a geographical sense

2) Officially designated the location of the Regional Research Centers for Agroforestry. Criteria in order of priority for the selection of the locations might include:

   a) coverage of climatic, edaphic and biotic zones within India
   b) attractiveness to ICAR/University personnel
      housing, medical facilities and hospitals, schools
   c) infrastructure
      communication services, equipment development and maintenance services, continuous supply of water and electricity

3) Officially designated the location of a limited number of postgraduate educational programs in agroforestry. Criteria in order of priority for the selection of the location might include:

   a) Strength of the institute
      diversity of academic programs, quality of faculty, level of financial support, physical facilities, library services
   b) institute's proximity to the National or a Regional Center
   c) attractiveness to University personnel
      housing, medical facilities and hospitals, schools
   d) infrastructure
      communication services, equipment development and maintenance services, continuous supply of water and electricity
   e) ability to attract postgraduate degree candidates from throughout the nation

4) Officially provided the organizational structure and facilities needed to guide subproject activities. This would include:

   a) appointment of individuals to the SMC.
   b) approval of facilities/equipment required to implement subproject activities.

VIII. FINANCIAL PLAN

	US $	Percent of Total
Coordination		
US Univ Coordination Expense		
5 yrs @ $10000/yr @ 4 Univ	200,000	
SMC Coordination & Oper. Expenses		
Consultants, Travel, Equip, Misc	200,000	
USAID/India Indian Contractor		
24 months @ 1/2 time @ $1500/mo	18,000	
36 months @ 1/4 time @ $1500/mo	13,500	
Operating Expenses		
Travel & Per Diem	50,000	
Misc. (Telephone, Postage, Corresp.)	12,500	
SUBTOTAL	494,000	12.3%
Indian Trainers Training in U.S.		
Quantitative Biology		
2 Indian Sci @ 12 mo. @ $3,750/month	90,000	
Germplasm Technology		
2 Indian Sci @ 12 mo. @ $3,750/month	90,000	
Ecosystem Science		
2 Indian Sci @ 12 mo. @ $3,750/month	90,000	
Social Science		
2 Indian Sci @ 12 mo. @ $3,750/month	90,000	
SUBTOTAL	$360,000	8.9%

Workshops in India		
Agroforestry Modeling		
1 US University collaborator		
12 months @ $7500/mo	90,000	
Travel & Per Diem - Domestic	5,000	
Travel & Per Diem - International	10,500	
Operating Expenses	7,500	
Quantitative Method		
2 US Univ Sci @ 1.5 mo @ $7500/mo	22,500	
Travel & Per Diem @ $3500/Sci	7,000	
6 US Univ Sci Travel & Per Diem expenses	21,000	
Germplasm/Physiology		
2 US Univ Sci @ 1.5 mo @ $7500/mo	22,500	
Travel & Per Diem @ $3500/Sci	7,000	
6 US Univ Sci Travel & Per Diem expenses	21,000	
Ecosystem/Physiology		
2 US Univ Sci @ 1.5 mo @ $7500/mo	22,500	
Travel & Per Diem @ $3500/Sci	7,000	
6 US Univ Sci Travel & Per Diem expenses	21,000	
Social Sciences/Marketing		
2 US Univ Sci @ 1.5 mo @ $7500/mo	22,500	
Travel & Per Diem @ $3500/Sci	7,000	
4 US Univ Sci Travel & Per Diem expenses	14,000	
SUBTOTAL	$308,000	7.7%
Postgraduate Education		
Course work Programs in US Universities		
M.Sc 9-month course work program		
2 Indian Sci/yr @ 4 yrs @ $18,000/Sci	144,000	
PhD 18-month course work program		
4 Indian Sci/yr @ 3 yrs @ $36,000/Sci	432,000	
Institutional Support at 2 SAUs		
Equip, Library, Travel, Misc	200,000	
SUBTOTAL	$776,000	19.3%

Collaborative Research		
Quantitative Methods		
1 US Univ Scientist to India/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	30,000	
US Scientist - summer salary	24,000	
2 Indian Scientists to the US/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	60,000	
Germplasm/Physiology		
2 US Univ Scientist to India/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	60,000	
US Scientist - summer salary	48,000	
4 Indian Scientists to the US/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	120,000	
Ecosystem/Physiology		
2 US Univ Scientist to India/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	60,000	
US Scientist - summer salary	48,000	
4 Indian Scientists to the US/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	120,000	
Social Sciences		
1 US Univ Scientist to India/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	30,000	
US Scientist - summer salary	24,000	
2 Indian Scientists to the US/yr		
Trvl/Per Diem Exp. @ 4 yr @ $7500/Sci	60,000	
SUBTOTAL	$684,000	17.0%
Equipment		
National Center		
Analytical Laboratory	500,000	
Expert System	150,000	
Regional Centers		
Quantitative Science	200,000	
Germplasm Technology	150,000	
Ecosystem Science	300,000	
Social Science	100,000	
SUBTOTAL	$1,400,000	34.8%
GRAND TOTAL	$4,022,000	

APPENDIX A: AICRPA OVERVIEW REPORT

Locations of the existing centers of the All India Coordinated Research Project on Agroforestry at ICAR institutes and state agricultural universities are shown in Figure A-1.

AICRPA Objectives

i) Collection, screening and selection of promising germplasm of indigenous and exotic species from analogue ecological regions.

ii) Breeding and genetic improvement of tree crops and fodder species to develop compatible associations in consonance with the cultural practices of local population.

iii) Developing techniques of cultural practices (i.e. land preparation, propagation, spacing, thinning, pruning, pollarding) and lopping and harvesting systems suitable for different agroforestry i.e. Agri-horti-pasto-silvi combinations) acceptable to local populace. This will help in ascertaining inter-cropping without reduction in crop yields as far as possible and evolving combinations of food and feed crops for nutrient production all the year round.

iv) Developing sequential system of inter-cropping so that the inter and under space on the land is utilized as long as possible, by crops and later until rotation with shade-tolerant fodder shrubs and grasses, with appropriate management practices.

v) Replacing shifting cultivation with stable cultivation by adopting appropriate packages of practices of land management related to agroforestry based on its capability.

vi) Evaluation of the economics of different agroforestry systems and establishing its correlation with the aims and objectives of resource management viz. conservation, development and utilization.

