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INTERNATIONAL AND REGIONAL ORGANIZATIONS AND NETWORKS INVOLVED IN TROPICAL FORESTRY RESEARCH: A STOCK TAKING

(Agenda Item 3)

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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INTERNATIONAL AND REGIONAL ORGANIZATIONS AND NETWORKS INVOLVED IN TROPICAL FORESTRY RESEARCH:
A Stock Taking

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CONTENTS

LIST OF ACRONYMS USED

ASEAN-US	Association of South-East Asian Networks-United States of America
CAMCORE	Central America and Mexico Cooperative on Conifer Resources
CATIE	Centro Agronomica Tropical de Investigacion y Ensenance
CIAT	Centro Internacional de Agricultura Tropical
CPR	Common Property Resources Network
CSIRO	Commonwealth Scientific and Industrial Research Organization
CTB	Centre Technique du Bois et de l'Ameublement
CTFT	Centre Technique Forestier Tropical
DANIDA	Danish International Development Agency
EAPI	Environment and Policy Institute
FAO	Food and Agriculture Organization of the United Nations
F/FRED	Forestry and Fuelwood Research and Development Project
FINNIDA	Finland International Development Agency
FORI	Forest Reserch Institute
FPL	Forest Products Laboratory
FRDC	Forest Research and Development Center
FRIM	Forestry Research Institute of Malaysia
FRIN	Forestry Research Institute of Nigeria
IARCs	International Agricultural Research Centers
IBPGR	International Board for Plant Genetic Resources
ICIMOD	International Center for Integrated Mountain Development
ICRAF	International Council for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Center
IDS	Institute of Development Studies

IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment and Development
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Center for Africa
INPA	Instituto Nacional de Pesquisas Amaconicas
IPT	Instituto de Pesquisas Tecnologicas
ISNAR	International Service for National Agricultural Research
ITF	Institute of Tropical Forestry
ITFFR	International Task Force on Forestry Research
ITTO	International Timber Trade Organization
IUCN	International Union for the Conservation of Nature and Natural Resources
IUFRO	International Union of Forestry Research Organizations
LDC	Less Developed Countries
MAB	Man and Biosphere Program (UNESCO)
NFTA	Nitrogen Fixing Trees Association
ODI	Overseas Development Institute
OFI	Oxford Forestry Institute
RFF	Resources For the Future
SAFRI	South African Forestry Research Institute
SFN	Social Forestry Network
SPDC	IUFRO Special Program for Developing Countries
TFAP	Tropical Forestry Action Plan
TROPENBOS	Tropical Forests Program
WB	World Bank
WRI	World Resources Institute

INTRODUCTION

A realistic strategy to address the key problems identified within the global Tropical Forestry Action Plan (TFAP) should include increased research. Participants at the 1988 Bellagio Forestry II (Wiston House) meeting on Tropical Forestry Research concluded that adding forestry research to the CG system might be an effective way to achieve part of the needed expansion. In subsequent meetings of various representative groups of the CG[1], it was decided to explore the options for such incorporation.

In considering how this incorporation might take place, the TAC decided that it needed a systematic stock taking of how three groups--CG centers, other international/regional centers, and regional networks of national organizations--fit currently within the five priority categories of research put forth at the Bellagio Forestry II meeting. An ad hoc panel was formed to carry out this task. The present paper provides the results.

Priority research areas considered

The Panel considered the five related research subject areas identified as priorities by the Bellagio Forestry II participants and by the International Task Force on Forestry Research (ITFFR) in its exhaustive investigation of the subject.[2] The five areas are:

* Forestry's role in agroforestry, watershed and arid zone land use management;
* Natural forest conservation and management;
* Tree breeding and tree improvement;
* Forest utilization and market research; and
* Policy and socioeconomic research.

Details on key research issues under each heading are provided in Section III, where we also discuss organizations and networks working in each area.

Problems being addressed and basis for assigning priorities.

The priority given to each of these areas by the ITFFR was based on an assessment of potential contributions to solving critical forest resource and land use related problems facing large segments of the world's population. It was concluded at Bellagio II that research results in the above five areas can significantly improve the contribution that forests and trees make to:

* food security and sustainable agriculture;
* energy security;
* protection of natural tropical forest ecosystems and biological diversity; and
* meeting mankind's need for essential, basic products such as housing and paper, and, in the process, creating much needed employment opportunities and sustainable export expansion opportunities.

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[1] See "Proposal to incorporate forestry research into the CG system." Agenda Item 12, Consultative Group Meeting, May 29-June 2, 1989, Canberra, Australia.

[2] International Task Force on Forestry Research. 1988. A Global Research Strategy for Tropical Forestry. Sponsored by the Rockefeller Foundation, the UNDP, the World Bank, and the FAO. New York: UNDP. 88 pp. plus 17 background papers.

These are the four substantive issue areas addressed by the Tropical Forest Action Plan (TFAP), now endorsed by more than 60 tropical countries and most major donor nations.

Mechanism needed to mobilize funds, and to coordinate, monitor and guide research.

It was recognized clearly at Bellagio II and by the ITFFR that an international funding and coordinating mechanism is needed for forestry. An obvious model was that initiated for agricultural research some decades ago when a coordinated effort was developed through the CG system to mobilize expanded funding for agricultural research to tackle the major problem of hunger.

The mechanism needed for forestry research should be able to:

* mobilize increased funding for forestry research;
* support scientists and research organizations in carrying out active, productive research in priority areas;
* provide for close linkages with research in related fields such as agriculture and animal husbandry;
* facilitate communication and cooperation among various research groups working in different areas of research, e.g., through provision of data bases, through networks and training activities.

Mobilizing increased funding. International funding for forestry development and conservation activity has more than doubled over the past few years, from about US$500 million per year in 1984-85 to more than US$1,000 million in 1988. While research shared in the expansion, concern over the continuing lag in research led those involved in the TFAP implementation to recommend that the Bellagio Forestry II meeting focus on forestry research.

Among other things, it was pointed out that while overall funding has increased, research still only receives 5 percent of the total funding for forestry, as compared, for example, with about 10 percent of the total funding for agriculture. Bellagio II participants concluded that some mechanism was needed to mobilize and coordinate funding for forestry research.

Supporting expansion of active, productive research. It was recognized that three things need to be improved in order to get a significant expansion and improvement in forestry research:

First, in some areas of research, existing international or regional research institutions should be strengthened to provide centralized research that then can be mobilized by local and national institutions through adaptive research.

Second, local research capacity and activity needs to be supported with funding and with training programs for researchers and administrators.

Third, productive research networks need to be expanded or created for some types of research to focus efforts, to mobilize complementary research talents and facilities in different countries and to facilitate sharing of information and techniques. There are many smaller and medium sized research organizations working on common problems,

but without the benefit of being able to share research methodologies and techniques, germ plasm, research results and so forth. Further, there are some major, national research organizations, such as FRIM in Malaysia, FRIN in Nigeria, and INPA in Brazil,that usefully could provide leadership in regional networks that would include the smaller and less advanced organizations in their regions.

The Panel is not referring simply to information networks, although they also have their place. Rather, we are considering here networks where a group of organizations or scientists actually are implementing research together or carrying out research in a complementary fashion. The Panel's interpretation of the four main types considered relevant and found at present in forestry research is presented in Annex 1.

The principles for success of networks, as reviewed by Plucknett and Smith (1984) with additions by Burley (1985), can be summarized as follows:

* The problem must be clearly defined and a research agenda agreed upon
* The problem should be common to several participants
* Strong self-interest must exist in each collaborator
* Outside funding should exist at least for the birth and initial functioning of the network
* Staff must be sufficiently trained and expert to make significant contributions
* Strong leadership is required, having the confidence of all the participants in a network
* Information should be shared among all collaborators through a range of media
* Participators should develop mechanisms for the extension of research results to the eventual user
* Networks should not be considered permanent institutions but should show flexibility to cope with the range of skills and requirements of the participants.

Linking with agricultural research. Several of the five priority research areas, such as watershed management, agroforestry, tree breeding, and policy research, complement and support the commodity oriented research of the IARC's. In fact, some IARC's already are doing limited research related to priority forestry areas, e.g., in agroforestry (See Section II).

Giving forestry a close connection with the CG agricultural research system could result in useful complementarities. It could create a more effective approach for insuring adequacy and continuity of funding which is essential for resolution of longer term natural resource issues, such as forestry research addresses. The connection also could help in focusing research more sharply on critical issues and help in establishing an effective monitoring and quality control system for forestry research.

Facilitating communication and cooperation. It was recognized at Bellagio II that the five different types of forestry research put forth as priorities are related in terms of developing effective solutions to critical problems. A communication mechanism is needed to facilitate coordination so that research groups can develop and propose their research program directions and budgets on the basis of where their programs fit within an overall framework for solving key problems.

Cooperation and integration are needed in forestry research

As indicated in table 1, each of the five research areas has something to contribute in each of the four TFAP opportunity areas. Thus, some international mechanism is desirable to insure balance and integration in forestry research so all the pieces of the puzzle are addressed and fit together to resolve the problems and to take advantage of the opportunities. In most of the opportunity areas there is a critical need to bring together technical, economic and sociological research in an integrated fashion.

For example, it has been widely recognized that a coordinated approach is needed in developing effective solutions to the problem of tropical deforestation and resulting loss of biological diversity and other environmental values derived from the remaining 2 billion hectares of tropical forests. Research results are required in all five priority research areas put forth above. Thus:

* Agroforestry, dry land and upland watershed management research can contribute to more sustainable farming systems on lands bordering the remaining natural forests, thus relieving some of the pressures on them;

* tree improvement through research on selection and breeding of fast growing multipurpose tree species can provide the means for increasing the productivity of agroforestry and other managed rural forest activities, thus relieving even further the pressures on natural forests; it also can provide means for improving industrial plantations, which can take some pressure off the natural tropical forest;

* improved tree utilization, through research on efficiency of wood stoves, secondary wood utilization, tropical forest food production, etc., can help to improve natural forest management, can relieve pressures on remaining wood supplies, and can divert pressures from natural tropical forests to plantation forests; it also can help improve utilization and management of natural forests by expanding the number of species used.

* research on natural forest conservation and management can provide the rationale and the technologies for managing forests on a sustainable basis rather than destroying them for inappropriate reasons; it also is directly related to in situ and ex situ conservation of biological diversity;

* policy and socio-economics research, such as recent work on the Amazon region, provides a framework within which countries can develop their policies to reduce deforestation and to encourage sustainable natural forest management and utilization.

Scope and organization of the Report

The above brief overview merely touches on the thinking that has preceded this panel's deliberations. It provides a sense of the context within which the following review of existing activity and organizations is undertaken.

The report discusses each of the priority research areas and highlights some of the associated research accomplishments and needs. It then identifies key international or regional organizations and networks doing research related to each of the five topics.

Table 1. Recommended Research Priorities

(Classified by research fields and TFAP opportunity areas)

RESEARCH FIELDS	TFAP OPPORTUNITY AREAS			
	1. Forestry and Sustainable Agriculture	2. Energy Issues	3. Forest Ecosystems	4. Forest Industries
A. Agro-forestry and Watershed Management	Forest/agriculture/ energy interactions Agro-forestry systems, e.g., - alley cropping - shelterbelts - fodder productivity Watershed management and land reclamation Arid zone management	Close spacing biomass farming many of the (same as in 1.A, since fuel is a major component for agro-forestry)	Buffer zones - sustainable agriculture systems Germ-plasm and agricultural crops, e.g., oil palm Shifting cultivation	(Sale of products from activities in 1.A and 2.A)
B. Natural Forest Ecology and Management	Game, fish and other food products from the forest Natural savannah woodlands management	Pollarding and coppicing yields Forest area and biomass inventories and access studies Natural woodland studies (see 1.B)	Ethno-botanical research Ecosystem research Pest and disease research	Alternative silvicultural techniques
C. Tree Breeding and Tree Improvement	Rapid propagation of MPTS in arid zones Nitrogen-fixing species Seed collection and storage and direct seeding Breeding for salt and stress tolerance Cash crop and local use	See 1.C	Germ-plasm collection and storage (oil palm, rubber, coffee) Studies of genetic variability	Tree selection, improvement and establishment (e.g., eucalypts, pines and other other species
D. Utilization and Marketing	Markets for farm tree crops and products	Local market studies Stove studies Fuel efficiency	Medicinal plants and other useful outputs from the natural forest	Increased use of lesser-known species Conversion technologies Small-scale industry development
E. Policy and Socio-Economics	Common property issues Economics of agro-forestry Socio-economics of watershed management Tenure issues Incentives	Inter-sectoral policy issues (Other studies indicated in 1.E)	Buffer zone policy research Policy reform studies Economics of lesser-known species and non-wood products	Concession policies, pricing - rent capture Small-scale industry and employment Incentives for sustai[illegible] yield

Source: ITFFR 1988

TABLE 1

The organizations/networks considered include: a) the CG centers (IARC's), b) the IUFRO[3] Special Programme for Developing Countries (SPDC), and c) other key networks and organizations not included under the heading of "nonassociated centers." With the exception of the SPDC, this latter group is being covered by other studies being undertaken by the TAC.

The terms of reference for the Panel include a detailed stock taking of the SPDC, using an outline of topics similar to that used for the other non-associated centers. Such a review is provided in a separate paper. The SPDC also is referred to in Section III in terms of how it contributes to progress in specific areas of forestry research. ICRAF, the other major nonassociated center that deals with forestry related research, also is being reviewed by another TAC panel, although some comments also will be made here in terms of how ICRAF fits into the overall picture.

