Chapter 12

Education, Research, and Technology Transfer

HIGHLIGHTS

Education

- Most education to support sustainable use of tropical forest resources must be done by tropical nations' own universities and technical schools. But these schools generally are new, small, and not yet capable of the task.
- U.S. universities can help sustain tropical forest resources both by educating professionals for work in tropical areas and by supporting the development of the tropical universities' capabilities.
- To provide adequate instruction in tropical forest issues, U.S. universities need to make fundamental curriculum changes, adding more anthropological and sociological perspectives to the education of resource development specialists.
- Environmental education programs suffer from a lack of behavioral science expertise and from a lack of literature documenting the reasons for success and failure of past programs.

Research

- Fundamental and applied research, especially in the social sciences, are needed to develop more techniques that produce sufficient profits for investors and simultaneously conserve the renewability of forest resources.
- Research on tropical forest resources is poorly coordinated. Fundamental researchers know too little about what information applied researchers need, and applied researchers know too little about the needs of technology implementors.

Technology Transfer

- Innovative technologies, even successful ones, often do not spread beyond subsidized pilot projects. Improved technology transfer efforts are needed among researchers, between researchers and project managers, and between project managers and individual decisionmakers.

INTRODUCTION

Many technical opportunities to reverse tropical forest degradation are attracting attention from development assistance organizations and from tropical government agencies. Yet, neither governments, private entrepreneurs, nor local people are investing enough capital, land, and labor on these techniques. Methods to overcome these constraints on such investment include increased professional, technical, and environmental education, some research redirection, and improved technology transfer.

Inequitable and insecure land tenure and population growth cause forest resource management problems even more basic than those addressed by forestry education, research, and technology transfer. These problems are not amenable to direct action by the U.S. Con-

gress—they must be resolved by the tropical nations themselves.

U.S. assistance can enhance education and research, particularly in the social sciences. It also indirectly can help improve tropical nations' abilities to make fundamental changes in economic and social institutions.

EDUCATION

Professional Education and Technical Training

Progress in developing and implementing new forestry technologies is severely constrained by the scarcity of appropriately educated personnel. A severe shortage of field technicians and extension agents with suitable training further constrains implementation of existing technologies (4,18).

In the short term, an efficient mechanism for matching qualified people to the available jobs is necessary, and sufficient money and other incentives must be provided. Expatriates, including U.S. professionals, can carry out certain critical functions. However, over-reliance on expatriates is expensive, maintains dependency, may lead to adoption of inappropriate technologies, and contributes little to building a political consensus on the value of tropical forests. For these reasons and because the scope of tropical forest development problems and opportunities is so large, improvement in both the quantity and quality of education within tropical countries is essential to sustain tropical forest resources in the long run.

Forestry Education and Training Programs in Tropical Countries

Forestry degree programs are offered by 23 universities in tropical Africa, 55 in tropical Asia, and 39 in tropical America. In addition, tropical Africa has 59 technical schools offering forestry courses, tropical Asia has 118, and tropical America has 51. Nearly all of these, however, are new and produce few graduates each year.

Most of these professional and technical forestry programs have focused on commercial timber production and industrial processing. Now, however, the emphasis in tropical forest resource development is changing to include social forestry, agroforestry, and fuelwood forestry. To support this shift, the tropical forestry schools need to make some fundamental changes.

ENCOURAGE INTERDISCIPLINARY APPROACH

Professionals, including foresters, sometimes become too narrowly focused (8). This tendency is particularly troublesome in tropical forestry because the interactions between natural systems and social systems are so complex. Despite widespread agreement that the major constraints on improved forest resource management are socioeconomic and institutional, social perspectives remain underrepresented in forestry curricula.

> Forestry education has been strongly oriented toward biological sciences. It has not filled a critical need for professional understanding of and competence in determining the potential of forests in rural development: the social values in rural income and employment; reduction of urban migration; land use planning; diversification of agriculture; the linkages of the variety of products from forest resources with other sectors of the economy such as supplying raw material for low cost housing; nor with the way forest industry development can be directed to fit the various stages in the country's development (15).

Special efforts need to be taken to incorporate social science components into forestry and related program curricula. Too often, rural sociology, applied anthropology, education methodology, political science, and history are ignored. Although forest economics is included in many forestry curricula, it needs to incor-

porate an orientation more than industrial wood production and demand. Natural resource development planning, environmental quality assessment, and administrative and managerial skills also have been neglected. Knowledge of agronomy, soil science, range management, and animal husbandry is also important for forestry professionals in most tropical countries.

