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Trees on Small Farms
Multipurpose Tree Species Research For The Arid And Semi-Arid Tropics

Proceedings of the Network Workshop of the Forestry/Fuelwood Research and Development (F/FRED) Project held November 16-19, 1987 in Karachi, Pakistan

Edited by David A. Taylor and Lee Medema

Winrock International

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Trees on Small Farms: Multipurpose Tree Species Research for the Arid and Semi-arid Tropics is the proceedings of the network workshop of the Forestry/Fuelwood Research and Development (F/FRED) Project, held November 16-19, 1987 in Karachi, Pakistan. It was conducted by the F/FRED Project team in association with the Winrock International Institute for Agricultural Development, prime contractor for the F/FRED Project. Financial assistance was provided by the U.S. Agency for International Development.

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INTRODUCTION

In recognition of the rapid depletion of tropical forest resources and the increased scarcity of fuelwood and other tree products, the U.S. Agency for International Development (USAID) designed and funded the Forestry/Fuelwood Research and Development (F/FRED) Project. F/FRED provides a network through which scientists exchange research plans, methods and results on the production and use of trees to meet the needs of small-scale farmers in Asia. These fast-growing, high-yielding trees are appropriately termed multipurpose tree species (MPTS).

An important network activity is the establishment of standardized MPTS experimental trials to improve the efficiency and effectiveness of MPTS research. Cooperating scientists collect and analyze data on MPTS to determine site requirements, growth rates, and small farm uses.

To date, network trials have been established on 16 sites in the humid and semi-humid tropics. Participants are 10 Asian scientists from Indonesia, Malaysia, Pakistan, Philippines, Taiwan and Thailand.

This workshop provided a forum for scientists and administrators to discuss the establishment of a similar network of experimental trials for the arid and semi-arid tropics. Over 45 invited participants attended, representing 8 countries in Asia, Australia and the United States.

WORKSHOP SUMMARY

The workshop of the Forestry/Fuelwood Research and Development (F/FRED) Project on Multipurpose Tree Species Research for Small Farm Use in the Arid and Semi-arid Tropics was held November 16-19, 1987 at the Pearl Continental Hotel in Karachi, Pakistan. The workshop was attended by invited participants and by many observers from the Sind and Baluchistan Provincial Forestry Departments of Pakistan. A total of 115 people registered, representing Pakistan, India, Nepal, Sri Lanka, Thailand, Australia, Republic of China, and the United States.

The objectives of the workshop were threefold:

(1) Introduce the Forestry/Fuelwood Research and Development (F/FRED) Project to potential network participants,

(2) present and discuss on-going multipurpose tree species (MPTS) and social science research in the arid and semi-arid tropics, and

(3) prepare plans for future network research activities.

In addition to the introductory presentations on the F/FRED Project, participants received a packet of background information to stimulate informal discussion.

On-going research served as the topic of presentations that were grouped into four subject areas: MPTS research, socioeconomic research, germplasm resources, and experimental design, data collection and analysis.

Participants took part in a field trip to the "hurri" plantations of *Acacia nilotica* and the forest station at Miani in Sind Province near Hyderabad.

On the fourth day of the workshop, plans for future network research activities developed out of three working group sessions. Although there were no specific assignments of participants to groups, an integration of disciplines, research experience, and nationality was encouraged. Each group was given a list of questions to discuss. In a combined session afterwards, the groups reported the results of their discussions for consideration by the workshop.

The following is a list of the discussion questions, with a brief summary of responses.

(1) Who is interested in cooperating in arid and semi-arid zone network research?

The following institutions were mentioned as prospective cooperators, in part because most of these institutions were represented at the workshop. This is not, however, intended to be a complete list of network trial participants.

<u>Nepal</u>
- Tribuvan University
  - Institute of Forestry
  - Institute of Agricultural & Animal Sciences
- Forest Survey and Research Office (HMG)
- Winrock International - Agricultural Research Project

Pakistan

Pakistan Forest Institute
Punjab Forestry Research Institute
Pakistan Agricultural Research Council
University of Karachi
University of Sind
Arid Zone Research Institute
Atomic Energy Ag. Research Centre

Sri Lanka

Forestry Department
Coconut Research Institute

Thailand

Royal Forestry Department
Kasetsart University

India

Bharathidasan University
Tata Energy Research Institute Research Institute
Bharatiya Agro-Industries Foundation
Indian Council for Agricultural Research
Indian Council for Forestry Research
ICRISAT

(2) What kinds of MPTS research are most important?

A distinction should be made between research requirements of the two climatic zones encompassed by the term arid and semi-arid tropics. A definition of the semi-arid tropics based on annual rainfall (between 550 mm and 1200 mm) may serve as a guide for the establishment of separate network trials for arid and semi-arid priority species.

Two additional priority species were suggested for the arid zone -- *Prosopis cineraria* and *Prosopis juliflora*. The priority species were then grouped according to the new zones.

For the arid zone (annual rainfall less than 550 mm):

Prosopis cineraria
Prosopis juliflora
Acacia nilotica

For the semi-arid zone (annual rainfall between 550 mm and 1200 mm):

Acacia nilotica
Dalbergia sissoo
Eucalyptus camaldulensis

The limited viability of *Azadirachta indica* seed raised questions as to its inclusion in network experiments. The workshop participants considered species assessment, species improvement and species management to be the important research areas.

(3) What kinds of socioeconomic research would be useful for forestry researchers?

Economic -- This would include a benchmark survey of supply/demand situations, compatibility of agricultural and tree crop interaction in environmental and economic terms, and marketing studies.

Social -- This would include land tenure systems, assessments of the social structure and organizational patterns of farmer groups, baseline social surveys, and leadership patterns.

Cultural -- This would include group knowledge of trees for fuelwood, fodder, etc., assessing the acceptability patterns toward new ideas in terms of productivity and/or environmental considerations, and assessing the role and activity of women and children in working patterns.

(4) What germplasm is available for network experiments?

While in general terms it was agreed that the countries represented could supply the germplasm, this issue will require further assessment.

(5) What is the planting season for available sites?

Nepal: July-August
Pakistan: July-September and February-March
India: July-August
Sri Lanka: October-November

(6) Should some MPTS network experiments include on-farm research and, if so, how should the experiments be designed?

Research that is relevant to small farmers' needs can be conducted with the establishment of on-farm experiments, but that methodologies for such experiments with tree species are not yet available. One approach to removing this constraint would be to conduct experiment station research testing species, provenances, and management treatments, while at the same time developing methodologies for on-farm experiments.

The proposal for a follow-up workshop in the spring of 1988 met with general acceptance. It was agreed that at this second meeting the design and minimum data set for a network experiment would be developed following the guidelines proposed by participants at the Karachi workshop.

KEYNOTE ADDRESS BY THE INSPECTOR GENERAL OF FORESTS

It is a great honor for the Government and people of Pakistan to host this F/FRED workshop, which is expected to serve as a milestone to encourage tree planting to meet the needs of small farmers in member countries.

I am privileged to extend a warm welcome to the distinguished Chief Guest, the eminent visiting delegates, and to others of you who are participating in this inaugural session.

F/FRED is the acronym for the Forestry/Fuelwood Research and Development Project, which is sponsored and financed by the United States Agency for International Development (USAID) to help scientists in member countries address the needs of small farmers in the developing countries of South and Southeast Asia for fuelwood and other tree products. The countries participating in the F/FRED research network are: India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, and Thailand. All share common perceptions and similar problems regarding forestry and fuelwood shortages.

These countries are located mainly in the tropics, where the rural population depends upon biomass as its principal source of fuelwood for cooking and heating. Great pressure on the dwindling forest resources makes visible the need to increase wood production by undertaking farm and community programs.

The objective of improving both wood quality and yield can be achieved only by conducting research on species in arid, semi-arid, and humid regions of the member countries. To this end, research on four species -- *Acacia nilotica*, *Dalbergia sissoo*, *Eucalyptus camaldulensis* and *Azadirachta indica* -- is now being conducted in Pakistan.

Pakistan's forest resources are limited. Presently, about five percent of the country's land is under forest cover. It is becoming increasingly difficult to meet the demands of the growing populace for fuelwood, fodder, agricultural implements, and raw materials required for wood-based industries.

The problems and prospects of forestry in Pakistan are linked to the following factors:

- Fifty-one percent of Pakistan's area is arid, with an average annual rainfall of less than 100 mm. This zone includes four large deserts (Thal and Cholistan in Punjab, Thar in Sind, and Saihan desert in Baluchistan). In addition, there are more than a dozen small deserts scattered in the drier regions. These areas have been hit by severe droughts during the past several years, resulting in near famine conditions, particularly in the Thar and Cholistan deserts.

- Thirty-five percent of Pakistan's area is semi-arid, averaging less than 250 mm of rainfall annually. This area is heavily populated and extensively cultivated using canal water available from the Mangla and Tarbela reservoirs.

- Twelve percent of Pakistan's area is located in the Himalayan region. Because of favorable edaphic and climatic conditions, it supports 80% of the country's forest resources. The remaining forested area in Pakistan consists of: irrigated plantations (5%), riverain forests (6%), mangrove forests (8%), and linear plantations (1%).

- Inefficient water management of irrigated plantations, some of which are more than 100 years old, is caused by siltation or poor drainage. With the construction of the Mangla and Tarbela dams, the riverain forests in the provinces of Sind and Punjab are no longer inundated in summer; this has adversely affected forest regeneration and growth. The same is true of coastal forests that now receive less influx of fresh water from the Indus river and greater quantities of pollutants from industrial wastes and domestic sewage, particularly from Karachi.

- It is difficult to increase the forested area because suitable publicly-owned lands are not available. Forestry competes with agriculture for inadequate quantities of water, and natural conditions for forest growth are constrained by the problems of arid and semi-arid conditions coupled with increased population pressure and uncontrolled grazing.

More than 60% of the land in Pakistan is either already affected or likely to be affected by desertification. The suspended sediment load per km of drainage basin is one of the highest in the region. More than 1.2 million ha of land has already been affected by soil erosion, 4.2 million ha have been rendered unproductive by salinity, and another 2 million ha have become unarable due to waterlogging. In spite of reclamation efforts, large areas remain plagued by these problems.

Although the official figure for the country's forested land is 5%, actual productive forest area comprises less than 2%. Consequently, available timber per capita is only 0.013 m^3, as compared with per capita consumption of 0.024 m^3. Imports, which narrow the gap between supply and demand, have swollen to Rs. 1.7 billion per annum. Most likely, rising demand and declining supply will follow in the wake of increasing population and per capita income growth on the one hand, and shrinking forests on the other. It has been estimated that the present annual timber requirement of two million m^3 will double by the year 2000, and that firewood consumption will increase from the present 16 million m^3 to 30 million m^3 within the same time span.

Due to the widening gap between wood supply and fuelwood demand, the bulk of our domestic energy requirements are being met by kerosene oil, natural gas, electricity, cow dung, and agricultural wastes. All of these commodities could be used more profitably for industrial and crop production rather than for fuel consumption. Imports total 13,000 m^3 annually, costing more than Rs. 95 million. With pulp, paper, and other wood products, the foreign exchange bill has risen to Rs. 1.7 billion per year. It is now time to design a strategy not only to overcome the present deficit, but also to meet the increasing demands placed on public and private forests and farmlands.

Similar problems prevail in China, India, Bangladesh, Sri Lanka, Nepal, and Thailand, where rural populations experience mounting hardships due to shortages of fuelwood for cooking and heating. According to a report prepared by the Food and Agriculture Organization of the United Nations, Bangladesh, India, Indonesia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam have been rated as "fuelwood deficit countries," while Nepal was identified as a country of "acute scarcity." Burma is the only country in the region identified as having only a "potential deficit."

Approximately two billion people -- mostly rural, but not exclusively -- depend on firewood as their main source of energy for cooking and heating. Ninety percent of all the wood harvested annually is used for energy. It meets over two-thirds of the total energy consumption needs in 24 tropical countries, of which 16 are least-developed countries.

No alternative energy source will provide a viable substitute for fuelwood in the near future. In places where a surplus of wood for energy exists or could be created, wood-based energy can contribute to rural and industrial development, as well as to self-reliance in energy at the national level.

In view of the prevailing conditions in the tropics, the F/FRED member countries are striving to improve and expand the vegetative cover. The Government and people of Pakistan are working to increase wood production for construction, industrial and energy purposes. All state-owned coniferous forests in Murree Hills, Hazara, Malakand, and Azad Kashmir are being managed intensively. For that purpose, the Forest Development Corporation in North West Frontier Province and the Logging and Saw Milling Corporation in Azad Kashmir have been established. This has not only stopped unauthorized fellings, but has also increased the recovery of usable wood by 100%. Where additional management inputs could be arranged, the yield has increased by 200 to 300%, thereby meeting the increased requirement for construction timber.

In the hills of northern Pakistan, vast areas suitable for tree growth are presently bare. Phased planting of these areas is proceeding as financial resources become available. So far, more than 200,000 ha of land have been planted, thereby increasing the forest cover in North West Frontier Province alone from 12 to 13%.

Irrigated and riverain forests in Sind province are being improved. Based on a feasibility study prepared by a team of consultants to the Asian Development Bank, a $US 40 million Forestry Development Program in Sind is being developed. A plan for the improvement of coastal forests in Sind is also on the anvil.

Finally, farm and community forestry programs costing Rs. 530 million have been launched in all four provinces with the help of USAID. In Sind, the system of "hurri" plantations, practiced by farmers for over 100 years, is being improved as social, economic and technical studies are carried out by local and foreign experts under the Forestry Planning and Development Project.

The Prime Minister of Pakistan, when he inaugurated the Monsoon Tree Plantation campaign in August this year, expressed the desire that greater attention be given to afforestation of arid and desert areas in Sind Province. In compliance with his directive, the following steps have been taken:

- Two million masquits plants are being raised for planting in desert areas of Sind.
- Arrangements have been made for an American expert to render advice on large-scale planting of Prosopis spp., the main species in arid regions of Pakistan.
- The F/FRED conference here in Karachi and an earlier F/FRED Research Committee meeting in Peshawar are developing a strategy for future action.

It is a happy auguring that we have assembled here to deliberate upon a topic of immense importance to participating countries and vital to human needs. I hope the results of this F/FRED network workshop, as well as those of the Research Committee meeting held earlier at the Pakistan Forest Institute in Peshawar, will help guide scientists and foster cooperation among participating countries to improve and expand objective-oriented MPTS research.

I wish the workshop participants great success and express my gratitude to the distinguished Chief Guest and visiting delegates.

Thank you very much and God bless you.

OPENING ADDRESS BY THE CHIEF MINISTER OF SIND PROVINCE

I am grateful to the Forestry/Fuelwood Research and Development (F/FRED) Project for inviting me to inaugurate this workshop to establish a research network concerned with multipurpose tree species (MPTS) for the arid and semi-arid tropics. In view of the rapid depletion of tree resources in arid and semi-arid areas lands, the project's task is noble. The project is all the more commendable because it aims at meeting the fuelwood, fodder, and small timber requirements of small farmers in developing countries.

The reports of various United Nations agencies pertaining to the increase in desertification and the extent of fertile land going out of cultivation are alarming. One-third of the earth's surface (47 billion ha) is classified as arid and semi-arid and is populated by 850 million people, about 17% of the world's population. It is estimated that about 280 million people are living in the areas directly threatened by desertification. About 20 million ha are deteriorating each year through the desertification process, resulting in a production loss of US$26 million. This situation deserves the most urgent attention of governments and peoples.

In Pakistan, about 57.1 million ha are classified as arid, and 17.1 million ha as semi-arid. These classifications are based on relative severity of climatic elements such as precipitation, temperature, availability of moisture, and type of vegetation. Through unwise land-use practices, man has contributed to the degradation of soils and the over-grazing of vegetation. However, other factors have helped to produce these phenomena. Low water availability is caused by high evapo-transpiration rates, absence of humid air streams, high temperatures, reduced ground water recharge, and decreased river flows. Additionally, the high velocity of sand-laden winds causes physical damage to crops, life, and property. Sandstorms block roads and rail tracks, choke irrigation channels, engulf villages, and encroach upon rich agricultural lands. This is the scenario in all arid regions and leads to massive human tragedies. Desertification is ongoing, carrying in its wake misery and poverty.

Desert vegetation has provided fodder for domestic and wild animals since time immemorial. Cutting for small timber and fuelwood has reduced the vegetation to mere scrub. There is heavy pressure on this vegetation in winter when millions of goats, sheep, camels, and cattle leave the hills in search of grazing grounds. When fodder is scarce, jand (*Prosopis cineraria*) and babul (*Acacia nilotica*) trees are completely lopped and only stubs of the branches are left, which sprout the next year with depleted vigor. To meet the requirements of cooking and heating, plants are dug out by their roots and are used as fuelwood. The deserts are expanding at a fast pace, engulfing rich agricultural land. Under such hostile biotic and climatic conditions, it is hard to expect any natural recovery of vegetation, and it has become impossible to develop a feasible plan of reforestation/afforestation.

The socioeconomic conditions in these areas have played a significant role in the deterioration of forest resources. Communities living here have largely agricultural and pastoral economies. People's needs have continually clashed with policymakers' plans for vegetation conservancy. The people make a living from their meager agricultural resources and pastoral activity, and with the passage of time, site conditions have deteriorated.

People living in these arid and semi-arid areas need fuel for cooking and heating, fodder trees in times of scarce animal feed, material for thatching, small timber for agricultural implements and small household items, doors, persian wheels, etc. Additionally, they need trees

for shade and shelter around their dwellings. Above all, tree windbreaks are essential to protect their agricultural crops from scorching, sand-laden winds. The constant migration of people from these areas to cities in search of better jobs and living conditions can be checked only by improving the living conditions of the rural poor. The answer lies in making a sincere effort towards greening the deserts by making available those tree species required by the people, and by adopting measures that foster natural regeneration.

In the province of Sind, the desert areas of Thar cover more than 44,000 sq. mi. With timely and adequate rains and controlled grazing, soils of these deserts have the potential to sustain good plant growth. This year the monsoon rains failed, and the people living there face unprecedented misery. Trees, though, have withstood the drought conditions and have provided the only source of fodder for millions of livestock. Without the trees, the situation would have been a complete catastrophe. You are scientists of high caliber. Your motives and intentions are praiseworthy. The arid and semi-arid regions must be tamed and their potential harnessed for the benefit of the people living there. While exotic species may be introduced, indigenous species should not be forgotten and improved tree management methods should be explored. I would also suggest that research studies be conducted on private lands so that communities may be convinced of your results and adopt the findings. Improvement of the quality and quantity of tree fodder is another area requiring work.

With these words I declare the workshop open, in the fervent hope that the challenging issues will be discussed thoroughly, and that practicable recommendations will emerge.

RESULTS AND LESSONS FROM THE ESTABLISHMENT OF THE F/FRED NETWORK IN THE HUMID AND SUB-HUMID TROPICS

K.G. MacDicken
D.A. Taylor

Network Team Leader/MPTS Specialist and Project Staff Member, respectively
Winrock International

Activities during the first year of network research on multipurpose tree species (MPTS) under the Forestry/Fuelwood Research and Development (F/FRED) Project have included the design and implementation of the 1987 network trials in the humid and sub-humid tropics, development of a regional research plan for control of the Leucaena psyllid, enactment of a research grant program, initiation of national organizing meetings, and a workshop on MPTS for Small Farm Use. From this experience, lessons may be drawn on the value of clear national research priorities, standardized methodology, interdisciplinary cooperation, donor coordination, and germplasm collection and dissemination. Coordinated network activity can improve regional MPTS research in general, as well as the quality and focus of individual research programs.

INTRODUCTION

Network research of the Forestry/Fuelwood Research and Development (F/FRED) Project formally began in the humid and sub-humid tropics with the Forestry Networks workshop held in Bangkok, September 1986. At that workshop, participants developed a structure for the network and initiated plans for multi-location network field experiments on priority multipurpose tree species (MPTS) of the humid and sub-humid tropics.

This initial network was based on the shared problems of cooperating scientists working with priority tree species best suited to the climatic conditions of the humid and sub-humid tropics. These scientists shared problems involving selection, improvement and management of tree species for multiple purposes. At that time, the foundation was laid for a similar environment-based network for research on three priority MPTS in the arid and semi-arid tropics. *Acacia nilotica*, *Dalbergia sissoo* and *Eucalyptus camaldulensis* were selected as the three priority species for this environmental zone network.

F/FRED ACTIVITIES TO DATE

At a meeting held in Kuala Lumpur in December 1986, researchers designed a series of network field trials for the humid and sub-humid tropics. Participants at this meeting played an important role in the advancement of the network by agreeing on a design and a standard methodology for the 1987 network experiment. A randomized complete block design was agreed upon, using a

3 x 2 x 3 factorial where two genotypes of each of three priority species are observed under three management regimes.

In January 1987, the present Coordinating Unit staff established itself in Bangkok and, based on discussions with network scientists, began assembling a strategy for network development. By sponsoring meetings and workshops, funding limited research projects, and providing short-term training for scientists, the F/FRED Project is developing lines of communication among researchers interested in MPTS research in the biophysical and social sciences. These activities primarily aim to coordinate efforts, so that the limited financial and human resources of national research programs are not wasted through duplication or lack of effective communications between institutions working on similar problems.

One of the first opportunities for network coordination presented itself in an unlikely form: the leucaena psyllid, or "jumping plant louse" (*Heteropsylla cubana*), which by early 1987 had inflicted serious damage to *Leucaena leucocephala* in five countries in Southeast Asia. A series of meetings, beginning in November 1986 in Hawaii and culminating last June with a meeting in Manila, yielded a comprehensive regional plan for psyllid control. The plan put forward suggestions for an integrated approach involving:

- o accelerated research on psyllid-resistant or -tolerant leucaenas,
- o psyllid biology,
- o biological control of the pest, and
- o species diversification.

The psyllid control plan calls for further research, and lays a foundation for cooperation among different national scientific communities and donor agencies according to the research priorities expressed by each. The regional research plan is now being used as a basis for funding allocation of additional psyllid research by the U.S. Agency for International Development (USAID), the International Development Research Centre of Canada (IDRC), and the Asian Development Bank (ADB).

Like the psyllid meetings, other network workshops and conferences can lead to better communications among scientists and a coordinated approach to solving MPTS research problems. F/FRED has co-sponsored with IDRC and the Food and Agriculture Organization (FAO) a workshop on MPTS for Small Farm Use, where 35 papers were presented and discussed. These papers provided an overview of present knowledge on small farm use of MPTS in Asia, and pointed out deficiencies in that knowledge and in methodologies used to evaluate MPTS.

Besides coordinating efforts, the F/FRED network is designed to improve the quality of MPTS research and fill critical research gaps. One of the most effective ways this has been achieved in the humid and sub-humid zone has been through the commitment of participating institutions to conduct multi-location field trials based on a uniform design and methodology. The Kuala Lumpur meeting supplied the basis -- an experiment designed by network participants and a minimum data set -- which the Coordinating Unit and the F/FRED Global Research Unit at the University of Hawaii have been able to support, and which we hope to support in further biological and social science activities. F/FRED has funded the collection of good quality germplasm of the priority species and has distributed it to participating institutions, along with instruction guides, operational funds and equipment support. The F/FRED Global Research Unit in Hawaii has arranged for soil

characterizations of 12 of the experiment sites and has developed the experiment database for recording and analyzing field trial data using microcomputers. A series of four-day training courses will help researchers and technicians to use the standard data collection methods and the MPTS experiment database. F/FRED is also providing microcomputers to a number of the cooperating institutions for use with the trials.

In connection with the experiments, a socioeconomic data set is also being developed to link with the MPTS data being collected for the trials. Several scientists from Asia, the U.S., and Latin America met last month in Hawaii to begin development of this minimum data set, and to discuss how it should be collected. The project has engaged two consultants to follow up that meeting with firm recommendations early in 1988.

One of the benefits of the network trials has already been realized: cooperators in the humid zone share a degree of uniformity in the manner in which they conduct at least one experiment. As experience is gained from these trials, these methods and the minimum data set will be refined in a process which will result in widespread use of variables which are measured, recorded and analyzed in a standard way. This advance will allow comparisons of results from a much wider range of experiments than is now possible, including site characterizations and descriptions of soil and climate. In the spring of 1988, cooperators will begin to see greater benefits. At that time, each participating researcher will have access to data from 16 experiment sites, although each cooperator has been responsible for planting no more than 2 sites.