Research done by the International donors and UN agencies has been excluded from this stock taking, since the purpose is not to review the accomplishments of these groups. Some of them (e.g., FAO and the World Bank) carry out forestry research and participate directly in research programs as sponsors and advisers. Further, it should be noted that the CG/TAC has in the past contracted various studies to FAO. ITTO also has been excluded, even though it goes beyond being a funding organization to incorporate plans for an extensive research program of direct relevance to the topics discussed below. In fact, this program could become a major contributor to research results related to tropical forest conservation and management and to improved utilization.

Finally, it should be emphasized that the purpose of this paper is to present an objective stock taking of what currently is happening internationally in the five priority research areas. The terms of reference do not include in-depth, on-site evaluations of on-going programs to assess their adequacy and their capacity for expansion.

[3] IUFRO is the International Union of Forestry Research Organizations, founded in 1892. It is one of the oldest scientific associations, with more than 600 member institutions in some 100 countries. More than 15,000 scientists benefit from the widespread networking activity carried out through IUFRO in all areas

I. THE GLOBAL RESEARCH SYSTEM ADDRESSING TROPICAL FORESTRY[4].

The majority of organizations in developing countries that carry out forestry and forest products research are small; and there is wide variation among them in terms of number of scientists and other trained staff, support for individual scientists, infrastructure, and funding.

Some of the research dealing with certain specific priority areas of the TFAP is done by organizations outside the traditional forestry research system. This is true, for example, in research areas such as agroforestry and nitrogen fixing tree species. These organizations have to be included in a longer term, coordinated research program.

Respondents to an ITFFR questionnaire identified lack of trained personnel as the most critical problem facing developing country forestry research organizations. A study of a sample of 39 developing country forestry research institutions revealed a median number of scientists per organization of only 16 (Bengston, Xu and Gregersen 1988). About two-thirds of the sampled organizations had between 0 and 5 Ph.D. and between 0 and 10 Masters-level scientists. Almost half the sampled organizations had only between 0 and 10 technicians. Investment in education and training for researchers and expansion of forestry research capacity is a critical need which must be addressed.

Expenditure on forestry research in the tropical regions was on the order of magnitude of only US$180 million in 1981. As two points of comparison, the U.S. Forest Service alone spent US$128 million on research in 1981 ($143 million budget in 1989); and total expenditure on agricultural research in LDC's was around US$2,200 million.

Developing countries accounted for only 12 percent of the total expenditure on forestry research worldwide in 1981 (Mergen et al. 1988). Based on past expenditure trends, total expenditure today on TFAP related research in LDC's is probably somewhere between US$220 and 250 million.

In 1986, the latest year for which there are comprehensive statistics, international donors provided some US$46 million of assistance for forestry research (FAO 1987a, b). This means that only about 20-25 percent of the total expenditure on forestry research in LDC's was funded by international donors as compared to about 40 percent in agriculture.

As mentioned earlier, the percentage of bilateral and multilateral aid for agriculture spent on research is about 10 percent, whereas only 5 percent of total bilateral and multilateral assistance for forestry is used for research.

A better perspective on past levels of expenditure on forestry research in LDC's can be gained by looking at such expenditure as a percent of the value of production of forest products. These percentages for forestry research are in the 0.05 to 0.12 percent range and are considerably below the percentages for agriculture. Also, the percentages in LDC's are about 5 times lower than the comparable percentages for forestry research in developed countries (Mergen et al. 1988). The value of nonmarketed outputs was not

[4] This section is based on Gregersen 1988 and the conclusions of the ITFFR.

included in the Mergen et al. calculations. If they had been, the ratios would be even lower.

Clearly, investment in forestry research is very low in LDC's in comparison with the value of goods and services flowing from the forestry sector and the divestment of capital taking place due to deforestation.

II. FORESTRY RELATED RESEARCH WITHIN THE CG SYSTEM

For the main part, the IARC's are not involved in forestry related research, with the exception of agroforestry. Interest in this area grew in the early 1980's. Initial work involved testing tree and shrub species suitable for agroforestry systems. Now work has been extended to the evaluation of interactions between woody perennial legumes and annual crops, with particular attention being paid to the effects of the systems on yields of associated agricultural crops.

While it is uncertain the extent to which existing mandates of the Centers have been formally revised to accommodate agroforestry research, there is evidence that governing boards and the CGIAR encourage the new developments, with TAC ensuring that a perspective on the main center objectives is maintained.

Seven centers (CIAT, IITA, ICRISAT, ILCA, IBPGR, IFPRI AND ISNAR) have reported some work in agroforestry research or related areas. Below we summarize their involvement. Annex 2 provides greater detail, including some information on plans for the future.

CIAT

CIAT's involvement with agroforestry has been channelled along commodity lines, with the exception of the Tropical Pasture Program in which a concerted effort has been made to collect and evaluate tree and shrub legumes with potential as sources of forage. The principal characteristic assessed has been high dry matter production in acid infertile soils. CIAT recognizes the potential role of tree crops, managed fallows and other agroforestry elements in the design of sustainable agricultural systems.

IITA

This center has developed the "alley farming" system of agroforestry for the humid tropics of West and Central Africa. Work on this system in the last fifteen years in the forest/savanna transition zone has shown that alley crop farming is a better integrated way of maintaining productivity in the degradable soils of the humid and sub-humid tropics. IITA plans to extend the work to other major agroecological zones (humid forests, moist savanna and the inland valley ecosystems).

ICRISAT

Agroforestry is an important component of this center's Resource Management Program involving cropping systems, land and water management, and economics. The use of pigeon pea (in place of leucaena) to create alleys within which millet and chickpea are grown has produced some very good results. Future study will include evaluation of

genotypes and long term assessment of changes in soil structure and fertility, and the eventual development of packages for testing by NARS.

ILCA

ILCA has an active work program as part of its Animal Feed Resources Thrust, which seeks to alleviate the feed shortages which constrain livestock output in almost every production system of Sub-Saharan Africa. Special emphasis is being given to the integration legumes in mixed crop-livestock farming systems to achieve stable and sustainable feed and food production in Sub-Saharan Africa.

ILCA has an on-going program of work to investigate the potential of multi-purpose tree species (MPTS's) in different production systems appropriate to the main agroecological zones, and has developed a forward plan to 1993 to pursue this work in cooperation with IITA, ICRAF, NFTA as well as with NARS. On-going work on MPTS's includes only initial evaluation of tree species and their importance in alley farming.

IBPGR

IBPGR is interested in conserving fruit trees (mainly cultivars and wild species), woody species of value to the agriculture or agroecological environment in the arid and semi-arid zones, and some commodity crops (cacao, rubber, coffee and coconut). It has played a role in research and development related to ex situ conservation, and its texts on seed conservation are basic for storage of tree seed as well as agricultural crops. IBPGR also maintains an interest in in situ conservation, and results of research sponsored by it provide data for organizations involved with ecosystem conservation.

IFPRI

This institute has a global mandate for policy analysis, especially at the macro policy level. It has recently initiated collaborative study on agroforestry with CIAT in Amazonia. It also has completed some innovative research on fuelwood-agriculture relationships in Nepal, specifically looking at how fuelwood gathering time affects agricultural production activities of women.

ISNAR

The main function of ISNAR is strengthening national agricultural research capacity. ISNAR has not had forestry in its program of assistance to NARS, but it is now at the point of adding forestry or agroforestry expertise to its staff to enable it to do so.

III. KEY RESEARCH ORGANIZATIONS AND NETWORKS WORKING IN PRIORITY AREAS OF TROPICAL FORESTRY RESEARCH

In what follows, we discuss briefly the types of organizations and networks involved in each of the five priority areas of research mentioned above. We also discuss the nature of the research requirements in each of the five areas and how such requirements relate to the solving of the key problems identified within the TFAP. Since these relationships and the potential gains from research were explored in great detail in the ITFFR report to Bellagio II, we do not spend much time on the topic here. Finally, as in the case of the ITFFR and the Bellagio II participants, we look at priorities for research in terms of how such research can contribute to solving problems.

An overview of research priorities in relation to the problem areas emphasized by the TFAP is provided in Table 1.

The organizations and networks cited below are only a few of the ones--both national and international--which deal with tropical forestry research. We have attempted to highlight a variety of key organizations, focusing mainly on those that are international or regional in scope. A few national organizations also are highlighted because of their lengthy and successful operation and their potential as leaders in the international arena.

1. Agroforestry, dry land and watershed management research.

This area of research deals basically with the role of trees in rural land and water management systems. Enough evidence has accumulated to indicate that trees can a play significant role in moving towards sustainable agricultural production and food security, both because of the moderating effects trees can have in agricultural environments (e.g., use of shelterbelts) and because of the role trees play in providing fuel needed to cook food and make it digestible. Trees also can provide fodder for livestock and cash incomes for farmers. Because of the close food and agriculture relationships involved here, agroforestry is the main area in which CG/IARC's currently are undertaking research (see Section II).

Trees and improved land husbandry can have significant impacts in terms of the hydrology of watersheds. The interactions of this area of research with the other four are significant in terms of solving critical land use problems.

Agroforestry systems that increase, or at least sustain, productivity of agricultural lands can have an indirect role to play in halting deforestation by reducing the pressures for land clearing as more permanent food-tree crop production systems reduce the depletion of existing agricultural lands and thus the need for land clearing.

The nature and extent of the contribution of research in this area will depend on the extent to which researchers understand and react to their potential role in developing solutions to the broader issues mentioned above.

Research Needs and Priorities

The ITFFR identified the following specific priorities in this category:

Agroforestry research. Most of the earlier agroforestry research was descriptive and involved with developing diagnostic methodologies. What is needed now is an increased focus on research that quantifies physical interactions between trees and farm crops under varying ecological conditions and under varying patterns of interaction and management. Research also needs to focus on agroforestry systems in terms of their economic and social viability and their ecological sustainability.

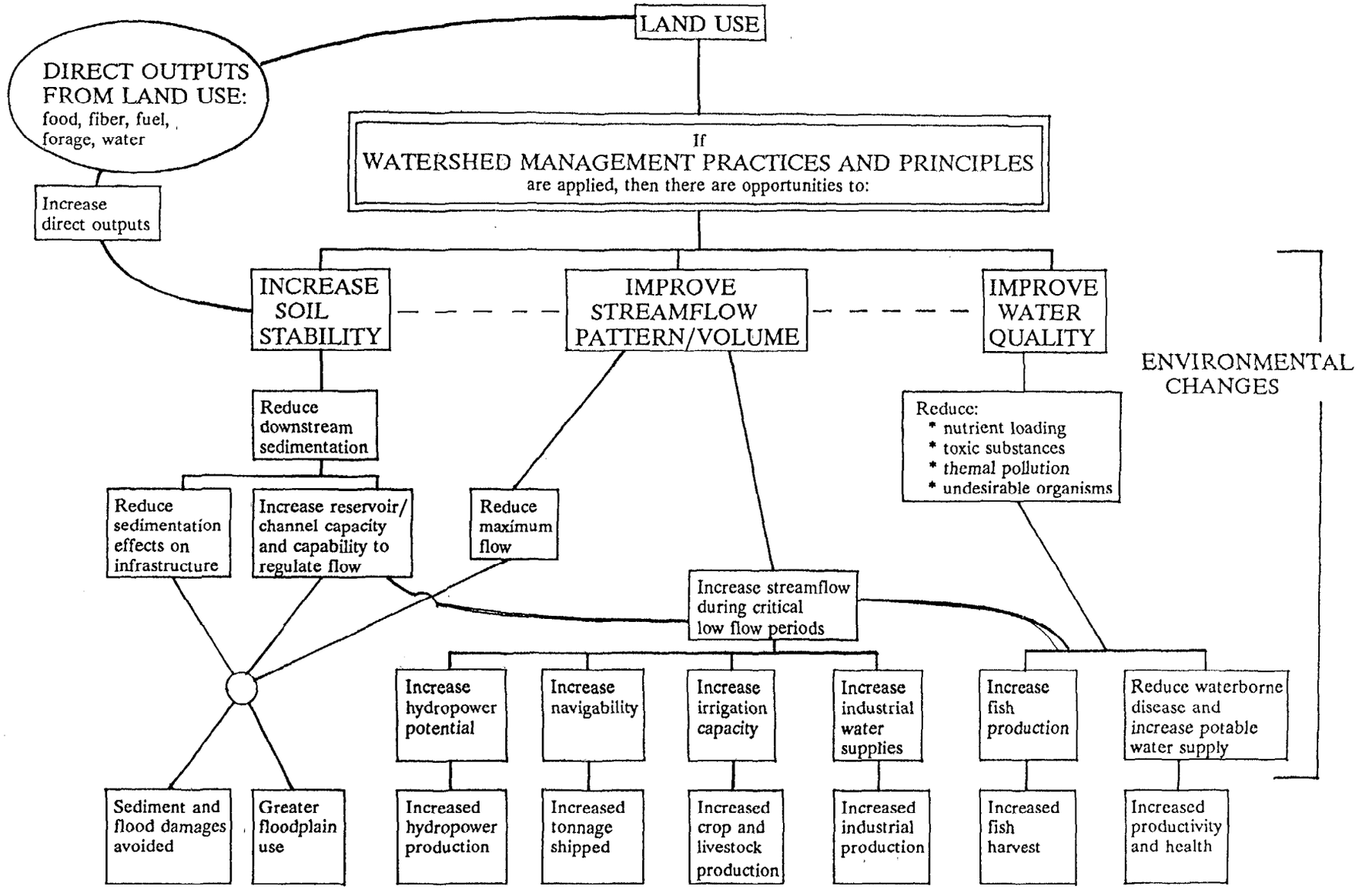
Specifically, great gains can be made by focusing on such quantification dealing with trees in pasture systems, alley cropping, use of nitrogen fixing species, and fruit trees in agroforestry systems, and multiple uses of trees in farming systems, with a main focus on fuelwood production. Examples of productive past research in these areas are provided in Annex 3.