There are two ways to broaden forestry education: provide continuing education in social and agricultural sciences to forest professionals and forestry school faculty, and support the addition or joint appointments of social scientists as faculty in forestry schools. The disadvantage of the first approach is that many of these people may not have an inclination or aptitude for the social sciences. The problem with the second approach is that social scientists in tropical nations may not understand the relationship between their discipline and forestry. This can be ameliorated by providing in-house training in forestry and the natural sciences for social scientists. It would not, however, solve the problem of how to attract top quality social scientists into a field that is undersupported and generally viewed as less prestigious than other fields such as health and education.

DEVELOP TEACHING MATERIALS AND FACILITIES

Many faculty members in tropical universities were educated in developed countries. Thus, they are likely to teach concepts and use course materials appropriate for capital-intensive production forestry in temperate zones. But under tropical conditions the temperate zone forestry technologies may not be economically feasible or socially desirable. Further, temperate zone techniques can be poorly adapted to ecological conditions in the Tropics and may require equipment or skilled labor that is not available (35).

Teaching materials relevant to tropical forests are scarce. While some appropriate information and course materials are available, they are poorly distributed. This situation could improve if teachers and researchers were to receive support to develop original course materials. Teaching materials developed in tropical countries can be evaluated for their applicability in other countries. Funds could be provided to modify, translate, and distribute these materials internationally. Some surprisingly simple and inexpensive efforts can be very effective. For example, botanists have produced inexpensive and accurate tree identification handbooks by photocopying leaf, twig, flower, and seed specimens that are available in U.S. herbaria (21).

Many tropical forestry schools also lack adequate library and computer facilities, field and laboratory equipment, and arboretum or herbarium facilities. Computers, programmable calculators, and software can greatly facilitate teaching, research, and forest management. For tropical forestry schools, minicomputers are advantageous because they are relatively inexpensive and easy to operate and repair.

Museums can be teaching tools of great importance to tropical forestry. In the United States, the Smithsonian Institution, Chicago's Field Museum of Natural History, the Missouri Botanical Garden, New York Botanical Garden, and certain museums affiliated with universities are examples. Museums in tropical countries unfortunately are seldom teaching museums. They are underfinanced and not particularly useful to forestry education. Supporting development of good teaching museums with well-stocked and well-curated herbariums and arboretums would be an effective way to improve tropical forestry education (4).

RECRUIT APPROPRIATE PEOPLE

Forestry education is not a prestigious profession in most tropical countries. Careers in this field do not offer the social or financial benefits that many other fields offer. Forestry school faculties in many countries are poorly paid and many of the best quickly move on to other occupations. In some countries, teaching staff are borrowed from the Forestry Department but are selected on the basis of seniority rather than teaching ability. Consequently, forestry education is severely constrained by a shortage of qualified teachers (28) and univer-

sity forestry programs have difficulty competing with other programs for funds, facilities, and top quality students and scientists.

U.S. scientists could increase their effort to help their colleagues in tropical schools gain international recognition and, thus, prestige in their universities. Development assistance agencies also could invest additional money in graduate programs for tropical forestry schools, provide continuing education opportunities for faculty, provide scholarships, sponsor research, and develop facilities (e.g., libraries, laboratories, field stations). Developing facilities alone can be a waste of foreign assistance funds, however, if expert personnel are not available or developed simultaneously (4).

DEVELOP GRADUATE PROGRAMS

Few forestry schools in the Tropics offer graduate degrees. Although the development of a strong undergraduate program is the first priority in forestry education, graduate schools are important to produce future educators, researchers, and upper-level decisionmakers. Graduate programs also are important because they involve students and faculty in modern current research. Without a research component, it is difficult for forestry and related disciplines to attract and retain top quality students and faculty.

SUPPORT TECHNICAL SCHOOL PROGRAMS

The shortage of adequately trained forestry extension agents in rural areas probably is a greater constraint on resource-sustaining technologies than the lack of professional personnel. The need for field technicians and extension workers will increase as tropical nations begin to manage forests, promote agroforestry, and disseminate improved wood-use technologies. In particular, more women should be educated as foresters, technicians, and extension agents because women are heavily involved in using forest resources and in many cultures they can be reached best by other women (20).

Recruiting students to work as forestry technicians is a problem. Few students who complete technical training take field jobs and many who do may leave them soon. Educated people generally prefer to live in urban areas, making it difficult to retain good field staff. Innovative approaches to this problem need to be developed, supported, and documented. For example, it may be useful to increase recruitment from rural areas, although this might necessitate expanding technical schools' programs to offer remedial work in basic academic skills.

U.S. forestry schools can improve technical schools in the Tropics by helping produce training materials. Also they can support education of technical school instructors through training programs organized by the Food and Agriculture Organization (FAO) or other organizations. U.S. forestry schools generally do not have the ability to contribute more directly to training technicians and extension agents for tropical forestry and agroforestry (4).