Proposed Seventh 5-Year Plan Outlay

Item	AICRPA	National Center	Total
	. . . . . Rupees in Lakhs		
Recurring Costs	168.90	22.90	191.80
Nonrecurring Costs	30.43	17.10	47.53
TOTAL	199.33	40.00	239.33
ICAR share	149.50	40.00	189.50
State share	49.83	-	49.83

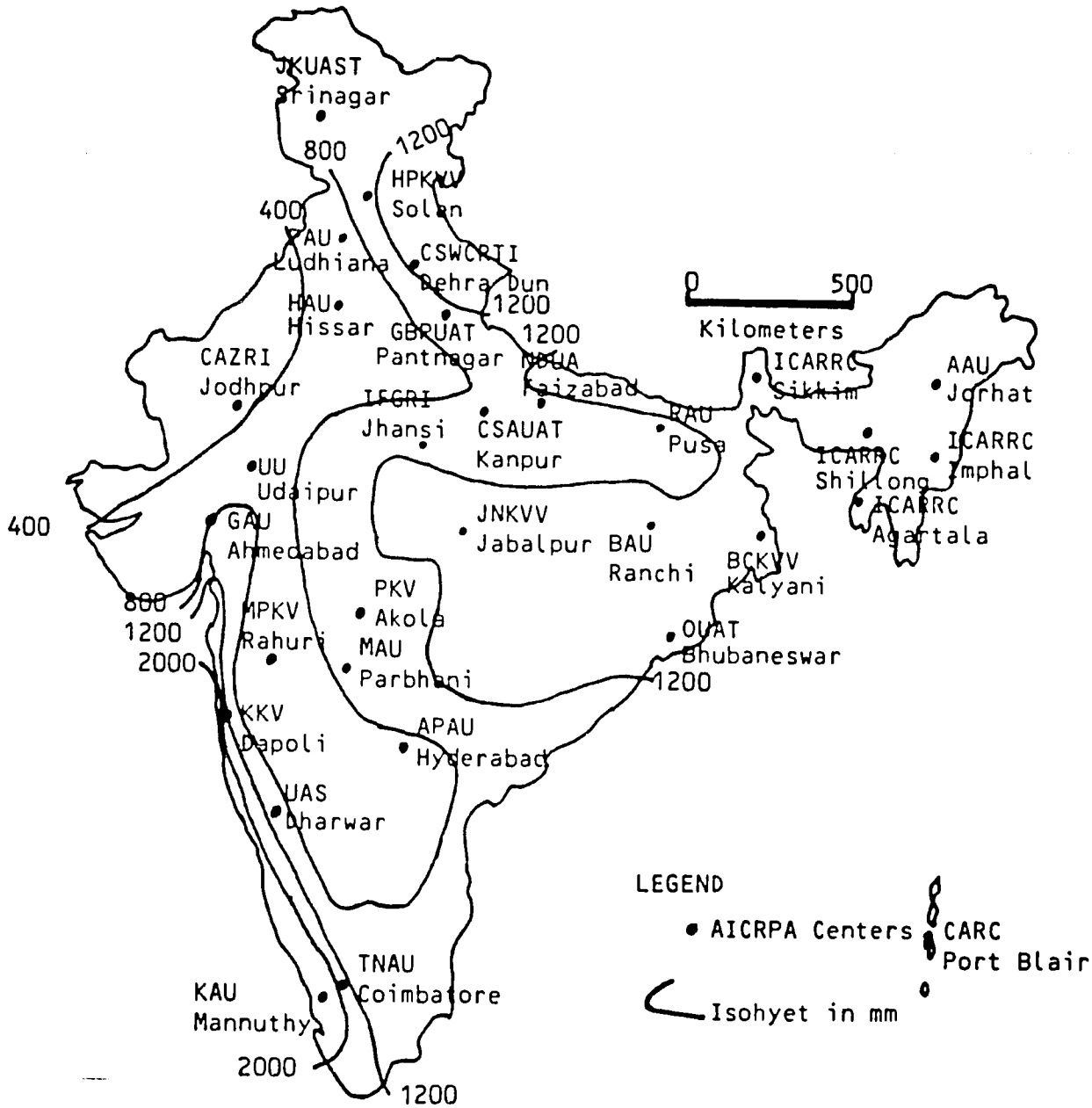


FIGURE A-1. Location of AICRPA Centers by rainfall zone.

Coordinating Unit

The unit is located in New Delhi and is staffed with a Project Coordinator and two scientists.

ICAR Research Institutes

Eight ICAR research institutes participate in the agroforestry project. To undertake project activities three scientist positions were sanctioned at each institute. The eight institutes are :

Central Soil and Water Conserv. Res. & Training Inst.	Dehra Dun	Denuded lands & lands vulnerable to erosion
Central Arid Zone Res. Inst.	Jodhpur	Arid Zone region
Indian Grasslands & Fodder Res. Inst.	Jhansi	Marginal, submarginal & Wastelands
ICAR Res. Complex	Shillong Agartala Sikkim Imphal	Humid eastern hill region
Central Agric. Res. Complex	Port Blair	Humid tropical climatic zone

State Agricultural Universities

Twelve universities participate in the agroforestry project. To undertake project activities four scientist positions were sanctioned at each university. The twelve universities are:

HP Krishi Vishva Vidhyala	Solan	Sub-temperate/sub-tropical
Punjab Agric. Univ.	Ludhiana	Indo-gangetic plains
Gujarat Agric. Univ.	Dhantiwada	Semi-arid to arid western region
Univ. of Agric. Sci.	Dharwar	Transitional rain shadow
Tamil Nadu Agric. Univ.	Coimbatore	Semi-arid southern region
Kerala Agric. Univ.	Mannuthy	Heavy rainfall region of western ghats