Watershed management research, with emphasis on identification and quantification of upstream/downstream interrelationships and effects of alteration of land use practices. Using agroforestry and other community tree growing practices to reduce erosion presents a particularly promising area for research. Options for on-farm and community fuelwood production to take pressures off fragile natural woodlands should be studied.

Watershed management research should be systems oriented and needs to focus on the types of linkages indicated in figure 1. Much of the past research in this area has been focused too narrowly on one or another aspect of watershed management. For example, while we have learned a great deal about the hydrologic cycle under different environmental conditions, we have neglected research on the quantification of upstream-downstream relationships as they relate to changes in the availability of goods and services. This is a good example of a problem area where integrated research is needed in the biological, physical and social sciences. In sum, we need research on biophysical relationships, socio-economic conditions associated with adoption of watershed management practices, and incentives for local participation in programs. Some examples of the research which has been carried out are presented in Annex 3.

Dry zone woodland management research, with emphasis on low cost technologies for improving sustainable productivity of these lands to assure protection with production of fuelwood and other needed outputs. Water management becomes one major issue that needs immediate attention. Shelterbelts are a specific topic which has received some initial attention. Much more effort is needed in this area. Also, more research is needed on the optimum combination of shade trees and pasture in dry zones and the allelopathic effects of some tree species on adjacent vegetation. Research on silvi-pastoral systems also is needed, along with analysis of options for use of live fences in containing livestock. Examples of productive past research on dry land forestry are included in Annex 3.

In addition, research of central importance to watershed management and dry zone forestry includes work on selection and breeding of drought resistant trees, management of natural woodlands, tenure policies and other policy considerations. These topics, and examples of research dealing with them, are given in other sections.


LAND USE
DIRECT OUTPUTS FROM LAND USE:
food, fiber, fuel, forage, water
Increase direct outputs
If
WATERSHED MANAGEMENT PRACTICES AND PRINCIPLES
are applied, then there are opportunities to:
INCREASE SOIL STABILITY
IMPROVE STREAMFLOW PATTERN/VOLUME
IMPROVE WATER QUALITY
ENVIRONMENTAL CHANGES
Reduce downstream sedimentation
Reduce:
* nutrient loading
* toxic substances
* themal pollution
* undesirable organisms
Reduce sedimentation effects on infrastructure
Increase reservoir/ channel capacity and capability to regulate flow
Reduce maximum flow
Increase streamflow during critical low flow periods
Increase hydropower potential
Increase navigability
Increase irrigation capacity
Increase industrial water supplies
Increase fish production
Reduce waterborne disease and increase potable water supply
Sediment and flood damages avoided
Greater floodplain use
Increased hydropower production
Increased tonnage shipped
Increased crop and livestock production
Increased industrial production
Increased fish harvest
Increased productivity and health
DOWNSTREAM BENEFITS

Examples of organizations and networks involved:

Many of the research examples cited in Annex 3 have been carried out by researchers working in national research institutes or departments, often with support from international agencies or bilateral programs. Some of these researchers have benefitted from participation in networks dealing with use of trees in agroforestry, dryland and watershed management systems. Some of the key organizations and networks involved include the following:

ICRAF (International Council for Research in Agroforestry) has been involved primarily in documenting existing agroforestry systems. It also has been developing methodologies for diagnosis and design of agroforestry systems. It's field research has been focused so far on on-farm agroforestry systems in Africa. Natural forest and woodland food-fodder-fuel-fibre systems have been studied by other groups as indicated below. As mentioned, a separate detailed stock-taking of ICRAF activities and scope is being prepared by the TAC.

CATIE (Centro Agronomico Tropical de Investigacion y Ensenanza) has major research efforts underway in agroforestry, watershed management and multipurpose tree species. Its main research focus is on the Central American countries, where it has strong and active research, training and development networks established in several areas, including multipurpose tree species and agroforestry. It has for many years, been a major conduit for international funding going into these research areas in Central America. Its training and research programs complement each other in terms of building national research capacities. CATIE's training is oriented toward all of Latin America.

ICIMOD (The International Centre for Integrated Mountain Development) is a centre for multidisciplinary documentation and information dissemination, training, and applied research, and provides consultative services on resource management and development activities in mountain regions. It is located in Kathmandu, Nepal. The primary objective of ICIMOD is to promote economically and environmentally sound development in the Hindu Kush-Himalayas and to improve the well-being of the local population.

F/FRED Network (Forestry and Fuelwood Research and Development Network). This Project, which was started in 1985 to some extent as a follow-up to a SPDC workshop in Kandy, Sri Lanka, has as its mandate to help scientists in the developing world meet the needs of small-scale farmers for fuelwood and other tree products. The project focuses on multipurpose tree species. It is funded by the U.S. Agency for International Development. The F/FRED Project was approved as a global one to provide funds for and promote networks dealing with research on all aspects of multipurpose tree species. However, the first phase (1985-90) focuses only on Asian countries. The three year review of this project has just been completed. In general, it received a favorable review, although some areas of needed improvement were pointed out, e.g., in the area of socio-economics research.

ASEAN-US watershed network. This USAID sponsored network involves organizations in Indonesia, Philippines, Malaysia, and Thailand in improving

watershed management in the region. Part of its interest is in fostering expanded, productive research and disseminating results from such research.

French funded/FAO executed network project (GCP/RAF/234/FRA). The project is in the development stage. The basic question addressed in the first stage is: what government input and external assistance is needed in order (i) to meet the internal demands for reproductive materials for forestry development projects, and (ii) to genetically improve and conserve the most promising species. Project proposals have been prepared in 14 countries. A regional program for 9 CILSS countries has been prepared in close collaboration with the SPDC. Two workshops are planned for late 1989 and early 1990.

CTFT (Centre Technique Forestier Tropical, France). CTFT has put emphasis on watershed management in Africa in recent years, especially in Madagascar and Burkina Faso. Also, watershed management work is sponsored in French Guyana. Results have potential application in many areas of the Amazon.

IUFRO/SPDC. Some of the SPDC's problem identification and definition work in Africa, e.g., that associated with silvi-pastoral management research in Sahelian and North Sudanian Africa, complements the work of ICRAF. Also, much of the networking activity dealing with multipurpose tree species fits in directly with the broader objectives for agroforestry and tree improvement research as put forth by the ITFTFR and Bellagio Forestry II participants. One concrete outcome from a SPDC workshop in Nairobi in January of 1986 is a networking project among 17 countries in Sahelian and North Sudanian region of Africa. This is briefly described below.

2. Natural forest conservation and management

About one-fifth of the land area of the world is covered with tropical forests and woodlands. Yet, these forests are disappearing at the rate of more than 11 million hectares per year. A major expansion in research is needed to understand better the nature of tropical forests, what their destruction (or what their conservation) means to the welfare of the world, and how these forests can be managed to provide goods and services on a sustainable basis.

The research

Need for research in this area has been documented in some detail in the ITFFR report and accompanying background papers. Priority research areas identified within this category are as follows:

Animal and plant species identification and classification, and ethnobotanical research, with an emphasis on human uses of the various species from the tropical forest. It is estimated that less than 20 percent of the animal and plant species of the tropics have been identified and only a small proportion of the known species have been investigated in detail.

Management for nonwood products, with an emphasis on how local management for these nonwood products can be integrated with sustained yield timber management and

with broader-based management for the conservation of biological diversity and maintenance of the tropical forest gene pool.

Wildland management for wildlife. Here we emphasize the need to consider wildlife management both in terms of conservation and maintenance of endangered species and in terms of wildlife for food, which is extremely important in many parts of the tropics. (In a number of countries, well over three quarters of the animal protein consumed by rural inhabitants comes from game or bush meat derived from natural forests and woodlands).

Management for sustained yield wood production, with an emphasis on maintenance of forest quality and biological diversity within the natural, managed forest. Major efforts are needed in the areas of inventory/remote sensing and monitoring. Research on forest protection is also needed. Emphasis should be given to the ecological foundations on which to base sound, sustainable management practices.

Examples of productive research in these subject areas are presented in Annex 3.

Key organizations and networks include:

World Wildlife Fund Network. This network, consisting of some 23 national organizations and 2 associates, collectively has put into action more than 4,000 projects in some 130 countries. Many of these projects involve research components related to conservation of biological diversity in tropical forests and other aspects of natural tropical forest management. The organizations involved have annual budgets that total over $85 million per year. Since its founding in 1961, it has evolved an effective means to draw on a global network of scientists and conservationists.

IUCN (International Union for the Conservation of Nature and Natural Resources). The IUCN funds a variety of research dealing with aspects of natural tropical forest conservation and management. Specific projects have dealt with wildlife issues, deforestation, non-timber outputs, and so forth.

CATIE has been studying forest management in secondary forests and in mountain forests. It has a regional project financed by the Scandinavian countries with the participation of the IUCN for the management of protected forests.

IUFRO/SPDC has held several workshops in Africa to identify priority problem areas for research. These workshops have led to the implementation of FAO project GCP/RAF/234/FRA, discussed above, which includes a research network proposal on silvi-pastoral management of natural forests in Sahelian and North Sudanian Africa.

CTFT (Centre Technique Forestiere Tropical). CTFT and Cote d'Ivoire have been doing research on alternative natural forest management systems since 1976. The program has been extended to Central African Republic and to French Guyana.

Tropenbos. This programme, initiated by the Netherlands in 1986 with a global mandate, has the goal to conserve, develop and manage the humid tropical forests through research, education and training. Tropenbos is directed towards providing

quick answers to fill gaps in existing knowledge. The status of this program is unclear at present.

Other groups or networks which bear mentioning include: FRDC (Forest Research and Development Center) in Bogor, Indonesia, FRIM (Malaysia); FORI (Forest Research Institute), Los Banos, Philippines, Kasetsart University in Thailand, INPA in Manaus, Earthscan/IIED in London; the Ordinariat fur Weltforstwirtschaft in Hamburg (Brunig), the ITF (Institute of Tropical Forestry of the U.S.Department of Agriculture, Forest Service), Puerto Rico, IICA-TROPICOS network for the Amazon, headquartered in Brazil, R3S (Research network on resistance to drought) operating in a number of African countries with support from research institutions from Belgium, Federal Republic of Germany, France and Netherlands.

3. Tree breeding and tree improvement research

Forestry is still dealing with wild populations of tree species. In this sense, it has a long ways to go to catch up to agriculture. But what this also means is that low cost provenance trial research can have major payoffs in terms of yield increases in forestry. Indeed, this was amply documented in the ITFFR Report and accompanying background reports.

The research

Major areas of priority identified by the ITFTFR include:

Selection and improvement of multipurpose tree species, with particular emphasis on species which can be used within agroforestry systems and by rural communities in meeting their basic needs, including fuel, fodder, food and construction materials. A major focus should remain on nitrogen fixing species. Work on salt and stress tolerance in dry zones should be continued.

Selection and improvement of fast-growing industrial tree species, with an emphasis on species adapted to particular agroclimatic conditions and product needs. Work on eucalypts, pines, rubber and other well known producers should continue.

Tree and stand establishment and management, with emphasis on establishing trees on adverse sites, improving nursery practices, afforestation and reforestation technologies; also research on development of growth and yield models.

Vegetative propagation as a tool for reproducing clones derived from improved species. This is a critical area of research in West Africa and other regions.

Identification, conservation, collection and storage of germ plasm. While much work has been done in this area, much more is needed to insure an adequate supply of germplasm.

Examples of productive research in these subject areas are presented in Annex 3.

Key organizations and networks.

This is probably the most highly developed area of research in terms of organizational commitment, focus of organizations and in terms of results. It is difficult to limit the examples, since there are many good ones. However, the following illustrate some of the successful models which have evolved over the past few decades.

CATIE. Tree selection and improvement have been areas of concern for a number of years. Currently, CATIE is working in this area through the MADELENA (multipurpose tree species) project funded by USAID. It also is working in improvement of nitrogen fixing trees and is working with selection and improvement of economically valuable species and in the development of seed stands all over Central America. CATIE receives support for this work from USAID, NORAD and other groups. (Details on the MADELENA network project are given in Annex 2).

NFTA (Nitrogen Fixing Tree Association). The network activity managed by NFTA is an extremely effective one for the level of funding involved ($350,000 per year for research, education and extension involving over 3,000 associates in more than 100 countries). NFTA relies heavily on a scientist to scientist network (as opposed to an institutional network where organizations make up the members). In the NFTA network, scientists working on research related to any aspect of NFT's interact directly. The network activity is expanding.

IDRC sponsored Bamboo/rattan networks. The International Development Research Centre (IDRC) of Canada funds and provides technical support for two forestry research networks, one dealing with Rattan and one with Bamboo. The Program Officer closely supervises and monitors research activities funded and carried out under the program. Canada provides about $2 million a year in support of the two networks.