IN-SERVICE TRAINING

Even if actions to improve forestry education programs begin soon, a substantial lag will occur before those students are in influential positions. Therefore, it is also important to update training of resource management professionals and technicians.

In-service training enables staff to keep up with advances in forestry techniques and in related fields such as agriculture, livestock management, and soil and water conservation. It is particularly important for social forestry projects because conventional forestry education has included so little training on social aspects of resource development. Unfortunately, with the existing shortages of qualified professionals and technicians, it often is difficult to release forest department staff for extended training courses (40).

The United Nations FAO Forestry Department has developed a program to support in-service training of forestry personnel in developing countries. This program receives some financial support through the U.S. contribution to FAO, and this seems an effective channel for continued or increased U.S. support of in-service training. However, at present

U.S. experts play only a small part in the FAO Forestry program.

Opportunities for the U.S. in Tropical Forestry Education and Training

The United States has important expertise and experience in forestry education and has some experts in tropical forestry, botany, zoology, soils, and related topics scattered among U.S. academic institutions. These experts are contributing in a piecemeal but significant fashion to education of U.S. and tropical country foresters and other professionals interested in tropical forest resources.

In the fall of 1982, some 487 students from developing countries were enrolled at U.S. forestry schools, and a survey of 44 North American forestry schools found 33 were anticipating expansion of their international forestry activities (25). Newsletters, directories, and other networks to facilitate communication among tropical forest experts are being established, for example, by the International Society of Tropical Foresters.

IMPROVE THE CAPABILITIES OF U.S. UNIVERSITIES

Most U.S. universities have had only peripheral interests and activities in tropical forestry. This is, in part, because few U.S. faculty have experience in tropical forestry. Many of those work for State-supported universities where overseas work is not well-regarded (43). Consequently, those who seek overseas forestry work often are professionals at the beginning of their careers or those nearing retirement (4).

Few courses offered by U.S. forestry schools focus on the Tropics or on international economic and political interactions and resource interdependence (34). Some U.S. universities can give foreign students an excellent education in the fundamentals of basic science, forest management, forest industries, and quantitative methods (26). But education on the applied aspects of tropical forest management and ecology mostly is lacking. If U.S. forestry schools are to play an effective role in technology transfer to the Tropics, changes must be made in the curricula. Special attention has to be paid to the appropriateness of the technologies taught. Otherwise, students from the Tropics will not be able to apply their newly acquired knowledge. Few U.S. schools are well equipped to train U.S. or foreign students in social or community forestry.

> The training of foresters gives them a sense that they command an expertness and set of skills which permits them to diagnose and prescribe for society. Community forestry turns that upside down so that the professional becomes a coordinator and facilitator of diagnoses and prescriptions made by the community (6).

This change requires development of communications and public relations skills as well as sensitivity to cultural factors (13,30).

Lack of a tropical setting for field courses constrains U.S. universities' ability to serve the needs of students who are to work in the Tropics. Education cannot be limited to the classroom. Field courses and internships including field work are essential (38). Both the social and natural science aspects of tropical forestry involve problem-solving skills that are better learned in the field than in classroom lectures and laboratory exercises (28).

ENHANCE COMMUNICATION BETWEEN TROPICAL SCHOOLS AND U.S. INSTITUTIONS

The faculty, administrators, and students in tropical schools often find it difficult to locate particular expertise in U.S. universities. **Twinning** and **consortia** are two mechanisms that are used to facilitate communication between U.S. and tropical nation schools. Twinning refers to the establishment of a special long-term association between a forestry school in the Tropics and one in another country.

A twinning arrangement can help develop teaching and research capabilities in both institutions (4,47). It offers the advantage of continuity, providing time for faculty and administrators on both sides to understand the problems and opportunities in the other country.

It also provides the opportunity to develop good working relationships.

Twinning could be used to broaden tropical forestry education. For example, some U.S. universities have strong social science expertise that could be applied to forest resource development issues. U.S. faculty can help develop teaching materials, design or conduct research, and temporarily substitute for tropical university faculty when they are absent for course material development, advanced education, or in-service training.

Twinning, however, has disadvantages. U.S. universities are likely to perceive little benefit to themselves from participating. Thus, twinning activities may be assigned a low priority unless there is sufficient external funding (4). The exchange of faculty, students, and information may end up being one-way—from tropical country institution to developed country university. Also, since no single U.S. university offers a comprehensive program in tropical forest resources, limiting access to the expertise available in just one U.S. university could be a disadvantage to the tropical university.