31

Univ. of Udaipur	Udaipur	Semi-arid transitional zone
Assam Agric. Univ.	Jorhat	High rainfall northeastern region
Sher-e-Kashmir Univ. of Agric. & Tech.	Srinagar	Temperate region
Orissa Univ. of Agric. & Tech.	Bhubaneshwar	Sub-humid plains region
Bidhan Chandra Krishi Vidyalaya	Kalyani	Humid/moist regions of eastern plains
G.B. Pant Univ. of Agric. & Tech.	Pantnagar	Tarai region

Seventh 5-Year Plan Coordinated-Project Modification

In April 1985 eleven additional centers were established at state agricultural universities. To undertake project activities three scientist positions were sanctioned at each university. The eleven universities are:

Haryana Agric. Univ.	Hissar
Mahatma Phule Krishi Vidyapeeth	Rahuri
Punjabrao Krishi Vidyapeeth	Akola
Marathwada Agric. Univ.	Parbhani
Konkan Agric. Univ.	Dapoli
Andhra Pradesh Agric. Univ.	Hyderabad
Jawaharlal Nehru Krishi Vishwa Vidyalaya	Jabalpur
Rajendra Agric. Univ.	Pusa
Birsa Agric. Univ.	Ranchi
Narendra Dev Univ. of Agric. & Tech.	Faizabad
Chandra Shekhar Azad Univ. of Agric. & Tech.	Kanpur

Coordinated Project Personnel

The following table gives the scientific staffing pattern of the original 20 agroforestry centers.

Center	Scientist positions sanctioned 1 Apr. 1983	Positions filled on 1 Apr. 1985
Coordinating Unit		
Project Coordinator	1	0
Scientist S-2	2	2
ICAR Institutes		
Scientist S-2	8	3
Scientist S-1	16	0
Agricultural Universities		
Scientist S-2	12	4
Scientist S-1	36	11
TOTAL	75	20

Additional scientists at ICAR institutes and SAUs are doing agroforestry research, but are not included in the AICRPA staffing pattern.

APPENDIX B: TEAM VISIT REPORT

Dehra Dun

The research programs of the Central Soil and Water Conservation Research & Training Institute (CSWCRTI) are broadly focused on problems related to soil and water conservation and watershed management and also include projects on agroforestry, silvi-pastoral, agri-horticultural and agro-silvicultural cropping systems. Efforts are being made to determine the production potential of the various cropping systems, compatibility of different crops, competition for moisture, nutrients, light and space, and utilization of class V to VII lands for production of fuel, timber, fodder and fiber. The species of trees and grasses tried on expressively bouldery poor soils are Grewia oppositifolio, Bohinia perpurea, Leucaena leucocephala, Albizia lebbek, Cympopogan fuhus and Eulaliopsis binata.

Work has also been done on rehabilitation of areas spoiled by mining and landslides. The impact of these systems on soil and water conservation receives major emphasis. The work done so far indicates that certain agricultural crops like ginger and turmeric can be grown along with the perennial crops, and that the agroforestry system not only helps in soil and water conservation but also generates higher income per unit area.

Jodhpur

At the Central Arid Zone Research Institute (CAZRI) intensive work has been done on integrated survey of dry areas, moisture conservation in sandy soils, stabilization of sand dunes, windbreaks, shelterbelts, nutrient management, optimum use of scarce water resource, use of saline water for irrigation, soil-water-plant relationships, dryland agriculture, selection and breeding of promising crops, silvipastoral and agroforestry cropping systems, arid horticulture, animal production, and socio-economic surveys. The hostile climatic conditions, low and erratic rainfall, intense solar radiation, frequent droughts, high wind speed and poor soils with low water and nutrient retention capacity occurring in Western Rajasthan necessitate tree planting along with agricultural crops and grasses to enable the farmers to reduce the high risk of failure of annual crops and to meet the growing demands for fuelwood, timber, and fodder. The system of agroforestry incorporating the simultaneous growth of Khejri (Prosopis cineraria) amidst the agricultural crops has been in common vogue in arid tracts of Rajasthan for a long time.

Prosopis cineraria is reported to serve as an excellent source of fodder, to enrich the soil in nitrogen and organic matter and to provide fuel wood and local products without any detrimental effect on the companion agricultural crops like pearl millet, legumes and oilseeds.

Recently, cultivation of ber (Zizyphus Mauritiana) and Acacia tortilis in sandy deserts has gained popularity as a result of demonstrations laid out on farmers' fields through Lab to Land and Operational Research Project (ORP) programs. In the areas where shifting sand dunes and high velocity winds are a common feature, adoption of agroforestry will not only reduce these hazards but will also enhance the productivity and improve the environment of the area for people and livestock. Successful stabilization of sand dunes has been achieved by raising plantations of Acacia tortilis and Prosopis juliflora. A number of tree species and grasses have been evaluated and promising ones for local conditions have been identified. Acacia albida seems to be very promising as it becomes leafless in rainy season but quite leafy in winter season when there is acute shortage of fodder. The Institute organized a Summer Institute on Agroforestry in 1984, the printed proceedings of which contain valuable information.

Pune

The Central Research Station of Bhartiya Agro-Industries Foundation (BAIF), a non-government voluntary organization was established in 1972 with the dedicated mission of Manubhai Desai near the village Urulikanchan about 30 km away from Pune. Besides dairy cattle development, BAIF is undertaking work in farm-forestry and silvi-pastoral production systems. BAIF has introduced effective land-use programs on barren, degraded lands and has laid great stress on Subabul (Leucaena leucocephala) which is a fast growing and nitrogen-fixing fodder tree. Subabul has been grown very successfully on waste lands with gravelly, shallow and poor soils as a pure crop as well as on field bunds and borders or in lines in combination with fodder grasses like Hybrid Napier and guinea grass. Subabul has been found to have multiple uses such as fuelwood, fodder, timber, charcoal, poles, paper pulp, and shelter belts and is considered to enrich the soil in nitrogen and organic matter. Subabul is reported to have gained favor of the local farming community. Various agronomic practices for maximizing the yield of subabul have been worked out for the local conditions. BAIF has also initiated an evaluation of fruit trees and has extended its activities in the states of Maharashtra, Karnataka and Gujarat.