The IDRC networks have evolved slowly from a small beginning. The two networks now include 16 separate research projects, involving scientists from several Asian countries. Individual scientists are provided with funding to meet specific needs. Work is monitored frequently by an experienced program officer. Periodically, major regional meetings are held to bring together researchers within each network to discuss progress, problems, and research priorities. For example, meetings of the rattan network were held in 1984 & 1987.

Tropical Pine Provenance Research Network. This network, coordinated by the Oxford Forestry Institute has proven to be an effective and active network that involves numerous functions associated with research on, and development of, tropical pines (see fig.1).

CAMCORE (Central American and Mexican Cooperative in Conifer Resources). This is a cooperative network founded in 1980 and managed by the North Carolina State University. It includes major companies, as well as CATIE and SAFRI). Members establish seed provenance trials and are involved in training activities. It is moving into broadleaved species.

DANIDA Forest Seed Centre (DFSC). Network contacts extend to some South East Asian and African countries; it also has close links to FAO. It has training courses,

evaluates internationally coordinated provenance trials and seed collection for establishment of seed stands, pilot plantations, and gene resources conservation.

SPDC. This is the area in which the SPDC has been most active. Annex 1 provides the details on what it has been doing in this area. The 1984 Kandy workshop on multipurpose tree species research contributed to the establishment of the F/FRED project, discussed above. The two Nairobi workshops (1985 and 1987) have led to the formulation of two concrete research network proposals with accompanying country level proposals.

CSIRO. This organization has a long experience working with developing countries in the distribution of seed for research work. Its Tree Seed Center has developed through its SATDC (Seed of Australian Trees for Developing Countries) project a number of other activities such as training in the field of seed technology.

CTFT. CTFT has since the fifties collaborated continuously in forestry research with a number of French speaking countries in Africa. Implementation of the CTFT tree improvement program has permitted it to set up close collaboration with FAO and organizations such as CSIRO and to develop cooperation between the African countries concerned.

4. Utilization and market development research

Forest products and wood utilization research is traditionally associated with the private sector and the forest products industry. However, there is ample scope for the public sector to become involved in utilization research more broadly defined to include non-wood forest utilization and nonindustrial wood utilization. Research in this area is critical in terms of switching from utilization of the natural tropical forest to utilization of managed plantations. Further, recent studies sponsored by the FAO indicate that in many countries, forest and tree based small scale enterprises provide the major source of off-farm employment in rural areas. Thus, in areas where employment creation and maintenance are major social goals, the public sector has a direct interest in forest and tree utilization research.

The research

Priority areas put forth by the ITFTFR include:

Utilization of lesser known species and nonwood products from the tropical forest, with particular emphasis on utilization technologies that can be widely disseminated and utilized by local communities, given their skills and factor endowments. Wildlife also included in this category.

More complete utilization of currently commercial species. There are significant opportunities to reduce roundwood requirements by finding means to more completely utilize those tree which are harvested.

Research to adapt already existing technologies to local conditions and to improve production efficiency (greater utilization of existing capacity and higher yields). The ITFFR Report indicates a number of important technologies that are ready for adaptive research in developing countries.

Local market studies and research on market structures and functioning.

Small scale industrial organization and management.

Technology for utilization of plantation timber (small sizes, young trees)

Examples of productive research in these subject areas are presented in Annex 3.

Key organizations/networks

This is an area of research where there are few operating networks, yet great opportunity to gain from such networking. Examples of organizations which could lead in the development of such networks are:

FRIM (Forest Research Institute of Malaysia). FRIM has a reputation for solid work in the forest products area and has accomplished a lot in terms of utilization of commercially lesser known species. FRIM scientists also have an interest in non-timber products utilization, a topic which is becoming of much wider interest and links with research area 3 above.

FRIN (Forestry Research Institute of Nigeria). FRIN is one of the oldest research institutes in West Africa. It has taken the lead in developing the use of lesser known species (LKS)in its region. FRIN participates in a number of international networks, although none in the utilization area.

Forest Products Research and Development Institute/Los Banos, Philippines. This organization has a long standing reputation as a solid research organization in the forest products area.

IPT (Instituto de Pesquisas Tecnologicas). This Brazilian organization has taken the lead in recent IUFRO/SPDC work to identify priority research topics and to mobilize networks in the forest products utilization and marketing areas.

INPA (Instituto Nacional de Pesquisas da Amazonia. This is the Brazilian national institute for research on the Amazon. It has an active program of research and networks quite extensively with scientists in other countries. It could well serve as a lead organization for research related to Amazonian development.

IUFRO/SPDC. The SPDC has collaborated with IUFRO Project Group 5.01 in carrying out two workshop/meetings in South America to explore possibilities for research networks in utilization. One proposal for such a network is ready to be considered for funding.(EXPAND)

Other organizations which bear mention include: CTFT, FPL (Forest Products Lab/USDA, Forest Service); CTB (Centre Technique du Bois et de l'Ameublement, Paris).

5. Policy and socio-economics research

Experience from the 1980's has clearly indicated that policy interventions will be critical elements in a strategy to stem tropical deforestation and improve land use and watershed management. Many of the most significant interventions will involve policies outside the forest sector.

Table 2 provides an overview of the main TFAP related policy issues that need to be addressed by researchers. Annex 3 provides examples of productive research in the above subject areas.

The research

Priorities within this category of research include:

Promotion of small-scale sustainable industry, with an emphasis on the relation of raw material supplies to employment creation

Potentials for increased government rent capture for utilization of natural tropical forests, with an emphasis on how such increased rent capture can be tied to increasing the sustainability of natural tropical forest management.

Policy reforms to promote reductions in deforestation, including study of both the direct impacts of policies in the forestry sector and indirect impacts from policies in other sectors such as agriculture and energy; this also includes research on the viability of the institutions dealing with the issues identified in the TFAP.

Common property management associated with forestry

Understanding better the incentives which motivate smallholders to grow trees, with emphasis on the effectiveness and efficiency of alternative incentive mechanisms designed to stimulate local participation in tree growing and conservation activities.

Integrated watershed management research, with emphasis on systems studies of integrated watershed management to reduce on-site and downstream damages from erosion, stream flow alterations and water pollution. Much of the research needed relates to policy options and tenure and incentive mechanisms to encourage sound land use. Questions of economic viability also need to be addressed.

Key research organizations/networks

This is an area of research where it is difficult to identify key organizations, since much of the productive research is carried out by individuals within universities and other institutions that cannot as "organizations" be characterized as strong in the area of forest policy and related research. Any coordinating mechanism developed in the future should have the capacity to identify and mobilize individual research talents in an effective manner. One model for doing so is the recently established $1 million dollar grant program of the Rockefeller Foundation through the Osborne Center for Economic Development (World Wildlife Fund/Conservation Foundation). In a coordinated fashion, it provides grants for individual researchers to pursue research on priority policy related topics.

Table 2. TFAP Policy and Economics Related Research Needs in Relation to the Recommendations of Bellagio I[1]

TFAP areas of concern[3] / Bellagio I Recommendations[2]	A Forestry and Sustainable Agriculture	B Fuelwood	C Protection of Tropical Forest Ecosystems	D Forest Industries
1. Quantifying the costs of inaction	-economic interrelationships between trees and sustainable agriculture -benefits and costs foregone -watershed management benefits	-potentials for subsitute fuels -effects of overexploitation for fuelwood	-losses being incurred due deforestation and degradation -costs of action -appropriate distribution of costs	-opportunity costs, e.g., imports vs. domestic production
2. Incorporating recommendations for action into national development plans	-relating TFAP activities to national development goals -institutional mechanisms for incorporation	-relate fuelwood to national energy plans, needs, sources	-agricultural and other policies in relation to forest protection goals -quantifying the benefits of protection to the nation	-understanding the role of industry in national development -role of small scale labor intensive tree-based industry
3. Promoting community participation	-alternative incentive policies and mechanisms (including both market and nonmarket ones) -role of different groups	-energy pricing policies -alternative incentives -fuel conservation policies and programs	-role of conservation NGO's -world community role	-role of cooperatives and local community business -employment policies
4. Encouraging private sector participation	-appropriate market policies and regulatory mechanisms -developing extension capability	-energy pricing policy -fuelwood market rationalization -loans and subsidies to encourage action	-agricultural reform policies (subsidies for land settlement, etc.)	-incentives for sustained yield management -market research -pricing policies -small scale industry development
5. Policy reforms	-land use regulations -land and tree tenure policies -pricing policies -administrative reforms	-energy pricing policies -tenure reform -role of government and regulation and subsidization	-alternative agricultural taxation policies -land tenure reforms -buffer zone policies	-stumpage pricing policies -concession policies -timber trade policies (logs vs. processing; export pricing, taxes, etc.)
6. Protecting tropical forests	-land settlement policies -role of agricultural or land use intensification	-alternative fuel potentials -policies regarding harvest, e.g., savanna woodlands	-policies regarding reserves parks, etc. -determining critical minimum size reserves	-concession policies -economics of nondestructive, sustained yield management
7. Integration of forestry into broader land-use concerns	-policies and administrative reform for closer integration of forestry and agriculture	-energy conservation policies -administrative coordination of energy policies and programs	-alternatives for developing buffers around reserves -expanding nondestructive uses of forests	-haromonizing industrial use of forests with other uses -sustained yield forestry areas as buffer zones
8. Monitoring of tropical deforestation	-monitoring role of on-farm vegetative barriers in slowing down desertification and deforestation	-role of fuelwood in deforestation vs. degradation of tropical forests	-how to use monitoring results in more effective ways -how to develop better early warning signals	-impact of industrial development on deforestation and forest degradation

1/ Each item in the body of the table should be prefaced by: "Research is needed on..." followed by the item in the table. It should be noted that many of the items listed require a synthesis of policy, economics, and technical research in order to reach answers that productively can be used in operational planning and decision making.

2/ Recommendations 8 (strengthening research), 10 (coordinating international action) and 11 (follow-up) are not included, since they are subsumed under items in the body of the table.

3/ The fifth TFAP area of concern, institutions, is subsumed within the body of the table, i.e., institutional development is assumed to be part of the solution for resolving issues related to the other areas of concern.

There is little networking that is going on at present in forest policy research, although for some particular policy research needs, there are some good opportunities to benefit from networking, for example, policy and economic issues related to incentives, public policies affecting deforestation, and policy and economic issues related to agroforestry. Some of the organizations with future potential include:

EAPI (East-West Center, Environment and Policy Institute). The EAPI has a broad network of collaborators throughout Asia that work on policy problems of common interest, including agroforestry, social forestry, watershed management, deforestation and so forth. It also is involved in extensive training activities, including in the area of policy research. It has a relatively large staff of natural resource professionals, most of whom carry out research related to forestry in the TFAP context. EAPI is funded primarily by the U.S. government, with additional support from private foundations and other contractors.

WRI/IIED (World Resources Institute/International Institute for Environment and Development). This group already has carried out significant policy research related to tropical deforestation and management and NGO's in the forestry sector. Much of the work was done with twinning arrangements between WRI and a researcher in a developing country. WRI/IIED is funded mainly by private foundations, although it also has contracts with government and international agencies.

CATIE is doing intensive work on incentives in the Central American region and will begin similar work in the second phase of its watershed management project.

Two research related information networks include:

Social Forestry Network. This network, headquartered in London, is an information network for individuals interested in social forestry. Funded by the Ford Foundation and the Aga Khan Foundation, it is housed in the Agricultural Administration Unit of the Overseas Development Institute, London. The SFN publishes a periodic newsletter, distributes key research papers on social forestry to its list of more than 800 members (as of 1987), and publishes a register of members. About 45% are Third World members and 55% are First World members.

Common Property Resource Network. The Common Property Resource Network seeks to disseminate information dealing with common property resources, their management, and policies related to their use, and to foster communication between professionals such as policymakers, administrators, researchers, and educators. The CPR Network is administered by the University of Minnesota's Center for Natural Resource Policy and Management, with the active collaboration of the Board on Science and Technology for International Development (National Academy of Sciences).

Other organizations which bear mentioning include: Institute of Development Studies (IDS) University of Sussex; Forestry for Sustainable Development Program, University of Minnesota; Resources for the Future, Inc. a nonprofit private foundation in Washington; Harvard Institute of International Development; Oxford Forestry Institute.

IV. ON-GOING TRAINING AND EDUCATION PROGRAMS RELEVANT FOR FORESTRY RESEARCH

Training and education for forestry research has not been widespread in developing countries and has mainly been on an ad hoc basis. Many forestry researchers from these countries receive their education from developed country institutions (ITFFR questionnaire results). Many of these educational institutions have neither the experience and knowledge nor the interest in research problems facing developing countries.

A few specialized workshops and short courses have been conducted by the SPDC, FAO, OFI, IITF/USDA and universities in various countries. Funding has been very limited for this type of activity. In some cases, forestry researchers benefit from courses and work done by groups such as ISNAR, EDI/World Bank, and other groups focusing primarily on agricultural research management in developing countries.

FINNIDA, under its Forestry Training Program has been putting on short courses in forestry research management for english speaking countries. CATIE every year has two activities, one a short course (3 months) on methodologies in agroforestry research and one hands-on, in-service training program for agroforestry research. Both activities are presented in Spanish.

V. FOCUSING ON THE CONTEXT WITHIN WHICH THE PANEL REPORT SHOULD BE CONSIDERED

The present discussion of priority forestry research areas and the organizations doing research in these areas is a first step in moving toward decisions on how to mobilize and effectively utilize expanded funding and support for forestry research. Such an expansion has been called for by a number of donors and international groups in order to address critical global and local problems. The question is how to achieve the expansion most effectively.