Consortia of U.S. universities can resolve some of twinning's disadvantages because they can provide a wider range of expertise to the tropical institutions. The consortium can direct tropical faculty, administrators, or students to programs best suited to their needs. Some such consortia already exist (ch. 5). However, neither twinning nor consortia are able to resolve several major constraints on development of U.S. expertise in tropical forestry (4). These include:

1. Insufficient faculty competence in tropical forest resource fields.
2. Lack of tropical forest environments in which to teach tropical forest resource management.
3. Lack of a suitable setting for relevant faculty and graduate student research.
4. Lack of a center for exchange of ideas among tropical forest resource scholars.
5. Lack of a center to house necessary collateral institutions, including a tropical herbarium, tropical wood collection, and tropical arboretum.

These constraints could be overcome by designating and developing institutions, located in U.S. humid tropical and semiarid areas, to serve as centers of excellence in tropical forest resource development. The primary purpose of such centers would be to advance tropical forest resource education. They also could conduct research programs and act as information clearinghouses. For these centers, tropical forest resources would not be a peripheral interest; they would be the main focus. And because the research and teaching could be applied to resource development in the area where the centers are located, they should receive support from State and territorial organizations.

If emphasis on the special importance of social sciences, economic botany, and other disciplines were written into the charters of such centers, they could become more truly interdisciplinary than are conventional forestry schools. It would be difficult to assign permanently at one location the breadth of expertise necessary for an excellent program on tropical forest resources. This could be accomplished by using a core staff of research scientists together with a series of short-term assignments of faculty from various institutions (4).

The information clearinghouse function of the centers of excellence could serve not only education organizations but also resource development agencies in tropical nations. The centers could identify:

- appropriate U.S. organizations where people from tropical countries could obtain graduate and post-graduate training,
- U.S. organizations where tropical universities can find institution-building expertise,
- tropical organizations interested in collaborative research and instruction with U.S. universities,
- sources of funding available for these exchanges, and
- expertise on various new or existing technologies.

The U.S. Forest Service has a program providing such information for AID projects. Evaluations indicate that the quality of AID's forestry-related projects has been substantially im

proved by this relatively inexpensive effort. Centers of excellence could extend this broker function to institutions other than AID.

Locating the centers of excellence in the United States would help assure continuity and stability of funding, thus giving better opportunity for long-term research, training, and service capabilities (4). Associating such centers with existing institutions could avoid the costs and risks of establishing entirely new facilities. For example, the U.S. Forest Service Institutes in Puerto Rico and Hawaii could be developed as centers of excellence to serve tropical America and tropical Asia, respectively. Similarly, the Kleberg Wildlife Research Institute in Kingsville, Tex., which conducts some research and training in semiarid land forestry, could be strengthened and broadened to become a center of excellence.

A major drawback to the center of excellence concept is that substantial Federal funding might be necessary. Another disadvantage is that the U.S. tropical island locations are not biologically typical of forest resources on tropical continents, and none of the U.S. locations have sociological or institutional conditions similar to tropical nations. The centers might overcome these constraints by arranging to use facilities at tropical universities as field stations or by helping tropical schools develop new field stations.

An alternative to establishing new centers would be for the United States to offer support to international institutions that are working to provide tropical forest resource education and research programs, such as the International Council for Research on Agroforestry (ICRAF) located in Kenya, the United Nations University (UNU) headquartered in Japan, and the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Costa Rica. These institutions have cooperative programs with universities in other tropical countries. Concentrating the U.S. effort on existing international institutions would not be a complete substitute for a U.S. center of excellence, however. The forestry mandates of these institutions are relatively narrow—their forestry efforts focus mainly on agroforestry and, except for ICRAF, their major emphasis is on annual crop agriculture.

Environmental Education

One reason why the forestry sector has been relatively neglected in many tropical countries is that decisionmakers and the general public are unaware of the costs of forest degradation and the benefits of forest maintenance. Environmental education is a term that covers a broad range of efforts to change people's behavior by 1) giving them knowledge regarding interactions between natural resources and the quality of their lives, 2) inspiring an emotional commitment to environmental quality, and 3) teaching what actions individuals and groups can take to sustain or improve the productivity of their environment.

To change people's attitudes toward natural resources, an education program should be based not only on technical knowledge of environmental sciences but also on knowledge of the psychological and cultural factors that motivate human behavior (39). However, environmental educators are generally not trained in the sciences of human behavior and so do not apply the scientific method to improve environmental education techniques. Trial and error with little basis in scientific theory can lead to improvements if the reasons for success and failure are documented. Unfortunately, environmental education programs in tropical nations, perhaps because they are so small relative to the problems they address, seldom set aside sufficient funds or time for evaluation and documentation (45).