Rahuri

The Mahatma Phule Krishi Vidyapeeth has its main campus at Rahuri with three other campuses, one each at Pune, Kolhapur and Dhule. In general, major research is being done at the Rahuri campus. The research program on agroforestry, which is being only done at Rahuri, has recently been strengthened under National Agricultural Research Project (NARP). There is a proposal to open a separate Department of Agroforestry at the

Rahuri campus. Since an appreciable area in Maharashtra state has marginal and degraded lands, agroforestry has great scope to meet the local needs. Work on silvi-pastoral systems was started at Rahuri in 1975 and subsequently, work on other agroforestry systems has also been taken up. Species like Leucaena leucocephala, Dalbergia sissoo, Albizia sp. and Sesbania ejyptica have shown good promise. The local farmers are taking interest in adopting agroforestry cropping systems because of their fuel and fodder crisis.

Bangalore

The University of Agricultural Sciences (UAS) has done research work on agroforestry at GKVK campus, Bangalore, and has raised successfully, large scale plantations of several tree species such as Eucalyptus hybrid, Acacia auriculiformis, Casuarina equisetifolia, Silver Oak, bamboo, and Grewia sp. on deep soils as well as on shallow rocky soils. Some tree species like Acacia nilotica var Cupressiformis, Prosopis juliflora, Acacia auriculiformis, Casuarina equisetifolia, and Albizia sp. have been tried recently on field borders and bunds and also in widely spaced rows in agricultural fields. The large scale plantations of many tree species raised on varied habitats including shallow, poor, rocky soils and deep soils at UAS, Bangalore, can serve as good teaching material for the students of graduate/postgraduate programs in forestry. Experiments in silvi-horti and horti-pastoral systems are also underway.

Dharwar

Dharwar campus, UAS has a center of AICRPA and has initiated three experiments as per the approved technical program of the project, through several other experiments concerning land use system, silviculture and crop introduction have been in progress since 1976. The field experiments are being conducted at the Agricultural Research Station, Prabhunagar (about 20 km away from Dharwar) which has black and lateritic soils and does not have an irrigation facility. The studies of AICRPA are on (1) agri-silvi and horti-pastoral system involving chilli and sorghum as agricultural crops, teak as a silvicultural crop, papaya as a horticultural crop, and subabul and grass as pastoral crops on red gravelly soils; (2) mixed cropping of erect growing species, namely Tectona grandis, Eucalyptus tereticornis, Gravellia robusta, Acacia auriculiformis and Dalbergia sissoo along with tamarind; and (3) determination of suitable spacing and felling intensity in the tree species Eucalyptus tereticornis, Casuarina equisetifolia and Leucaena leucocephala for fuel and timber. Since these experiments have been started recently no conclusive results are yet available. It is hoped

that after the results of research under AICRPA are obtained and the well-proven technologies are demonstrated in the field, the small farmers who are hesitant at present to adopt agroforestry will start taking up these programs.

Coimbatore

The research work on agroforestry under AICRPA at Tamil Nadu Agricultural University (TNAU) began in September, 1983, at the Forestry Research Station, Mettupalayam which is situated at the foot of the Kotagiri hills about 40 km away from Coimbatore. The Station has a farm area of 200 ha with coarse-textured gravelly red soil and receives annual rainfall of 830 mm. The Department of Forestry in the University, which came into being in 1973, was integrated with the research station at Mettupalayam in 1982. The research thrust has been in production forestry and agroforestry with major attention on the tree species like Eucalyptus, Leucaena, Casuarina, Acacias, neem and silk cotton. Work is also being done on introduction and evaluation of new indigenous and exotic tree species. Studies have been conducted on fodder crops like maize, sorghum and cowpea and other agricultural crops like pearl millet, cotton, red gram, horse gram, green gram and gingelly in the alleys of fast growing tree species, namely Eucalyptus, Leucaena and Casuarina under both irrigated and unirrigated conditions. Eucalyptus has been found to cause maximum reduction and Casuarina minimum in the growth of associate crops. Experiments have been initiated on alley-cropping with fruit crops like acid lime, lemon, mandrin orange, jack, mango, sapota and guava. The main constraints to tree growing on the farmers' fields are the long gestation period, mortality of saplings during summer, non-availability of adequate planting material in time, lack of knowledge of the farmers about the choice of species and management practices, and marketing. TNAU has recently started a teaching program offering the B.Sc degree in Forestry with an initial ceiling of 20 students and may develop a postgraduate teaching program in forestry in due course.

Ootacamond

Ootacamond center of the Central Soil & Water Conservation Research & Training Institute was established in 1955 in the Nilgiri hills which have a varied climate due to variations in altitude ranging from 700 m to 2633 m and receives annual rainfall of 1310 mm. The lower hills have tropical, middle hills subtropical and higher hills temperate climates. The high intensity rain storms cause run off and soil degradation if the slopes are not covered with vegetation and if suitable soil conservation practices are not followed. The soils of the area are acidic lateritic.

The land capability classification has been done on the basis of slope and soil depth. The areas with more than 33 per cent slope should be put under permanent vegetation. Cultivation of agricultural crops on lower slopes is done on bench terraces. Work on agroforestry including silvi-pasture, horti-pasture and agri-horticulture has been carried out, using forest tree species like Eucalyptus globulus, Eucalyptus grandis, Acacia mearsii and Pinus petula, fruit plants like plum, and an annual crop of potato. The cultivation of potato is reported to improve the growth of associated tree crops, while the tree plantations have resulted in reduced runoff and soil erosion, increased soil fertility and greater yield of good quality water. The Center has developed a suitable package of practices of cropping systems and efficient soil and water conservation for different slopes, and is conducting regular training programs for Research Assistants.