Another means by which F/FRED is supporting network research is through small research grants made to individual cooperators or institutions. For the most part, these limited grants serve as "seed money" for national and other research programs. In the case of psyllid research, F/FRED is funding several small studies in high-priority research areas not currently supported by other donors or national programs. F/FRED is also sponsoring socioeconomic studies in Thailand, Indonesia, Malaysia and the Philippines, in addition to co-sponsoring a study in Bangladesh on homestead forests.

Under a recent agreement, F/FRED will sponsor six Asian scientists to pursue Ph.D. studies at Michigan State University, returning to their home institutions to complete their research and dissertations. Three of these fellowships will be in the biological sciences and three in the social sciences.

Besides network coordination and research support, the F/FRED Coordinating Unit has developed a plan for short-term training based on the training needs expressed by Asian scientists. The plan provides sponsorship of participants to existing offerings in the region, as well as trainings on microcomputer use in forestry, proposal preparation, and integration of social and forest sciences.

Twinning between Asian institutions, proposed by Salleh Mohammed Nor of the Forest Research Institute of Malaysia (FRIM), forms another part of the F/FRED training plan. Institutions having memoranda of understanding (MOUs) with the project will be paired to exchange scientists for three to six months. This will strengthen ties between institutions and expose scientists to other research programs.

LESSONS FROM THE HUMID AND SUB-HUMID ZONE

Network activity in the humid and sub-humid zone has been underway for only a year. One set of field trials has been established in 6 countries. After site visits and review by network scientists, a second set is planned to begin late in 1988. Even at this early stage, though, some lessons can be drawn as F/FRED begins work in the arid and semi-arid zone.

First among these is the need to coordinate *national* research agendas before developing a regional agenda. The psyllid plan demonstrated the importance of clarifying research priorities within countries before beginning a coordinated effort among countries. The Coordinating Unit has encouraged the establishment of national organizing meetings that bring together, at least once a year, MPTS researchers in both the biological and social sciences of each country. From these meetings, a list of research priorities for each participating country will emerge for the network Research Committee to consider. The first of these meetings have already taken place in Pakistan, Philippines, Thailand, and Taiwan.

A second lesson is the importance of standardization in research methods. The scientists at the meeting in Kuala Lumpur exercised great professional cooperation in developing the plan for the first set of network field trials. Their model can serve, both in substance and in spirit, those who meet next spring to plan the first network trials for the arid and semi-arid zone. The standardization of methods means more than establishing experiments with common design and germplasm, however. It means seriously considering the improvement of methodologies used in assessing the value of MPTS for use on small farms. Too often researchers compare results without recognizing their differences in assumptions and parameters. The standardization process must include an understanding of what characteristics of MPTS are most important to small farmers, as well as reliable assessment methodologies for biological research.

A third lesson learned is the importance of cooperation and communication among agriculturists, foresters and social scientists. In order to be effective in improving the small farm productivity of MPTS, scientists must understand the small farm environment in which the trees will be grown. This does not mean the soil and climatic environment only, but also the socioeconomic environment. Communications and cooperation among researchers with knowledge of agronomy, forestry, economics, and social survey methods are critical to this understanding.

Donor coordination is also important. Each donor agency has strengths and weaknesses which determine the limits of its effectiveness. For example, in the area of psyllid research support, both the ADB and IDRC have substantial funds available for psyllid research, yet have been unable to encourage and support regional coordination of psyllid researchers. The F/FRED project, on the other hand, has little money for research grants, but has effectively used travel and workshop funds to support the development of a coordinated regional plan for psyllid research. One of the lessons learned from the past year's effort in the humid and sub-humid zone network is that donors need to understand the strengths and weaknesses of their research support programs, and work together to bridge as many research "gaps" as possible.

F/FRED's experience also has pointed up the importance of regional support for germplasm collection and dissemination efforts. The use of shared germplasm resources in multi-location trials is critical to the success of these experiments. Without regional support for exploration of new genetic materials or identification and dissemination of seed from well-documented collections,

multi-location trials will fail. Without regular communication concerning seed sources and coordinated evaluation of germplasm performance from these seed sources, species assessment and tree improvement will be limited to local experience, which is often restricted to a limited germplasm base.

Experience of the last year has shown that the exchange of information made possible by a network can lead to the improvement of research not only on the regional scale, but for each institution and individual scientist as well. Through twinning of institutions, theme workshops and site tours -- in addition to collaboration in research planning and field experiments -- each scientist's work can gain through contact with other researchers.

With this workshop, we intensify our efforts to gain these benefits -- from coordination and collaboration -- for MPTS research in the arid and semi-arid areas of South Asia, where, even more than in the humid region, the small farmer with limited resources faces a harsh climate and few choices. A difficult road lies ahead, but our research network can use the lessons gained from experience to develop, with the farmers, alternatives for the future.

THE SOCIAL SCIENCE COMPONENT OF THE F/FRED PROJECT

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The Forestry/Fuelwood Research and Development (F/FRED) Project is integrating the work of social and biological scientists to develop research on multipurpose tree species (MPTS) that addresses actual needs of small farmers in Asia. A look at a Nepali village raises questions pertaining to existing management practices and rights to tree resources that researchers must consider. The F/FRED project approaches an integrated assessment of these issues through its activities in network development, short- and long-term training, and research support. The development of a minimum data set for socioeconomic information and uniform methods of data collection will be an important contribution towards improving interdisciplinary cooperation among scientists and incorporating farmers' knowledge into research programs.

INTRODUCTION

The Forestry/Fuelwood Research and Development (F/FRED) Project provides a unique opportunity for biological and social scientists to work together in their efforts to better the condition of the rural poor in Asia. Social scientists can provide foresters and agronomists with information on the land management practices of the rural poor for both private and commonly held property, the place of trees in farm management systems, and what potentials exist for innovation in the village use of multipurpose tree species (MPTS). With this information, biological scientists can design experiments that reflect farmers' actual management practices in order to improve trees already used by farmers and to test other species under actual management conditions. Eventually, the F/FRED network will probably conduct on-farm field trials, which will further strengthen the links among biological and social science researchers and farmers.

Farm forestry and community forestry are not new concepts to farmers in Asia, who have long grown trees around their homes and in their fields for a variety of purposes, such as fodder, fuelwood, fruit, building material, and shade. Each society and culture -- each village in fact -- has a unique system of managing land and forest resources. Tree management and use depends on the social, economic and cultural environment as much as it depends on the physical environment. A brief visit to one village in the hills of Nepal can reveal several systems of tree management and use, and may raise questions relevant to research programming.

SCENES FROM A VILLAGE

1. A woman stands on a wall bordering a road, stretching to cut a few branches from a tree. This scene, typical in many Asian villages, shows that leaves are an important tree product, usually used for fodder. This scene also raises many questions. What purposes other than fodder does this

tree serve? Who has rights to its use? For different uses, are there different rights to the tree? Can an improved species be grown here beside the highway, where anyone may have access to it and where the air is regularly polluted with engine exhaust? How could the tree or its management be improved to yield more fodder or better wood? Who would plant the tree here and who would care for it?

2. A single, one-year old *Leucaena leucocephala* grows near a house surrounded by vegetables, flowering plants and a small stand of *Cannabis sativa*. On small farms, trees are more often grown as components of mixed systems than as monocultures. Why has the farmer planted this Leucaena here? How will he use it? How does it interact with the surrounding plants, given his system of management?

3. Many villages in Asia, particularly South Asia, have commonly owned and managed lands. On top of the hill near the village is a commons where cattle are allowed to graze -- but whose cattle? How are grazing rights allocated? Scattered throughout the commons trees grow on piles of rocks. The land is common property, but these trees are the private property of the people who planted them. The tree's owner can use it for his or her own needs, rent it to another villager, or sell it. In some communities, land may be owned by one person while trees on that land belong to another. With a system of combined of rights, who determines where trees are planted and how they are used? What improvements can be made to such a management system? What improvements can be made under a common property system? How can the species grown on the rocks in this Nepali village be improved? Can another species better suited to the conditions be introduced there?

4. A few trees grow along a path in the village, but not by chance. They were planted or, more likely, selected by villagers from naturally generating shoots. Why did they choose these particular trees? In some places, certain species are grown for cultural or religious reasons. Others are avoided due to beliefs associated with them, or because the names of the trees carry negative associations.

The demand for tree products for use by the rural poor, most critical in the arid and semi-arid tropics, poses an important challenge to F/FRED. Clearly, social and biological scientists must work together to understand how, where, and why farmers grow and use trees before they can successfully -- with the farmers -- improve the existing systems of tree use. The F/FRED project encourages interdisciplinary cooperation among scientists through three general categories of activities: network development, training, and research support.

NETWORK DEVELOPMENT

An important element of the F/FRED program is the development of a single research network of biological and social scientists. With a single research network, the results of social science research can be directly applied to the improvement and development of multipurpose trees, and the experience of foresters and agronomists can be applied to the design and programming of social science research.

The network will be guided in its sponsorship of regional research by the F/FRED Research Committee, which consists of both social and biological scientists. The Research Committee sets priorities for the provision of small grants to both social and biological scientists.

THE SOCIAL SCIENCE COMPONENT OF F/FRED

The project co-sponsors workshops where issues concerning the improvement and use of MPTS are discussed and research results exchanged. The first such co-sponsored workshop was the workshop on Multipurpose Tree Species for Small Farm Use, held in November 1987 in Thailand, in association with the Food and Agricultural Organization (FAO) and the International Development Research Centre (IDRC). Among the topics discussed as potential themes for a second workshop, now under planning, is the broad area of policy issues in MPTS research, including marketing, property rights, integration of agriculture and forestry research, and the use of research outputs in extension programs and policy.

TRAINING

F/FRED provides both short- and long-term training. Under the project, six fellowships for Ph.D. study will be awarded, three each in the biological and social sciences. All six Asian candidates will study together at one university to encourage regional and interdisciplinary cooperation.

The social science component of the project is evident in the short-term training program in three ways:

1) Short-courses are being prepared on Forestry Concepts for Social Scientists and Social Science Concepts for Foresters. Researchers and administrators participating in these courses will gain a greater understanding of the work and research of scientists in other disciplines. It is also hoped that the courses will encourage more interdisciplinary work by the participants. Other courses being developed under F/FRED include Forestry Research Management and Forest Research Methods. Additional courses will be developed as network participants identify further training needs unmet by existing offerings.

2) Social scientists are invited to participate in existing regional training programs on topics concerning the management and use of multipurpose trees in farm and community forestry systems.

3) F/FRED is co-sponsoring a variety of short-courses, seminars and workshops planned and organized by network participants in conjunction with the regional programs of the project to meet their national research needs.

RESEARCH SUPPORT

The F/FRED Network research agenda emphasizes both biological and social science research. Small grants have been provided for network socioeconomic studies. Five social science case studies -- on farmer access to, management, and use of MPTS -- are being conducted in conjunction with the 1987 Network Trials. Two studies take place in Thailand, and one each in the Philippines, Malaysia, and Indonesia.

These grants will increase in number with the development of network experiments in the arid and semi-arid tropics, with the initiation of a second set of humid and sub-humid network trials, and most importantly, with the development and implementation of a series of regional studies using common methods for research and analysis.

Consultants are conducting two studies to assess the potential social and economic impacts of the improvement of multipurpose trees through biotechnology proposed in other F/FRED-sponsored studies on tissue culture, mycorrhizae, Rhizobium, and the use of gums and resins.

A most important part of the social science component of the F/FRED project is the development of a farm and village forestry minimum data set, and the design of standardized methods for its collection and for broader village studies. A planning meeting of several social scientists from Asia and Latin America took place in early October 1987 to begin development of a standardized methodology and a minimum data set, which together will create a number of opportunities, including:

1. rapid appraisal of farmers' current land and forest management practices,

2. enhanced understanding of the place of trees and tree products in farmers' lifestyles,

3. exchange, and in some areas integration, of data from biological and social science studies,

4. means for comparing tree use across national and cultural boundaries, focusing on important common and location-specific factors of farmer use of trees.

5. development of an information system to help in national policy formation, extension work, and the establishment of research priorities and design.

CONCLUSION

We often hear that villagers need trees, and this is true. But it should be remembered that they already grow and use trees. We need to learn more about their established methods of growing, managing and using trees. Using their valuable indigenous knowledge in combination with scientific knowledge of tree improvement, we -- researchers, extension agents, and government officials -- can work more effectively with the rural poor to improve their livelihood and their lives.

GLOBAL RESEARCH AND NETWORK EXPERIMENT DESIGN: AN OVERVIEW

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The F/FRED Global Research Unit in Hawaii is supporting the 1987 network experiments in the humid and sub-humid environmental tropics through a number of activities, including the development of the F/FRED Information and Decision Support System (IADSS), provision of site soil characterizations, and system trainings on microcomputers. Predictive models will be developed for the network. In designing and executing network experiments, sites should be carefully chosen and characterized according to clear objectives.

INTRODUCTION

The Global Research Unit of the Forestry/Fuelwood Research and Development (F/FRED) Project, located on the Island of Maui with the University of Hawaii, is developing the Information and Decision Support System (IADSS). This system is a software package that uses dBase III+ and is compiled with Quicksilver, which allows scientists in the F/FRED Research Network to manage, analyze and interpret field trial data. It also gives cooperators access to bibliographic references relevant to research on multipurpose tree species (MPTS), and a directory of MPTS specialists worldwide. The system has developed through study of existing databases and through discussions of F/FRED collaborators and specialists from key forestry and agricultural organizations.

THE INFORMATION AND DECISION SUPPORT SYSTEM

In the generation, management and use of data from F/FRED network trials, the network collaborator is the driving force. IADSS is not a system that resides only in a central location, either in Hawaii or Bangkok. It is a dynamic system that each collaborator will have and be able to modify according to his needs. Because of this, the system format provides a common set of data management options. The user selects operational options within the system by entering "add", "search", "modify", "delete", or "print".

The first use of IADSS has been the experiment database, which was designed to support the 1987 network trials in the humid and sub-humid tropics according to the minimum data set (MDS) developed by the researchers who met last year at Kuala Lumpur. The experiment database is ideally suited for comparative analyses from a series of trials having a common treatment design and a standardized methodology for the collection of tree and trial site information. Its flexibility allows it to be adapted to incorporate other experiment objectives that may be considered important by scientists working in the arid and semi-arid tropics. These specific objectives, together with a design for a network experiment for the arid and semi-arid tropics, will be determined at a meeting in the spring of 1988. The network scientists at that meeting will determine the end uses of the

information gained from these trials, define the MDS for the experiment around these uses, and standardize the experiment methodology.

In the case of the 1987 humid and sub-humid zone trials, each cooperator enters the MDS directly into the experiment database on a microcomputer. Direct entry by research technicians reduces opportunities for incorrect data entry and simplifies the data management process. For this purpose, the system has been designed to be as "user-friendly" as possible, so that one does not need to be a computer specialist to enter or manage trial information.

The experiment database is linked with a data graphics and analysis package. Upon entry of the field measurement data, database files on experiment design and calculated plot data are merged and analyzed using a customized version of a commercial statistical package. This link between the experiment field data and analysis eliminates the need for tedious manual calculations. A summary of the analysis appears on the screen, with a graphics display of the distribution of data, to help the cooperator interpret the experiment. After each measurement period, cooperators will update the experiment database. The data will be aggregated, analyzed and distributed to all network cooperators for their interpretation.

OTHER ACTIVITIES

Besides design of the experiment database for the 1987 field trials, the Global Research Unit, in conjunction with the the F/FRED Coordinating Unit in Bangkok, is providing network cooperators with soil characterizations of each of the trial sites and training in standardized methodology and data collection. All of the sites for the 1987 network trials have been characterized by a team of soil scientists using the Soil Taxonomy classification system, and summary characterizations have been recorded on the "site descriptor--soil" form of the experiment database. These will prove useful in modeling species performance. Also, a four-day training course on standardized field data collection and data entry are taking place in each of the countries involved in the present trials.

Other databases that already form part of IADSS include a network directory of MPTS specialists and a bibliography of MPTS citations with abstracts. Future additions will include a summary database of related MPTS research records, as well as village, soils, and economic databases.

Another function of the Global Research Unit is worldwide coordination with other scientists working in the field of MPTS information and database management. In developing the design for IADSS, contacts have been established with the Tropical Agronomic Center for Research and Education (CATIE) in Costa Rica and the International Council for Research in Agroforestry (ICRAF) in Kenya. F/FRED also has ties with the Division of Forest Research at the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Australian Centre for International Agricultural Research (ACIAR) in Australia. Through these contacts, the the F/FRED team in Hawaii is exploring avenues of collaboration with other efforts in the area of MPTS information management.

PREDICTIVE MODELING AND MPTS TECHNOLOGY TRANSFER

Historically, transfer of improved technologies from experiment sites to actual applications has involved trial and error. This method is effective where time and resources pose no constraint. A

more cost-effective method, however, is the transfer of a given technology to sites where the environment is most closely analagous to the experiment site. With MPTS, transfer by analogy can minimize mismatches between the requirements of a particular tree species and the biological and socioeconomic characteristics of a planting site. Still, this method of transfer is restricted by the range of experiment environments from which analogies can be drawn. In broadening the range of experiment sites, multi-location network experiments provide an excellent instrument for improving analogue transfer. To develop an environmental model, for example, the data gained from a range of experiment site environments can be used to extend the predictive capability of analogue transfer. Simulation modeling offers another, more comprehensive method of transfer than environmental modeling. This second type of predictive model can mimic the biological processes of wood and biomass production, for example, through systems analysis.

When adequate data has been collected through the 1987 network trials, the summarized data can be used to estimate predictive environmental models of species performance and to validate predictions from simulation models. These models will help scientists to predict the performance of tested species under several management regimes at non-experiment sites based on environmental characteristics, and arrive at the most promising match between tree crop requirements and location characteristics.

NETWORK EXPERIMENT DESIGN

With these specified objectives, it is helpful to outline some of the considerations involved in the design of a network experiment that influence the effectiveness and value of these kinds of models and their interpretation.

In analyzing the data from multi-location trials and developing a predictive model, the most basic data analysis consists of calculating the average of measurement data collected at the sites. Average species performance is a model of sorts, although its value and extrapolability will be limited unless the sites are merely replications. This predictive model is simply the average value, and it will "predict" the same average performance for any given site. We may determine later if this type of model is adequate for the purposes of our network. However, if we add characterizations of the experiment sites to our model -- the soil, climate and weather conditions under which the tested species performed -- then we can establish relationships between species performance and site environment that enhance our predictive capability.

In conducting a network trial on species assessment and management, the scientist *expects* to see differences in performance between treatments and between sites. It may not be enough to conclude merely that there is significant variance in performance of a species over a given range of site conditions. What the scienists may want to do is to examine *how* the differences in recorded performance vary among the sites. Do the differences among the experimental treatments, calculated for each trial, remain constant from one trial site to another? If not, can the variance be graphed and the nature of the site-by-treatment interaction established?

For the purpose of analyzing important site-by-treatment interactions, site information should be measured before and during the trials. In this respect also, the designers of a network experiment should ensure that the experiment sites are carefully selected to represent a range of site variables. To be able to determine interactions, researchers must carefully choose the range of sites so that, to the extent possible, all combinations of site variables are represented. For example, the designers of the 1987 humid zone trials anticipated that soil texture and precipitation might be

interaction factors. In that instance, sites exhibiting the full range of soil texture and precipitation combinations would be most useful for predictive modeling purposes. Without the use of an adequate range of sites, it would be impossible to establish the nature of the interactions with a degree of accuracy adequate for prediction at non-experiment sites.

It may be that in the arid and semi-arid tropics, for example, previous farmer use of the species will be considered to be an important site factor, in addition to moisture conditions. In that case, care should be taken to select sites that provide a uniform distribution of expected site precipitations for villages with and without previous use of the priority species.

CONCLUSION

Hard data from multi-location trials, taken with a set of standard data collection techniques, will be a major contribution of the F/FRED network to its cooperators. Good quality data will command the attention of other scientists working in the field of MPTS research. To the extent that the designers of the arid and semi-arid network experiments define the intended uses of the trial information and develop a MDS that serves these ends, with site variables that can be represented by a suitable gradient of experiment sites, the network trials will also provide a valuable tool for assessing the likely performance of species on locations away from experiment sites.

DISCUSSION

The importance of both the management of each trial and conformity to the standardized methodology was noted. The anticipated output would be the predictive capabilities regarding the suitability of a species and its reaction to management practices. It was agreed that the use of reliable extrapolations for prediction would reduce speculation on adaptation of species.

The origins of the germplasm used in network experiments should be well documented, and in selecting experiments sites, practical considerations such as road access should not be overlooked.

GLOSSARY OF TERMS

Experimental Design -- A set of rules for assigning treatments to experiment plots. When all replications of each treatment are assigned to the plots completely at random (without restriction), the design is called a *completely randomized design*.

When the plots are arranged in subgroups or *blocks* so that the variability among plots within a block is minimized and the randomization is restricted so that each treatment occurs in each block, the experimental design is called a *randomized complete block design* (RBCD). When

each treatment is replicated once in each block, the number of blocks is equal to the number of replications. This is the most common RBCD.

An *augmented block design* is an RBCD with additional, non-replicated treatments in each block.

Experimental Error -- A measure of variability determined from replication of the treatments, commonly called the variance of an experiment. This is used in calculation of the standard error of a treatment mean.

Field Plot -- A specified land area associated with a treatment.

Network Trials -- A series of experiments with identical or similar treatment designs.

Randomization (or, *Randomized Experiments*) -- A specification of assigning treatments to the plots so that each treatment is equally likely to be assigned to any given plot.

Replication -- Repetition of plots with the same treatment. Replication should not be confused with samples (e.g., trees) within a plot.

Sampling Error -- A measure of within-plot variability, determined from samples within a field plot (e.g., tree-to-tree variability within a plot).

Treatment -- A generic term used in comparative trials to describe the effect of a procedure (agent or intervention). Treatments can be physical, as with cutting managements, or definitional, as with species or planting dates. Each type of treatment is commonly called a treatment factor

Treatment Design -- A structural arrangement of treatments. A single-factor treatment design will normally have two or more categorical states (e.g., species or management packages), or three to five quantitative levels (e.g., rates of fertilizer or planting density). The number of treaments is the number of qualitative states or the number of quantitative levels.

A two-factor treatment design is a factorial arrangement of treatments where the number of possible treatments is the product of the number of levels (or states) for each of the two factors. Each treatment is a factorial combination of one level of one factor with one level of the second factor.

Trial (or *Experiment*) -- A set of plots with one or more treatments. A demonstration plot is commonly associated with one relatively large plot on a farmer's field with one treatment.

A *comparative trial* is a set of plots with two or more treatments, whereas a *replicated trial* is a set of plots in which each treatment is replicated at least twice.

TOWARDS A SOCIOECONOMIC DATABASE ON SMALL FARM USE OF MULTIPURPOSE TREE SPECIES

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A good understanding of the socioeconomic system facilitates the adoption of multipurpose tree species (MPTS) by small farmers. As the F/FRED project develops its socioeconomic database, questions regarding profitability, farmers' objectives, and infrastructure must be considered. A series of inter-related subsets -- such as forestry-farming linkages, infrastructure, and organizations and institutions -- form a framework for the database.

To integrate the biophysical and socioeconomic approaches to MPTS research, researchers must bridge disciplinary borders. Scientists should involve farmers in the research process to develop viable options. This "action research" approach contrasts with the classical view of professionalism, in which there is little interaction between researchers and users. The new approach has implications for policy and extension in its focus on the local and institutional realities of rural development.

WHY A SOCIOECONOMIC DATABASE?