While the Panel has not been asked at this time to propose any specifics on how to achieve effective results, we do feel it desirable to set forth as clearly as possible our interpretation of the context within which decisions need to be made.

As a panel, we have developed a preliminary perspective on some of the main institutional options that might be further examined by the TAC. Clearly, the various options will need much discussion by TAC before any institutional analysis is undertaken and decisions are made.

One option the Panel believes is not appropriate at this time is the development of a large new international center similar to IARC's such as IRRI and CYMMIT, with their focus on a single crop and emphasis on plant breeding.

The reasons for rejecting this option are the following:

** there are major differences between agricultural food crops and forestry outputs which argue against establishing such large, highly focused research centers for forestry; for example, forestry has:

* much smaller available national research workforces to do in-country adaptive research;
* wider variation in biological/environmental conditions which must be considered in order to make progress; and
* greater variation in research issues which need to be addressed (in a coordinated fashion) to tackle effectively key forest resource and land use related problems such as deforestation and loss of biological diversity, watershed deterioration, fuelwood scarcities, and so forth.

** in any case, given current funding possibilities, it is unrealistic to propose building and implementing major new international or regional forestry research centers similar to the existing IARC's.

Suggested strategy

Given the well recognized weaknesses in national forestry research capacity in many developing countries, a realistic approach to expanding productive forestry research must involve a combination of efforts to strengthen local research institutions. Activities should include support for national forestry research centers and the building up of regional support mechanisms such as networks and existing international and regional research organizations so they can produce results that are adaptable in specific country situations.

The Panel believes that if a centralized system such as the CG is to effectively get involved in this type of support activity, then there also will be a need for a central, international mechanism for forestry research to provide for priority setting, coordination of proposals for funding and funding distribution, and monitoring of research results and progress. Such functions are needed by the CG in order to make decisions regarding the most productive allocation of resources over time.

The Panel believes that this type of strategy is a realistic one that the TAC/CGIAR should consider. If a decision is made to expand into the forestry research area, then three elements of support need to be considered in looking at institutional options to implement the strategy. In the view of the Panel, these elements and the functions which need to be considered within each are:

1) establishing an international mechanism:
   * to help establish broad areas of research priorities and to assess the potential gains from research in each;
   * to mobilize expanded funding for forestry research in the priority areas of research;
   * to facilitate identification and establishment of research networks;
   * to act as a broker between networks and potential donors;
   * to encourage communication and links between networks, including those working in different priority research areas; to build up information networks;
   * to provide overview, coordinating, and monitoring functions to insure relevance, quality and continuity in programs and reliable assessments of programs for donors; and
   * to organize international training activities

2) building productive research networks and supporting expansion of some existing international and regional research centers:
   * to help focus on specific priority problems and topics;
   * to help get needed research done;
   * to mobilize and develop complementary research talent and capacity;
   * to mobilize existing knowledge (research results) more effectively through extension or outreach programs;
   * to organize the training of research personnel and to organize information and documentation services;

3) building up and strengthening national research capacity
   * to deal effectively with the priority issues associated with each country's forestry situation and its links with other sectors; and its link with other countries;
   * to provide means for adaptive research needed to apply locally the results from international and regional research centers and from networking activity;

The Panel believes that the CG system could provide an appropriate vehicle for implementing this strategy for action.

The on-going forestry related work being done by some of the existing CG centers, such as IITA, ILCA, ICRISAT, IFPRI, CIAT, and IBPGR provides strong support for other research going on, particularly in areas such as agroforestry. The future activity of these centers could be coordinated with research by such non-associated centers as ICRAF,

one of the centers being reviewed by TAC. ICRAF is an example of an international organization that would fit into category 2) above.

The IUFRO/SPDC has put forth plans for evolving into an autonomous and expanded tropical forestry research center or council which could serve as the international mechanism mentioned in category 1) above. The appropriateness of the SPDC plans in terms of any forestry involvement in the CG would have to be studied in detail along with the other institutional options available.

Future action

The Panel sees the present paper as providing TAC with some of the background information needed to deal with some specific issues which arise because the CGIAR is not in a position to take on all the required forestry research. In the view of the Panel, major questions to be addressed are the following:

* there already is on-going, albeit limited, forestry related research in existing IARC's; should that work be expanded within the CG system?

* should the CG take on other priority areas of forestry research? If so, which areas, and to what extent?

* how should the existing areas and any newly chosen areas be integrated into the system in terms of institutional mechanisms? Should it be through existing IARC's, through other organizations, support of formal networks, or through some combination of the above?

When considering forestry within the CGIAR, the broader context of forestry research must be kept in mind. If forestry becomes a part of the CG, the question of links with the work of the non-CG forestry research community and the funding efforts of that community will become a critical consideration. A particular concern is that CG involvement not lead to reduced support for the work going on outside the CG system.

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ANNEX 1

NETWORKS AND FORESTRY RESEARCH: SOME COMMENTS

Introduction

Networking has become quite widely used in forestry research (Burley 1989). In approaching research networks for forestry we perceive the need to follow the basic principles that have governed successful research networks in the past.

The principles for success of networks, as reviewed by Plucknett and Smith (1984) with additions by Burley (1985), can be summarized as follows:

(i) The problem must be clearly defined and a research agenda agreed upon
(ii) The problem should be common to several participants
(iii) Strong self-interest must exist in each collaborator
(iv) Outside funding should exist at least for the birth and initial functioning of the network
(v) Staff must be sufficiently trained and expert to make significant contributions
(vi) Strong leadership is required, having the confidence of all the participants in a network
(vii) Information should be shared among all collaborators through a range of media
(viii) Participators should develop mechanisms for the extension of research results to the eventual user
(ix) Networks should not be considered permanent institutions but should show flexibility to cope with the range of skills and requirements of the participants.

Four types of research networks are used in forestry:

- information networks
- networks of research projects or activities
- research project networks of decentralized type
- research project networks of centralized type.

The following features can be used to define the different types of networks: objectives, principal activities, participants, participation intensity, participation bases, number of members, costs and investments, principal products.

Each network has its own unique features and, thus, does not necessarily fit exactly in one or the other type defined here, but an attempt is made here to classify existing arrangements according to their principal features.

Information networks

There are many information networks dealing with forestry. Two groups characterize the type very well: the working groups of IUFRO and the FAO networks like the Dendroenergy Network, the Agroforestry Network, the Watershed Management Network operating separately in each of the regions. The Social Forestry Network can be considered in this group. General features include:

- The objective of this type of network is to exchange information among institutions and/or individuals that are working on research related to a specific problem or discipline of forestry.

- The principal activities are newsletters, periodic meetings (regional or global depending on the scope of the group), direct information exchange between particular members and technical consultations using the expertise of some of the members (in the case of the FAO networks).

- The participants operate as individuals (IUFRO networks) or on an institutional basis (FAO networks).

- The intensity of participation depends on the interest of the individual members. Participation in the network is flexible because it does not involve any type of agreement, contract, or formal interaction.

- The number of members is variable depending on the subject and level of interest. Some are quite large.

- The cost of the network to members is low, normally only a membership fee (IUFRO), or even nothing (FAO). Operating costs are only the ones associated with the participation in the meetings (daily allowances, travel expenses). In the case of the FAO networks, the technical consultations take place sharing the costs.
- The principal products are proceedings of meetings, newsletters, reports of expert panels and the personal and institutional linkages created in the group.

Networks of research projects

This type of network, in the case of forestry, normally is based on an evolution of an information network. Examples of the type include: IUFRO Working Party S 2.02-13 on Sitka spruce provenance and breeding, and OFI network for species and provenance trials, and the NFTA. These are networks of researchers working on research projects with a common theme.

- The objective of this type of network is to link research projects or groups of trials of the same nature and give them a general orientation, support, and in some cases combined analysis of data. Many of the IUFRO working parties begin as information networks and evolve to networks of research projects.

- The principal activities depend on the wishes of the participants. In many cases they involve collection of germplasm, or installation of species trials. Most have special meetings and make consultations and exchange information.

- Normally, there are two groups of participants: a leading institution and the rest of the members. In the OFI network the lead is taken by the Oxford Forestry Institute. In the Nitrogen Fixing Trees Network, the leading institution is the University of Hawaii. The leading center normally is responsible for the collection and distribution of research material. It also proposes research methodologies and often undertakes

the combined analysis of information. The rest of the members take care of the costs of their operational activities and contribute to shared costs.

- The commitment to participation by the members is greater than in the information networks, because a concrete task is underway: real field experiments in most cases.

- Participation obviously is voluntary. Normally, the leading institution is handling a significant portion of the experiments because of its own interest in the subject. The rest of the institutions are participating on a voluntary basis and their activity depends on interest, budget, and continuity of personnel.

- The number of members in this type of network is variable.

- Normally there are no fixed fees involved. Costs borne by members are for installing and maintaining experiments, and processing and distributing data.

- The principal products are research results, cooperative and individual publications, research methods and the information and contacts between participants.

Research project networks of decentralized type

In the decentralized project network, each institution operates within its own traditional structure on a common problem. A leading institution is selected to coordinate research on a common problem by the members of the network. The member institutions define a project and then agree on what part of the project for which each of them will be responsible. The distinction between this network type and the previous one is that the project is commonly defined and parts are assigned to network members, while in the case of the network of research projects, each member undertakes all the parts of the research on the problem that is common to the members.

An example of a project network of decentralized type is CAMCORE, a cooperative that preserves germplasm of conifer species in Central America and Mexico. Another example is the F/FRED project for research in multiple purpose trees in Asia (at least in the initial stage).

- The objective of this type of network is to conduct jointly a specific research project normally covering coordinated activities in many countries.

- The principal activities of the network are to install, maintain and measure experiments, to process information for each experiment and for the continuation of experiments, to train people and to disseminate results and in certain cases to strengthen institutions.

- Participants in this type of network include a strong leading institution or an organization created especially to run the network and institutions conducting the research in the field. In the case of CAMCORE, the leading institution is the North Carolina State University and the members are major forestry companies in the USA and Latin America; all institutions are strong and have research units. In the case of F/FRED, Winrock (the executing organization) undertakes project coordination and

the participants are official forestry research institutions in Asia (not all of them are strong).

- The intensity of participation is high. Normally the research project is central to each one of the research units of the participating institutions. All the members of the project are relying on each other.

- The leading institution has a vital role in the coordination of activities and in the processing of information. In CAMCORE and F/FRED, each institution processes its own information, but in the leading institutions there is a unit that integrates information in a data base. Participation normally is established with a formal agreement between the institutions to accomplish certain objectives.

- This type of research project network includes only a few, limited institutions or organizations or companies that must be really interested in the research project. It should occupy a high priority among their research activities.

- This type of research project network can have a high cost, because they are not only networks, but networks resulting from a research project. The costs include the experiment installation, maintenance, data collecting, data processing, data base structure and functioning, training activities, meeting of different types, such as coordination meetings, technical meetings, publications, and so on. The costs may be shared by the project participants (CAMCORE) or can come from a donor agency (F/FRED with USAID funding).

- Products of this type of network are research results, a data base, publications, trained people, and more important a technology to solve a specific problem and strengthened institutions.

Research project networks of centralized type

A centralized project network involves a structure that is specially defined for the project purpose. A leading institution coordinates the activities and sets outposted personnel in each of the participating institutions or countries.

As examples of this type of research project are the MADELEÑA project in Central America and the agroforestry network AFRENA being developed by ICRAF.

- The objective of this type of network is to execute a research project with clear, specific objectives and a completely defined logical framework. Through the project the involved institutions develop particular technologies, disseminate them, train personnel and develop common research.

- The participants are a leading institution (in the mentioned examples CATIE and ICRAF) and a number of national research institutions. Normally the leading institutions are strong ones relative to the other participating institutions.

- The participation intensity if very high. The leading institution has a central staff and outposted personnel in the participating organizations. The project has a

common working plan and common research methodologies that should be followed by all participants.

- The bases for participation are inter-institutional agreements that to a large extent oblige the participating institutions to accomplish the working plans. The project paper and the working plans are participatory exercises that guarantee that the interests of all parties are well covered.

- The number of members generally is small, due to the high intensity of participation and work and to the difficulties that arise for coordination of a too big group of institutions and the associated costs.

- The costs of a research project network of this type are high because the group is doing research directly and because there are many activities related to institution building, like infrastructure (vehicles, instruments), education (fellowships), training (short courses, in-training services) and others.

- The principal products of this type of network are technology development, disseminated results and strengthened institutions. This type of network is most appropriate to deal with weak institutions where institution building is as important as the results of research.

Lessons learned from a regional, centralized research project network: The "MADELEÑA" project network

The case of the MADELEÑA project in Central America is used as an example of a centralized research project network.

CATIE is a research and training center in agriculture and natural resources for Central America. It has evolved since 1942 and, from the very beginning, has been one of the few institutions that integrates agriculture and natural resources in research, education and training. It also is one of the few subregional institutions with a wide mandate (not only a crop or crop group). Member countries include those of Central America and Panama. Researchers and students are recruited internationally.

In the area of natural resources, CATIE has many research projects such as the Regional Tree Crops Production Project (MADELEÑA), the Regional Watershed Management Project and the Regional Project for the Management of Protected Areas. A proposal for a regional project in Natural Forest Management is now being negotiated.