Ideally, environmental education should be incorporated into regular curricula at the primary school level. That is when basic attitudes and values are formed, and primary school will be many tropical people's only formal education. Practical considerations, however, constrain this broad and future-oriented approach. The few environmental education programs that exist are poorly funded and understaffed. Thus, priorities must be set to en-

sure the effective use of very limited educational resources. For U.S.-funded efforts, the most effective approach may be to focus first on those who make decisions of greater long-term impact—politicians, government officials, and faculty who are teaching potential future leaders.

Mass media can provide effective means to reach populations outside the classroom. They can be used to teach principles of ecology and resource management, to illuminate pressing resource development problems, and to explain how people can affect resource sustainability directly or by influencing public policy. Radio, newspapers, pamphlets, and comic books have been cost-effective tools for education in tropical countries. Environmental education activities also can be tied into development projects in their public outreach and monitoring and evaluation functions (36).

Principles of Environmental Education

The state of the art in environmental education is not sufficiently advanced to predict specifically what techniques will succeed in various situations. But a review of development assistance programs with environmental education components has indicated general principles for success in environmental education (45). Programs should:

- address specific resource problems,
- reach particular audiences,
- reach all the decisionmakers who must participate in the solution to the problem,
- be compatible with cultural values and personal motivations,
- include opportunities for continuing evaluation, documentation, and adaptation, and
- include opportunities and support to make the education effort ongoing and capable of spreading to other audiences. (45).

The environmental education task is straightforward only where benefits accrue directly to the decisionmaker. For example, a social forestry project in Northern Pakistan that seeks to change the use of steep deforested hillsides has had enthusiastic participation from farmers who want to preserve their land's productivity for the benefit of their children. However, getting government officials to allocate scarce resources to expand the program has not been so easy. The program benefits some upland farmers in a few years and more downstream farmers in many years, but it may never directly benefit the government personnel by bringing political recognition.

Another example that demonstrates several of the environmental education principles is a Peace Corps project in Paraguay that trained rural elementary school teachers in basic environmental education methods. The program was designed to include the faculty and staff from the schools officials from the Ministries of Agriculture and Education, and Peace Corps staff. Ministry officials were convinced of the importance of environmental education through workshops and discussions. To encourage the teachers, the Ministries agreed to provide salary increases for teachers in a pilot program who developed and evaluated an environmental education curriculum for their students. However, the importance of a multilevel approach became apparent when the Peace Corps diminished its involvement with ministry officials and focused only on the teachers. Ministry support declined and so the teachers could not spread the curriculum they had designed beyond the initial pilot project area. This suggests that the program may have failed to provide for the personal motivations of all levels of decisionmakers who would affect the program's success.

Because changes in human attitudes are difficult to effect and measure, environmental education efforts will remain difficult to evaluate, document, and duplicate. This gives the technology a disadvantage when competing with other, better developed technologies that have more easily measured results. Although environmental education lacks a strong basis in behavioral science, it can still progress if programs are documented by the practitioners.

RESEARCH

Fundamental and Applied Research

Sustaining tropical forest resources depends on implementing technologies that simultaneously can: 1) provide basic needs (food, fiber, fuel, construction materials, and cash), 2) sustain the renewability of the resources, and 3) be profitable and culturally acceptable to different groups with different levels of knowledge, skills, and resources. Technologies that meet all these requirements exist for only a few tropical forest situations, but probably could be developed for other kinds of forests with other socioeconomic conditions. Such technology development will require fundamental research on both natural and manipulated ecosystems, applied research on technologies appropriate for specific cultural and ecological conditions, projects implementing the technologies, and evaluation research that leads to continuous improvement and diffusion.

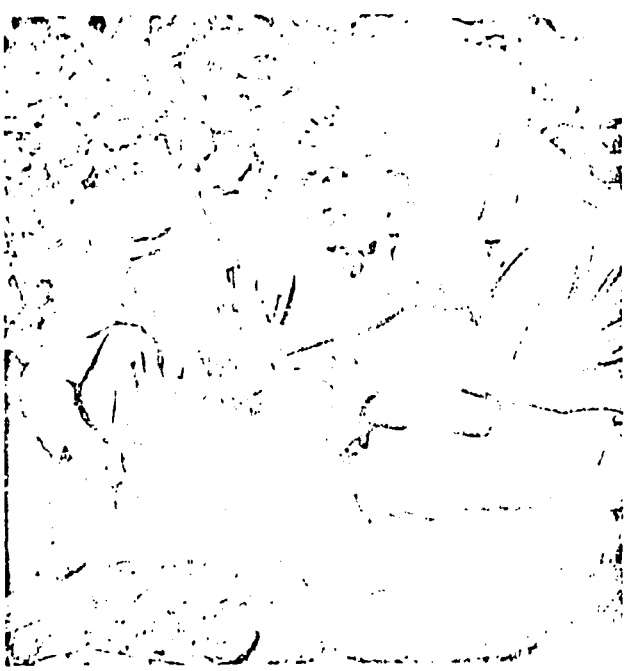

Photo credit U.N. Food and Agriculture Organization

Forestry research, both fundamental and applied, is often poorly linked to development programs. However, programs exist that can pay substantial returns on the research investment. Here a Teca tree is prepared for transplanting at the Magdalena Valley Corporation's research center at Santa Marta, Colombia