Hyderabad

The Central Research Institute for Dryland Agriculture (CRIDA) under ICAR was started as a coordinated research project in 1970 and was elevated to the status of an institute in 1985. It has four divisions: Crop Science, Resource Management, Design and Analysis, and Transfer of Technology at its headquarters located at Hyderabad. Its main mandate is to develop location-specific technologies for different agro-climatic conditions of India and to offer alternate contingency strategies of crop production for each aberrant weather situation with the ultimate objective of improving productivity of the dry farming areas.

In recent years CRIDA has also undertaken studies on more stable alternate land use systems including agroforestry, silvipasture and agro-horticulture for enhancing the overall productivity of the marginal and degraded lands. The field experiments are being conducted at two research farms; one at Hayatnagar and the other at Gunegal, both having average annual rainfall of about 750 mm. Hayatnagar farm has predominantly shallow coarse-textured red chalka soils underlain by murrum on multiple slopes, while Gunegal farm has comparatively deeper and more fertile soils on gentle slopes. The field experiments include Leucaena leucocephala with sorghum, pearl millet, castor, red gram and black gram or with grasses like Cenchrus ciliarus and Stylosanthus hamata in between the alleys. The loppings of Leucaena have been used either as fodder or as mulch. Similar alley cropping systems have been tried with fuel crops e.g. Acacia auriculiformis, Acacia tortilis and Acacia albida. The experiments on agri-horticulture include fruit crops, namely ber (Zizyphus mauritiana), custard apple, pomegranate, guava, phalsa and citrus, with annual crops like pigeon pea, sorghum, cowpea and horsegram in between the rows of trees. Contour-cum-bund cultivation on sloping land to conserve maximum rain water has yielded very encouraging

results in terms of both establishment and subsequent growth. The tree crop has caused maximum adverse effect on deep-rooted crops like castor and pigeon pea and minimum on shallow-rooted crops like sorghum and pear millet. The growth of annual crops has been higher in wider alleys than in narrow alleys. In silvi-pasture systems, Leucaena-Stylosanthus hamata has been found to be the best combination of those attempted.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established in 1972 on an area of 1394 hectares near village Patancheru about 25 km from Hyderabad. The multidisciplinary research has been focused primarily on five agricultural crops, namely sorghum, pearl millet, pigeon pea, chickpea and groundnut, and is being conducted on the experimental farm which comprises of almost two equal parts of red soils (Alfisols) and black soils (Vertisols). The major emphasis has been to evolve new high yielding crop varieties capable of giving high production under moisture stress and low input conditions, and to develop improved farming systems and cropping patterns including intercrops for small farms. ICRISAT has created close working relationships with several countries including India.

ICRISAT has recently initiated a few agroforestry experiments on coarse textured red soils including Leucaena leucocephala as the main woody plant and pigeon pea, sorghum, pearl millet, and castor as the annual crops. Different widths of alleys are also under trial. The observations indicate reduction in growth of associate annual crop adjacent to the row of Leucaena and relatively greater reduction in closely spaced alleys. Yield reduction is much higher in castor and pigeon pea than in sorghum and pearl millet. Detailed investigations have been initiated to assess separate effects of root competition for moisture and nutrients by employing suitable techniques and methodologies. An attempt is being made to provide basic principles for a better understanding of physiology of the tree/crop interface in particular and of the agroforestry systems in general. The systematic experimental designs adopted in the field to evaluate several factors with a minimum land requirement may be of interest to the scientists working in agroforestry at other places. Good opportunities for short duration, on-job training in specialized techniques of research for scientists working in agroforestry can be developed at ICRISAT in due course.

APPENDIX C: QUANTITATIVE METHODS REPORT

Introduction

Research on agroforestry systems involves a unique set of new challenges for statistical design and analysis. The major requirement of agroforestry research focuses attention on evaluation of tree-crop interactions, whereas traditional designs have primarily focused on monocultures. This section of the report considers current agroforestry research efforts in India from a statistical design aspect.

Methods

Observations are based on:

- Discussions with scientists concerning difficulties, problems, and strength of approaches.
- Field visits to see how designs were actually implemented.
- Lists of on-going projects (e.g. at MPKV-Rahuri in the area of agroforestry: 19 project designs and one large scale field trial for a total of approximately 1249 "plots".
- general publications, actual use of data collected and analytical procedures.

Locations were visited or discussions were held with scientists from:

1. AEC - Delhi
2. CSWCRTI - Dehra Dun
3. CAZRI - Jodhpur
4. MPKV - Rahuri
5. BAIF - Pune
6. UAS - Dharwar
7. UAS - Bangalore
8. TNAU - Coimbatore
9. CSWCRTI - Ootacamund
10. ICRISAT - Hyderabad
11. CRIDA - Hyderabad

General Results

The sum of experiences with designs in agroforestry shows the complete range of possibilities. This experience has not yet been formalized and many of the AICRPA projects are just now being initiated. Notable examples are:

1. Complete Factorial Randomized Block and Split-Plot Designs
   - At ICAR institution, these standard approaches are uniformly applied and well executed.

2. Overlaid Designs
   - Most noticeable applications were at CSWCRTI at both Dehra Dun and Ootacamund where watershed research objectives are overlaid on agroforestry randomized block designs.

3. Systematic Designs
   - ICRISAT probably has to-date the maximum use of systematic designs.

4. Potential for Demonstration Area Research (specific research use was not observed)
   - Watershed approaches (CSWCRTI)
   - Wasteland rehabilitation - (UAS)
   - Sand dune stabilization - (CAZRI)

5. Large Scale Sample Survey Research
   - TNAU has conducted observations in farmers' fields on existing agroforestry systems
   - Large scale inventory capability at CAZRI

Generally, there is no lack of experience in agroforestry design alternatives. However, the exchange of experience in experimental design between scientists has been on a very limited scale.

Current Situation

Formalized research efforts, the objectives of research, and efficient designs to meet these objectives in agroforestry are all relatively new. Agroforestry research multiplies the agronomic and forestry situation in terms of complexity and statistical challenge.