Background of the MADELEÑA project: In 1980 a regional project began in Central America under the name: Fuelwood and Alternative Sources of Energy. The project had two main directions. One oriented to the technology of fuelwood transformation into energy, and the other oriented to investigate the most appropriate species for fuelwood production in Central America. This second part of the project was financed by USAID/ROCAP and executed by CATIE in collaboration with the national forestry institutions of six Central American countries (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama). The project ran between 1980 and 1985, and tried about 150 different species for fuelwood production with a life zone approach. Soon

after the beginning of the project it was clear that the farmers of the region needed not only fuelwood, but many other products and also agroforestry systems in order to have returns and to have a sustainable agriculture. Considering this expanded scope, a new project was designed to run between 1986 and 1991: the Tree Crops Production Project or "MADELEÑA" project.

Objectives of the project: The purpose of the project is to improve the conditions and income of small farmers and to stop the deterioration of soils, through the incorporation of multiple use trees in farms.

The purpose should be achieved by strengthening the capabilities of CATIE and national level forestry, agricultural and educational institutions in Central America and Panama; and to develop, access, promote and disseminate on-farm, market-oriented tree cropping technologies.

The final beneficiaries of the project are the small farmers of the region and the counterpart institutions, mainly the forest services of the Central American countries. The project works also with the universities and with many official extension organizations and private groups in each participating country.

Organization of activities: The project functions as a research project network of a centralized type. Agreements were signed between CATIE and each one of the national forestry institutions in Panama, Costa Rica, Guatemala, Honduras and El Salvador. CATIE has a central staff at the headquarters consisting of a regional coordinator and silviculturalist, economists, sociologists, extensionists and data base management specialists. There are two outposted CATIE staff in each country, one silviculturalist and one economist. The project functions within the research unit of the counterpart institution. The relation between CATIE's personnel and national personnel in the countries is between 1:4 and 1:8. In each country there is a project committee. The project paper was prepared together in a participative form, as are the yearly working plans and budgets. Each quarter there is a regional meeting to review the status of the project or to discuss special aspects that are relevant at the time.

The project and the national institutions are contributing in balanced form to the needed resources in each country and there is strong support for all countries through CATIE's project staff and resources.

The most important results: The project has three components: research, dissemination, and training and education. The major achievements of the project will be described by component (see table below).

(a) Research

The principal products of the project are the creation of a research capacity in the national institutions, the development of a data base with silvicultural and socioeconomic information, the improvement of the germplasm base for reforestation, the development and improvement of existing incentive programs, and the identification and preparation of reforestation projects.

(i) Silvicultural research

- A regional silvicultural research program was developed for Central America and Panama. Common research standards and procedures were developed.

- Species selection: starting with 150 species, 14 more promising species have been selected.

- Trials have been made in species selection, provenances, nursery techniques, planting techniques, coppicing, pruning, thinning and yield plots control. Also, agroforestry systems are being studied.

- All experiments were installed according to ecological zones and priority areas in terms of needs for trees.

- There is now an experimental and demonstration plots network of more than 500 units throughout the region.

- Yield models for the 14 main species are being developed.

- A network of seed stands of the principal species is under management and producing seeds.

- One of the biggest data bases for trees in the world, the MIRA (Information Management on Tree Resources) system has been developed, with information on more than 6,000 plots, including seeds, soils, climate, treatments, dendrometry, and yield data. Standardized data collection procedures have been developed that are in use in all the countries.

(ii) Socioeconomic research

- Economic analyses of reforestation cases and projects are being made.

- More than 200 reforestation activities have been assigned in terms of yields and costs.

- Product identification and market studies for forest products in each country are being conducted.

- Attitudes of farmers to trees and reforestation are being determined.

- Studies of success and failure of social forestry projects in each country are being conducted.

- Demonstration farms are being established and analyzed in all the countries.

- Incentive policies for reforestation have been implemented or are being prepared in all the countries.

- Large social reforestation projects are being prepared to transfer the technologies of the project.

(b) Dissemination of the results

In all the countries the species and reforestation techniques of the project are being used by small farmers.

- A regional dissemination strategy was developed with central and national elements.
- Field days in demonstration plots and demonstrative farms are being conducted.
- All types of publications for different audiences are published.
- Audiovisuals and training materials for the dissemination of the developed technologies are prepared.
- The national institutions and private sector are contributing to the extension effort.
- Radio and television coverage is available for the project events.

(c) Training and education

A critical mass of well trained technicians is now available in the countries to support reforestation programs and projects. Many training activities are transferred to the national institutions. The quantity and quality of research in multiple purpose trees has been increased.

- A masters degree program in CATIE in silviculture, management and economics is operating.
- Teaching materials for the courses are prepared.
- Short courses at CATIE and in the countries related to the silviculture and economics of multiple purpose trees are being implemented. More than 10,000 man days of training have been accomplished.
- Collaboration exists with the national universities to transfer the training activities.

Relations with other projects: MADELEÑA has contacts with projects and institutions at international level like IUFRO, CAMCORE, ICRAF, F/FRED, CARE, and others. It also has strong linkages with many national projects in the countries. Many activities are conducted in a cooperative manner through exchanging information and experience.

Conclusions for a Research Strategy

The MADELEÑA Project includes some elements important for its success that can be taken into account in developing other research project networks of centralized type:

- The project has clear and relevant objectives, defined together between the national institutions and CATIE.
- The project is well funded in relation to the objectives, products, and activities.

- The donor institution has supported the project activities for nine years and will support it for three years more. This is one of the principal aspects necessary in a forestry research project continuity.

- Sufficient personnel in quality, level and quantity have been available in the countries and in CATIE headquarters.

- Silviculture and socioeconomic research plans were agreed on between collaborators. Participation has been a dominatant criterion in the project.

- The project has standardized methodologies for all the research activities and has developed a powerful data base. All the information is centralized and available for each country.

- The training and education effort has created a critical mass of well prepared personnel in each of the contributing countries.

- Rapid dissemination of technology has permitted the use of the species and systems in reforestation programs and projects of varying dimensions and will permit the implementation of more projects of larger scale.

- Planning, research analysis and administrative meetings between collaborators are frequent.

- The project has reached the decision makers and the farmer beneficiaries and all levels between. The strategy of the project is the participation of all the counterparts in the countries and to work directly in real conditions, putting experimental and demonstration plots on private farms.

- A regional documentation center gives support to the researchers in CATIE and the countries for bibliographical searches, documentation and editing of papers.

- A well established regional center has been coordinating the effort. All facilities of the center are available for project purposes.

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Results of the MADELEÑA Project

Output	Quantity
Field trials established	239
Seed stands under management	51
Demonstration farms established	38
Demonstration plots established	283
Education for Ph.D. supported	3
Education for M.Sc. supported	15
Education for technicians supported	6
Research theses supported	93
Training courses given	60
Publications:	
Internal reports	30
Technical reports	81
Extension materials	41
Conferences, lectures, and extension meetings	267
Field days	157
CATIE's personnel in headquarters	28
in countries	19
Counterpart institutional personnel	88

ANNEX 2

INVOLVEMENT OF CGIAR CENTERS IN FOREST-RELATED RESEARCH

The CGIAR system was not originally conceived as being involved in research on forestry. Thus, none of the CG Centers have had a mandate to undertake research related to forestry proper, nor have they in fact done so. However, in recent years--probably commencing in the early 1980's--some of the Centers have become interested in agricultural systems which incorporate trees as well as annual crops and livestock, and have commenced testing tree and shrub species suited to such systems.

As this work has evolved, the Centers also have begun to examine the interactions between woody perennial species and annual crops, with particular emphasis on complementarities and on the benefits conferred by the perennials in terms of shade, protection from wind damage, soil conversion, addition of nitrogen to the soil and its impact on yields of companion crops, and the use of the products of the woody species for animal feed, fuelwood, thatching, poles, or other purposes. Attention also is being paid to possible disadvantages from the combinations of trees or shrubs with annual crops: loss of annual crops output through trees occupying some of the land, loss of yield through competition for sunlight, moisture, or nutrients; shading effects, additional labor requirements; possible toxicity of leaves, pods, or seeds to humans or animals and so on.

It is not clear whether this rising interest in agroforestry and agrosilvipastoral systems has led to an explicit revision of the existing mandates of any Centers involved in such work. However, there seems to be a tacit agreement by their Boards and by the CGIAR that this type of research has potential value as a means of increasing the overall productivity of land and water resources, especially in the wetter tropics, stabilizing soil erosion and preventing the heavy run-off which occurs when land under trees or best suited to permanent cover is brought into production for annual crops, and possibly creating additional income and employment.

Centers which have reported some work or interest in this field are: IITA, ICRISAT, CIAT, ILCA, IBPGR, IFPRI, and ISNAR. Currently the most active work is being undertaken by the first four centers, i.e.:

IITA.

This Center has an established program based on "alley farming" systems for the humid tropics of West and Central Africa. (Alley farming is a system in which food crops are grown between rows of nitrogen-fixing leguminous trees). IITA has devoted considerable attention to agroecological characterization of those regions and has classified them into four main zones. These are:

1. The forest/savanna transition zone
2. The humid forest zone
3. The moist savanna zone
4. The inland valley ecosystem

Work on a synthesis of component technologies into viable systems, including alley cropping, has been underway for fifteen years in zone 1, and has now reached a stage

where some of these technologies, particularly alley farming, will be ready to hand over to the national programs for adaptation and extension in a relatively short time. It is concluded that agroforestry appears to be an important and suitable approach to maintaining productivity in the degradable soils of the humid and sub-humid tropics. However, alley farming is a better integrated way of achieving this objective than traditional bush fallow, where the crop and tree phases are separated in time, and large reserves of land are needed for the system to function properly. Bush fallow also makes heavy demands on labor for clearing land which has been under trees for several years. In a number of African countries it is becoming unsustainable, and it is essential and urgent to find viable alternative systems. Alley farming, as developed by IITA, may provide the answer to this difficult and challenging problem, both in Africa and in other regions of the humid tropics.

IITA plans to extend and adapt work on alley farming to zone 2 above, where a new substation has recently been established in the humid forest ecology, and to zone 3 in the moist savanna. Meanwhile work continues actively at its headquarters to improve alley farming systems in response to feedback from on-farm tests. Much of this feedback comes from the alley farming network which IITA has established in cooperation with ILCA. Fifteen African countries are participating in it.

A more detailed description of IITA's ongoing and projected work in this field is given in its new Strategic Plan to the year 2000, June 1988.

ICRISAT

Agroforestry is an important component of ICRISAT's Resource Management Program. Several groups are involved: cropping systems, land and water management, and economics. Early studies at ICRISAT Center used Leucaena as tree species in alley systems but cereals and legumes suffered badly from competition from water and nutrients. Economists reckoned leucaena was not an economic proposition in Indian SAT even before the arrival of psyllids.

For the last three years ICRISAT has tested alley cropping systems with pigeon pea as a tree substitute and obtained excellent evidence of complementarity with, e.g., millet and chickpea between rows. Future work at its Indian Headquarters will concentrate on the relative advantages and management of pigeon pea grown as a perennial harvested annually. ICRISAT also has collaborative agreements with the Indian Central Research Institute for Dryland Agriculture, Hyderabad, looking at systems with widely spaced *Acacia albida* and *Albizia lebbek* where the objective is to assess competition for light and water.

At ICRISAT's Sahelian Center, a program started in 1987 has main objectives of identifying genotypes most suitable for forage, fuel and windbreak uses from local and introduced accessions of Faidherbia and other spp. Competition for water and nutrients between trees and millet will be examined. A germplasm collection is being started in collaboration with local NARS.

Future work at both sites is likely to include further evaluation of genotypes and long-term assessment of changes in soil structure and fertility, and the eventual development of packages of practices for testing by NARS, and on farms. A detailed report on

ICRISAT's experience with agroforestry is to appear in the 1988 Annual Report, now in an advanced state of preparation.

CIAT

CIAT's involvement with agroforestry has been channelled along commodity lines, with no agroforestry research program per se. The involvement of the various commodity programs with agroforestry has been opportunistic rather than programmatic. Where researchers have seen a clear role for the integration of trees into production systems they have actively pursued these opportunities. For example, the Bean Program has been examining the use of trees for the support of pole beans grown on steep slopes in the Lakes region of central Africa (Rwanda, Burundi). Aside from support, trees in this production system also contribute firewood, fodder and aid in erosion control. Members of the Bean Program relied on existing expertise at ICRAF, IITA and development projects operating locally for appropriate germplasm and agronomic advice. However, the agroforestry aspect was a relatively minor component of the Bean Program's activities in the region.

Perhaps the major exception among the commodity programs at CIAT has been the Tropical Pastures Program. In the process of selecting and screening tropical legumes for inclusion in grass-legume pastures, the TPP has made a concerted effort to collect and evaluate tree and shrub legumes with potential as sources of forage. There has been extensive collection and evaluation of accessions of the genera Leucaena, Desmodium, Fleminghia, Gliricidia and others. The principal criterion for evaluation has been high dry matter production in the acid infertile soils that dominate the American lowland humid tropics. The TPP recognizes the potential value of tree and shrub legumes in pastures located in the humid tropics ecosystem not only as a source of forage but as a key component in establishing efficient nutrient capture and recycling that mimics natural ecosystem functioning.