Developing a proper understanding of the socioeconomic system is an integral activity within the program of the Forestry/Fuelwood Research and Development (F/FRED) Project on multipurpose tree species (MPTS). This understanding is particularly important considering the project aim that it "should result in sustainable land-use systems, raise incomes, and meet basic needs of rural people in the developing world" (Winrock-F/FRED 1987). The primary goal of the project is to apply technological know-how in a manner acceptable to farmers and accommodating to large-scale extension, using a combination of strong indigenous initiatives and sustainable external support services. The need to take into account the socioeconomic dimension is supported by the experience of the Nepal-Australia Forestry Project, which suggests: "Given a legal framework in which to operate, the technical aspects of nursery and plantation establishment pose relatively few problems . . . It cannot be overstressed that, in order to establish and manage viable plantations and forests protected by the people, the mechanisms employed to undertake this must be within the established social framework." (Applegate and Gilmour 1987)

In this context, a strong case can be made that proper orientation of policy and planning issues related to small farm use of MPTS requires a socioeconomic database. This paper highlights the principal variables to be incorporated in the database system, and is based on discussions at the F/FRED Planning Meeting on the Minimum Socioeconomic Database, held October 5-9, 1987, on Maui, Hawaii. A brief description of the methodological framework and related approached is included.

In considering the socioeconomic database, the following key questions posed by Carlos Reiche (1987), based on CATIE's experience with the Multipurpose Tree Project, are highly relevant.

1. What are the key economic variables affecting people's willingness to grow trees on the basis of *profitability*?

2. What kind of *interventions* or *incentives* are needed to stimulate growing trees under *different socioeconomic circumstances*?

3. What are the most *cost-effective ways* to stimulate and transfer multipurpose tree reforestation techniques?

4. What are the feasible and available *options* for growing trees, given the *small farmer's objectives and constraints*?

5. How much *income return* do the available options for tree-growing offer? What are the financial and economic constraints under different conditions and resource bases?

6. What *techniques and institutional measures* are required in order to bring about multipurpose tree reforestation?

A FRAMEWORK FOR THE SOCIOECONOMIC DATABASE

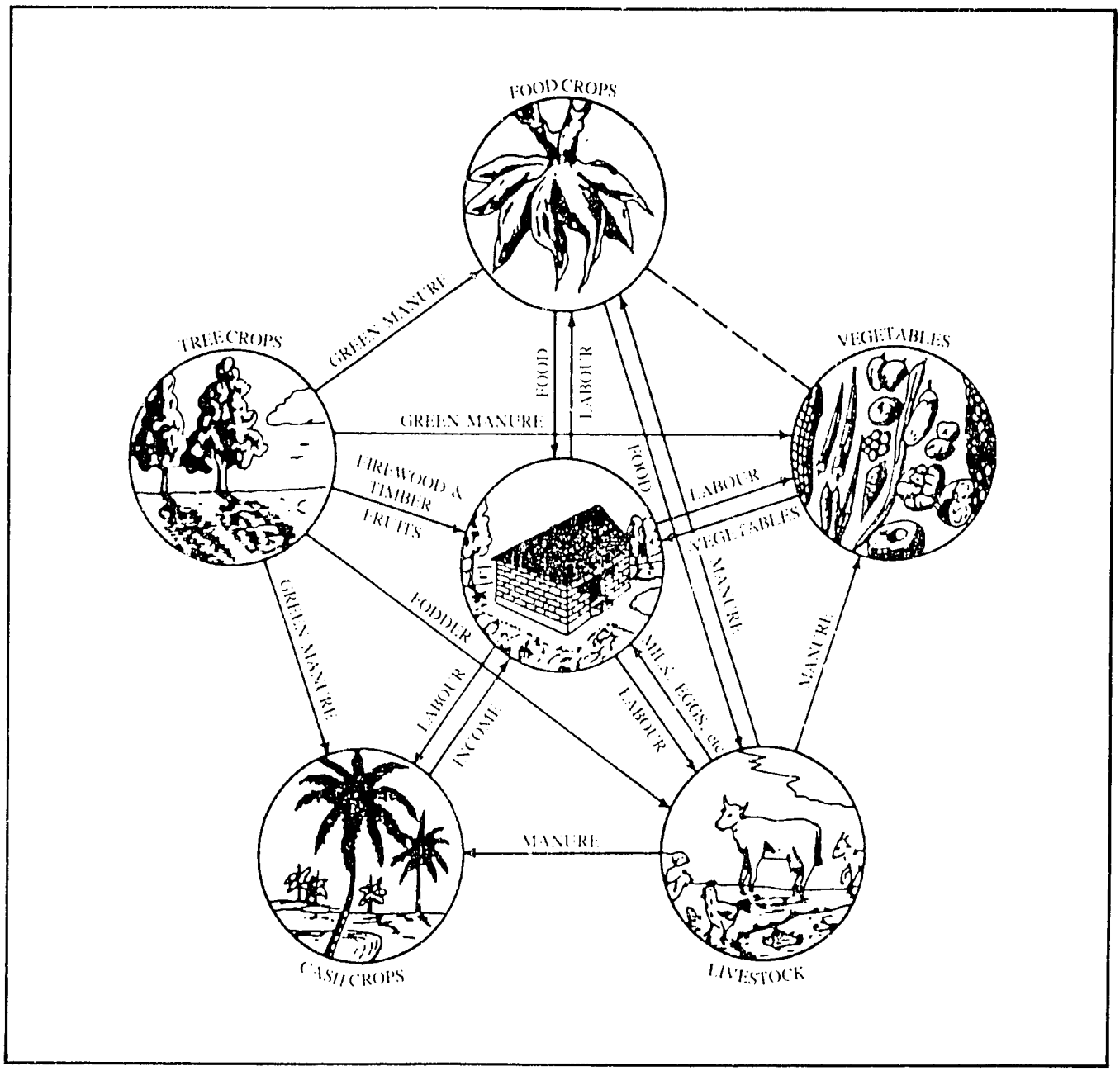
The F/FRED socioeconomic database will supplement the MPTS experiment database, which focuses on the physical and biological parameters related to the production and yield of priority tree species. The purposes of the socioeconomic database are: (1) to understand the compatibility of MPTS within the present socioeconomic framework, (2) to assess the strategies required for the acceptance and extension of MPTS, and (3) to establish guidelines for formulating policies and plans that the reflect the needs and priorities of the local population. A framework for the database system should consisting of at least three inter-related subsets: (1) farm forestry linkages and the state of subsistence, (2) infrastructure development, and (3) organizations and institutions.

Farm Forestry and the State of Subsistence

Clearly, the nature of most Asian economies is subsistence, dominated by an agrarian rural sector (see Mahat 1987, and Khattak 1987). Crop production, livestock husbandry and forestry intertwine in a mutually reinforcing and interdependent manner within the region's farming systems (Figure 1). The potentials and constraints of MPTS will have to fit within this subsistence framework, and the socioeconomic database will have to reflect these dynamics to be relevant. Variables that should be incorporated include:

- o Population and poverty
- o Land holding and use pattern
- o Livestock holding and husbandry pattern
- o Labor use pattern, including outmigration for seasonal employment
- o Tree use pattern *vis-a-vis* fuel consumption, crop production and animal husbandry

Figure 1. Schematic presentation of the interaction among major components of the homestead agroforestry system (Source: Nair and Sreedharan 1986 quoted by Singh 1986)



The database should be oriented to answer the following questions that bear directly on strategic planning and policy issues:

- o Why are forests or tree plantations required? What is the demand for tree products for fuelwood, fodder, animal bedding, construction timber, fencing, and industrial use?

- o How much tree plantation is required? What is the quantity and quality of available land? Are there potentials of intercropping trees and agricultural crops? Is there competition or complementarity between particular land uses (*e.g.*, agriculture, forest or grazing)?

- o What are the attitudes of local people regarding trees and forestry activities? Is there sufficient flexibility for innovations in their patterns of land use, labor use, and/or tree use? What are the potentials of risk-taking in new ventures under subsistence conditions?

Infrastructure Development

The three essential components within infrastructure that directly affect the promotion of MPTS for use on small farms include:

- o Transportation links
- o Market centers and other marketing opportunities
- o Government services and other external support systems

Their inclusion in the database follows from the premise that in experimenting with MPTS, the small farmer takes some risks. Using his own criteria, the farmer must first be convinced of the economic viability of using MPTS within the confines of the village, or for sale outside the village, or for both purposes. He must be assured of a regular supply of inputs such as seeds and saplings, credit, facilities, technical support, and reliable extension services. The related questions that the database would attempt to answer include:

- o What are the potential effects of road and/or trail conditions and of the distance to market centers and/or the district headquarters on the supply of required external inputs and on monitoring and supervision visits by external resource persons?

- o How is the price of material inputs affected? What is the marketability of tree products and estimated margin of profitability, given the current and/or projected market conditions?

- o What other incentives are available from government and other offices that could help build the confidence of local residents to undertake new initiatives (*e.g.*, provision of training programs, availability of subsidies and grants, technical support for planning, implementation and management, and market guarantees)?

Organizations and Institutions

It is essential to consider organizational and institutional issues at the village level as well as at the national level when planning the acceptance and diffusion of innovations in the use of MPTS. Variables of particular importance are:

- o Indigenous technical knowledge and management systems, particularly pertaining to tree use

- o Village leadership/cohesion patterns
- o Property rights related to land and tree tenure
- o Land and forest laws

The growing recognition of sound longstanding indigenous agroforestry practices is encouraging (see, for example, Singh 1987 and Tejwani 1987). Similarly, there is greater awareness of the need to understand people's institutions for forestry and fuelwood development (Morse *et al.* 1987, Dani and Campbell 1986, Dani *et al.* 1987). At the policymaking level, the need for favorable regulations concerning community forestry and property rights is receiving increasing attention (Applegate and Gilmour 1987, Singh 1986). Relevant policy questions include:

- o How compatible is the proposed use of MPTS with the indigenous agroforestry practices or forest management systems? What important lessons can be drawn from the indigenous systems concerning, for example, the species preference, complementarity in intercropping, and tree use patterns? Is there a possibility of blending systems of traditional knowledge with the more "modern" systems?

- o To what extent do the land and forest laws, tenancy rights, regulatory mechanisms, and other support systems reflect the local people's aspirations and consequently encourage or restrict local initiatives for agroforestry activities or forest plantations? What problems and prospects does tree planting on private and/or common property pose for regulatory and extension agencies?

- o What are the possibilities for organizational and institutional innovations, given the history of mutual collaboration or factionalism in the village? In what ways can external interventions effectively strengthen local residents' capability to innovate?

INTEGRATION OF BIOPHYSICAL AND SOCIOECONOMIC APPROACHES: A NOTE ON METHODOLOGY

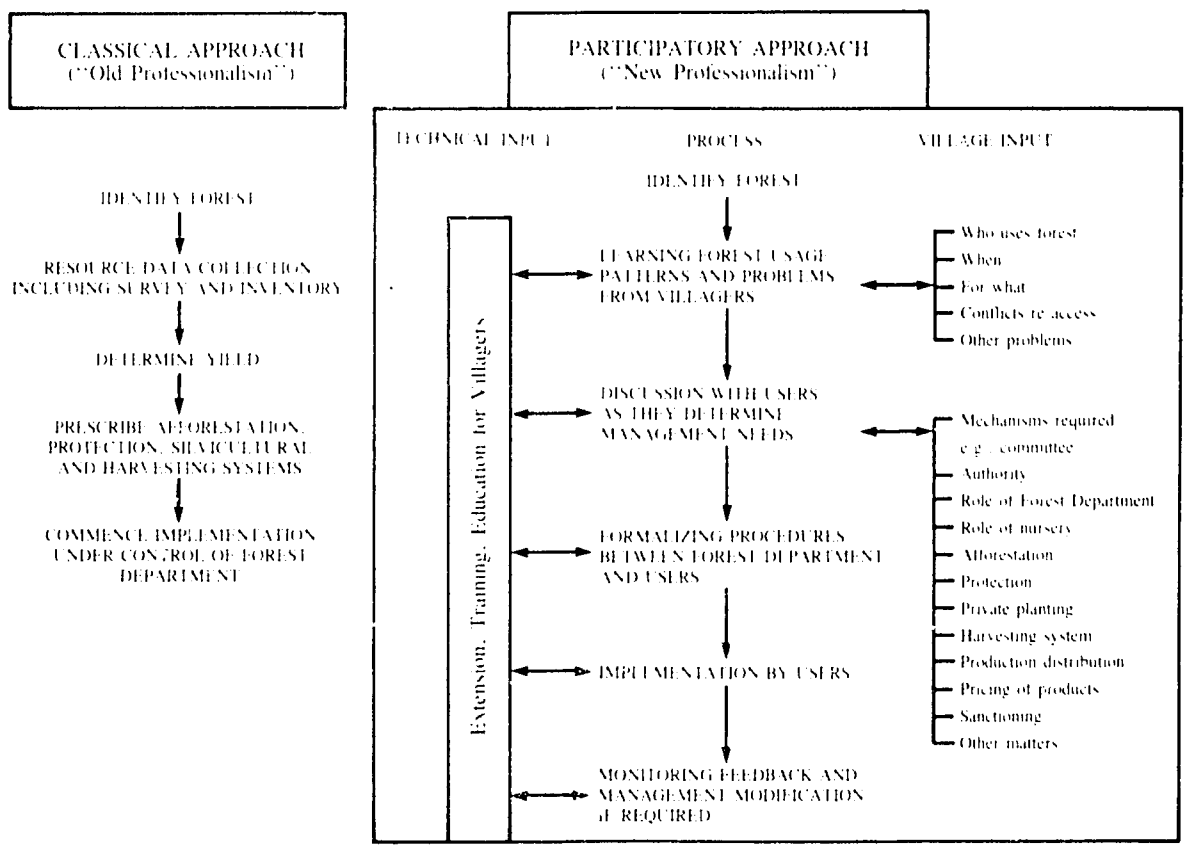
A detailed description of the methods of data collection for establishing the socioeconomic database is beyond the scope of this paper. A few principles pertaining to methods merit attention, however. First, scientists need to avoid separation of biophysical experiments and socioeconomic enquiries as different entities, and emphasize instead interactive research where there is no role differentiation. Biophysical scientists and social scientists should ward off narrow disciplinary arrogance and adopt an integrated approach. The following statement by a forester can serve as a research paradigm: "Forestry is not about trees, it is about people. It is about trees only insofar as they can serve the needs of people" (Westoby 1987). While this differs from the classic professionalist approach, its adoption provides the opportunity to integrate silvicultural practices with management issues of social needs and acceptability, and induces researchers to develop a range of options based on both silvicultural and end-use objectives that can be readily understood by people in the villages.

Secondly, strictly academic pursuits should be avoided. Silvicultural trials that ignore actual use patterns and production conditions have limited applicability. Of equally limited value is a socioeconomic database that does not entail involvement of local farmers in the experimental search for acceptable MPTS and management schemes. The most valuable approach would be "participatory action research," in which biophysical and social scientists interact with local residents as partners, sharing each other's knowledge to develop effective innovations for sustaining increased

productivity, encouraging sound environmental management practices and increasing self-reliance and quality of people's lives. A growing body of literature now advocates this position convincingly (*e.g.*, Bajracharya *et al.* 1987, Fisher and Malla 1987, Gilmour *et al.* 1987, Glover *et al.* 1987, and Morse *et al.* 1987).

Figure 2 contrasts the "new professionalism" described above with the "old professionalism" (Gilmour *et al.* 1987). The process includes the participation of professionals and users at all stages, from planning to implementation to monitoring and evaluation. Technical inputs come from professionals at all stages, with village level data collected as appropriate, with integration taking place in the process. This differs remarkably from the classical approach, where interaction between professionals and users is minimal and the prescriptions always come from the professionals.

Figure 2. Comparison of classical and participatory approaches to the development of forestry management (Source: Gilmour, King and Fisher 1987)



IMPLICATIONS FOR POLICY AND EXTENSION

The purpose of the socioeconomic database and the use of "action research" in selected villages is to gain necessary perspectives on how to increase productivity, encourage sound environmental practices, ensure sustainability, and promote self-reliance. Given that environmental degradation is accelerating under increasing population pressure and that corresponding innovations under subsistence conditions have not been forthcoming, the challenge is to find suitable alternatives that

respond to local needs and that are acceptable to the local population. MPTS play an important role in this endeavor. Selection of these options will have to be supported by organizational and institutional operational realities at local levels, both in terms of potentials and constraints, before any judgments can be made about their effectiveness. The socioeconomic database based on action research in selected villages will highlight these local dimensions *vis-a-vis* the national policy context. Although a limited number of cases makes generalization to all villages in any country impossible, village case studies will indicate the strengths and weaknesses of specific policies.

This new orientation in research and development is evident in a paradigm that promotes active interaction between professionals and the local population. The first cycle of activities will probably involve extensive dialogues, and some activities will be initiated based on common understanding. In the long term, scientists will be induced to conduct more need-based research based on village conditions. At the same time, exposing villagers to new knowledge will help revitalize, re-organize, or replace indigenous systems, depending on the situations and the confidence gained by community residents. New insights gained by professionals and users will impel the extension system and other support services to be more responsive to local needs.

Several innovative community social forestry projects in the region demonstrate the validity of this position in a preliminary way. The F/FRED research network can consolidate many of these findings and shed new light with frontier research. The integration of technological options, social needs, organizational requirements, and management skills through a partnership involving both professionals and users holds many promises, which international perspectives can only strengthen.

DISCUSSION

There is a need for forester training in techniques of information collection in order to adequately incorporate the farmers' perspective into the research process. One forester summarized the goal of research in four questions: 1) What is the existing situation? 2) What are the local needs? 3) What deficits exist? 4) What measures are required to meet these needs? Both foresters and social scientists are in accord on these general aims.

In response to the expressed concern that time may be a constraining factor to action research methods, the author replied that in fact the interactive approach to research is more efficient than traditional approaches in reaching viable end uses because the process integrates new and old knowledge.

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PRESENT AND PROSPECTIVE USES OF TREE SPECIES IN INDIA'S SEMI-ARID TROPICS

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To be successful, research on multipurpose tree species (MPTS) requires clear end-use objectives. Based largely on information from village studies in India's Semi-Arid Tropics, economic prospects of alternative MPTS end-use objectives are assessed, implications of current and prospective tree uses on villagers' welfare are discussed, and areas for future research are delineated. The most promising end uses include poles for small construction timber, fruit and fodder. The economic scope for using trees for mulch or village fuelwood is judged to be limited. More empirical research is needed on the optimal management of tree crops in sole stands, the consequences of rapid uptake of farm forestry systems, the demand for Leucaena, and the allocation of research resources to farm forestry and other economically important tree species vis-a-vis *other commodities.*

INTRODUCTION

This paper assesses, in a preliminary and intuitive manner, present and prospective end uses of tree species in India's semi-arid tropics (SAT). The material presented here draws heavily on Walker (1987). The assessment is limited in three respects: (1) its geographical focus is confined to several large production regions within India's SAT, (2) the evaluation does not center exclusively on multipurpose tree species (MPTS), and (3) the relevant literature has not been thoroughly reviewed. The assessment relies largely on longitudinal data from 10 villages representative of 5 broad soil, climatic, and cropping regions of India's SAT (See Figure 1). Table 1 lists the study villages and their salient features.

The paper is organized into three sections. Descriptive analytical information on end-use objectives is followed by a discussion of the implications of current and prospective tree uses on villagers' welfare. The paper concludes with a brief agenda for future research.

PRESENT AND PROSPECTIVE USES

To be successful, research on MPTS requires clear end-use objectives. Loppings for mulch or fodder, fruit, fuelwood for domestic use, wood for household construction, poles for commercial construction, commercial small timber for pulp, and wood for farm implements are only some of the potential end uses of trees in India's SAT. The demand for six end uses are evaluated here in ascending order of perceived prospects.

Figure 1. Areas identified for village selection in ICRISAT's Village-Level Studies.

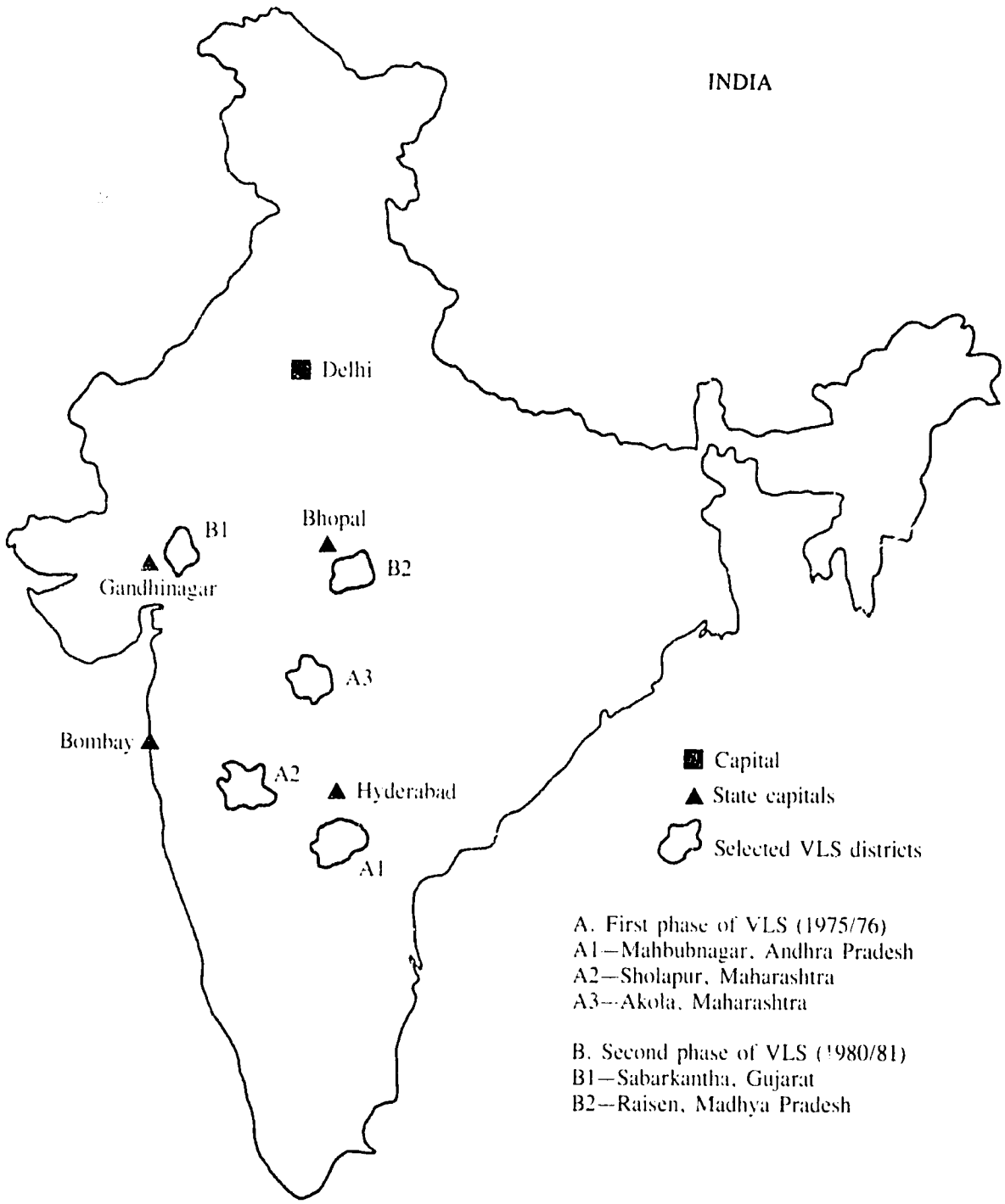


Table 1. Basic features of the study villages.

Characteristic features	State and village						
	Andhra Pradesh	Maharashtra		Gujarat		Madhya Pradesh	
	Aurepalle	Shirapur	Kanzara	Rampura	Boriya	Rampura Kalan	Papda
Soil type	Alfisols	Medium to deep Vertisols	Medium Vertisols	Sandy and sandy loam		Medium to deep Vertisols	
Annual rainfall (mm)[1]	653	597	976	702	978	1350	
Average size of operational holding (ha)	4.0	4.8	4.6	2.2	1.4	5.1	5.4
Extent of inter cropping[2]	36	47	74	23	70	46	10
Area operated per pair of bullocks (ha)	4.8	11.8	8.0	3.8	4.2	5.3	6.3
Area under ICRISAT crops[3]	35	84	32	37	47	19	9
Irrigation	20	11	4	38	13	2	2
Intensity of cropping (%)[4]	115	110	107	146	120	108	101
Postrainy season cropping[5]	17	67	6	33	18	76	90

[1] For the Madhya Pradesh villages, rainfall data are taken from official records of a neighboring town. For the other villages, daily data are recorded from rain gauges of the villages.