The purpose of **fundamental forestry research** is to increase understanding of the structure and functioning of forest ecosystems, the physiology of plants and animals, and their use by humans (33). This work serves as the foundation for the principles and techniques used in **applied forestry research,** which is directed toward solving particular problems or improving the use and conservation of forest resources (9). In practice, the distinction between fundamental and applied research often is difficult to make.

Fundamental and applied research on forest resource systems typically require long periods of study before firm conclusions can be drawn because:

- tree lifecycles are long,
- tropical forest components have complex interactions,
- some of these interactions manifest slowly as cycles of plant succession and climate occur, and
- interactions can be obscured by changes in weather and hydrologic flows,

Longer terms for research funding (4-5 year budgets) generally result in better research and, in the long run, more efficient use of research funds (12,33).

Moreover, applied forestry research usually must be site-specific, and transferring the results to other locations often necessitates repeating some of the research. Ecological and silvicultural research in natural forest management, soils, pests and diseases, watershed management, and wildlife are especially site-specific (9). Sociological research similarly is area-specific because of differences in cultures and local problems (20). Site-specificity, however, can be overemphasized. Well-designed applied research can produce general lessons that can be extrapolated and can accelerate research at other sites (12,46).

Research Priorities

Fundamental Research

Fundamental research on tropical forests has concentrated more on evolutionary biology than on tropical ecosystem processes (12). Much research seems simply to reaffirm what has been known for decades. Recognition that the moist tropical forest exists essentially in balance with its environment by recycling nutrients obtained from decaying plant material, not by drawing upon soil minerals, was recognized in 1937 (17). The relationship of chemistry and mineralogy to the hardening of certain soils in the hot, wet Tropics after forest clearing was described in 1956 (2). And because it was recognized that soils of the hot, wet Tropics largely were devoid of important plant nutrients, the overlying forest cover was described as early as 1958 as being ecologically "a desert covered by trees" (10).

Scientists have begun to recognize the need to shift research emphasis to include human manipulation of the ecosystems. The National Academy of Sciences Committee on Research Priorities in Tropical Biology has concluded that tropical ecosystem studies should concentrate on areas that are "selected because they are representative, diverse, and capable of experimental manipulation and because of scientific and societal importance."

The NAS report calls for in-depth study of four types of tropical ecosystems: infertile new world moist lowland forest, fertile new world moist lowland forest, Southeast Asian lowland forest, and new world deciduous forest. The report does not say what technique was used to calculate tradeoffs in choosing these four types. The semiarid open canopy forests and shrublands of the Tropics are poorly represented in the ranking, which suggests that the scientists on the NAS committee give higher priority to the goals related to biologically "rich" environments than to environments where the effects of resource degradation on humans are most immediate.

Regarding priorities for biological inventory, the NAS committee cites areas that contain the richest and most highly endemic biota and those containing biota in immediate danger of extinction. This includes the coastal forests of Ecuador, coastal southern Bahia and Espirito Santo in Brazil, the eastern and southern Brazilian Amazon, western and southern Cameroon and adjacent parts of Nigeria and Gabon, Hawaii, Madagascar, Sri Lanka, Borneo, Celebes, New Caledonia, and forested areas in Tanzania and Kenya.

The committee assigned highest priority to anthropological studies and to interdisciplinary rsearch on the historical, political, social, and economic phenomena that lead to ecological instability in the Tropics. In Mexico, Indonesia, and Thailand, ecological and anthropological research are being combined to investigate traditional resource use systems (16). This approach seems especially likely to lead to modern techniques that are at once profitable and resource conserving (16).

Applied Research

A common criticism of applied forestry research is that it is not focused on resource management needs. Many forest research institutes in developing countries study highly specialized topics to serve academic purposes (27). The management-oriented research that occurs has emphasized short-term trials of exotic species and specialized plantation techniques (5). Often research is based on outdated methods or is implemented incorrectly (22). Furthermore, most of the applied research in tropical forestry has been restricted to biophysical topics while many, perhaps most, of the real constraints are social, economic, or political (23,27).

Applied forest resources research can be made more relevant if the researchers understand the problems faced by technology implementors. Government project managers, extension agents, timber concessionaires, forest industry managers, users of nonindustrial private forests, and other potential users of research findings should help select the research topics (24).