As CIAT expands its activities in the humid tropics, particularly in the search for sustainable agricultural systems for the region, there is a clear recognition of the potential role of tree crops, managed fallows and other agroforestry elements in this environment. CIAT and IFPRI are currently involved in a special joint project analyzing the interrelationships between agriculture and natural resources in the Peruvian Amazon in an attempt to identify key technological components of sustainable agricultural production systems--and the policies necessary to support them--in this region. It is anticipated that various combinations of perennial species, exhibiting a variety of growth habits (trees, shrubs, ground covers) and fulfilling multiple roles complementing traditional food crops (rice, cassava, maize, pastures) will be necessary in the design of sustainable systems.

Rather than developing an in-house capacity for agroforestry research, it is anticipated that CIAT will continue to tap existing expertise at the national and international levels. Clearly IFPRI can play a key role in analyzing the economics of these complex agricultural production systems and in specifying the policy environment which will encourage their adoption and diffusion.

ILCA

ILCA has an active work program underway as part of its Animal Feed Resources Thrust, which seeks to alleviate the feed shortages which constrain livestock output in almost every production system of Sub-Saharan Africa. This program aims to provide adapted forage germplasm and suitable feed and feeding technologies to NARS and to ILCA/NARS commodity research programs. These technologies combine forage legumes, fodder trees, and agro-industrial by-products with natural feed resources. Special emphasis is being given to the integration of legumes in mixed crop-livestock farming systems so as to achieve stable and sustainable feed and food production in Sub-Saharan Africa.

ILCA has classified Sub-Saharan Africa into several broad agroecological zones from the point of view of the potential for different systems of animal production. It is testing multipurpose trees as part of its feed resources thrust in the humid, sub-humid, and highland zones, but not in the arid zone. ILCA notes that indigenous legume trees can be found in many production systems, but that their potential contribution to those systems and the constraints to their introduction in various agroecological zones of Sub-Saharan Africa are not well understood.

ILCA has both an ongoing program of work to investigate the potential of multipurpose trees in different production systems appropriate to the main agroecological zones, and has developed a forward plan to 1993 to pursue this work, with resources budgeted accordingly. It is cooperating actively with IITA, ICRAF, and other organizations such as the NFTA (Nitrogen-fixing Tree Association) in Hawaii. It also works with NARS, and as it develops its genebank collection of legumes, grasses, and browse in Africa, it will be undertaking collecting missions in collaboration with NARS.

Some specific ILCA activities involve the following:

(i) Initial evaluation of MPT species:

- For the highlands, testing browse species at a range of sites in Ethiopia from 1700 to 2800 m. altitude; including *Leucaena, Sesbania, Erythrina* and *Chamaecytisus palmensis*.

- Survey of use of indigenous browse in southeast Nigeria in collaboration with five national agricultural research institutions.

- Studies of fertilizer/rhizobium interaction in southwest Nigeria where *Leucaena* and *Gliricidia* grew poorly and were chlorotic in some alley-farming systems. This is a collaborative effort with IITA.

- Testing multipurpose tree legumes for the sub-humid zone of Nigeria, at three sites, with 22 nitrogen-fixing tree seeds obtained from NFTA, Hawaii. So far *Gliricidia* has not done as well in this zone as in the humid zone, and the performance of a wider range of species is to be evaluated.

(ii) Evaluation of MPT species in management systems--Alley Farming:

- A long-term alley farming trial to determine the effect of short grazed fallows on soil fertility and crop yields ended its first phase in 1986, and has now entered a second phase with an extended 4-year cropping period and a 2-year fallow in order to increase land use efficiency. The results are encouraging and a second trial, on a degraded soil, has been commenced.

- Fodder offtake and crop yields in alley farming. This was initiated in 1985 to examine the trade-off between the use of tree foliage to maintain soil fertility or as a feed for livestock. The opportunity cost of using some tree foliage as feed--which reduces maize yields somewhat, was more than offset by the value of increased animal productivity.

- Evaluation of multipurpose species in management systems--Intensive Feed Gardens. A study of the effect of inter-row spacing and cutting frequency of *Leucaena* fodder on tree productivity.

- Nutritive value of browse--effects of polyphenic compounds in forages from multipurpose fodder trees on growth, intake, and digestion in sheep and goats. *Acacia seyal, A. nilotica,* and *Sesbania sesban* are being studied in this trial.

IBPGR

IBPGR's current role

When IBPGR was created, a forester was included in the membership of the Board and for several years discussions were held on how far IBPGR should become involved with tree species. The early conclusion was that the IBPGR should not take on this type of work, in part due to the high costs envisaged, and in part because the members of the CGIAR wished to see major emphasis placed on agricultural species. Moreover, at that time pressure was on IBPGR to develop and operate networks, largely as a reaction to the axiom that time was running out to capture and conserve the variability of useful plants and that this should be addressed by establishing networks.

IBPGR has an interest in conserving, and is indeed involved with, a number of woody species as follows:

(i) fruit trees--but on a priority basis and therefore limited to a specific number of genepools (cultivars and wild species);

(ii) woody species of value to the agricultural or agroecological environment in the arid and semi-arid zones. This includes limited work on some browse or fuelwood species or those for multipurpose local use (e.g., *Leucaena; Sesbania*);

(iii) some cash crops such as cacao, rubber, coffee, coconut.

In many ways allocation of resources to these species has been of fairly low priority and piecemeal. IBPGR has tried to stimulate other organizations to do more in these areas.

IBPGR has played a role in the development of standards for seed storage, which are totally applicable to tree species (and for this reason the IBPGR Committee included a forester). IBPGR's research on defining recalcitrance/orthodox behavior of seeds has resulted in data on several tree genera. In practice, the IBPGR "blue books" on seed conservation are basic texts for storage of tree seed as well as agricultural crops.

IBPGR, in its catalytic role, co-sponsored in 1983 a planning workshop with ICRAF and CFI (Commonwealth Forestry Institute; now the Oxford Forestry Institute) on multipurpose tree germplasm to lay a basis for international cooperation. The proceedings and recommendations were published as a book by ICRAF. This includes a definition spanning interests in so-called agrisilviculture, agroforestry or social forestry or multipurpose trees and shrubs, i.e., "those which are deliberately grown or kept and managed for preferably more than one intended use, usually economically and/or ecologically motivated major products and/or services in any multipurpose land use systems, especially agroforestry systems." The discussions covered forest tree species, palms, bamboos and a range of ecologies.

IBPGR, because of its interest in the wide genepools, maintains an interest in in situ conservation, and results of research, e.g., on distribution and variation in *Mangofera, Citrus*, and *Prunus*, provide data for organizations involved with ecosystem conservation.

IBPGR was requested, based on its second external review, not to work directly on in situ conservation but to provide data and to maintain an overview. This is currently done through IBPGR's memorandum of understanding with IUCN (and its attendance at the IUCN Plant Advisory Group) and by participation in the Ad hoc Working Group on in situ conservation of the Ecosystem Conservation Group (FAO, UNESCO, UNEP, IUCN).

IBPGR work should complement that of other organizations involved in conservation of forest genetic resources, e.g., FAO, IUCN and UNESCO, CATIE, CAMCORE, ICRAF and many national programs. Some of these programs operate at the global level with significant accumulated experience. For example, under the overall guidance of the FAO Panel of Experts on Forest Gene Resources, established in 1968, FAO's Forestry Department helps coordinate action in the exploration, collection, evaluation, conservation and utilization of forest genetic resources at the global level. Action is carried out through collaboration with national institutes in developing countries and closely coordinated with work of other international institutes and organizations active in the field. Over the past 20 years, the Department has worked with and through some 30 institutes, leading to the exploration, collection and evaluation of approximately 20 globally important woody species. This activity also has led to initiation of networking activities involving some 50 additional species of global, regional or sub-regional importance. Activities generally include components of training as well as advice on methodologies and strategies to be used in sampling, collection, evaluation and handling of the genetic material collected, including storage. Over the years, standardized approaches have been accepted in many aspects of the work, leading to comparability between countries. Through its chairmanship in the Ad hoc Working Group on in situ conservation of plant genetic resources of the Ecosystem Conservation Group (recently extended to cover biological diversity in general), the Forestry Department of FAO has taken a leadership role in this important field, complementary to ex situ conservation and a basis for future action in improvement and breeding of crops and trees.

Other Work at CG Centers

Agroecological characterization: Besides the work of CIAT, IITA, ICRISAT, IBPGR, and ILCA in this field, several other Centers have incorporated this into their programs. These include CIMMYT, CIP, ICARDA, IRRI, and WARDA. Although this is not specifically directed towards forestry or agroforestry it will help to contribute understanding concerning agroecological situations in which the incorporation of woody perennials into farming systems may be feasible and desirable.

Policy analysis: Several Centers are working in this field within their own spheres of interest and specific geographical regions. IFPRI, however, has a global mandate, especially for work at the macro-policy level. Until recently it has not done any work related to agroforestry or forestry, but has now initiated the collaborative study with CIAT in Amazonia described earlier in this paper. It has completed a study in Nepal on the relationship between time required for fuelwood collection and agricultural productivity.

Beyond this, it has been given authority by its Board to examine the possibility of initiating a significant program related to environmental resource management, and has set up an internal study group to prepare a proposal, probably involving advice from a selected panel of experts.

Strengthening national agricultural research capacity: This is the main role of ISNAR within the CGIAR System, although it is also an important part of all Centers' efforts. Until now, ISNAR has not included forestry in its program of assistance to NARS; but it is now reviewing its future action in this field, and the possibility of adding forestry or agroforestry expertise to its staff to enable it to do so.

ANNEX 3

EXAMPLES OF RESEARCH IN THE FIVE PRIORITY AREAS

1. Examples of Agroforestry Watershed and Dryland Management

** Singh, Panday and Tiwari (1984) researched energy interrelationships for two Himalayan villages. They found that animals accounted for more than 70 percent of total energy input into the farming system. Beyond this, the animals themselves depended on the forest for 87 percent of their fodder. To sustain the existing system, more than five hectares of forest were needed per family, while the actual forest available was slightly over one hectare.

** Work by Flemming (1983) indicates that improved harvesting and management practices can increase significantly the yields from grass and forest grazing lands in Nepal. For example, the increase was from 1,200 to 6,000 kilogrammes per hectare per year for grasslands and from 3,000 to 6,000 kilogrammes per hectare per year for forest lands.

** Researchers have developed a method of predicting the influence of trees upon landslides (Hawley 1988). Reforestation can reduce shallow soil landsliding by at least 70 percent. The occurrence of landslides dramatically increased when forest areas were converted to pastures; over 60 percent of the converted areas had landslides. Productivity on these landslide areas was reduced by 20 percent to 30 percent for over 80 years following the landslides (Trustrum et al. 1984). This research did not follow the effects downstream--although research elsewhere suggests that landslides that occur into channels are major sources of sediment to downstream areas.

** Achlil (1984) reports 48 percent, 20 percent, and 17 percent reductions in peak monthly runoff, annual sediment transport, and peak monthly sediment transport, respectively, caused by improved farming, terracing, and tree planting in the Solo watershed on Java, Indonesia.

** Wiersum (1984) studied surface erosion rates under different agroforestry systems in Java, Indonesia. This led to better understanding of the role of trees, in combination with crops, in protecting the soil. Soil surface management was recommended--trees without soil conservation measures beneath them will not adequately control erosion.

** Openshaw (World Bank 1986a) summarizes the potential of improved management of natural savannah woodlands to contribute to tree fodder and fuelwood needs in the Sudan. Research has shown that, in many cases, application of simple management techniques, such as control of harvest and burning, can more than double sustainable outputs from less than one to two cubic metres per hectare per year (Winterbottom and Hazlewood 1987). Costs can be very low, creating cost-effective management opportunities. Similar results have been demonstrated for Niger and other countries.

** CATIE (Enriquez 1983) researched combinations of pasture and various tree species, such as *Cordia alliodora* and nitrogen-fixing *Erythrina poeppigaiana*. The presence of Erythrina resulted in a 70 percent increase in total grass and protein production. Other similar studies exist.

** Kang and Wilson (1984) have researched alley cropping in Nigeria, involving production of maize intercropped with rows of *Leucaena leucocephala*. Maize yields were consistently higher when Leucaena prunings were maintained on the fields. When nitrogen was added in addition to the prunings, yields increased even further.

** A well-documented case is the shelterbelt program in the Maijja valley of Niger. Use of windbreaks resulted in an average 17 percent increase in crop yield, despite the fact that land was taken out of crop production for growing the shelterbelts. In addition to the protection benefits, the shelterbelts provide fuelwood estimated at 52 cubic metres every four years per linear kilometre of windbreak, and fodder estimated at four tons every four years per linear kilometre of windbreak (Rorison and Dennison 1986; Long and Dennison 1986).

** Research by El-Lakany (1987) and others in Egypt has demonstrated yield increases as high as 47 percent for maize grown with windbreak protection. Protection benefits vary widely by crops.

** A shelterbelt research program in Nigeria was initiated in the '70s under IDRC sponsorship. At the expiration of the IDRC project in 1984, the Nigerian government was so impressed by the results achieved and the effects of shelterbelt on agricultural yield, livestock production and amelioration of the living conditions of the rural communities living in the immediate vicinity of the belts, that extra-budgetary funds have been provided to continue the research (personal communication, P. Kio).

** Farnsworth (1976) has researched the effects of shade or shelter trees and found that cattle with access to shelter gained 676 grammes per day, while the control group (without shade) only gained 472 grammes per day. Similarly, research has found that under high temperatures, milk yields increase when cattle have access to shade.