[2] % of gross cropped area.

[4] More than 100% means that farmers take more than one crop a year on some portion of their area.

Tree Mulches

Much of the enthusiasm for using tree biomass as mulch stems from experience in Africa's humid and sub-humid tropics, where alley cropping has demonstrated advantages over conventional cropping in forest or bush fallows, usually on acidic and often heavily-leached soils (Kang *et al.* 1981). These advantages derive largely from nutrient recycling and mulch incorporation on recently-cleared fallows. The comparative economic benefits from incorporating tree biomass as mulch have four possible sources (Sumberg *et al.* 1985, Hoekstra 1983):

1) cost of land clearing with conventional cropping and bush fallowing

2) progressive yield erosion under bush fallowing

3) scope for double-cropping a cereal in parts of Africa's SAT with a bimodal rainfall pattern

4) prohibitively expensive and/or unavailable fertilizer

Little if any economic advantage is conferred by these factors in India's SAT. Periodic fallowing is a luxury enjoyed by only the largest cultivator households who have extensive holdings of marginal land. Thus, land-clearing costs would not be charged against conventional cropping systems. Decline in yield erosion is not a significant factor in India's SAT, where fields have been under permanent cultivation for many years and where soil fertility is already low. For example, based on plot data and after accounting for technical progress, it would be difficult to show that yields have declined significantly since 1975 in the ICRISAT study villages. The problems of nutrient depletion and soil acidification are more acute in Africa's humid and sub-humid tropics, where bushfallowing is common, than in India's SAT, where permanent cultivation is the norm.

Opportunities to double-crop cereals are also rare in India's SAT. Furthermore, fertilizer availability, while still suffering from the occasional cyclical hiccup (Desai 1986), is adequate during most years and seasons, and the prospects are good that fertilizer will be increasingly available to SAT farmers.

The economics of substituting tree mulches, such as Leucaena prunings, for fertilizer warrants further discussion. Even a significant yield response to mulching may not be economical. Without significant change in soil structural properties or large nutrient carry-over effects, benefit from mulching should not be gauged by the increase in annual crop yields, but by the relative cost of fertilizer to achieve a similar response. Only benefits from mulching that cannot be gained by applying more fertilizer should be considered decisive. Under conditions of land scarcity, tree biomass is too precious to use as mulch when fertilizer is relatively cheap and readily available.

Currently, farmers do not apply tree biomass as mulch in any of the 10 study villages. The only example of mulching comes from the Sholapur villages, where farmers use sunhemp (*Crotalaria juncea*) as a mulch in the cultivation of irrigated table grapes -- the most labor- and input-intensive cropping system in any of the villages. Economic sense dictates that mulches, when used, will be applied to the highest value cash crops.

Village Fuelwood

India's recent large investment in social forestry has generated valuable information on farmer demand for alternative end uses of trees. One messages comes through clearly: farmers are reluctant to plant and harvest trees for sale as village firewood. The following reference applies generally to India's SAT:

> Gram panchayats (village governments)...thought of their plantations on common land as being primarily for poles and small timbers with some consideration for fodder, but almost none for fuelwood. Typically their plans for distribution of the produce revolved around either auctioning off the wood and fodder, or selling them at concessional rates to local people. Even here the notion of the market prevailed. In short,... fuelwood -- supposedly the first objective of social forestry -- has in reality become its last objective. (Blair 1986, p. 1318)

Although the need for village fuelwood appears to be alarmingly high, the effective demand is surprisingly low. This disparity between observers' expectations and farmers' realities is easily explained (Blair 1986). Several studies have shown that about 90% of all fuel consumed by rural households is not purchased, but collected from common property resources or supplied by private crop residues or animal dung (Bowonder *et al.* 1985, Jodha 1986). Women and children collect logs, twigs, sticks, dung, and crop by-products. Men view the opportunity cost of that labor as insignificant. Thus in making decisions, men will choose to market tree crops to increase their cash income rather than grow trees as fuel, which they generally regard as free (Blair 1986). While this situation may be lamentable, and while the educational transition (Caldwell *et al.* 1984) that is taking place in India's SAT may increase the opportunity cost of children's labor, investment in agroforestry research to increase village fuelwood consumption, in the near and medium-term future, is the economic equivalent of pushing on a string.

Although casual empiricism suggests that fuelwood availability for the rural poor throughout India's SAT is deteriorating, proliferation of *Prosopis juliflora* over the last several decades -- on village wastelands and along roadsides -- has gone largely unnoticed. Several surveys indicate that fuelwood availability has increased over time with the productivity of highly-coppiced *Prosopis juliflora* on marginal open access land (D. Hocking and K.P.C. Rao 1986, personal communication).

Some households in the drought-prone Mahbubnagar study villages now buy firewood, but their purchases amount to only about 1% of total village consumption expenditure. In the Akola villages, where biomass is more readily available, only government employees purchase fuelwood. In the Sholapur villages, households rely more heavily on dung as a source of cooking fuel. Unless village purchasing power expands dramatically, alternative fuel sources become much dearer, and competing end uses such as pulp for paper and poles for construction become decidedly less attractive, tree plantations for sale of village firewood will remain only a remote possibility.

Vegetative Barriers and Shelterbelts

Vegetative barriers are grown to protect against soil losses from surface runoff; shelterbelts are designed to reduce the effects of wind erosion. With the exception of some districts in the northwest, wind erosion in India's SAT is not severe. The objective of shelterbelts makes them more suitable to Africa's SAT, where sand blasting often severely reduces millet yield.

Species requirements for the use of trees as vegetative barriers are quite stringent: at least partial tolerance to heavy browsing, limited competition with field crops, and a readily perceived economic value. Depending on location-specific conditions, grasses may be more cost-effective as vegetative barriers than trees.

Fodder

The use of trees for fodder shows considerably more economic promise. Since 1980, the demand for fodder in India's SAT has clearly increased. Fueled by demand for milk in urban areas and smaller towns, fodder prices have more than kept up with inflation.

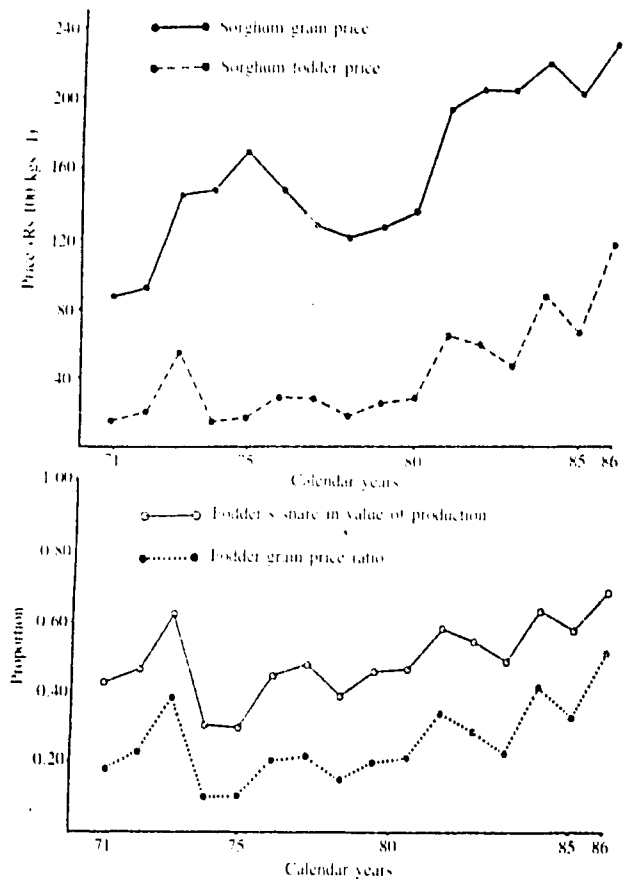
Figure 2 illustrates that trend for the Sholapur market, the center of post-rainy season sorghum production in India's SAT.

Since the severe drought in Maharashtra in 1972-73, sorghum fodder prices have increased steadily from about Rs. 15 per quintal of 100 kg in 1975 to Rs. 115 per quintal^{-1}. Growth in

sorghum fodder prices in Sholapur started well before the 1986 drought. Between the periods 1971-75 and 1982-86, the fodder/grain price ratios have almost doubled from 0.20 to 0.36 (lower graph, Figure 2). Based on grain and fodder yield data for post-rainy season sorghum, fodder's share in value of production has also advanced steadily since 1975. Similar trends of rising fodder/grain price ratios are evident in all of the study villages in the 1980's.

The impact of the rapidly increasing demand for fodder on the adoption of fodder species is unknown. Tree fodder is rarely marketed, and price information is scarce. As a result of social and farm forestry extension programs, a handful of farmers in several villages are now harvesting

Figure 2. Wholesale prices, ratios, and shares for sorghum fodder and grain in the Sholapur market from 1971-86.



Leucaena for fodder. When asked why, farmers responded that they prize Leucaena dry fodder more highly than sorghum dry fodder. But they rarely offer reliable information on how they intend to incorporate Leucaena into their farming systems. Economic questions remain concerning the ability of Leucaena to replace or complement other stovers, particularly sorghum straw; and the relative attractiveness of poles and fodder as end use objectives.

Fruit

In response to expanding market opportunities, a few farmers in several of the study villages are planting small orchards around productive dug wells. In the transition to fruit trees, the farmer often consolidates his activities around an assured irrigation source and plants one species before diversifying to others. Leucaena and other tree species often find a home in these orchards because they can be protected from browsing with the associated high level of management. Area under fruit tree plantation should continue to increase in several of the study villages.

Pulp, Poles, and Small Timber

Poles for construction and pulpwood for paper will most likely continue to offer the brightest prospects as end uses. Farm forestry systems -- primarily using eucalypts and casuarina -- are expanding rapidly in large regions of India's SAT. The area under eucalypt plantation is increasing, although farmers in the study villages have not benefitted from the farm forestry revolution nearly as much as growers in other regions. Some have planted eucalypts in marginal dryland fields, while others have sown them in more productive irrigated fields. In general, the seedlings planted on marginal dryland have suffered high mortality whereas those under irrigation have prospered.

TREES AND THE VILLAGERS' WELFARE

Income

Scattered trees in farmers' fields figure prominently in India's dryland agricultural landscape. Common species include *Acacia nilotica* (babul), *Annona squamosa* (custard apple), *Azadirachta indica* (neem), *Mangifera indica* (mango), *Melia azedarach* (bakain), and *Tamarindus indica* (tamarind). Tree counts in the study villages yield average densities ranging from 1-7 trees/ha^{-1}. In general, tree densities on private land have been too low to contribute substantially to village income.

But trees can be important revenue earners in geographical pockets of India's SAT. Of the study villages, the outstanding example is Aurepalle, which has about 2,000 productive toddy palm trees. The milky juice of the palm fruit is fermented and sold as palm liquor or toddy. Toddy tapping, a traditional caste occupation, engages about one quarter of the village population (Rao 1983). The toddy trade accounted for about 15% of total village income from 1975-84 and has gradually increased in importance in this decade.

Equity

The complexity of agroforestry systems featuring MPTS is sometimes cited as an advantage to resource-poor small farmers. It is maintained that these farmers are accustomed to complex intercropping systems, that they have more time for farm management, and that they rely less on hired labor (Bentley *et al.* 1984). Most likely, however, this advantage of complexity will not prevail in adoption behavior. Competition between woody perennials and annuals for soil moisture, which reduces the yields of annuals, severely constrains the potential of intercropping at narrow spacing in India's SAT (ICRISAT Annual Report 1985, p. 304). Other factors also indicate that large farmers will be the first to adopt the systems.

Two factors determine the differential consequences of tree species on small farm households *vis-a-vis* large farm households: (1) the pattern of adoption by the two groups, and (2) adoption's impact on the demand for casual labor. Observers often overlook the importance of the latter

issue. In the study villages, small farm households derive 30-50% of their income from earnings as casual agricultural labor.

The relatively low demand for labor of eucalypts is responsible, to a great extent, for their surge in popularity. In the tightening labor markets of the past decade, large farmers, particularly absentee landlords, find such systems attractive.

Farm forestry systems can hurt rural casual labor in another respect. After planting, the management of these systems usually responds to seasonal labor fluctuations with greater flexibility than annual croppings systems, which are more bound to seasons. This reduced seasonality in labor demand does not favor landless labor and small farm households, which find seasonal peaks in labor demand economically desirable except where mechanization is imminent.

The comparatively low labor use intensity of farm forestry systems also has implications for differential adoption behavior between large and small farm households. Low labor use intensity means that small farm households have less scope for exploiting their advantage, compared to large farm households, of a lower opportunity cost in supplying labor.

The long-term nature of farm forestry systems may also favor early adoption by larger farmers, who may be more willing to forgo consumption today in order to enhance tomorrow's consumption.

Relatively low and unseasonal labor-use intensity and potential differences in time preferences indicate that large farm households will participate more actively in the farm forestry revolution. In the green revolution, large farmers adopted first but small farmers soon caught up (Herdt 1987). Such differences in the diffusion of farm forestry systems, though, are more likely to endure.

Much of the preceding discussion is speculative, and addresses short-term equity objectives. One particularly neglected longer-term question centers on the consumption and investment behavior of large farmers who have profited handsomely from the early adoption of such systems. Do they consume and invest in ways that are conducive to local, regional and national economic growth? If the answer is yes, then the foregoing discussion loses much of its importance. Another relevant issue concerns the degree to which small and marginal farmers who, instead of producing for their subsistence needs or leasing their land to others, have planted eucalypts and have channelled their energies to more specialized, profitable (and often off-farm) activities. Few of these issues have received the empirical attention that they deserve.

With fruit trees, the labor consequences will likely be more benign and perhaps decidedly beneficial. But fruit crop production requires greater management skills than farm forestry systems that use eucalypts. If the study villages are any indication, such management skills are scarce in India's SAT.

While it is still too early to judge the impact of farm forestry on the labor market, the question of who adopts first has an obvious initial answer: those who adopt early in the study villages come from the ranks of the most progressive large farmers. Some of these farmers may have inherited little or no land, but by the time they planted trees in their fields they had relatively more land than others in the village.

Nutrition

Tree products can influence nutrition indirectly through income, or directly through consumption. Although tree products directly contribute little to the overall nutritional status of the study villages, they contribute proportionately more to the intake of those nutrients, such as B-caroten and ascorbic acid, characterized by the largest deficiencies. Even so, tree products only contribute 5-15% of the total intake of these vitamins.

Risk Benefits

Risk benefits are those supplied by institutional or technological means that allow risk-averse decision makers to reduce fluctuations in income. This, in turn, reduces variability in consumption (Newbery and Stiglitz 1981). Because trees are often assumed as being more drought-tolerant than annual crops, it is only natural to suppose that tree products would be prized highly in low income years. Farmers could also cut trees for sale to compensate for these years of low income. But this common sense observation may not carry much force in the SAT of India.

If tree production also drops sharply in low income years, or if resource-poor households have access to fairly efficient means of risk adjustment, benefits are likely to be small. For example, farmers in the study villages seldom part with land to mitigate income variability (Cain 1981). Moreover, with the exception of the Sholapur villages (where the fodder costs of maintaining livestock rises sharply during prolonged drought), asset disposal is not the preferred first or even second line of defense to adjust to income risk. The risk adjustment measure preferred by the overwhelming majority of households is consumption credit. Farmers will not be enticed to cut down trees that they have planted until sources of consumption credit are exhausted, or until public works schemes are no longer locally available.

RESEARCH IMPLICATIONS

What do these points imply for MPTS research in India's semi-arid regions? First, more research should be directed to study optimal management of tree crops, particularly *Leucaena leucocephala*, in sole stands for end uses such as fodder and poles. The main interaction between trees and annuals will most likely be the income generation taking place at the household level. Donor interest in agroforestry has, perhaps, obscured this emerging empirical truth. Unless strong complementary effects can be found, more proximal or field-level interactions will either be economically unimportant or too location-specific for general research.

This author believes that the research establishment may have been slow to respond to the needs of the rapidly expanding farm forestry systems. Tree species in these systems, as well as indigenous species such as toddy palms, may be discriminated against in the allocation of research resources. An assessment of research resource allocation on tree species in general and farm forestry species in particular should rank high on the research agenda, although adequate data may not be available at this time. The emphasis on agroforestry research has to some extent directed experimental attention away from farm forestry systems already adopted by farmers in favor of new systems that farmers do not now plant, and which they may not reasonably hope to plant in the immediate future.

In the area of economics research, priority should be given to the consequences of rapid uptake of farm forestry systems. Research should also explore reasons for the slow development of tree

fodder markets in the SAT of India. By studying the Leucaena leafmeal markets that have developed in some countries in Southeast Asia, F/FRED's regional research network could improve understanding of the evolution of such markets.

With the threat of an infestation by the Leucana psyllid, a study of the demand for Leucaena seed and seedlings in India's SAT may be timely. Before investing in research to control this pest, the demand for Leucaena should be ascertained.

Finally, more information is needed concerning the relative demand for MPTS and single-purpose trees. Under what conditions is multiplicity of purposes an advantage? An analogy can be drawn to multipurpose wheeled tool carriers, in which several research institutes, including ICRISAT, have made a considerable investment. In a forthcoming book, Paul Starkey argues persuasively that farmers want single-purpose implements and equipment. Investing in a multipurpose implement, for example, involves more risk because in the event of machine breakdown, *all* of the machine's multiple operations cease. Perhaps work in this area has already been done. Such research would enhance our understanding of when and where multipurpose trees best suit the farming systems of resource-poor households in semi-arid regions.

DISCUSSION

How applicable to arid regions are statements made regarding demand for fuelwood and windbreaks in SAT? While an increase in fuelwood demand for semi-arid regions may not take place until the future, it is a more immediate concern in arid regions.

Large farmers may adopt agroforestry systems more quickly than small farmers. Donors have focused on adoption by small farmers, not necessarily for optimum productivity but for reasons of equity.

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EXISTING MPTS RESEARCH

The development of new experimental MPTS trials must recognize and be based upon previo and existing research efforts.

A study of previous and ongoing research helps to identify potentially beneficial topics for future research, and identify gaps in research that require investigation. The following presentations attempt to provide an overview of existing MPTS research efforts in Pakistan, India, Sri Lanka, and Nepal.

REVIEW OF RESEARCH DONE IN PAKISTAN ON ACACIA NILOTICA, DALBERGIA SISSOO, EUCALYPTUS CAMALDULENSIS AND AZADIRACHTA INDICA

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Acacia nilotica, Dalbergia sissoo, Eucalyptus camaldulensis *and* Azadirachta indica *are the four species designated by the F/FRED project as priority multipurpose species (MPTS) in the arid and semi-arid tropics.* A. nilotica *and* Dalbergia sissoo *are indigenous to Pakistan and are widely grown by farmers. The other two have been more recently introduced as promising species. This paper reviews the characteristics of each and relevant research that has been conducted in Pakistan concerning nursery techniques, seed source and species trials, field planting, management, farmer use, the tree/crop interface, and optimum water requirements.*

This paper provides an overview of the multipurpose tree species (MPTS) selected by the Forestry/Fuelwood Research and Development (F/FRED) Project as priority species for the arid and semi-arid tropics, and reviews related research conducted in Pakistan. Of the four species dealt with in this paper, *Acacia nilotica* and *Dalbergia sissoo* are native to Pakistan, while *Eucalyptus camaldulensis* and *Azadirachta indica* are exotic.

ACACIA NILOTICA

A. nilotica is a moderate-sized, fast-growing evergreen tree with a large, spreading crown. It is indigenous to the province of Sind but is grown throughout the plain of Pakistan and, despite its frost-tender nature, good specimens are found scattered even in the foot hills. *A. nilotica* ranks among the trees most commonly planted on agricultural and marginal lands. A tenacious multipurpose tree having end uses such as fuelwood, timber, tannin, and fodder, it has become a favorite of the country's farmers and herders. Because of its tolerance of salinity and alkalinity, it has long been grown in the province of Sind to reclaim marginal soils. During times of fodder scarcity, it is a tree on which farmers depend.

A. nilotica flowers twice a year, in September/October and January, and seed becomes available in May and June. Germination is accelerated by soaking the seed for 24 hours before sun-drying and sowing. To improve and quicken germination, farmers keep the seed in cow dung for 8 - 10 days. The seed is collected from the livestock pens where it is abundant in the droppings. Foresters also collect the seed for large-scale afforestation.

The species is most commonly planted by sowing treated seeds, which germinate after one to two weeks. In the province of Sind, river banks are sown by spreading seed from boats in the receding flood waters of the river Indus. Farmers usually sow the seed in lines or in pits, a method known as "spot sowing". The practice of planting seed in polythene tubes for later

outplanting has recently been introduced. Tree maintenance practices accepted by farmers include cleaning, pruning and thinning to reduce crowding in the early stages.

A. nilotica is grown on a rotation of 20 years, with 2 thinnings at 7-year intervals in the riverain forests and 5-year intervals in the irrigated plantations. The crop is often harvested at the age of 20 years, yielding construction timber that is very hard and durable and used extensively for pit props in mines. Large quantities of the wood are converted into charcoal. The bark is used in the dyeing of leather. With the expansion Pakistani industry, the wood of this species shows great potential.

A sub-species known as *A. nilotica* var. *cupressiformis* grows straight and fairly tall, yielding better timber than the other varieties. For use as fuelwood, however, the other branchy sub-species yield a greater quantity of wood.

DALBERGIA SISSOO

Dalbergia sissoo, known in Pakistan as shisham or tahli, is a deciduous tree with an irregular crown, large-sized but rarely straight-growing. An unidentified variety grown in North West Frontier Province, near Peshawar, has drooping branches but a clean straight bole and good heart wood, making it prized for furniture-making. Dalbergia is indigenous to the sub-Himalayan tract, and is found as high as 1,200 m. It is Pakistan's most popular timber species, cultivated throughout the Indus valley for firewood, furniture and construction timber, fodder, and charcoal. It is also the tree most commonly grown with crops; farmers plant it singly, as a windbreak, or in block plantations.

Dalbergia sheds its leaves during the cold season, with a new flush of leaves and fragrant flowers appearing in February/March. Seed becomes available in November/December. When sown in the nursery, germination starts within 7-10 days and may continue for 3 weeks. Generally, the tree is propagated by root shoot cuttings, but farmers also sow the seed directly. Raising plants in polythene tubes is becoming more popular.

The plantations raised from root shoot cuttings are worked on 20-year rotations for fuelwood and small timber, and 60-year rotations for larger timber. The thinning interval is usually five to six years.

EUCALYPTUS CAMALDULENSIS

Eucalyptus camaldulensis -- known locally as safeda, gond or lachi -- has an erect and symmetrical stem but is often irregular in shape, with drooping foliage. The bark is smooth ashy grey or whitish. *E. camaldulensis* grows under a variety of climatic and soil conditions, varying from the waterlogged or saline soils and marginal lands in the plains and foot hills, up to an elevation of about 1,200 m in the north. Flowers appear in May and June and seed is available in September.

Eucalypts were first introduced to the subcontinent in 1843, when they were planted as single trees, arboreta and roadside plants. Interest in Eucalyptus rose in 1900, when it was feared that fungal attack could cause severe losses to *Dalbergia sissoo* plantations. Still, no substantial area was planted for 50 years. Efforts to test more species of Eucalypts was revived with the arrival of

Mr. G.E. Brockway, an Australian expert, in 1965. Over the years, many foresters have visited Australia looking for species suitable to Pakistan's climate. In the process, arboreta were established at Pirawala, Changa Manga and Chichawatni, and field trials were conducted at several sites.

The planting program received a new impetus in 1970 when it was found that *E. camaldulensis* could be raised without irrigation in a rainfall zone of 350 mm. Millions of trees were raised in nurseries and planted in dry areas, along roadside avenues and in irrigated plantations. Still, farmers are slow to adopt the species for two reasons. First, they are more committed to the traditional species of *Dalbergia sissoo*. *Acacia nilotica* and poplars. Also, the refractory nature of the wood has slowed the full idenfication of end uses.