An exchange of information with local people also is usually necessary to correctly iden-

tify resource development problems. Yet, processes to allocate research funds usually involve little interaction with local people until after the topic is set (20). Researchers need to increase their sensitivity to what is achievable in situations where capital and management skills are scarce and where labor is abundant but costly (14).

Before 1980, few systematic attempts had been made to establish comprehensive priorities for applied tropical forest research or to coordinate programs. Since then, various organizations have recognized that the limited research funds must be used more efficiently and have produced priority lists. Tables 32, 33, and 34 show priorities identified by the

Table 32.—U.S. Priorities for Applied Research

I. Reforestation and afforestation
- A. Species selection
- B. Erosion control
- C. Maintenance of soil fertility
- D. Nursery establishment and planting techniques
- E. Protection
  - 1. Grazing animals
  - 2. Pests and disease
  - 3. Fire
- F. Shelterbelt configurations

II. Meeting the demand for fuels
- A. Alternatives to fuelwood
- B. More efficient, culturally acceptable woodstoves and charcoal production techniques

III. Industrial forestry and conservation
- A. Properties of species currently not used by industry
- B. Techniques for decreasing wood losses in harvesting, transport, storage, and processing

IV. Remote sensing applications

V. Integration of forest management into comprehensive rural development
- A. Multiple-use management
- B. Combinations of activities
- C. Incentives for carrying out sound management

VI. Economics
- A. Relationship between forest land management and watersheds
- B. Value of wildlife
- C. Relative merits of village woodlots, farm forestry, reforestation, agroforestry, and strip planting
- D. Demonstration effects of forestry programs

SOURCE: U.S Interagency Task Force on Tropical Forests, *The World's Tropical Forests: A Policy Strategy and Program for the United States* (Washington, D.C.: U.S. Government Printing Office, 1980).

Table 33.—World Bank/FAO Priorities for Forestry Research in Developing Countries

I. Forestry in relation to agriculture and rural development
- A. Sociological and institutional research
- B. Farming systems using trees
- C. Watersheds (catchments) and range management
- D. Wildlife in relation to rural welfare

II. Forestry in relation to energy production and use
- A. Silviculture of biomass/fuelwood species and systems
- B. Yield, harvesting, and properties
- C. Industrial research related to village technology
- D. Comparison with alternative fuels (social, technical, and economic efficiency)
- E. Wood-based derivatives

III. Management and conservation of existing resources (mainly natural forests)
- A. Resource survey
- B. Conservation
- C. Silvicultural systems for natural forests
- D. Whole tree use
- E. Use and marketing of secondary species
- F. Wood preservation

IV. Industrial forestry
- A. Silviculture and management
- B. Wood properties

SOURCE: World Bank/Food and Agriculture Organization, *Forestry Needs in Developing Countries: Time for a Reappraisal?* paper for 17th IUFRO Congress, Kyoto, Japan, Sept. 6-17, 1981.

Table 34.—The East-West Center's Priority List for Scientific Forestry Research

Rank	Subject
1	Ecology
2	Silviculture
3	Agroforestry
4	Reforestation, afforestation
5	Watershed management, hydrology
6	Fuel, bioenergy
7	Forest industries and use
8	Surveys and inventories
9	Education, research, and training
10	Policy and planning
11	Logging and transport
12	Nursery practice
13	Genetics
14	Marketing
15	Economics, especially of product processing
16	Land tenure
17	Soils
18	Protection of wood products
19	Forest products (technological)

SOURCE: E. Brunig, *Summary Report on the Asia-Pacific Regional Workshop for Forest Research Directors* (Honolulu, Hawaii, East-West Center Environment and Policy Institute, 1982).

U.S. Interagency Task Force (43), The World Bank/FAO (47), and the East-West Center Conference (5).

The recent creation of research priority lists suggests that organizations funding applied tropical forestry research may begin to exert more control over which topics are investigated. Other recent developments suggest that the scientists who do forestry research are recognizing the urgency of tropical forest resource problems and are ready to cooperate with coordination efforts.

For example, the International Union of Forestry Research Organizations (IUFRO) has concentrated on timber production for use in the industrialized nations. Now, it is shifting its focus to forestry in the developing nations and is organizing a series of international workshops on fuelwood systems and multipurpose trees for reforestation of degraded lands. These workshops are expected to guide research funding by donor agencies such as AID. Meanwhile, AID is substantially increasing its funding for forestry research over the next 10 years.