2. Examples of Research in the Area of Natural Tropical Forest Conservation and Management

Examples of past research in these priority areas show the useful results that can be obtained:

** Winterbottom and Hazlewood (1987) have summarized research being undertaken in the Gusselbodi forest in Niger. This research has shown that simple, low-cost management techniques in the natural forest, such as early burning and careful timing of lopping and felling, can produce three cubic metres of fuelwood per hectare per year, or roughly six times the yield that is generally assumed for unmanaged forests. At the same time, a number of other products results (gums, fodder, medicines).

** Research by Anderson et al. (1987) documented the significant economic and ecological roles that the naturally occurring babassu palm (*Orbignya* spp.) plays in the Maranhao state of Brazil. Some 64 percent of total cash and noncash income in three municipios of Maranhao came from babassu products during the peak harvest period of October to December. This has policy implications in terms of protection and management. Findings led to management guidelines for the palm areas.

** Based on his research, Repetto (1988) notes that nonwood forest products brought in US$120 million in 1982 in Indonesia. Most of the associated harvesting and production activity involved employment in local economies, whereas much of the wood export value was retained by timber companies as profits.

** Two major anti-cancer compounds derived from the periwinkle plant, which only occurs naturally in Madagascar. With these drugs, there is now a 99 percent chance of remission in children suffering from lymphocytic leukaemia and a 58 percent chance of remission from Hodgkin's disease.

** Based on previous experiences in improving natural forests, gathered in several West African countries between 1945-1965 CTFT and SO.DE.FOR started in 1976 a research programme on different management systems on three types of Forest of Cote d'Ivoire. In subsequent years this programme was extended to Central African Republic and French Guyana. This long-term research work has already given some indications on the dynamics of tropical moist forest and early results on response to interventions such as thinning and selective logging. This research should lead in the future to simple silvicultural prescriptions applicable to large areas (personal communication C. Cossalter).

** Many otherwise obscure insect species in the tropics have major economic importance. For example, the oil palm (*Elaeis guineensis*) is pollinated in the wild in Africa by a weevil (*Elaeidobius kamerunicus*). The oil palm was introduced in what is now Malaysia in 1917 without the weevil and thus required costly, inefficient hand pollination. In 1980-81 the pollinator was collected from its native habitat in the forests of the Cameroon and brought to Malaysia after a six month quarantine; significant improvement in pollination resulted, with the percentage of fruit set increasing by 8 to 28 percent. After considering other factors of production, it is estimated that the increase in national oil palm production could reach 12.3 percent (Salleh Mohd. Nor, personal communication). The improvement was worth some US$50 to US$60 million in foreign exchange in the first year alone (Goodland 1985).

** Research by Dourojeanni (1978 as cited in Falconer 1987) showed that in the Ucayali region of the Peruvian Amazon, some 85 percent of protein consumed came from wild game and fish. Similar results were obtained in a study of the forest from Botswana (Butynski and von Richter 1974).

3. Examples of Research in the Area of Tree Improvement and Tree Breeding Research

Examples of past research include the following:

** FAO's project on genetic resources of the arid zones, focussing on woody species, is a worldwide effort. The initial eight countries involved collected seed, explored natural ranges of species (mainly Acacia and Prosopis species) conserved sands on site, evaluated materials, did field trials and made seed available to other countries. Over the years 1980-1987, a total of 281 well-documented seedlots (provenances) of 43 species were explored, and seed distributed for testing and conservation. Work was undertaken in at least one institution in some 17 countries. The potential yield gains from use of results of this work are significant.

** Research has shown that great gains in productivity can be made simply by identifying and selecting the seed source most adapted to planting locality. In provenance trials in Nigeria with *E. camaldulensis*, the best provenance had a mean annual increment of 17.3 cubic meters per hectare, while the poorest only had 5.1 cubic meters (FAO 1979). In the Congo and Brazil, the yield of eucalyptus plantations has been increased by up to 80 percent by selection of the best seed sources (Chaperon 1978; Brune and Zobel 1981). FAO, CTFT, DANIDA and other groups have established seed procurement systems around the world which aim at improved seed selection, exchange and distribution.

** Panday (1982) has shown the great variation in production of dry matter (DM) in different fodder tree species, which in the Himalayan region varies from as low as five to seven kilogrammes to as high as 50-70 kilogrammes annually per tree. There are significant implications in terms of tree selection and selection of provenances for given species.

** Research in India by Pathak and Patil (1982) found that the difference in forage production between the best and worst provenances of *Luecaena leucocephala* over a three-year period were around 70 percent.

** Much useful work on nitrogen-fixing trees has been done by various countries (Senegal, Egypt, China) and various groups including CTFT/ORSTOM, NFTA, IITA, FAO and others. Dommergues (1987) indicates the importance of research in this area. Certain trees can fix significant amounts of nitrogen in the humid tropics, substituting at least partially for purchased nitrogen fertilizers or providing a source where access to fertilizers is limited.

** Genetic improvement research over the past 15 years in Brazil has resulted in doubling eucalyptus yields from 33 to 70 cubic meters per hectare per year (Aracruz Florestal).

** Research has contributed in a major way to the five-fold increase in rubber yields achieved in Malaysia since 1920. The estimated rate of return on investment in rubber tree research in Malaysia is 22 percent (Pee 1977).

** FRIN has had major achievements in the area of vegetative reproduction of *Triplochiton scleroxylon*, an indigenous species threatened with over-exploitation almost to the point of extinction. Due to difficult phenology (it fruits every five years), the only reliable means of mass regeneration in plantation is by vegetation propagation, a system now perfected for the species and being extended to equally valuable but silviculturally difficult indigenous species, particularly the West African mahoganies. The project is the nucleus of the proposed network of West African Hardwood Improvement Project being considered for sponsorship by the EEC (personal communication P. Kio).

** Large-scale trials of mechanised afforestation in the semi-arid zone of Nigeria has been attracting tremendous interest inside and outside the country. As a strategy to save the remaining moist forest stands of the south, emphasis for large-scale plantations has shifted to the Savanna belt of Nigeria which makes up over 75% of the country's land area. The project is sponsored by the Japanese International Cooperation Agency (JICA) and plans to set up 690 ha of plantation of pines (*Pinus caribaea, P. oocarpa*), eucalypts (*E. citriodora, E. cloesiana, E. camaldulensis*, and *E. saligna*) and some indigenous savanna species (*Prosopis africana, Parkia biglobosa, Acacia* spp., and *Khaya senegalensis*). The project is in its third year of operation and has executed several espacement and land preparation experiments, some of which are already showing astonishing results in terms of highly improved growth rates (personal communication, P. Kio).

** A program of eucalyptus selection and breeding initiated in the early 1950s by CTFT in the Congo has led to improved commercial plantations that are planned to produce several million cubic meters of wood per year, mainly for pulp and paper. Mean annual growth per hectare is in the 25-40 cubic meter range (L. Huguet, personal communication).

** In the Tree Seed Centre programme for developing countries of Australia's CSIRO, estimates were made of the value of timber and areas likely to be planted with improved seed in nine developing countries. Financial internal rates of return on incremental investment in the most productive seeds were calculated (Development Digest 1988). They ranged from 22 percent in Lesotho to over 80 percent at Dongmen, China. In addition to financial benefits from timber, other benefits included improved tree form, earlier harvest possibilities, reduced maintenance, and improvements in agroforestry and soil conservation results.

** OFI has promoted worldwide distribution and use of Central American tropical pines through its research network. Through the network, OFI has helped collect, distribute, test, and evaluate various genetic stocks of these pines. By exchanging seed, standardizing experimental design, and developing information systems, the network has enabled countries to match the genetic material to a site, thereby increasing plantation yields.

4. Examples of Utilization Research

Examples of useful research include the following:

** Economics research by Reiche and Campos (1986) shows that drying coffee in Costa Rica with electricity is about six times--and using diesel fuel is three to four times--more expensive than using wood. This type of research has significant direct implications for fuelwood and other energy markets and indirect implications for policies on forest protection and energy in Costa Rica.

** Research has permitted Malaysia to increase the number of species it uses commercially from 100 to more than 654 in 100 timber groups (Salleh Mohd. Nor, personal communication). Similar progress in species utilization has been made in Costa Rica and other countries. Research in the Philippines, Colombia and several developed countries has vastly increased the range of species from the natural tropical forest which can be utilized in paper production, thus opening up opportunities for productive, sustainable use of previously unused resources.

** Ten years ago, rubberwood was unknown as a commercial species in Malaysia. Research on species properties, processing, protection and utilization led the way to markets for rubberwood. As a result Malaysia exported over 258,000 cubic meters of rubberwood in 1987 with a value over M$37 million (Salleh Mohd. Nor, personal communication).

** As one of the oldest research institutes in West Africa, FRIN has taken the lead in popularizing the use of lesser known species (LKS), having expanded the resource base of the timber industry twofold by conducting research into the LKS properties (strength, seasoning characteristics and durability) at first in collaboration with Princes Risborough Laboratory in Britain and, from the 1970's, in its own laboratory at Ibadan.

** Research in six countries reported by Fisseha (1987) indicates that the contribution of forest-based SSEs to total SSE employment varies between 13 and 34 percent. Their contribution to total value added varies between 16 and 47 percent, and to total value of production from 14 to 49 percent. In all cases forest-based SSEs were one of the more important sectors.

** Some of the developed country technologies which are being considered because of potential rapid payoffs in tropical countries through adaptive research include:

* power backup rolls for veneer production, which permit higher veneer recovery and peeling of difficult species;
* press drying in paper making, which uses short fiber hardwoods and consumes less energy;
* wood preservation to overcome decay and termite problems;
* improved wood engineering for cost savings and other benefits in housing production;
* developing uses for lesser-known species;
* waferboard and other reconstituted wood products technologies permit use of many different species and treatment for fire, decay, and insect resistance; and
* improved harvesting and transport technologies which can lower costs and reduce environmental damage from logging.

** Bengston (1984, 1985) found average economic rates of return (ERR) of 19-22 percent for structural particle board research and 34-40 percent for lumber and wood products research in the United States. Haygreen et al. (1986) calculated that public investment in all timber utilization research in the United States had economic rates of return between 14 and 36 percent, depending on assumptions used concerning costs to be included. (In the lowest rate, 14 percent, all costs of research on timber management, forest products utilization, and forest products marketing were included).

5. Examples of Policy and Socioeconomic Research

Examples of useful research include the following:

** Kumar and Hotchkiss (1988, in press) show how the progressive encroachment of cultivation into forested areas forces women and other members of farm families to walk increasing distances to gather fuelwood and fodder from trees. This reduces the time that they can work on their farms and reduces farm productivity. As a result, families are forced into a further extension of area under crops to produce enough food, perpetuating a downward spiral of decreasing output from both arable and forest areas.

** Arnold (1987) reviewed selected research on agroforestry from an economic point of view. He considered the influence of relative scarcity of factors of production on farmers' decisions and found that they often maximize returns to labor input rather than capital. Often this is because the opportunity cost of labor is high, and tree growing takes less labor and involves more flexible timing.

** Dewees (World Bank 1986b) researched how farmers in parts of Kenya are conditioned by availability of capital and labor. In areas where labor is scarce, tree growing may take place where the returns per hectare are lower than from other crops, but the returns to labor are some 50 percent greater than from maize production. Reduced risk also entered the picture.

** Research at CATIE shows that returns to farmers can be more than twice as high when pure pasture management using post fences is changed to pasture management using living fences with clumps of trees scattered throughout the pasture (personal communication from R. de Camino).

** Anderson (1987) carried out detailed research on the economics of multipurpose tree species in Nigeria. The results indicate that rates of return can increase from 7.4 to 16.9 percent when soil conservation benefits are included in addition to wood and fruit benefits in agroforestry components, and from 4.7 to 21.8 percent when shelterbelt soil conservation benefits are added to wood benefits (poles and fuelwood) alone.

** An ILO study in 1987 showed that subsidy policies to encourage substitution of kerosene for wood-based fuels were very effective in Addis Ababa, Ethiopia; some 60 percent of the population shifted to kerosene within four years. On the other hand, a World Bank household energy study in 1974 showed that in Senegal it was the more affluent urban households who benefitted from the campaign initiated in 1974 to encourage substitution of butane for wood-based charcoal. At the national level, introduction of liquid propane gas led to savings of only about 16-17,000 tons of charcoal annually, after 13 years of promotion and subsidization. The impact on forest conservation has been minimal.

** A recent study by the WRI (Repetto 1988) reveals that, in Indonesia, Sabah/Malaysia, Ghana and the Philippines, government policies on forest revenue systems and wood-processing industries provided strong economic incentives, which led to accelerated rates of forest depletion and substantial losses of government revenue, due to lack of adequate rent capture from concessionaires. The economic losses due to these policies, in addition to other social and environmental impacts, are enormous.

** Research by Hecht and Schwartzman (1988) indicate that the costs of recuperation of three million hectares of degraded forest land in Acre, Brazil, would be some US$781 million in direct recuperation costs and some US$150 million in extractive benefits foregone.

** Santa Cruz (1988) researched the Chilean forestry incentives program (Law 701) and concluded that the financial rates of return on *Pinus radiata* growing are, on average, high enough without incentives to attract investment. However when Law 701 was passed, there were high risks and uncertainties surrounding investment in pine growing, and particularly a lack of secure markets and liquidity of such investment over the first years. The development of the major Chilean pine export business would likely have been delayed a number of years without the incentives to ease the burden of risk and uncertainty.

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