Agronomy		Forestry
- Few Species		- Many species
- Relatively uniform plant material site conditions	Agroforestry	- Large variation in plant material site conditions
- Similar small sized plants		- Large variation in plant sizes
- Generally monoculture		- Always mixtures
- Short time spans		- Long time spans

The variations within site (on-farm) may be smaller in agroforestry than in the general forestry context but all other aspects tend to be increased through potential numbers of species combinations, cropping patterns and cultural treatments.

Most of the scientific manpower resource currently available for agroforestry is from agriculture and most of the statistical approaches are modified from agronomic field research experience. Several major areas of difficulty are noted:

- Researchers frequently expressed a lack of confidence in experimental designs to provide desired results plus a lack of familiarity with some of the procedures needed to attain the desired results. A major source of this problem arises from the fact that the agronomy experience, where there is relative uniformity and well understood designs, is being applied to the new and highly variable agroforestry situation.

- Organizationally, statistical expertise is relatively isolated from agroforestry research efforts. It is obvious that statistical consulting is used for experimental design and possibly at the end of an experiment for analysis but there are several problems as indicated below:

  -- high potential for communication failure resulting in the scientist not getting the exact design needed.
  -- the statistical consultant may not necessarily be familiar enough with agroforestry to anticipate the many pitfalls.

- Researchers frequently need statistical support groups as hurdles to research rather than effectively using them as a tool to:

  -- strengthen study design.
  -- expedite research.
  -- make research more efficient.

- Lack of direct access by researchers to computer facilities greatly reduces the effective use of data collected. Much of the analyses is done "in-house" through calculations of averages and variances to avoid lengthy time delays. Lack of access to computers in a real time sense has probably placed a major constraint on modeling and efficient data use since these activities cannot be done on a calculator.

- Field space limitations are recognized as a major constraint in agroforestry research. Scientists appear to have a desire to test many levels of treatments to get close to an "optimum" or an empirical hypotheses. Coupled with research on large plants requiring commensurately larger plots over a long time and simultaneous inclusion of competitive agronomic experiments, the tendency is to reduce plot size to a bare minimum to conserve space. Results are generally:

  -- Small plots have a tendency to not represent actual or desired situation/systems largely through edge effects.
  -- Inevitable mortality in perennial crops over long time periods may interfere with the planned treatment effect (e.g. density or spatial pattern).
  -- Need for intermediate measurements and destructive sampling has a high potential for altering the actual effect of the planned treatment or having inadequate material available.

- Constraints on field space have led to a wide consideration of space efficient systematic designs (e.g. Huxley). Most observations on these designs were obtained from ICRISAT where there is several years experience. Major advantages noted were that the designs do conserve space while providing many treatment levels and good visual demonstration of effects. If total experimental time is short enough, results would be valuable in designing more efficient traditional experiments (e.g. focus on fewer key treatment levels). Major shortcomings noted were:

  -- Systematic errors introduced because a significant factor was not initially recognized. A specific example is the effect of wind direction interacting with the systematic crop-tree pattern to create unexpected growth results.
  -- Information obtained on the control component is generally limited. Control estimates are generally the most important treatment level (i.e. pure crop and pure tree) since this is what other treatments are contrasted against.
  -- Designs are conservative in area but there is generally no place for a multidisciplinary team to work (e.g. root studies in a density trial). Designs tend to be best suited for a single objective experiment. Destructive sampling for intermediate measurements is also a key problem.
  -- The initial level of sophistication in analysis is much higher than traditional designs. Frequently, regression analysis and modeling will be required to obtain desired results.

Statistical Designs

A high priority research area in quantitative methods focuses on more efficient statistical designs. A major problem with agroforestry is that most likely a set of "standard" designs will not be possible as in agronomy. This is due to:

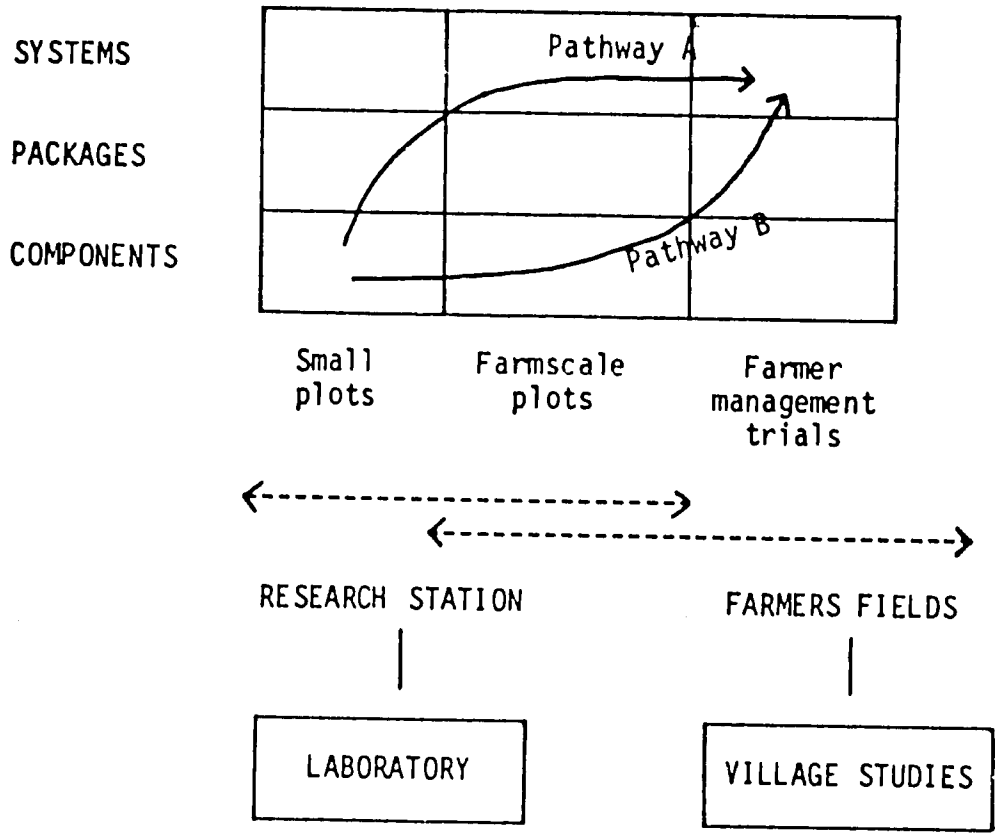
- -- Rapidly changing research needs as knowledge is gained.
- -- The need to carefully tailor the design to the hypotheses being examined.
- -- The need to tailor the design specifically for:
  - environmental conditions.
  - time perspective involved.
  - cultural treatments proposed.
  - size of plants.
  - destructive sampling and intermediate measurements.