Monographs have been prepared on *E. camaldulensis*, *E. microtheca* and *E. tereticornis* have been prepared emphasizing that these are the species most important for large-scale planting in Pakistan, and recommending plantation of *E. microtheca* in areas where *E. camaldulensis* and *E. tereticornis* have not given encouraging results.

Eucalyptus is most commonly propagated by planting 6- to 9-month old tube seedlings at a conventional spacing of 3 x 2 m on a short rotation of 15-20 years (Qadri 1983, Sheikh 1984).

AZADIRACHTA INDICA

Azadirachta indica is indigenous to the central and southern parts of India, and has been casually introduced in Pakistan by foresters interested in the species. The tree is generally found in the lower Punjab and Sind regions, although good specimens are also available in Lahore Cantt. The species can withstand minor salt concentrations and can grow in calcareous formations.

Flowers appear from March to May and the fruit is available from June to August. Azadirachta seed has low viability and should be sown immediately after collection. Before sowing, the seed should be depulped and soaked in water for a few hours. Germination takes place in about 10 days.

Because it is frost tender, Azadirachta has not found much favor with foresters. This is an important species for the lower Punjab and Sind, however, and large-scale planting should be encouraged, particularly on farmland.

NURSERY TECHNIQUES

With the objective of finding the optimum size of stock for field planting, a study used 3-, 6- and 24-month old *E. camaldulensis* seedlings in outplanting. The 6-month old seedlings demonstrated the best survival and growth rates. Although 24-month old plants were tallest due to their initial heighth advantage, these were slender with few leaves while 3- and 6-month old seedlings were sturdy and had large numbers of leaves. The study suggested that for field planting, seedlings should be between 30 - 36 cm high, a height normally attained in 6 - 8 months (Sheikh 1978).

Data collected in a nursery showed that the cost of raising one eucalyptus plant was about 15 paisas (approximately $US 0.01), including the cost of the polythene tube. In subsequent studies,

the cost per plant rose to 100 paisas/plant ($US 0.06) due to increases in the cost of polythene and labor rates.

Nursery techniques for raising *E. camaldulensis* on a large scale have been described by several authors (Qadri 1983, Sheikh 1984), with instructions on seed collection, sowing, proper soil mixtures, size of polythene containers, transplanting, and transportation. Field planting techniques outlining instructions for site preparation, planting methods, fertilization, weeding, and the use of insecticide have been included also. The cost of raising 1 ha of eucalyptus was estimated at $US 100 in 1982.

An experiment aimed at determining the effect of polythene tube size on seedling growth was initiated in January, 1970, with tube sizes ranging from 15 to 23 cm in lenght, and 2.5 to 7.5 cm in diameter. Among other species, *E. camaldulensis* and *Acacia nilotica* were tested. Tube sizes of 15 x 6.25 cm (45 perforations) and 15 x 5 cm (36 perforations) were found to be most suitable and economical. It was noted that although seedlings grew better in tubes of greater diameter, the cost of the bags proved uneconomical (Sheikh 1984).

In another study of the effect of tube size on seedling development, *E. camaldulensis* and *Leucaena leucocephala* were planted in polythene tubes of two sizes: 17 x 2.5 cm and 15 x 4.5 cm. The results confirmed the earlier finding that plants grow better in polythene tubes of greater diameter. Researchers also noted that these species should not be kept in the nursery stage for more than eight months, after which time they tend to become weak, suffer from unbalanced root-shoot ratio, and have poorer chances of survival in the field (Sheikh 1984).

Based on research conducted on nursery and field planting techniques of *Acacia nilotica*, *Dalbergia sissoo*, and *E. camaldulensis*, recommendations have been made for the benefit of the field foresters. Time and method of seed collection, storage, sowing, pricking of seedlings, shading, and watering have been outlined. (Sheikh 1986, unpublished).

SEED SOURCE AND SPECIES TRIALS

Initiation of a program of seed selection and establishment of seed orchards has been emphasized with those species of Eucalyptus which have proven successful in Pakistan. Introduction of Australian species has also been suggested, but this should be restricted to small quantities of seed from selected species and provenances that show wide variation in natural distribution patterns (Bode 1967). Pryor (1968) identified the most suitable species for Pakistan's ecological conditions: *Eucalyptus tereticornis*, *E. camaldulensis*, *E. microtheca*, *E. citriodora*, and *E. melanophloia*.

Reports of comparative growth of 10-year old specimens of 52 Eucalyptus species raised at Peshawar have revealed large variation in survival, diameter and height. These differences were found to be highly significant for height and diameter, and not significant for survival rate. Of the species tested, *E. macarthurii* proved to be the fastest growing, attaining a diameter of 22.5 cm, followed by *E. botriodes*, *E. kitsoniana*, and *E. crebra*. *E. camaldulensis* attained a diameter of 16.5 cm. The authors recommended further field studies, preferably provenance trials of the promising species under different ecological conditions (Siddiqui and Hussain 1980).

A 6-year old trial of 22 provenances of *E. camaldulensis* from Australia resulted in the recommendation of 6 provenances for large-scale planting, the most promising being from Newcastle

Waters Creek, followed by Katherine. Both of these originate in the Northern Territories (Hafeez and Sheikh 1972).

The trees were compared again at 10 years, with results consistent with the earlier observations. The growth differences among various provenances were statistically significant. The fastest-growing provenances compared favorably with *Dalbergia sissoo* and *Acacia nilotica* plantations similar site conditions (Siddiqui et al. 1979).

Seed source trials of *Acacia nilotica* and *Prosopis cineraria* began in 1984 in collaboration with a FAO/International Board on Plant Genetic Resources (IBPGR) project. Of 11 sources from India and Pakistan, the 1986 data showed that *A. nilotica* Haryana 1081 seed had obtained an average height of 3.26 m, followed by Patoki (Pakistan) source 1168, which attained 2.87 m and showed the best survival. Similarly, the fastest growing *Prosopis cineraria* source was India 1090, with an average height of 1.78 m after three growing seasons, while Pakistan 1184, with an average height of 1.54 m, showed the best survival rate of 95% (Anon 1987).

FIELD PLANTINGS

Acacia nilotica and *Prosopis cineraria* were aerially seeded in the riverain forest of Sind. After one month, 48 seedlings per 3.35 m^2 were counted over the area seeded first. The operation, considered a success, sowed a total of 2,030 ha, at a cost of $US 200/ha (Kermani 1974).

The effect of root length on survival and growth of nine-month old *E. camaldulensis* seedlings raised in polythene tubes was studied. Special polythene tubes were designed to accommodate roots of 18, 30, 45, and 60 cm length. Plants with root length of 30 cm showed the highest survival rate. The heights obtained after a period of seven months (more than 1 m in all cases) did not differ significantly (Sheikh 1978).

E. camaldulensis was also tested under different plant spacings and irrigation regimes on a short rotation at Chichawatni. While no difference was noted between performance under flood and trench methods of irrigation, it was observed that the area planted at a spacing of 1.5 m x 1.5 m yielded 95 m^3/ha, while those planted at 2.25 x 2.25 m yielded only 61 m^3/ha, and trees planted at 3 x 3 m produced 38 m^3/ha after 4.5 years. The same results were obtained in the irrigated plantations of Pirawala and Bahawalpur. Wider-spaced trees showed higher weed infestation (Sheikh 1982). These observations on the effect of spacing were confirmed by those of another, small-scale study (Sheikh 1984).

In a species evaluation study conducted in Setharja on saline soils varying in Ph from 8.5 to 9.5, *A. nilotica* performed best, with 100% survival and an average height of 2.6 m after one year. *E. camaldulensis* also performed well in that study, and again on the waterlogged soil of the Shorekot plantation (Sheikh 1986).

PLANTING AND MANAGEMENT

Forests of *Dalbergia sissoo*, *Morus alba*, *Salmalia malabarica*, *Acacia nilotica*, hybrid Poplars, and Eucalypts have been grown on the wastelands of the Indus plain that have come under irrigation, an area of 0.2 million ha. Foresters in this area are concerned with irrigation issues such as layout, flow, and water distribution, in addition to silvicultural operations management, exploitation

and regeneration. After areas of 20 - 24 ha have been levelled and prepared, trees are planted either in trenches or in level plots. In the case of *Dalbergia sissoo*, 6 - 9 month old root shoot cuttings are planted at a spacing of 2 x 3 m. *Acacia nilotica* is generally patch- or line-sown, while Eucalyptus stock is raised in polythene tubes.

Dalbergia sissoo is thinned at 5, 10, and 15 years, with a final felling at 20 - 22 years, when the trees have an average diamter of 30 cm. This leaves 25 trees/ha to become timber trees on a rotation of 40 - 60 years. The average total yield from thinnings amounts to 100 m^3/ha, with another 90 - 100 m^3/ha available from the final felling. *Acacia nilotica* and *E. camaldulensis* are worked on a rotation of 15 - 30 years, with no trees left to become timber trees (Sheikh 1986).

Five species, including *E. camaldulensis* and *Leucaena leucocephala*, were tested under saline conditions (Ph 8.5) at Military Dairy Farm, Risalpur. After one and a half years, Leucaena showed a better survival rate of 66% compared to 56% for Eucalyptus. Eucalyptus grew fastest, reaching an average height of 1.5 m (Anon 1987).

Spacing tests of *Dalbergia sissoo* showed that trees planted at 4 x 4 m spacing grew faster, both in height and diameter, than trees planted at either 3 x 3 m or 2 x 2 m. However, the trees in the closest spacing had more length of clear bole and relatively fewer and thinner branches (Anon 1987).

BLOCK PLANTATIONS BY FARMERS

A study focusing on the system of *Acacia nilotica* block plantation practiced in Sind province, known as "hurries", showed that the practice benefits the farmer by improving agricultural land and subsequent agricultural yields. The system provides a financial return of about $US 100/ha/yr from the sale of the wood, with a cost/benefit ratio of 1:1.72. The wood, much used for pit props in the mining industry, fetches high prices in the timber and fuelwood markets as well.

"Hurries" are grown at spacings as close as 0.9 x 0.9 m. Although the plantations showed good diameter growth up to 5 years of age (2.3 cm annually), the rate subsequently declines due to crop congestion. The report suggests that growth could be enhanced with the introduction of pruning, cleaning and thinning practices

The study outlined areas for further research, and emphasized the need for forest department encouragement of the practice (Sheikh 1986).

TREE/CROP INTERFACE

Farmers are often reluctant to grow trees on farmland in the fear that they will compete with crops for moisture and nutrients, and that they will act as disease carriers, thereby reducing the yield of agricultural crops (Sheikh 1972).

Studies using scattered trees of *Acacia nilotica* and *Dalbergia sissoo* in farmer's fields set out to determine the effect of tree shade on wheat yields. It was found that the trees did adversely affect wheat yields, particularly on plants within 2 m of the trees (Sheikh and Haq 1978).

Another experiment was conducted to study the effect of *E. camaldulensis* as a shelterbelt on cotton and maize production. The shelterbelts were planted with three rows of trees in each belt, at an in-row spacing of 1 m and 2m between each row. In 5.5 years the tree attained an average height of 15 m and an average diameter of 15 - 20 cm. Findings showed that within 10 m of the belts, both cotton and maize production were adversely affected by shade and root competition for water and nutrients. Beyond 10 m, however, the belt was found to have a positive effect on crop yield (Sheikh and Haq 1986).

In the Thal desert, *Dalbergia sissoo* was planted perpendicular to the prevailing wind as a shelterbelt for wheat crops. Six-month old Dalbergia root shoot cuttings were planted in three belts spaced 122 m apart, with 3 rows per belt. The cuttings were planted at an in-row spacing of 3 m, with 2 m between each row. With a 90% survival rate, the trees gained an average height of 4 m in 3 years. When wheat yield at various distances from the belts were measured, it was found that although yields near the belt (0-3 m) were low (1,000 kg/ha) compared to those further from the belt (2,000 kg/ha at 35-40 m; 1,450 kg/ha at 55-60 m), the farmer obtained a net increase of 1 quintal/ha. With the increase in tree size there was a reduction in average wheat yield.

Another study in the same desert region measured the effect of *Dalbergia sissoo* on wheat yields, with similar results. In no case was the average yield with the trees less than the control crop (Sheikh and Haq 1986).

In Sind province, the forest department leased land for three years to study the effect of agricultural crops such as cotton, wheat, sesamum and sorghum on *Acacia nilotica* production. It was reported at the end of that time that the tree crop yield from the agricultural land was greater than the average yield from the land where no cropping was done. The report concluded that the trees had benefitted from the additional irrigation, land cultivation and fertilization. The trees did not depress the agricultural crop yields (Kermani 1980).

WATER REQUIREMENTS FOR OPTIMUM GROWTH

A number of experiments have been undertaken to study the optimal irrigation regimes for various tree species. One study, begun in Peshawar in 1986, tested *E. camaldulensis*, *Dalbergia sissoo*, *Acacia nilotica* and four other species to determine the effect of irrigation frequency on growth. The trees were irrigated at intervals of 10, 20, 30, and 40 days. *E. camaldulensis* demonstrated the best growth under most frequencies of irrigation. The trees irrigated at 10- and 20-day intervals showed the best growth for all species (Anon 1987).

GROWTH AND YIELD DATA

Provisional yield volume tables prepared for *Acacia nilotica*, *Dalbergia sissoo*, and *Eucalyptus camaldulensis*, are summarized in Table 1 (Hafeez 1973, Hussain and Glennie 1978, Hussain and Abbas 1974). For Eucalyptus, the figures are based on three spacings: 1.5 x 1.5 m, 3 x 1.8 m, and 3 x 3 m.

Table 1. Mean annual increment (MAI) per hectare, according to site quality and rotation cycle.

Species	Rotation Period (years)	MAI (m^3/ha) Site Quality I	II	III
Acacia nilotica	20	10.3	8.4	6.4
Dalbergia sissoo	20	11.2	8.4	5.9
Eucalyptus camaldulensis	10	22.2	15.0	9.1

RECOMMENDATIONS

Of the four priority species, *Dalbergia sissoo* and *Acacia nilotica* have been more extensively planted than *E. camaldulensis* and *Azadirachta indica*. Areas for further research include seed source trials, species water requirements, and species comparison trials. Seed orchards and desert research and demonstration centers should be established and supported.

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MULTIPURPOSE TREE SPECIES RESEARCH IN ARID AND SEMI-ARID REGIONS OF INDIA

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In the arid and semi-arid regions of India, multipurpose trees offer a drought-resistant, low-labor supplement or alternative to agricultural crops for fodder, fuel and food. Studies have compared survival and growth rates of priority exotic and indigenous species on degraded soils the tree/crop interface in agroforestry systems. Leucaena leucocephala, Acacia nilotica *and* Prosopis juliflora *have shown promise. This paper reviews Indian research on these species in agroforestry systems and under desert and saline conditions. More studies are needed on soil tree/crop interactions, and on management practices.*

INTRODUCTION

Arid and semi-arid regions occupy vast areas of India and are characterized by scanty and erratic rainfall, a prolonged dry season, high temperatures, poor ground water quality, degraded soils, and shifting sand dunes. These conditions are further aggravated by uncontrolled grazing a huge livestock population and reckless deforestation, both of which accelerate the desertificatio process. Under these conditions, agricultural crops fail altogether or produce very low yields, an the local people live at a subsistence level. The proverb, "Forests precede civilizations but desert succeed them" applies to these regions and emphasizes the need for growing multipurpose trees these fragile ecosystems, either in block plantations or as a component of agroforestry systems. Multipurpose trees provide timber, fuel, fodder, food, fertilizer, and other products on the one hand, and minimize the hazards of run-off, erosion, drought and related environmental deteriorati on the other.

In recent years, India has experienced an acute shortage of fuelwood and fodder. The fuelwo requirement in 1980 was about 184 million m^3, as compared with an availability of only 17 million m^3, and is expected to rise to about 225 million m^3 by the year 2000. Likewise, the present annu production of fodder is approximately 40 million tons, providing hardly one-third of the requirements of 414 million livestock. According to the estimates of the National Dairy Research Institute, the shortfall in 1985 amounted to 258, 5, and 26 million tons of green fodders, grasses, and crop residues, respectively. With the realization that growing multipurpose trees will contribute immensely to alleviating fuelwood and fodder shortages, the Prime Minister of India ha set a target of afforesting 5 million ha annually with fodder and firewood tree species.

SPECIES SUITABILITY

The arid and semi-arid zones of India are endowed with a variety of soils that differ greatly in depth, texture, structure, nutrient retention capacity, salinity/sodicity, calcareousness, and other characteristics. The significant soils belong to vertisols and related black soils, alfisols and relate red soils, aridisols, and entisols. These properties have a significant effect on the success of tree plantations.

Many tree species can be grown on arid and semi-arid tracts, depending upon moisture availability and local soil, climate, and socioeconomic conditions. The selected species should, in addition to providing various tree products, be able to:

- o thrive well under moisture stress and harsh climatic conditions
- o grow on inhospitable soils of the given area
- o develop root systems under conditions of impervious subsoil
- o establish easily, grow fast, and respond positively to local management practices
- o fix nitrogen and improve soil fertility
- o interact favorably with other crops in agroforestry systems
- o resist pests and diseases
- o yield a favorable cost-benefit ratio and generate employment opportunities
- o improve the local micro-climate and ecological environment

Suitable species have been identified and are listed in Table 1 according to rainfall distribution (Singh *et al.* 1987).

Table 1. Trees suitable for locations in India with different rainfall distribution.

Locations with good annual rainfall	Locations with moderate rainfall	Locations with poor annual rainfall
(Varanasi, Rewa, Bhubaneswar, Ranchi)	(Indore, Akola, Solapur Hyderabad, Anantpur, Bangalore, Bellary)	(Dantiwala, Jhansi, Hoshiarpur, Hissar, Jodhpur, Rajkot)
Alnus nepalensis	*Acacia nilotica*	*Acacia nilotica*
Bauhinia purpurea	*Ailanthus excelsa*	*A. catechu*
Casuarina equisetifolia	*Albizzia lebbek*	*A. albida*
Dalbergia sissoo	*Azadirachta indica*	*A. aneura*
Emblica officinalis	*Butea monosperma*	*A. senegal*
Gmelina arborea	*Casuarina equisetifolia*	*Colobhospermum mopane*
Grevia optica	*Dalbergia sissoo*	*Eucalyptus camaldulensis*
Grevillea robusta	*Eucalyptus species*	*Parkinsonia aculeata*
Hardwickia binata	*Leucaena leucocephala*	*Prosopis cineraria*
Melia azedirach	*Tamarindus indica*	*Prosopis juliflora*
Morus alba	*Tamarix articulata*	*Pithecellobium dulce*
Poplar species		
Sesbania species		
Terminalia species		

FIELD TRIALS ON MULTIPURPOSE TREES

An agroforestry system is any sustainable land management system that integrates a symbiotic combination of trees, annuals and animals and enables diversified production on available land

resources. *Leucaena leucocephala*, which is fast-growing and nitrogen fixing, has received considerable attention in recent years for fodder and fuel use and is also being tested as a component of agroforestry systems. In an alley-cropping experiment conducted without irrigation at Hyderabad, *Leucaena leucocephala* was observed to reduce the yields of the following four crops grown in the alleys, by the respective percentages: castor (62%), pigeon pea (61%), sorghum (48%), and pearl millet (30%) (Singh et al. 1987). In the third year, however, an increase of 14% was recorded in the yield of pearl millet as compared to the crop grown outside the alley (see Table 2).

Table 2. Response of arable crops in alleys with *Leucaena leucocephala* at Hyderabad.

Crop	1984		1985		1986		Percent mean reduction
	Grain kg/ha	% reduction	Grain kg/ha	% reduction	Grain kg/ha	% reduction	
Sorghum	548	49	636	68	909	11	48
Pearl millet	720	53	997	51	2026	+14	30
Pigeon Pea	227	61	9	65	--	--	61
Castor	284	56	149	77	211	47	62

It has been observed that Leucaena adds organic matter and nitrogen, particularly in the upper 15 cm of the soil, whereas Eucalyptus hybrids deplete soil nitrogen content. Shakarnarayan (1984) reported an increase in the amount organic matter, nitrogen and phosphorus under the growth of 14-year old *Prosopis cineraria*, as compared to the bare site and *Prosopis juliflora* growth of the same age (see Table 3).

Table 3. Changes in soil fertility status under *P. cineraria*, *P. juliflora*, and bare field.

Tree Community	O. M. (%)		N (%)		P_2O_5 (%)	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
Prosopis cineraria	0.57	0.29	0.042	0.026	0.425	0.375
Prosopis juliflora	0.38	0.31	0.033	0.029	0.287	0.325
Bare field	0.37	0.21	0.020	0.020	0.287	0.350

The effect of lopping *Leucaena leucocephala* for green leaf manure with an intercrop of sorghum was examined in an experiment conducted on black soil (vertisol) at Solapur. Green manuring increased the green yield and nitrogen uptake of sorghum (see Table 4)(Venkateswarlu 1986).

Table 4. Effect of alley cropping with *Leucaena leucocephala* on grain yield of post-rainy sorghum grown in vertisol at Solapur.

System	Grain Yield (t/ha)	Total N Uptake (kg/ha)
No leucaena; no lopping	1.17	31.6
No leucanea; lopping	1.46	39.2
Leucaena; no lopping	0.94	24.6
Leucaena; lopping	1.33	35.1
LSD (0.25)	0.183	

In a field study of eight top feed tree species planted in 1986 at 10m x 10m spacing on degraded soil, Korwar and Osman (1986) observed fastest growth for *Leucaena leucocephala* (see Table 5). *Acacia senegal*, *A. aneura*, *A. nilotica*, and *Leucaena leucocephala* showed higher survival rates than the other species.

Table 5. Average height and survival rates for eight top feed species.

Species	Height (cm)	Survival (%)
Acacia albida	71	29
Acacia aneura	82	71
Acacia mangium	73	31
Acacia nilotica	76	65
Acacia senegal	75	73
Leucaena leucocephala	107	69
Prosopis cineraria	73	23
Sesbania grandiflora	73	11

Variations in growth of tree species often reflect variations in soil characteristics. Acacia nilotica, however, shows a fairly consistent performance even on sites of varying soil characteristics. The data in Table 6 is based on an experiment conducted at Bellary, Karnataka (heavy black clay soil), Vasad, Gujarat (ravine land) and Agra, U.P. (eroded alluvial soil) (Prajapati *et al.* 1984).

TREE PLANTATIONS IN DESERT AREAS

About 11% of India's land area is desert, of which 90% is located in the northwestern region. Approximately 60% of India's arid area is found in Rajasthan and requires an intensive afforestation

program, particularly on wastelands, marginal lands, sand dunes, community land and farm lands. Silvi-horticultural and silvi-pastoral systems also have great potential.

Table 6. Growth performance of eight-year old Acacia nilotica plantations at three different locations.

Growth Character	Bellary	Vasad	Agra
Height (cm)	922	965	845
Mean annual increment (cm)	95	99	88
Girth at breast height (m)	15.4	13.5	13.2
Fuelwood yield (t/ha)	30.2	26.1	27.1

Tree plantations on sandy tracts of Rajasthan provide not only fuel, fodder and timber, but also reduce the hazard of wind erosion. *Prosopis cineraria* is an excellent fuel and fodder tree. It tolerates moisture deficiency, drifting sands, grazing and extreme climatic conditions, and is capable of enriching soil and supplying highly nutritious leaf fodder. Grown extensively by farmers as a component of agroforestry systems, it is amenable to lopping and interacts positively with associated annual intercrops. The combination of *Pennisetum typhoides* with *P. cineraria* is a common practice in many areas.

Acacia tortalis, an exotic tree, has shown very high survival and growth rates in arid tracts of Rajasthan, Gujarat, and Haryana. In its later growth stages it competes with companion arable crops for moisture and nutrients. *Acacia nilotica*, *Salvadora persica*, *Zizyphus mauritania*, *Tamarix sp.* and *Prosopis juliflora* have also been found suitable for semi-arid areas with partial shifting sand dunes.

The data on comparative performance of some indigenous and exotic species in the desert area of Rajasthan are presented in Table 7 (Muthana 1984). This shows that the fast growth of some indigenous species compare favorably with that of exotic species.