Within the area of agroforestry sufficient data either exists or will soon exist to perform detailed design analysis. Aspects to be considered would be:

- -- Minimum land area designs including randomized block and split-plot design.
  - incomplete block and confounded designs.
  - sequential designs.
  - novel systematic designs.
- -- Techniques for combining of experiments over time and space and how this interacts with the basic design pattern.
- -- Sampling within experimental designs with particular focus on destructive sampling for intermediate measurements.
- -- Missing data techniques and mortality replacement policy with particular focus on how this interacts with the basic design.
- -- Sampling designs appropriate for large scale existing agroforestry systems.

Recommendations

The general goal of agroforestry research is to be able to transfer research results to farmers' fields as quickly as possible. The role of statistical design in this effort can be displayed as follows (ICRISAT, 1986).

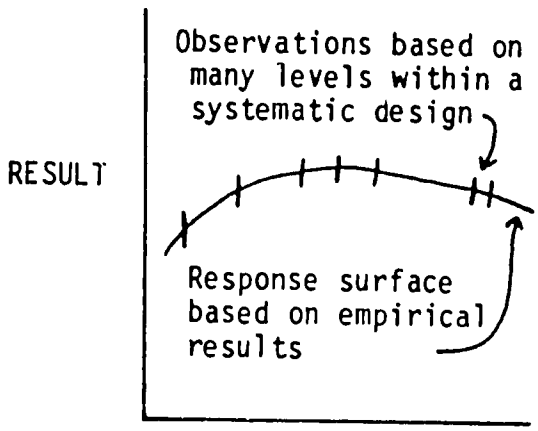


The time component of the graph assumes that each round of agroforestry field experimentation may last 5-10 years. It is possible that agroforestry "package" research could remain on small plots within a research station for 10-15 years before operational scale work begins. An additional major danger is that a treatment effect that exists under highly controlled conditions with manipulated populations may not exist when confronted with natural variability.

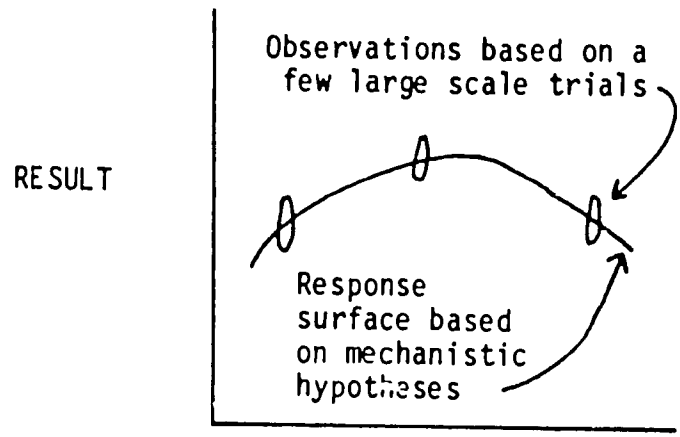
The traditional research approach follows Pathway-A where more time and attention are spent on components and packages as restricted by small plots. Total time involved in this pathway would be long in agroforestry with the long term nature of the research. The ability to enhance the farmer-scientist interaction would be minimal. Pathway-B however, would be more efficient in terms of time in that components and packages would be examined in farmer fields at an early stage with heavy emphasis on farmer participation. To move efficiently along this track would involve the following stringent requirements:

- Concise statement of mechanistic hypothesis including predictions of proposed research outcomes and explanations of why the results are expected. This is in contrast to the development of empirically derived hypotheses.

- Well coordinated team research efforts where the right measurements are being taken and the quality of the measurements is adequate for several uses.
- Sophisticated analysis and process modeling that identifies significant interactions of components. To have the ability, to examine in detail the mechanistic hypothesis and to both interpolate and extrapolate to situations not included in the design. This difference can be viewed as follows:



"Systems Patterns"



"Systems Patterns"

The general direction may tend to lead to:

- Better understanding of the agroforestry systems.
- Results more reflective of what can actually be achieved.

Key Subproject Components

The subproject design includes several key components that focus attention on strengthening science through mechanistic hypotheses, improving efficiency through improved quantitative methods and improving the farmer/scientist interaction through research design.

- The agroforestry model workshop will lay the foundation for the formulation of mechanistic hypotheses, identify major information gaps and prioritize information needs.

- The continuation of the agroforestry modeling effort will be through the development of an expert system (combination of people and computers) including a centralized data base and modeling effort.

- The National Center will provide quality control guidance on measurement techniques and principles to ensure adequacy of results.

- The two large scale ecosystem analysis projects should be designed to address all aspects of agroforestry. Efforts should immediately move the scientists to the field through the use of "farm-sized" plots. Results, when formulated in a modeling context should provide answers to agroforestry questions plus mechanistic hypotheses in realistic terms.

- Training programs in quantitative methods are designed to be rapidly available for scientists involved in team agroforestry research. These programs would include hardware, software and essential techniques for attacking the sophisticated analysis and modeling requirements of agroforestry. A suggested outline is given in the following section.

Training Plan for Quantitative Methods

1. Basic skills (First Year)

Objective:	Acquaint scientists with the use and maintenance of personal computors and software systems. Introduce basic principle related to process modeling.
Duration:	3 week summer workshop.
Personnel:	Select two scientists (preferably non-statisticians) from each regional center.
Topics:	Familiarization with PC/Maintenance Data Management/Spreadsheet Designs and Sampling Regression Modeling Process Modeling and Forecasting

Equipment: One set per center

- 512k PC with floppy disk and 10 megabyte hard disk drive, printer, software to include a spreadsheet package and a statistical package with graphics. Supply of paper, printer ribbons and floppy disks.
- Each center would have the facilities for an air conditioned, dust free room, an assured supply of quality electricity (possibly battery).