TREE GROWTH ON SALT-AFFECTED AREAS

Large areas of the arid and semi-arid regions of India (about 7 million ha) are affected by saline and alkaline soils. Much of this is common village land and available for tree plantation. Based on detailed field studies, Yadav and Singh (1970) established a range of soil salinity and sodicity tolerance for certain tree species.

The work done on highly deteriorated alkali land at Karnal shows that treating the soil in the planting pit (90 cm x 90 cm) with gypsum and FYM, along with little fertilizer application, resulted in satisfactory establishment and growth of *Prosopis juliflora*, *Acacia nilotica* and *Eucalyptus hybrid* (see Table 8)(Yadav *et al.* 1975). Planting tree seedlings in augur holes (15 cm x 180 cm) following treatment of the soil with gypsum + FYM has also been tested (Sandhu and Abrol 1981). Mehta (1987) has reported that treatment of alkali soil in pits, using 10 kg sand and 5 kg pyrites,

produced satisfactory growth of *Prosopis juliflora*, *Albizzia lebbek* and other species in the Hardoi district of Uttar Pradesh.

Table 7. Comparative performance of some indigenous and exotic tree species.

Species	Year of Planting	Establishment (%)	Mean Growth (cm) Height	Mean Growth (cm) Annual Increment
Indigenous				
Acacia nilotica	1973	42	300	89.8
Ailanthus excelsa	1963	77	537	39.5
Albizzia lebbek	1973	85	198	51.4
Azadirachta indica	1962	100	576	40.0
Cassia siamea	1973	100	349	97.1
Dalbergia sissoo	1972	92	342	68.6
Hardwickia binata	1962	100	489	33.7
Prosopis cineraria	1962	100	317	19.0
Tecomella undulata	1962	92	432	27.9
Exotic				
Acacia tortilis	1962	100	704	95.7
Eucalyptus camaldulensis	1961	73	941	62.5
Eucalyptus melanophloia	1961	82	1179	75.3
Eucalyptus tereticornis	1961	55	1038	62.8
Prosopis juliflora	1965	31	858	65.8

Table 8. Height increment (cm) of tree species on alkali soil (Sept. 1974 to Sept. 1975), five years after planting.

Soil Statement	*Acacia nilotica*	*Eucalyptus hybrid*	*Prosopis juliflora*	*Albizzia lebbek*	*Terminalia arjuna*
Original soil	40	33	46	15	25
FYM	76	62	81	46	68
Gypsum	88	91	92	62	85
Gypsum + FYM	102	120	102	71	95
Soil replacement	107	119	100	87	98
Fertilizer	91	103	94	57	80
No fertilizer	75	74	76	56	69

INDIA

Field experiments conducted in Haryana on a highly saline soil with a high water table of salty ground water (Tomar and Gupta 1984) revealed that *Acacia nilotica*, *Prosopis juliflora* and *Tamarix articulata* exhibited greater height increment when planted on raised ridges, whereas *Acacia tortilis*, *Leucaena leucocephala* and *Terminalia arjuna* showed better performance with subsurface planting.

According to Pathak *et al.* (1987), fruit trees like *Psidium guajava*, *Cassia carandes*, *Syzigium cuminii*, *Grewia subinequalis* and pomegranate have performed well under conditions of high exchangeable sodium content. The experience gained at Faizlabad shows that tolerant fruit trees should be included in farm forestry practices on alkali lands.

CONCLUSIONS

Scientific information on the selection of tree species best suited to the specific edaphic, climatic and socioeconomic conditions of degraded lands in the arid and semi-arid areas is very limited. Nursery techniques, planting and propagation methods, water and fertilizer management, germplasm collection and evaluation, and genetic improvement all require further study. Growing tree species on problem soils (*e.g.*, saline and alkali soils, sand dunes, heavy black soils, eroded lands, soils with calcic or other impervious layer in the subsoil) need special attention. Indigenous multipurpose trees that are better adapted to the local environment and socioeconomic infrastructure should receive major emphasis. Detailed studies are needed on the rooting patterns of different plants, and on competition between woody perennials and annuals, with the objective of preparing suitable agroforestry models.

DISCUSSION

Regarding soil manipulation, the question was raised that since green manuring from tree cuttings contributes to soil nutrient content and nitrogen fixation, wouldn't it help to improve the condition of alkaline soils? Given the returns to the farmer's labor, though, a rice crop would serve better to provide green manure and soil reclamation than tree cuttings.

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RESEARCH ON MULTIPURPOSE TREE SPECIES FOR SMALL FARMS IN SRI LANKA

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Agroforestry systems have long been practiced informally in Sri Lanka. As part of the Master Plan for Forestry in Sri Lanka, government agencies have begun formal experimentation on multipurpose tree species (MPTS) and agricultural crops. Experiments on priority species established by the Forest Department in 1985 focus on intercropping forest species with food and spice crops and tobacco. Experiments conducted at the Coconut Research Institute have yielded preliminary results on the effects of intercropping other MPTS under established coconut palm trees for different end uses.

INTRODUCTION

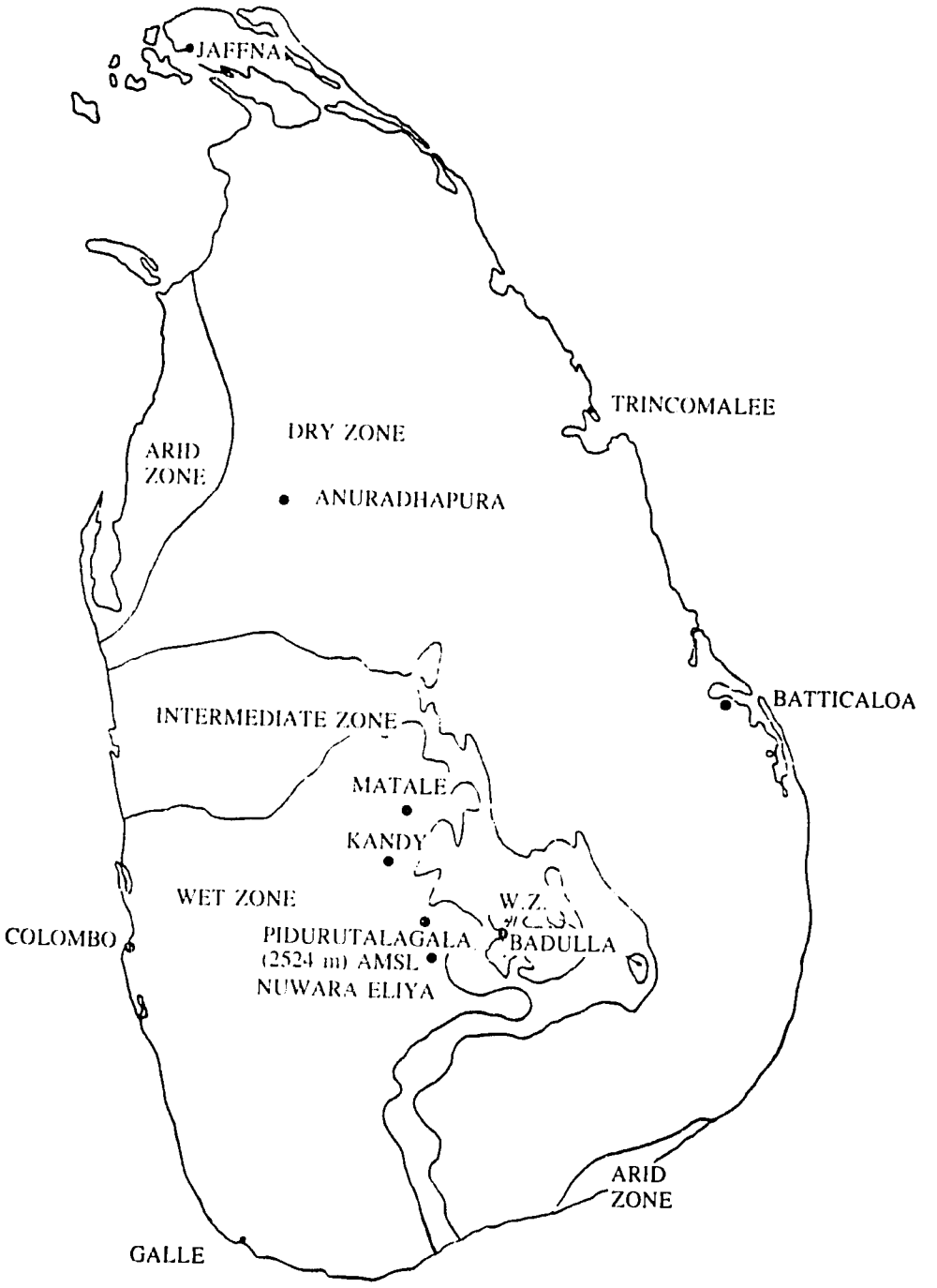
As in most developing countries in Asia, the forest resources of Sri Lanka are rapidly dwindling. During the past three decades total forest tree cover has been reduced by half. This is attributed mainly to shifting cultivation, accelerated development programs, and population growth.

In Sri Lanka, the agricultural sector contributes 28% of the GDP and makes up about 60% of total export earnings, employing 50% of the work force and generating nearly 30% of government revenue. The wide range of climatic conditions that prevail in the country permit the cultivation of a variety of crops. Paddy rice is grown throughout the country. Tea, rubber, and coconut predominate in the wet zone. Spice crops such as coffee, pepper, nutmeg, and cardomom are grown in home gardens in the wet and intermediate zones. Food crops dominate farming in the dry and intermediate zones. Farming is intensive and highly commercialized in the northernmost portion of the country (See Figure 1).

The phrase "fuelwood crisis", used to explain tropical deforestation in many forestry essays, does not appear to apply to Sri Lanka, according to the Master Plan for Forestry in Sri Lanka (1986). It has been found that 80% of the country's fuelwood needs, and 50% of industrial wood needs, are supplied by non-forest wood resources such as private gardens, homesteads, roadside and avenue trees and farms.

A number of government agencies in Sri Lanka, particularly the Forest Department, have recognized the significance of this finding and are strengthening their activities to promote tree planting through a number of programs already active in many other Asian countries. The main programs involve community and social forestry, farmers' woodlots, and mixed crop plantations of trees and agricultural crops on small farms. This last system, practiced for many decades in an informal manner, has now assumed the new name of agroforestry. The selection of appropriate species is critical to the success of these newly styled forestry ventures.

Figure 1. Map Of Sri Lanka Showing The Different Climatic Zones



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SRI LANKA

The traditional practice of planting long rotation monocultures of Eucalyptus and Pinus species is now restricted to industrial plantations. Despite the utility of these species for producing wood for an expanding population in the developing world, environmentalists oppose the planting of such exotics, citing their alleged ill effects on the environment. In view of this debate, the forestry sector has sought more acceptable alternative species. As a result, tree scientists have become interested in the popularization of multipurpose tree species (MPTS).

The IUFRO Research Planning Workshop on MPTS was held in Sri Lanka in 1984. This workshop paved the way for the establishment of the Forestry/Fuelwood Research and Development (F/FRED) network, which is funded by the U.S. Agency for International Development (USAID) and managed by Winrock International with the cooperation of the countries in Asia. Sri Lanka joined this network in 1986 to benefit from the research experiences in other countries and to share innovations in MPTS research.

A number of Sri Lankan institutions are currently conducting research programs on MPTS. The main institutions involved are: 1) the Forest Department, 2) Minor Export Crops Department, 3) the Agriculture Department, and 4) the Coconut Research Institute. The research activities of each institution aim to increase productivity of both agricultural and forest crops, although the species used and the configuration of the trials vary depending on each institution's specialty and the local climatic conditions. This paper will focus on the research conducted by the Forest Department and the Coconut Research Institute.

FOREST DEPARTMENT ACTIVITIES

In 1982 the Forest Department, with the assistance of the Asian Development Bank (ADB), embarked on the Community Forestry Project, which included a strong agroforestry research component and a farmers' woodlot component. Both of these are closely linked to farm forestry, and the Research Division is making a concerted effort to develop viable systems models for duplication on farms.

Agroforestry research trials are being conducted at Agaratenna. The station covers about 80 ha and is largely grassland (predominantly Guinea grass). The altitude of the trial sites varies from 650 m to 790 m. Some silvicultural trials are also being conducted there, predominantly on nitrogen-fixing tree species (NFTS).

All of the research programs at Agaratenna started in 1986, except for one trial established in 1985. The station is located in the agroclimatic mid-country intermediate zone, which receives rainfall sufficient to establish plantations only during the northeast monsoon period. Trials are planted only in November and December.

1986 Program: Intercropping Forest Species and Food Crops

A trial intercropping forest species and food crops used existing plots of forest species established in December 1985. Eight tree species were planted on 10 approximately half-acre plots. Five crop species -- cowpea, brinjal, chillies, capsicum and tomato -- were planted in seven blocks in December 1986 in between one-year old trees. Two Gliricidia plots of closer spacings (1.5 x 1.5 m and 2 x 2 m) were found unsuitable for cultivation of crops due to heavy shade, and were therefore planted with pepper as a future demonstration plot (See Table 1).

Table 1. Species studied in existing trials, NFTS and non-NFTS, with spacings.

Species	Spacing (m)
Leucaena spp.	5.0 x 1.5
Calliandra calothyrsus	5.0 x 1.5
Eucalyptus camaldulensis	5.0 x 2.0
Eucalyptus grandis	5.0 x 2.0
Acacia mangium	5.0 x 2.0
Acacia auriculiformis	5.0 x 2.0
Gliricidia sepium	5.0 x 1.5
Gliricidia sepium	2.0 x 2.0
Gliricidia sepium	1.5 x 1.5

Table 2 shows the height and diameter at breast height (DBH) at one and a half years for each of the species.

Table 2. Height and diameter at breast height after 1.5 years.

Species	Height (m)	DBH (cm)
Leucaena spp.	8.4	6.23
Calliandra calothyrsus	5.3	6.17
Eucalyptus camaldulensis	7.8	6.17
Eucalyptus grandis	4.7	4.26
Acacia mangium	4.2	4.48
Acacia auriculiformis	6.0	6.14
Gliricidia sepium	5.8	5.28

The food crop species were planted at the end of each year under rainfed conditions. None of the tree species were pruned in the first year. The following results were obtained for the food crops.

Tomato was planted under partial shade of Gliricidia. A severe fungal attack, which chemical spraying could not satisfactorily control, affected the crop in its younger stage. Shade conditions favored the spread of the disease, and affected plants subsequently died before any yield could be obtained.

Brinjal (variety SM 164) was successfully grown under *Leucaena spp.* and *Eucalyptus camaldulensis*. The crop was planted 0.5 m from tree rows at a spacing of 60 x 60 cm. The yield for two plots with different tree species was about 9,000 kg/ha for each (plots received only about

75% full sunlight). The yield obtained from the same field under full sunlight was about 12,000 kg/ha.

Capsicum (variety CA-8) was grown under Leucaena at 60 x 60 cm spacing with a yield of 4,000 kg/ha (75% sunlight), as compared to open field yield of 5,500 kg/ha.

Chillies (variety MI-2) grown with Leucaena at a spacing of 90 x 30 cm produced a green pod yield of 500 kg/ha. Some of the green pods were sun-dried and sold as dry pods (4 kg of green pods = 1 kg dry pods). Open field plots yielded 500 kg/ha (green pods).

Cowpea (var. Arlington) was grown in plots of *Acacia auriculiformis*, *A. mangium*, *Calliandra calothyrsus* and *Eucalyptus grandis*. Shade of the *E. grandis* plot was low compared to other plots. The yield was around 1,200 kg/ha in all blocks. The plots received about 60-80% direct sunlight. Yield under full sunlight was 1,300 kg/ha.

This trial will be continued in the next few years. In the first year no organic matter was added to the soil, and therefore the various plots differed only in the amount of sunlight received. In the second year, however, all tree species except *Eucalyptus spp.* will be pruned to provide the plots with more sunlight and organic matter. Crop yields from those plots will be compared with open field plots.

Intercropping Forest Species and Spice Crops

A long-term trial intercropping forest species with minor exported spice crops was planted (see Table 3). Forest species were planted in the first year, with pepper and coffee to be planted in the second year after the establishment of shade. Yield of spice crops and height and diameter growth of trees will be measured.

Table 3. Species and spacing of forest species and spice crops intercropping trial.

Species	Spacing (m)
Leucaena leucocephala	3 x 3
Gliricidia sepium	3 x 3
Eucalyptus tereticornis	3 x 3
Pepper (*Piper nigrum*)	on Gliricidia
Coffee (*Coffea spp.*)	3 x 3 interplanted

Home Garden Models

Two home garden models were established, with spice crops to be planted in the second year after the establishment of shade, as in the trial above. The models will assess economic productivity of fuelwood and fruit species and the salable yield of crops and spices.

Model One occupies 0.25 ha and contains the following species (quantities in parenthesis): *E. tereticornis* (92), Artocarpus (4), Arecanut (32), mango (8), papaya (38), banana (38), coffee (54),

pepper or Gliricidia (50), and avocado (4), totaling 320 plants. Intercropping will start in the second year.

Model Two contains 157 trees on 0.16 ha, with 22 species of fuelwood, timber, fruit and MPTS, with coffee and pepper to be planted later. This model will test the adaptability of various fruit species in the prevailing climatic conditions, and will be used as a demonstration plot in the future.

Intercropping Forest Species with Tobacco

Forest species (*Eucalyptus tereticornis* and *Gliricidia sepium*) have been planted in three rows at a spacing of 1 m, with trees 3 m apart in staggered rows and 10 m between rows. Alleys were clean-weeded and tobacco was planted in December 1986. It is expected that soil erosion on steep-sloped tobacco plantations can be controlled somewhat by planting closely-spaced tree rows. Tree rows eventually form natural terraces and provide fuelwood for tobacco farmers. Trees will be pruned as required to avoid sunlight competition with the tobacco.

Intercropping Gliricidia, Tea, and Cardamon

Land with degraded tea and heavily-overgrown Gliricidia was selected for a trial intercropping Gliricidia, tea and cardamon (*Eletaria cardamon*). Every second row of tea was removed and replaced with cardamon. Crop productivity and market values will be recorded in the experiment.

1987 Research Program

Research trials on NFTS began in collaboration with the Nitrogen Fixing Tree Association (NFTA). The trial established at Kurunegala in the intermediate climatic zone (mean annual rainfall of 1250 mm) records the relative performance of different species (See Table 4). Several non-NFTS were included in the experiment for comparison.

New trials involving NFTS are expected to be established in the next planting season, with further agroforestry trials on alley cropping using different combinations of trees and crops, and silvicultural trials testing provenances of Gliricidia in collaboration with Oxford Forestry Institute.

Further Research Needs

Research on NFTS by the Forest Department in Sri Lanka is supported by the Agriculture Department and the University at Peradeniya. Further research should compare and quantify the benefits of planting NFTS pure and in mixture with non-NFTS. Other areas for research include the biological nitrogen fixation capability of species, the effectiveness of bacteria and fungi symbiosis, nodule formation, environmental stress factors, and character of litter and mulches of NFTS.

COCONUT RESEARCH INSTITUTE ACTIVITIES

Several research projects are in progress on MPTS in coconut plantations at the Coconut Research Institute (CRI). The main objectives of these trials are to:

1) develop economically feasible farming systems suitable for increasing copra production using MPTS under different environmental conditions; and

2) develop cropping systems that will increase the productivity of coconut lands in areas suitable for multiple cropping with forestry/fuelwood crops.

Table 4. NFTS Species Trial at Kumbalpola after one year, planted November 1986.

Species	Code No.	Total height (m)	Survival (%)
Acacia auriculiformis	269	3.15	100
Acacia mangium	276	2.44	100
Acacia nilotica	282	0.77	100
Albizzia falcataria	10	1.4	100
Albizzia proceia	253	2.62	80
Cassia siamea	76	1.99	100
Calliandra calothyrsus	267	2.52	100
Enterolobium cyclocarpum	277	1.98	100
Gliricidia sepium	248	2.26	100
Leucaena leucocephala	K 8	3.12	100
Leucaena leucocephala	K 636	1.99	100
Leucaena leucocephala	K 743	3.37	100
Pithecollobium dulce	236	1.91	90
Prosopis alba	275	0.48	90
Samanaea saman	25	1.40	100
Casuarina equisetifolia	F.D.	1.93	100
Eucalyptus camaldulensis	F.D.	3.48	100
Eucalyptus tereticornis	F.D.	2.13	100
Dalbergia sissoo	F.D.	2.10	100
Gliricidia sepium	F.D.	3.34	100
Eucalyptus alba	F.D.	3.21	100
Pinus caribea	F.D.	0.33	40

Research Projects

One study aims to evaluate *Leucaena leucocephala* and *Gliricidia sepium* under coconut in different agro-ecological zones and soil types. The climatic zones studied ranged from Wet zone, Wet Intermediate zone, to Dry Intermediate and Dry zones. The soil types included ultisols and entisols (sandy and sandy loams). The tree crops are planted as double rows of 2 x 0.9 m in the coconut avenue, at a density of around 1,900 plants/ha (adequate space for the coconut manure circle). Lopping is done at intervals of three months (at 1 m height) after one year. Preliminary results show that Leucaena and Gliricidia produced green matter of 7-10 tons/ha during the first year, and 12-16 tons/ha during the second year. Firewood production was 8-15 tons/ha during the first year and 14-20 tons/ha during the second year. It was evident that Gliricidia is well adapted to the various climates and soil types tested, whereas Leucaena performed better in dry areas and preferred light soils.

Another experiment tests Leucaena and Gliricidia as sources of green manure. The first part of this experiment tested the utility of Gliricidia for rehabilitation of low-yielding plantations. Trenches of 30 cm wide and 30 cm depth were dug 30 cm away from the coconut bole to prune

older roots. Gliricidia loppings were then placed in the trenches and buried. Copra yields were observed to increase significantly after three years as a result.

The second part of this experiment involved the incorporation of Leucaena and Gliricidia around palms for green manure. Fresh loppings of each species were incorporated at a 2-meter radius around the palm, to a depth of 22 cm. Improvement in the soil physical structure was seen within a short time. It is anticipated that the treatment may serve as a substitute for nitrogen fertilizer, reducing fertilizer costs by around 40 percent.

A third experiment at CRI explores the use of Leucaena and Gliricidia in a coconut/pasture/cattle system. Two rows of Leucaena were planted 2 m apart in the coconut avenue. Gliricidia and Leucaena were planted 1 m apart alternately along the fence. Mixtures of grasses and legumes were grown under the coconut trees where cattle are reared at the rate of 4 animals/ha. Results revealed significant increases in live weight gains of more than 300 g/day in bull calves and heifer calves fed with Gliricidia and Leucaena. Those crops served as dry season feeds and also supplied mulch for coconut palms.

A further study examined production of fuel and timber of *Leucaena leucocephala* grown in different planting systems under coconut, and its effect on nut production.

The following planting systems were used:

a) Two rows of Leucaena, 2 m apart with in-row spacing of 0.6 m under coconut

b) Single row of Leucaena, planted with within-row spacing of 0.6 m

c) Leucaena double-row planting in alternate rows under coconut

d) Leucaena single-row planting in alternate rows under coconut

e) Control (without Leucaena)

Thus far, no adverse effects have been observed with any of the systems. The system of Leucaena double-rows in alternate rows appears to produce better Leucaena plants as well as better coconut plants.

Finally, CRI is conducting an evaluation of NFTS in the Intermediate zone. Twenty introduced NFTS are being tested for local adaptability in the Low Country Intermediate zone of Sri Lanka. The experiment was planted in June, 1985. Preliminary results have identified the following six species as promising, based on satisfactory yields of green matter and fuelwood:

Leucaena leucocephala (K 636)
Gliricidia sepium
Acacia auriculiformis
Acacia mangium
Enterolobium cyclocarpum

Future research will continue to explore the potential for intercropping other MPTS with coconut trees.