2. Primary Concepts (Second and Subsequent Years)

Objective: Build on the first year experience at an increased skill level. Increase focus on advanced statistical techniques and process modeling.

Duration: 3 week summer workshop.

Personnel: Same personnel as the first workshop.

Topics: Same general design as the first workshop but in greater depth.

Equipment: Same equipment as the first workshop.

3. Specialized Workshops (Third and Subsequent Years)

Objective: To provide indepth, specialized quantitative training in subject areas identified by the agroforestry scientists.

Duration: 1-3 week summer workshop.

Personnel: Individuals who have completed the first two workshops.

Topics: Chosen on the basis of scientist needs.

Equipment: Based on workshop topic.

APPENDIX D: AGROFORESTRY TRAINING REPORT

The practice of agroforestry has been in vogue in India for a long time, but it has not been followed on definite scientifically based principles including suitability of crop species, physiological behavior of different plants, compatibility of associated crops, competition for moisture, nutrients, shade and space, relative productive potential of different crop combinations, cost-benefit ratio, environmental changes, soil health and related aspects. Since India is endowed with a variety of soils, water resources, geomorphological features, climatic conditions, crop plants, socio-economic patterns and size of farm holdings, intensive research of both basic and applied nature is needed with the ultimate objective of developing well tested package of technologies based on sound scientific principles suited to different situations. To derive full benefit of research findings, rapid transfer of new or improved technologies through modern extension methods will also be essential.

Development of scientifically based agroforestry systems has become imperative because of shrinking land resources as a result of large scale non-agricultural activities like industrialization, urbanization, communication and other developmental programs, acute shortage of fuelwood, timber and fodder, increasing multiple demands of ever expanding population, disturbances in ecosystem, environmental pollution, soil and water conservation problems and numerous such other factors. Adoption of scientifically based agroforestry systems will help not only in generating higher income per unit area and per unit time but also in achieving rational utilization of limited land and water resources and in maintaining proper soil and environmental conditions.

Efficient conduct of research and rapid transfer of improved technologies for achieving tangible results requires competent scientists in different disciplines and capable extension specialists. For this purpose the need for training of desired quality at appropriate levels suited to the different requirements is quite obvious.

Present Training Facilities in India

Training in forestry, agriculture and other fields related to agroforestry is imparted at present by several organizations, like state agricultural universities, research institutes of ICAR, and the Forest Research Institute & Colleges (FRI&C). The course contents, duration and emphasis in training are varying considerably from one organization to another. The background of the trainees in respect of educational qualifications and experience is also of varied nature.

Central Soil & Water Conservation Research and Training Institute

The Institute offers two kinds of training for inservice persons - (1) for officers and (2) for assistants. So far a total of about 6500 persons have been trained. The training for gazetted officers is conducted at Dehra Dun for a duration of 5 1/2 months (two batches in a year) and enables the trainees to acquire a working technical knowledge of different facets of soil and water conservation with emphasis on land use according to its capability, integrated approach in planning soil and water conservation projects and watershed management. The training includes theory and practicals in disciplines like soil science, agronomy, plant breeding, forestry, engineering and hydrology.

The training for the non-gazetted assistants is imparted at Kota (Rajasthan), Bellary (Karnataka), Ootacamund (Tamil Nadu) and also at Damodar Valley Corporation, Hazaribagh (Bihar). This training is relatively more practical-oriented and prepares the trainees for implementing various programs of soil and water conservation in the field.

Besides the two kinds of training as detailed above, the Institute also organizes short term courses on special subjects for on-the-job purpose. Although these training programs include elements of agroforestry systems, they do not seem to have been designed such as to meet the full requirements.

Forest Research Institute & Colleges

FRI&C are under the GOI and mainly impart three kinds of training - (1) for Indian Forest Service, (2) for State Forest Service, and (3) for Forest Rangers. The training for Indian Forest Service is given at the Indian Forest College, Dehra Dun to the candidates with bachelor or master's degree selected through the Union Public Service Commission. The training is of two years' duration and encompasses theory and practical courses in several subjects covered under the overall discipline of forestry. The training for the State Forest Service is offered to the candidates with minimum bachelor's degree selected through their respective state public service commissions and is imparted at three places, namely Dehra Dun (U.P.), Coimbatore (Tamil Nadu) and Burnihat (Assam). This is a two years' course covering different subjects of forestry. The training for the forest rangers is imparted to the candidates with minimum intermediate qualification selected through the different state public service commissions, and is imparted at nine places - four colleges of the FRI&C and five colleges of the State Forest Departments (U.P., M.P., Orissa, Maharashtra and Gujarat). Though there is a certain amount of difference in the emphasis being given in each of the above three courses, the major objective seems to develop the trainees into capable practical foresters.

The candidates selected for Indian Forest Service and State Forest Service join service under the Central and State Forest Departments on completion of their training and are not available for scientific posts in Indian Council of Agricultural Research (ICAR) in the discipline of forestry. Hence a serious difficulty is being experienced in getting suitable candidates for manning these posts. As a consequence, ICAR often has to draw upon the persons specialized in other disciplines like agronomy, plant breeding, and horticulture for appointment to the posts in forestry. Although some state agricultural universities have opened Departments of Forestry and others will also soon have Departments of Forestry, it will take a long time before candidates with Master's degree in forestry/agroforestry become available for recruitment to the posts in forestry in ICAR.

Under the present circumstances, it is necessary to provide requisite training to the scientists who undertake agroforestry research programs at ICAR centers. The training imparted at the FRI&C, even if availed of by developing a proper administrative mechanism through ICAR, may not serve the purpose, as agroforestry requires major emphasis on an integrated well-balanced combination of agriculture and forestry.