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RESEARCH ON MULTIPURPOSE TREE SPECIES IN THE SEMI-ARID REGIONS OF NEPAL

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Nepal's topography gives rise to a wide spectrum of climates, with semi-arid conditions occurring in the Western Tarai. The introduction of multipurpose tree species (MPTS) is being promoted in response to tree scarcity caused by irregular fellings. Dalbergia sissoo *is the most important MPTS for Nepal, usually propagated by stump planting.* Eucalyptus camaldulensis *has recently been introduced on small farms. Although irregular budgeting has constrained MPTS research in the past, a new national research plan is being developed.*

INTRODUCTION

Nepal is a small country situated in the middle Himalayas having an area of 147,485 sq. mi. (Land Resources Mapping Project 1986). The country can be divided into seven natural zones which occur in the following sequence from south to north:

1) Tarai
2) Siwalik hills
3) Mahabharat lekh
4) Midlands
5) Himalaya
6) Inner Himalaya
7) Tibetan-Marginal mountains

The Tarai constitutes only 17% of the total land area; thus the mountain region embraces the largest area in Nepal. The complex arrangement of land forms results in differences in exposure to sunlight and monsoon winds and makes for acute climatic differences between adjacent areas. Hence the wide variety in climate -- from the summer tropical heat and humidity of the Tarai to the colder, dry continental and alpine winter climate of the middle and northern sections.

Moving from south to north, there is generally a decrease in precipitation, rocks become stronger and the rate of erosion decreases. Western Nepal receives less summer rainfall (760-1,140 mm) than the eastern part of the country (1,780-2,160 mm) in the period from April thru July, although western Nepal receives more rainfall in winter than eastern Nepal.

The semi-arid tropics of Nepal are found in the western Tarai, where the temperature sometimes reaches 37 to 42 degrees C. During the hottest periods the region suffers a hot wind, locally called 'loo.'

There are approximately 1.5 million land holdings in Nepal, with an average holding size of 1.23 ha. The average family size is six to eight persons, according to the 1981 census, and the population is growing at a rate of 2.5%. Livestock pressure is also high (7.5 head of cattle per

household), with many unproductive animals. About 50% of the country's farmers are full- or part-time tenant farmers.

Until a few decades ago Nepal was rich in forests, and people's wood needs were met by the adjoining forests. Due to irregular and indiscriminate fellings, however, local situations now range from adequate wood supplies in some areas to acute scarcity in other areas. In the expanding regions of wood scarcity, attention has been focused on raising multipurpose tree species (MPTS). The formerly robust forests of *Shorea robusta* in the Western Taral forests have now either completely disappeared or possess only dry deciduous types with scattered trees.

Surface soils in the region are generally sandy loams, and have a medium-textured subsoil, often calcareous. These are neutral to mildly alkaline, varying in depth from shallow to moderately deep. Soil temperatures at 30 cm depth run as high as 28-29 degrees C in the months of May to September (Climatological Records of Nepal 1984).

MULTIPURPOSE TREE SPECIES

The MPTS that figures most prominently in the semi-arid region of Nepal is *Dalbergia sissoo*. *Bambusa sp.* and *Dendrocalamus sp.* are also important. Eucalypts have not yet been introduced on any appreciable scale in the region, although small farmers in other regions have begun to grow them.

About 30 species of bamboo occur in Nepal. Some (*e.g.*, *Bambusa sp.*) are planted by villagers around their settlements, primarily for basket-making. Until recently, most of them had not been documented. A research team of the HMG's Forest Department is now identifying and documenting these species.

Azadirachta indica is found on the Taral up to an elevation of 900 m (Jackson 1987). Farmers plant this species extensively, although not on a commercial scale. To date little research has been done on its growth rate.

More is known about *Dalbergia sissoo*, which is popular and widely planted. Its low maintenance requirement makes it popular for plantation along field boundaries. For concentrated plantations, the following site qualities are now recognized for this species (White 1987):

Site Quality 1 -- loams, silty-clay loams, sandy loam; water table no deeper than 8 m; or, MAI (stemwood volume over bark): 8-16 m^3/ha.

Site Quality 2 -- silty loams, sandy-clay loams, loamy sand; water table inaccessible to plant roots; or, MAI: 3-8 m^3/ha.

Site Quality 3 -- sandy, silty-loamy sands, stones, gravels; variable shallow topsoil; water table inaccessible; or, MAI: 0-3 m^3/ha.

The Department of Medicinal Plants is now micro-propagating *D. sissoo*, *Eucalyptus camaldulensis* and bamboo, and field trials using tissue culture seedlings are to begin soon.

Many areas have been cleared for urban settlements or agriculture, making large areas are no longer available for planting on a large scale. Demands on existing forest resources can no longer

be sustained. Social forestry, therefore, offers the only solution to future needs. The Community Forestry organization is gradually widening its scope of work. Because there are limits, however, to what government agencies can do, their primary role must be that of a catalyst. If MPTS are to make a significant impact in Nepal, they will have to be incorporated into the lifestyle of the farmers.

The Institute of Forestry has recently encouraged socioeconomic studies to determine popular attitudes concerning the use and planting of trees. These studies will contribute to the formulation of strategies for fostering tree planting on private and community lands.

A draft master plan for research, prepared with help from the World Bank and the government of Finland, is now under discussion. Agroforestry studies and improved management of important indigenous fodder trees, such as *Artocarpus lakoocha* and *Bauhinia purpurea*, have been given high priority, along with new plantings of species preferred by farmers for both fuelwood and fodder. Funding constraints, however, hamper research efforts such as further field trials.

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GERMPLASM RESOURCES

A key to understanding the genetic variability and environmental requirements of trees is to test germplasm of documented quality and origin in known environments. To have significant long-term value, therefore, experimental trials require standard supplies of well-documented MPTS germplasm.

Nepal does not have significant germplasm resources of *Acacia nilotica* or *Azadirachta indica*, but the Department of Forests has developed seed orchards for *Dalbergia sissoo* and, with Australian support, is collecting and testing seed for the development of *Eucalyptus camaldulensis* reserves.

In India, research on *Acacia nilotica* has studied three varieties of the species: *telia*, *vediana* and *cupressiformis*. Of these, *cupressiformis* has shown the most promise. Provenance trials on *Azadirachta indica* have only recently begun. The species flowers in March-May, and has exhibited good germination when sown immediately after fallen seeds are collected. Its viability is severely limited, however. *Dalbergia sissoo* grows by roadsides in the provinces of Punjab, Uttar Pradesh, Bengal and Assam. The Goada variety of Uttar Pradesh has tested most promisingly in provenance trials. *Eucalyptus camaldulensis* has shown mixed results in studies in India. The Eucalyptus Centre of Hyderabad has conducted provenance trials since 1979. International provenance trials have taken place in Kothagum, Andhra Pradesh since 1982.

The following presentations provide an attempt to identify the sources and availability of germplasm for the F/FRED priority species in Pakistan and Australia, and outline relevant considerations.

GERMPLASM RESOURCES OF ACACIA NILOTICA, DALBERGIA SISSOO, AND EUCALYPTUS CAMALDULENSIS IN PAKISTAN

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Genetic research at the Pakistan Forest Institute (PFI) has followed an integrated approach of exploration and collection, screening and evaluation, conservation, and utilization. Acacia nilotica, Dalbergia sissoo, *and* Eucalyptus camaldulensis *are species well suited to Pakistan that have been included in this research. This paper briefly describes the distribution and silvicultural characteristics of each, and outlines PFI's species identification and improvement activities.*

INTRODUCTION

Considering a germplasm resource to be "a genetically determined trait of economic significance, an individual that carries such a trait, or a collection of such individuals" (Oldfield 1984), it is important that trees possessing such economically significant traits should be selected for *ex-situ* and *in-situ* conservation.

Genetic improvement of wild timber species in developing countries requires the same integrated approach that has been applied in agriculture, which essentially consists of: exploration and collection, screening and evaluation, conservation, and utilization. Since the early 1960's, the Pakistan Forest Institute (PFI) in Peshawar has undertaken studies on germplasm resources of coniferous and broad-leaved species following these steps. These studies have been carried out with the assistance of the U.S. Department of Agriculture (USDA), the Danish Forest Seed Center (DANIDA) and the Food and Agriculture Organization (FAO). In 1979, FAO initiated a global project for the better use and conservation of arboreal genetic resources for rural areas. Pakistan participated with seven other countries, with financial assistance from the International Board on Plant Genetic Resources, to gather information and genetic material for the purposes of evaluation and conservation. For the arid and semi-arid areas, the project focused on fuel, fodder and shelter trees, which for Pakistan included *Acacia nilotica* and *Prosopis cineraria*.

Dalbergia sissoo and *Eucalyptus camaldulensis* also figure prominently in Pakistan's industrial and fuelwood uses, and are planted in irrigated plantations in the provinces of Punjab and Sind. Robust and adapted to harsh environments, these species are planted by the provincial forest departments on state- and privately-owned lands, and along roadsides and canal banks. The wood is useful for furniture, fuel, fence posts and poles, while the trees provide shade, shelter and improved soil conservation.

DALBERGIA SISSOO ROXB. (SHISHAM)

Dalbergia sissoo is a large deciduous tree with a light crown that is found throughout Pakistan.

It grows fast, although its crooked stem rarely produces straight logs of desirable length. Dalbergia furnishes one of the most important timbers in India and Pakistan and provides excellent fuel. In rural areas, its leaves are also used for fuel when they shed in late autumn.

Distribution

Dalbergia is found throughout the sub-Himalayan tract from the Indus to Assam, and in Himalayan valleys usually up to 1,000 m elevation but ascending as high as 1,500 m. (Troup 1921). The species occurs along rivers on the plains. Dalbergia grows best on alluvial soil in river beds throughout its natural range, and appears as a straggling bush at its highest sites in northern Pakistan.

Silvicultural characteristics

Dalbergia sissoo demands strong light; in typically dense stands, the weaker trees are crowded out. Although leaves are sometimes affected by severe frost, it is frost hardy. The seedlings are drought-sensitive, and trees grown in irrigated plantations die in periods of non-irrigation. It requires well-drained soil. The species is prey to the fungal pest *Fomes lucidus*.

Dalbergia reproduces easily through seed, coppice shoots and root suckers, with seed ripening in December and January. Planting by root-shoot cuttings (stumps) is the most common method, done to supplement coppice regeneration. In Pakistan's irrigated plantations, it is grown both as a pure crop and mixed with mulberry, with an average annual timber and fuelwood yield of 6.5-13.0 m^3/ha during early years. Dalbergia is grown on a rotation of 20-22 years, with standards of 44 and 66 years age (Siddiqui 1979, Ghani 1974).

Germplasm resources

Dalbergia sissoo exhibits great diversity in growth rate and stem form in plantations. A number of straight-stemmed trees were selected in North West Frontier Province and Punjab as a step toward species improvement. Altogether, 425 trees were marked in Mardan, Piranwala, Chichawatni, Changamanga, Dapher, Muzaffargarh, Faisalabad, and Bahawalpur. Research efforts established seed and clonal orchards in Peshawar, Chichawatni and Mirpur Methalo. Dalbergia has also been included in broad-leaved species trials at Nowshehra, Gatwala and Miani. Growth characteristics of the half-sibling progenies have yielded estimates of heritability (Vidakovic and Siddiqui 1968, Vidakovic and Ahsan 1970, Rehman and Hussain 1986). These estimates were generally low and varied with test sites, seed sources and progenies.

ACACIA NILOTICA SYN *A. ARABICA* WILLD. (BABUL)

Acacia nilotica is a moderate-sized, almost evergreen tree with a short trunk, spreading crown, feathery compound leaves, and stipular spines on the branches. The *cupressiformis* variety is the most commonly recognized of three, and is planted by farmers in arid and semi-arid areas of Pakistan for its shape and shade (Siddiqui 1975).

The most economically important tree in the dry plains of India and Pakistan, *A. nilotica* has a whitish and large sapwood. The heartwood is pink, turning reddish brown on exposure, and is hard and durable if well seasoned. Uses for the wood include mining pit props, construction, carts, farming implements, boat construction, and fuel. The bark is used in tanning leather. Pods, twigs

and leaves serve as fodder for cattle, goats and sheep. Babul plantations produce honey. Its thorny branches provide good fencing material on farms, and its ability to fix nitrogen improves the soil. Lac is grown on the trees in Sind Province.

Distribution

Acacia nilotica appears to be indigenous to the Sind Province of Pakistan and central regions of India. Although the species is frost-tender, it grows in almost all of the drier regions of Pakistan, including the northern districts where severe frost is common. It does not occur in hilly regions.

Silvicultural characteristics

Although *Acacia nilotica* occurs in dry regions, it requires irrigation to thrive in arid climates. In the low rainfall regions of Sind, trees depend on river flooding. The species occurs most commonly on inundated riverain alluvium and black cotton soils. With considerable soil moisture, babul appears to be capable of growing on saline soil.

Babul is a gregarious tree, occurring in pure stands or as the prevalent species in mixed populations. It demands strong light, regenerating naturally and cultivated easily by seed. In most localities the seed ripens in July. The coppicing ability of *A. nilotica* varies greatly.

Germplasm resources

Trees have been selected for improved frost resistance. Plantations and nursery stock in northern Pakistan are particularly susceptible to frost damage (Siddiqui 1975). The IBPGR/FAO project launched in 1981 studied the following three methods of improving Acacia and Prosopis species:

a) *Acacia nilotica* seed of indigenous and exotic origins were tested against other species with seed provided by DANIDA. Six sources of *Acacia nilotica* from India were compared with four indigenous sources provided by Ghazi Ghat, Attock, D.I. Khan and Patoki. Field planting of these trials has taken place at Dhabeji in Sind and at Dagar Kotali in Punjab.

b) Seventy-five *Acacia nilotica* var. *cupressiformis* trees were selected and marked in nine locations in three provinces for suitability for farm use. From selected progenies, two seedling orchards have been established at Miani and Kharian for afforestation.

c) *A. nilotica* performance has been compared with that of other broad-leaved species under different ecological conditions, with results that place it among the best performers.

EUCALYPTUS CAMALDULENSIS DEHN.

Eucalyptus camaldulensis is native to Australia and was one of the first species of eucalypts to be introduced abroad, introduced to Pakistan in 1867 (Siddiqui *et al.* 1979). It is Australia's most important inland hardwood, with uses ranging from honey production to shelterbelts to sawn wood. A large evergreen with a thick smooth red-gum type bark, it does not usually grow straight. The wood of *E. camaldulensis* grown in Pakistan is light grey sapwood and reddish-brown heartwood, good for pulp and paper, fence posts, and fiberboard and particleboard. After careful seasoning it supplies good furniture, construction materials, firewood and charcoal (Siddiqui *et al.* 1984, 1986).

Distribution

From Australia, the species was introduced to many countries in Asia, Africa, North and South America, and Europe in the latter half of the last century. It is now widely planted, with the plantation area and wood production on these continents now greater than that of its natural forests in Australia.

Silvicultural Characteristics

In its natural habitat, *E. camaldulensis* grows under a variety of ecological conditions and thus shows great diversity in its morphological features (Pryor 1967). In Pakistan, the species grows best on exposed sites and is planted extensively in both linear and block plantations, on both irrigated and rainfed sites. Plants 6-12 months old are raised in plastic nursery containers. The seed ripens in July and August. Its good coppicing ability has generally not been exploited. With the combined effects of genetic diversity and impure seed, the tree crop of *E. camaldulensis* is not uniform, with reported annual yields ranging from 15-20 m^3/ha.

Germplasm Resources

E. camaldulensis is found to grow in varied environments of both sub-tropical and tropical regions of Pakistan. It has been found growing on saline and water-logged soils, and under arid conditions. Many species trials conducted in Pakistan indicate its suitability for afforestation (Siddiqui *et al.* 1979, Pryor 1967, Qadri 1970, and Khan 1955).

Genetic improvement of the species has come about through procurement of quality seed from Australia, selection of plus trees from existing plantations, and the subsequent establishment of progeny trials and seed stands.

Species elimination trials using seed supplied from Australia 20 years ago indicated that of the 56 species, *E. camaldulensis* grew best in Pakistan (Hafeez and Sheikh 1972). Preliminary results from later trials also suggest that *E. camaldulensis* is better suited for conditions in Pakistan than *E. grandis* and *E. urophylla*. The Alice Springs provenance has shown highest growth rates (Siddiqui *et al.* 1979). Seed stands of proven provenances exist at PFI and at Speena shaga. Progeny trials were established at Chichawatni and Jamrud, with plans for the best progenies to be included in future breeding programs.

The wide genetic diversity of this species, with tremendous variation at the nursery stage, has made the tasks of differentiation and classification very difficult. Only now is genetic uniformity being achieved at PFI. With the wide range of Australian provenances and the pending taxonomic classifications, *E. camaldulensis* offers great potential for exploration, identification and experimentation.

DISCUSSION

Regarding the genetic variety of *E. camaldulensis*, it was noted that provenance selection should be given higher research priority than breeding for improved stock, given the relative difficulties of plant breeding.

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GENETIC RESOURCES OF EUCALYPTUS CAMALDULENSIS

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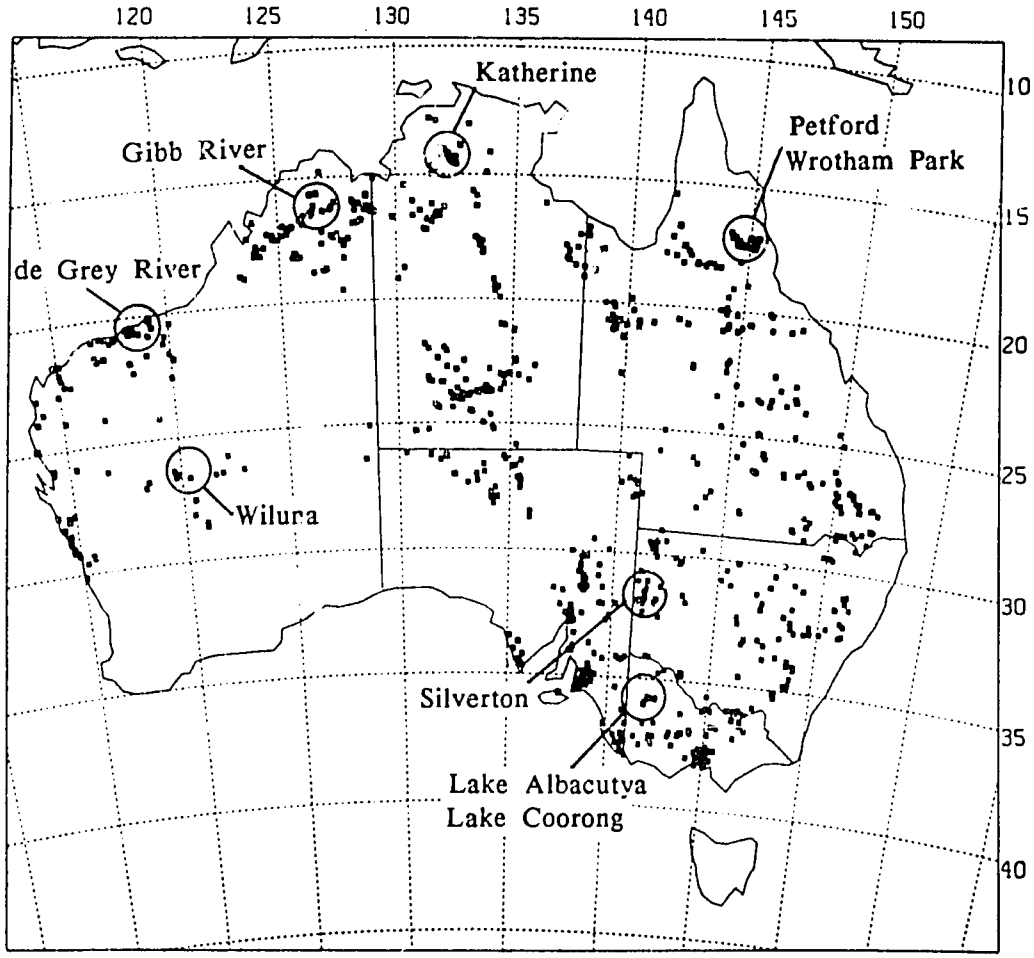
Eucalyptus camaldulensis has the largest distribution and range of variability of any of the eucalypts. Widely planted as an exotic, it provides wood products for industrial and domestic use. Considerable variation has been found with respect to growth, wood properties, leaf oil content and tolerance to drought, salt or frost at the provenance level. Intra-provenance variation is important and is being increasingly understood and utilized. Information from well-conducted trials of a broad range of provenances is essential for optimal use of the species. The problems of seed availability from a wide range of provenances are discussed.

INTRODUCTION

The most widely distributed of the eucalypts, *Eucalyptus camaldulensis* Dehnh., is also one of the most variable (Figure 1). In the hot, dry inland of Australia, it is confined to watercourses where it can rely on ground water stored from infrequent flooding. In less arid regions, *E. camaldulensis* sometimes spreads away from its typical riverine habitat to occupy plains and hill slopes. It can be found on the margins of salt lakes and on a variety of soil types, most typically sandy alluvial. Except for a few populations in southern Australia that occur on shallow soils over limestone, the species is not adapted to calcareous soils. *E. camaldulensis* grows in temperate and tropical climates with rainfall from 200 to 1100 mm annually, with summer rains in the north and winter rains in the south of the continent. The most extensive natural stands are found along the banks and wide flood plains of the Murray-Darling river system in the inland of southeastern Australia. In this region, large trees, often more than 200 years old, are cut for sawn timber, railway sleepers and charcoal.

E. camaldulensis is perhaps the world's most widely used tree species for plantings in arid and semi-arid lands. In addition to extensive (but largely unrecorded) plantings for shade and shelter in many parts of the world, over 500,000 ha of plantations have been established (Anon, 1979), mainly in the Mediterranean Region and particularly in Spain and Morocco. Seed for these plantings comes largely from local land races established using southern Australian provenances. Planting in the tropics, especially in southeast Asia and Brazil, is increasing with greater availability of the climatically-adapted northern provenances. This increase is reflected by the high world demand for seed from these northern provenances, with an estimated 2 tons of seed currently exported annually from northern Queensland alone. (The seed is quite small; each ton yields about 600 million germinants.) Another measure of the importance of E. camaldulensis is the large and increasing demand for small quantities of seed for research. In the two and a half years since January 1985, the CSIRO Tree Seed Centre in Canberra has sent 71 kg of *E. camaldulensis* to 348 researchers in 79 countries. About 30% of the 1,700 seedlots went to India, Nepal and Zimbabwe.

Figure 1. Natural distribution of *E. camaldulensis*, with better-known areas highlighted.



The success of this species as an exotic is attributed to:

- o its superiority to other trees in wood production on dry, infertile sites;
- o its tolerance of extreme drought and high temperature, combined with rapid growth when water is available;
- o deep penetration of roots;
- o tolerance of periodic waterlogging and soil salinity;
- o some tolerance of frost;
- o good coppicing ability; and
- o utility of its wood.

The primary observed uses for the wood have been for poles, posts, firewood, and charcoal. In Argentina, Israel, Mexico and Spain it is used for hardboard and particle board; in Burma, California, Morocco, Portugal and Spain it serves as paper pulp. In India, Nepal, Pakistan and Tanzania it is grown in agroforestry systems and is a good source of honey.

The ease with which the seed can be stored, supplied and germinated has contributed to the success of this species as an exotic. Doran et al. (1987) reported that *E. camaldulensis* seed stored well, with no apparent loss in viability after nearly 10 years.

BIOGEOGRAPHY

Two forms of *E. camaldulensis* -- northern and southern -- have been recognized. The northern form typically has rounded operculi on the flower buds, broad glaucous juvenile leaves, fairly straight stems, white bark, and seedlings which normally bear lignotubers. The southern form has rostrate operculi, narrow non-glaucous juvenile leaves, rather crooked stems, grey bark, and seedlings in which lignotuber development is rare. Despite the contrast between forms in incidence of lignotubers, there appears to be no difference between them in ability to coppice after felling. All provenances tested have coppiced well.

No distinct boundary appears to exist between the northern and southern forms; most studies suggest both clinal and mosaic patterns of variation. There is evidence of discontinuous variation in the species from one drainage basin to another, as there is less chance of gene flow between basins than within each (Turnbull, 1973). Varietal or sub-specific names are not used in *E. camaldulensis*, and plantation foresters seem content to describe their plantation by the name of the place where the seed was originally collected; for example, 'Albacutya camaldulensis' and 'Petford camaldulensis.'

Eucalyptus camaldulensis is closely related to other well-known species, such as *E. tereticornis*, *E. brassiana* and *E. exserta*. It has long been recognized that where the distributions of *E. camaldulensis* and *E. tereticornis* make contact, there are zones of introgression where the shape of buds and fruits is intermediate between the two species. This occurs in eastern Victoria and in southern, central and far-north Queensland, for example. There is speculation, largely based on the operculum shape of the floral bud and the presence of black-seeded individuals, that stands near Petford commonly referred to as being *E. camaldulensis* are actually an intermediate form occurring in a zone of gradual change between the two species.

In plantations outside Australia, *E. camaldulensis* has been shown to hybridize readily with *E. grandis*, *E. tereticornis* and other species of the sub-genus Symphyomyrtus (Griffin et al., forthcoming). Natural hybrids between *E. camaldulensis* and *E. alba* are common in northern Australia.

PROVENANCE VARIATION

As might be expected, given its broad range of natural habitats, *E. camaldulensis* demonstrates considerable variation. Eldridge (1975) has reviewed results of provenance trials in detail. In the past, the features which limited wider use of the species were poor growth in summer-rainfall areas (due to the use of poorly adapted provenances), insufficent frost tolerance, intolerance of very

calcareous soils, and crooked stems. Each of these properties varies within and between provenances, and the importance of provenance choice is now recognized.

Provenance variation has been recorded in:

- o growth rate
- o wood properties
- o tolerance to salinity
- o drought tolerance
- o frost tolerance
- o leaf oil content and polyphenols

Growth Rate

In general, southern provenances (*e.g.*, Lake Albacutya) have shown superior growth in the Mediterranean winter-rainfall zone, and the northern provenances (*e.g.*, Petford, Katherine, Gibb River) have performed better in the tropical summer-rainfall zones.

A major international series of provenance trials was initiated by the Food and Agriculture Organization (FAO) in 1964 on over 30 provenances covering most of the natural range of the species. Seed was distributed to 18 countries, and by 1970 24 cooperative trials had been established. Marked variation in performance between provenances has been reported (Lacaze 1977), with the ranking of provenances dependent on climatic and edaphic conditions of the planting site. The large differential is indicated by the fact that in a tropical area at Afaka in Nigeria, volume yield at age five for the best provenance was three times that of the worst. Observations at this site at 13 years confirmed the variation and ranking pattern reported at 5 years (Otegbeye 1985) and demonstrated that provenance variation contributed greatly to the observed variation of height and girth. At Gan Hadar in Israel, in a Mediterranean climate, the difference in volume ratio at age 10 was 8 to 1 (Lacaze 1977). Major findings from this FAO trial included:

o Lake Albacutya provenance performed very well in Mediteranean zones, in both vigor and form;

o Katherine and Petford provenances performed well in the tropics.

Davidson *et al.* (1975) recorded the success of northern Australian provenances in Bangladesh, where considerable provenance variation occurred. In one case, the best provenance (Petford) after 5 years had an MAI (stemwood volume over bark) of 17 m^3/ha/yr, and the worst (Fitzroy Crossing, W.A.) had an MAI of 2.2 m^3/ha/yr. Similar results have been achieved in Nepal, where suitable provenances have been identified from north Queensland (Emu Creek, Lappa Junction, Wrotham Park, Irvinebank) for further planting and investigation (White 1986a).

Wood Properties

E. camaldulensis shows a wide variety in wood properties between properties. In the FAO trial in Italy, basic density at 10 years varied from 443 kg/m^3 to 593 kg/m^3. In Zimbabwe at almost 8 years, basic density varied from 487 to 576 kg/m^3 among provenances. A signficant decrease in density followed provenance origin from north to south (Barrett and Carter 1976).

Trials in India and Pakistan (Ghosh *et al.* 1977, Siddiqui *et al.* 1979) yielded variations in wood density and growth rate similar to those of the Italian trials. Particularly high values for basic density of tropical provenances (610 to 640 kg/m^3) were found in Sri Lanka by Vivekanandan (1978).

El Lakany *et al.* (1980) examined fibre length of 7 provenances at 2 years. They found a significant difference between provenances, but no indication of a consistent difference between northern and southern forms.

Tolerance to Salinity

E. camaldulensis has been highly regarded for its tolerance of soil salinity. While it has been known that some populations have greater tolerance than others (Karschon and Zohar 1975), well-controlled experiments of genetic variation in salt tolerance have only recently been established. Table 1 shows the considerable variation between provenances (Thomson *et al.* 1987).

Table 1. Ranking of *E. camaldulensis* provenances in order of decreasing tolerance of NaCl, in glasshouse trials.

		NaCl concentration (mM) causing mortality[1]										
Provenance	State	Mean	S.E.	Homogeneous subsets[2]								
DeGrey River	WA	636	11	a								
Silverton	NSW	613	13	a	b							
Wiluna	WA	608	12	a	b							
Pentecost River	WA	587	11		b	c						
Emu Creek	Qld	565	12			c	d					
Quilpie	Qld	532	13				d	e				
Kangaroo Island	SA	522	12					e	f			
Lake Albacutya	Vic	510	12					e	f			
Whiteheads Creek	Vic	507	13					e	f			
Minlaton	SA	503	14					e	f	g		
Douglas	Vic	499	13					e	f	g		
Katherine	NT	490	13						f	g		
Moree	NSW	466	12							g		

[1]Seawater is equivalent ca. 550 mM
[2]Provenances which do not share a common letter have means that are significantly different at the 5% level

Sands (1981) examined the salt tolerance of three southern provenances and found that at 400 mM, all the seedlings from Lake Albacutya were healthy despite reduced growth; almost all the Shepparton seedlings died; Port Lincoln seedlings showed intermediate performance.

The salinity level in the root zone at the site of origin, while important to differences in NaCl tolerance in eucalypts generally, does not correlate with NaCl tolerance in *E. camaldulensis*. Localized selection for tolerance occurs for plants growing on more saline sites, although some

populations growing in soils of low salt content (*e.g.*, the DeGrey River population) also show high levels of tolerance. While salt-tolerant trees may be found in non-saline environments, it is more effective to concentrate searches for salt-tolerant genotypes in environments where salinity is likely to exert a strong selective force (Thomson *et al.* 1987).

Drought Tolerance

Studies have shown that the Lake Albacutya provenance has physiological adaptions to drought under experimental conditions (Awe *et al.* 1976, Moreshet 1981, Grunwald and Karschon 1982). Its rapid proliferation of seedlings was thought to grant it greater tolerance of moisture stress than other provenances, although the studies do not explain why, in arid areas of northern Nigeria (Jackson and Ojo 1973) and near the Kalahari Desert in Zimbabwe (Barrett and Carter 1970, R.D. Barnes in personal communication), the Katherine provenance has proved the most drought resistant of several tested, including Lake Albacutya. Katherine provenance also performed well on difficult sites in Bangladesh (Davidson *et al.* 1985). Other particularly drought-tolerant provenances include Silverton, Alice Springs, Newcastle Waters and Mundiwindi.

Frost Tolerance

E. camaldulensis survives winter frosts to about -10 degrees C in the higher reaches of streams in southeastern Australia, and about -7 degrees C in the semi-desert areas near the center of the continent. In both areas, severe radiation frosts follow a series of increasingly cold nights.

Seedlings of southern provenances have been found to be more resistant to winter frosts than northern provenances (Larsen 1967, Pryor and Byrne 1969). Awe and Shepherd (1975) investigated frost tolerance of four provenances in controlled experiments. After hardening to simulate winter conditions, the two southern provenances (Moree and Nathalia) proved more resistant to damage in a frost chamber. Without hardening, however (as in spring frosts), the two northern provenances (Katherine and Agnew) showed more resistance and would be useful in many regions too warm for hardening, where sudden frost follows a period of mild weather. White (1986a) recorded chill damage to leaves and buds of *E. camaldulensis* following abrupt changes in minimum temperature in the Tarai of Nepal. Under these conditions, Gilbert River provenance sustained less damage than Petford, which in turn suffered less damage than Katherine or Gibb River provenances.

Further screening should be done to find provenances with greater frost tolerance.

Leaf Oil Content and Polyphenols

Studies have shown significant differences in the chemistry of leaf extracts among the provenances. Banks and Hillis (1969) found the polyphenol composition of mature leaves, seedling leaves and seeds to be distinctive for the northern and southern forms, and within these major divisions further groupings that followed the drainage system pattern.

The more economically important leaf oils obtained from eucalypts are complex mixtures of volatile organic compounds, and include cineole (used in pharmaceuticals), phellandrene (used in the manufacture of disinfectants and germicides), and citronellal (used in the perfume industry). The 'medicinal' oils, containing more than 70% cineole and no phellandrene, are in greatest demand and command the best prices.

The oil yield from the leaves and the proportion of the different constituents vary considerably according to the species, age, and condition of the leaves. To be commercially interesting, a species should contain more than 2% fresh weight oil, with composition high in one or two important chemicals. Among the hundreds of eucalypt species, fewer than 20 have been exploited for their essential oils. Due to the lack of information on cineole-producing eucalypts in the tropics, world cineole production has depended mostly on temperate species. In recent studies, however, some tropical provenances of E. camaldulensis, including Petford, were found to have surprisingly high levels of cineole (K.J. White, J.C. Doran in personal communications). Further work needs to explore how cineole can be simply and cheaply extracted to obtain an important additional product.

SELECTION OF PROVENANCE MATERIAL FOR TESTING

The Commonwealth Scientific and Industrial Research Organization's (CSIRO) National Tree Seed Centre is often requested to select a range of provenance material of *E. camaldulensis* for trial. Factors considered when making such a selection usually include:

a) climate of the test site;

b) results and experience with *E. camaldulensis* elsewhere under similar soil and climatic conditions;

c) results with other species tested at or near the experimental site; and

d) availability of seed.

Techniques described by Booth (1987) can be used to identify areas in Australia with climatic conditions similar to those of locations abroad. While climatic matching is not a complete response to the task of provenance selection, it can supplement consideration of the above factors.

The following are examples of common site-matching requests and general recommendations.

- For sites in the seasonally-dry tropics: Petford, Katherine, and Gibb River
- For temperate areas with winter rainfall: Lake Albacutya, Lake Coorong, Lake Hindmarsh
- For saline sites: De Grey, Wiluna, Silverton

INTRA-PROVENANCE VARIATION

Recent research shows that as much variation exists among families of individual provenances as between provenances. This information has brought about the modification of seed collection techniques, resulting in more collections maintained as individual tree collections.

Outstanding families are common within provenances that may rank 3,4 or 5 in a test of 20 provenances. By keeping families separate, superior material can be easily identified and used, and inbreeding of the introduced population can be limited.

AVAILABILITY OF SEED AND SEED COLLECTION

Availability of quality seed of known origin often limits the introduction and testing of a new species. Fortunately, in the case of *E. camaldulensis*, CSIRO's National Tree Seed Centre currently has 157 different bulk seedlots in stock, and a further 798 seedlots maintained as seed from individual parent trees. This collection has developed over 25 years, and has its foundations in the 1964 FAO-sponsored collections. Subsequent FAO support and major collaborative collections--with organizations such as Brazil's Agricultural Research Corporation, France's Centre Technique Forestier Tropical, U.S. Department of Agriculture, and the Australian Development Assistance Bureau -- have assisted in developing this collection.

To meet CSIRO's strict standards for seed collection, parent trees are at least 100 m apart and precisely described with respect to botanical identity, collection location, habitat, soil, date of collection and number of parent trees. A seed certificate providing information on geographic origin, viability, and the number of trees sampled accompanies all seed distributed by the Tree Seed Centre. This information is computerized to minimize transcription errors and improve handling efficiency. Researchers requiring additional seed origin information can request copies of the original provenance record sheets completed during the collection. Recipients of CSIRO seed are urged to use the unique 5-figure seedlot number which accompanies the seed. This number provides the key to the record-keeping system and is now commonly used for international eucalypt research.

Seed distributed by the Tree Seed Centre is priced according to a formula based on the cost of collection and processing, and is relatively expensive. Prospective purchasers should be aware, however, that excessive economy in obtaining seed may jeopardize the results of their research programs, and the value of resulting plantations. CSIRO has a long-standing policy of exchanging seed whenever an appropriate arrangement can be made (Turnbull and Doran 1984).

COMMERCIAL SUPPLY OF SEED

The Tree Seed Centre's primary aim is to provide authenticated and representative samples of Australian tree seed to researchers. Further seed requirements may be secured through commercial seed suppliers or State forest services. The safeguards to employ when dealing with commercial seed companies are described by Turnbull (1983). Purchasers must give the dealer an accurate specification of the seed required and confirm that the dealer is in a position to meet the specification before an agreement is concluded. For example, most commercial seed collectors in Australia can specify the origin of the seed they supply. Australia has no tree seed certification scheme, however, and it is recommended that the buyer obtain details of the seed origin before purchase. Buyers should not assume that the seed of eucalypts or other Australian genera will necessarily be supplied from trees growing in Australia. Seed from exotic plantations is now common in the seed trade.

While there is no immediate threat, concern has been expressed at the conservation of natural stands of important provenances. FAO-sponsored collections of Petford, Katherine and Gibb River provenances, performed in 1977, have served to establish *ex situ* conservation stands in Nigeria and Thailand under a joint FAO/UNEP project (Anon 1984). Resource conservation stands established in 1985 by the Zimbabwe Forestry Commission may be future sources of high quality seed for Petford and other provenances.

TREE IMPROVEMENT AND FUTURE STRATEGIES

For an effective long-term program of genetic improvement of a eucalypt plantation, Eldridge (1978) suggested that, among other things, researchers examine the base population to see if it is the best provenance, and whether it contains enough variability for continuous selection over several generations. The possibility that original provenance material may have been based upon seed from only a few individuals highlights obvious genetic dangers in using thinned provenance trials as seed stands. Moreover, due to significant inter-family variation, many of the retained trees may belong to even fewer families. Thus the base may be inadequate for a breeding program to service a large plantation program. Increasingly, researchers are returning to the origins of their most promising provenances and making broad-based collections from 50 or more individuals in order to form an adequate foundation for breeding.

Techniques for clonal propagation of *E. camaldulensis* through cuttings are well established and represent the final step in matching a species to particular sites. It is prudent to make extensive provenance and family assessments before pursuing the cuttings option, and to bear in mind the need to complement a clonal program with a carefully-planned crossing program.

Intensive sampling of natural stands of *E. camaldulensis* is vital to future research, and is expensive. Detailed planning is required, together with full cooperation with an individual or institution in the proposed collecting areas. Turnbull (1983) stresses the need for project planners to consider seed supply during feasibility studies and to initiate seed procurement from external sources 1-2 years before the nursery phase. Failure to allow adequate time for seed procurement can place a program at risk.

International donor agencies and governments should recognize that seed supply is crucial to the success of tree planting projects, and that sponsorship of special seed collection expeditions is a legitimate and productive use of their funds.

Users should reduce or eliminate dependence on external seed supplies at the earliest opportunity. The simplest way to grow seed is to establish seed production areas by heavily thinning suitable stands of wide genetic base. Using stands of appropriate composition can significantly improve plantations from first-generation introductions, which inevitably reflect the inbreeding of natural stands. Self-sufficiency in seed supply helps stabilize planting programs and, in developing countries, can save valuable foreign exchange.

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CLOSING REMARKS

John C. Cool, Natural Resources Management Program, Winrock International

This morning I am encouraged that an integration of information and perspectives has occurred at this workshop. Although it is unfortunate to dichotomize between biological and social scientists, I would argue that the rules of rigorous biological science are much better defined than those of the social sciences. On the other hand, I hear the biological scientists saying, "We need to know if we are going to reach our target group and how to be more effective in relating what we do to the end user" -- in this case, the resource-poor rural farmer.

Given the demographic tidal wave described by the Chief Minister of Sind in his opening address, the issue of farmer size within the target group, in terms of land area controlled, may not be as important as the fact that they are resource-poor. Almost every country is likely to experience a doubling of its rural labor force during the next 25 years. Many of these people are not farmers at all, but are suppliers of rural labor. We should include in our calculations the landless and near-landless, and those who will be born into the population with no assured access to land. They, also, might comprise a target group.

It is exciting that the forestry profession is beginning to get the recognition that it deserves. I hope this will mean that the profession will be able to attract superior young people and sensitize them to the fact that biology is only one dimension of forestry, that other dimensions of forestry also demand their attention during their formative period.

Watershed management cannot be ignored. I have written some things about the great Indus food machine. This basin that is the backbone of Pakistan has the potential to produce food, fiber and forest products for a population much larger than the 100 million that currently depend on it. It is a global resource, one that requires a vision of management much broader than household agroforestry.

There are opportunities to make conceptual breakthroughs in discussions of degraded land and the large numbers of under-utilized rural poor in the next generation. There are negative factors to be considered. First, 65% of the land area of Pakistan is arid, semi-arid, or otherwise degraded. Some of that will never be productive, but a significant portion could be brought into productive use. A second factor is the rapidly growing rural population. How can something positive be made from these two negative factors? Perhaps the answer lies in foresters' imaginative efforts to begin to give rural people a set of incentives: secure land tenure, a market price that guarantees them a profitable investment of their time, and leasehold arrangements that make it possible for the rural poor to become productive managers of degraded lands.

This lies well beyond the scope of F/FRED's activities. Still, it is important that participants in the F/FRED network understand why this particular set of activities on which they are embarking can make a major contribution to all the nations of Asia. For the same applies, in varying ways, to all the countries involved in the F/FRED network. The question is, what can the network do immediately? There is a tendency to overload F/FRED, to ask it to do much more than it was designed to do. The network must define clearly its capacities and work within them to do a rigorous scientific job of generating usable knowledge based on the kind of cross-national comparative studies that form the core of F/FRED.

This should not constrain the F/FRED network from suggesting agendas for others, including the national forestry communities and the socioeconomic talent pool. As part of this project, or as a

follow-on, some attention might be given to increasing the pool, not just of technical capacity in the realm of forestry, but overall, by bringing younger professionals in and giving them the opportunity to use F/FRED as a learning vehicle. This is the best graduate program in which some young professionals could be involved. Some of the best and brightest people doing master's degree work in related fields might do research in association with F/FRED as part of their thesis effort.

I feel quite optimistic about the commitment of this group of professionals to recognize the monumental scale and complexity of their task but, nonetheless, to build some bridges and not lose sight of the ultimate objective of the resource-poor rural population.

Given that as our goal, we must be aware that time is a critical element. Scientifically, one might argue that the replication and validation of the network trials should take 5 years, 7 years, 10 years, but there is a need at every stage to ask the question, "So what?" What have we learned that has relevance to the problems which our political leaders face, to the problems of maintaining stability in our nation? All of this rests, finally, on what this program can deliver to make a significant difference to the well-being of resource-poor rural people.

Yar Mohammad Khan, Chief Conservator of Forests, North West Frontier Province, Pakistan

Who is interested in cooperation on arid and semi-arid network research? This workshop has dealt primarily with research organizations and institutes, but feedback from the end-user is needed. Research is for application by end-users. In this research, farmers are the most important link in the chain. They must be encouraged to cooperate and provide information on what is important to them for research. In this type of cooperation, then, we need not only foresters, but also land-use experts, soil scientists, and the farmers themselves.

The social and economic factors of this research are important. Unless we have good information about the social setting, projects will not be successful. When we have the end result, who will provide inputs to the farmers? Inputs of water, fertilizer, and seed must be taken into account before innovations can be applied. It also may be useful to consider the organization of farmers in community groups or cooperatives that may be more able to apply research results. The farmers' perceptions of a practice's economic viability will determine its acceptance.

How do we transfer the results of our research? For that we need the extension service. Our information system requires communication with the farmer for orientation and validation of research. We must have an effective method for technology transfer to the farmer.

Ta-Wei Hu, Chairman, Department of Forestry, Chinese Cultural University, Taipei, Taiwan

My colleagues here have already expressed the needs of farmers, and discussed how to meet these needs with a feasible network. I come here from the other world, so to speak -- the F/FRED network that developed last year for the humid and sub-humid tropics. When we began here in Karachi, I felt that many controversies might hamper the development of a network trial for the arid and semi-arid zone. But after the discussions of the past few days, a picture of a network and the basis for a trial have emerged.

The farmers of different countries have many needs. It is not possible for us to meet all these needs at one time. So we must find a place and a time to make a start. Right here is the place,

right now is the time for us to start our international network trials. They may give a meaningful result, a meaningful answer to the questions of which species and varieties should be planted, and which managements are most appropriate to the needs of farmers in different areas.

Appendices

FIELD TRIP SUMMARY

The workshop included a one-day field trip to the Miani Forest Research Station and the "hurri" plantations near Hyderabad.

"Hurries", block plantations of *Acacia nilotica* grown in marginal irrigated plots of cotton plantations, have been grown by farmers in the Sind province since the 1850's, when the practice was introduced as a condition of small land grants to farmers. *A. nilotica* seed is scattered over a marginally productive

A "hurri" stand of *A. nilotica*, with harvested trees in foreground.

Sharns-Ul-Haq Memon, Sind Forest Department, explains the practice of "hurries" to workshop participants as farmers look on.

plot and receives only runoff from the other irrigated cotton parcels. For the first season, the seedlings grow among the cotton crop. Later the stand is thinned and the cut trees are used for goat fodder. After five or six years the farmer will find a buyer for his tree crop and it will be harvested. The plot is then cleared of stumps and the reclaimed land planted with cotton for the next season of the rotation. The harvested timber is often used for pit props in the nearby mines. There is also a local market for the wood as fuel.

At the Miani station, foresters with the Sind Province Forest Deparment described species assessment and provenance trials on MPTS species, including the F/FRED priority species.

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MULTIPURPOSE TREE SPECIES RESEARCH FOR SMALL FARM USE IN THE ARID AND SEMI-ARID TROPICS

Program

Monday, November 16

10:00- 10:10	Opening Ceremony Recitation from the Koran
10:10- 11:10	Welcome Addresses M.I. Sheikh T.C. Niblock A. Jan G.A. Shah B.J. Sarhandi
11:10- 11:40	Break
11:40- 12:30	Structure and Overview of F/FRED (T.C. Niblock)
12:30- 14:00	Lunch
14:00- 14:40	Results and Lessons from the Humid and Semi-Humid Zone (K.G. MacDicken)
14:40- 15:00	F/FRED Committee Structure (L. Medema)
15:00- 15:30	Break
15:30- 16:00	The Social Science Component of the F/FRED Project (C.B. Mehl)
16:00- 16:30	F/FRED Global Research Activities (F.B. Cady)
16:30- 17:00	Towards a Socioeconomic Database on Small Farm Use of MPTS (D. Bajracharya)

Tuesday, November 17

08:00- 10:00	Existing MPTS Research for Small Farms in the Arid and Semi-Arid Tropics: An Overview (K. Oka, moderator) Sri Lanka (K. Vivekanandan) India (J.S.P. Yadav) Pakistan (M.I. Sheikh) Nepal (K.P. Prajapati)
10:00- 10:30	Break

10:30- 12:00	Social and Economic Considerations (C.B. Mehl, moderator) Present and Prospective Uses of Tree Species in India's Semi-arid Tropics (T.S. Walker) Traditional Sources of Advice for Farmers Planting Trees (J. Qureshi)
12:00- 13:30	Lunch
13:30- 15:10	Germplasm Resources for *Acacia nilotica*, *Dalbergia sissoo*, *Eucalyptus camaldulensis*, and *Azadirachta indica* (K.G. MacDicken, moderator) Nepal (R. Joshi) India (G. Cheema) Australia (S.J. Midgley) Pakistan (K. Siddiqui)
15:10- 15:30	Break
15:30- 16:30	Network Field Trial Design (F.B. Cady)
16:30- 17:00	Summary and Discussion (T.W. Hu, moderator)

Wednesday, November 18

7:00- 18:00	Field Trip to Farm Forest "Hurri" Plantations and the Miani Forest Research Station near Hyderabad

Thursday, November 19

8:00- 09:00	Definition of Small Groups (C.B. Mehl and T.W. Hu)
9:00- 10:30	Small Group Meetings on Network Field Trials
10:30- 11:00	Break
11:00- 12:00	Small Group Reports
12:00- 13:00	Lunch
13:00- 14:00	Planning Session for Future Network Activities
14:00- 14:30	Summary