Dissemination of Research Findings

Within many tropical countries, little communication takes place between research organizations and the government agencies that carry out resource development programs (47). In some countries, language barriers and the scarcity and cost of translation services cause difficulties. However, even within the United States a similar lack of communication occurs between forestry researchers and technology implementors (9). Researchers are not rewarded for publishing in popular literature, and the planners and managers of forest resource development projects seldom have the time or inclination to study technical reports in scientific journals.

Obstacles to effective dissemination include:

- lack of public recognition of the relevance and urgency of the situation,
- lack of political support,
- unwillingness to accept risks,
- inadequate verification and demonstration of findings,
- incompatibility between donor objectives and research needs,
- failure to use the potential of the popular media,
- inadequate funding of dissemination activities,
- incomprehensibility of dissemination presentations, and
- insufficient experience in dissemination (5).

Dissemination of research findings to decisionmakers and field staff could be improved with better organization and funding (27). IUFRO carries out some dissemination, but its role could be increased. IUFRO's official publications are issued in English, French, and German; the lack of Spanish translations is a deficiency. More study tours and exchanges among developing countries could increase technical cooperation (47).

Computerized information storage and retrieval systems exist in the United States and in other industrial nations that could be used to improve the dissemination of research results and, thus, could greatly enhance the benefits derived from research on tropical forest resources. Examples include the AGRICOLA bibliographic systems of USDA's National Library of Agriculture, Ecosystematics and other data bases at USDA's Economic Botany Laboratory, the Smithsonian Science Information Exchange, the U.S. Forest Service Current Information System, and the Commonwealth Forestry Institute System (Oxford, England).

The U.S. Forest Service has a popular periodical, *Treeplanter's Notes*, that disseminates research findings to forestry practitioners. The FAO Forestry Department does have a publication, *Unasylva*, but it has a broad focus and is aimed at government decisionmakers in the forestry sector, so it seldom gives the detail forestry practitioners need. Field-level managers need regional publications that are not overly technical (23). The U.S. Forest Service filled this role in one region with *The Carib-*

bean Forester until this publication was terminated in 1963.

AID supports a large number of small newsletters but these are not always well-publicized and most of them have a narrow focus (23). One effective newsletter published by AID, *Resources Report*, reviews technical reports and will send copies to less-developed-country subscribers who request them. More efforts also should be made to translate key research findings into local languages.

Summary

A number of institutional weaknesses in developing countries contribute to the inadequacy of forestry research. The most serious deficiency in many countries is the shortage of qualified scientists. Researchers often lack scientific skills as well as related skills in research management and administration, technical writing, research design and analysis, foreign language, and data processing (5). Mechanisms exist to provide in-service training to tropical nation scientists at universities and herbaria in the United States, and at the research stations of the Forest Service and other agencies of the Departments of Agriculture and Interior. A thorough review of such opportunities by the General Accounting Office or a similar agency might reveal ways to use them more effectively.

Well-qualified scientists in tropical nations often leave government service or emigrate abroad because of low pay and recognition; inadequate funding; limited research facilities, equipment, and libraries; or the shortage of suitable colleagues. Research is hindered in some countries by bureaucratic rigidities, overcentralization or fragmentation, lack of political support, and interagency rivalries (9,22,33). In many tropical cultures, little prestige is attached to forestry research because the educated, urban class views field work in rural areas as hardship duty appropriate only for lower level staff (22). U.S. scientists concerned about the degradation of tropical resources could act through their various professional organizations to enhance the prestige of their colleagues in tropical nations.

Although the United States has recognized strengths in the social sciences, the number of U.S. social scientists with expertise relevant to tropical forest resource development is not known. They may constitute one of the major U.S. academic strengths for research on technologies to sustain tropical forest resources. One or more centers of excellence in tropical forestry, as discussed earlier in this chapter, could serve to better coordinate the scattered U.S. research expertise.

TECHNOLOGY TRANSFER

Background

The experience of U.S. forestry organizations shows that many potentially profitable techniques languish for lack of effective technology transfer among scientists and between scientists and technology users (9). The tropical nations facing severe deforestation and rapid population growth cannot afford such inefficiency. Therefore, a concerted effort is needed to build local organizations' capacities to choose, receive, adapt, and deliver technologies appropriate to local circumstances.

Technology transfer is the business of the development assistance agencies, and the way in which they conduct their business has a major influence on whether renewable resources are kept renewable. The literature on technology transfer is voluminous but mainly theoretical, and little of this theory is focused on forest-related technologies. So OTA convened

an interdisciplinary panel to consider the conditions necessary for successful transfer of tropical forest resource technologies.

Necessary Conditions for Successful Technology Transfer

Nine key conditions for successful technology transfer were identified. **First,** the technology should be adapted to the local biophysical and socioeconomic environment of the users. The technology to be transferred should have been used successfully elsewhere under similar conditions, at least on a pilot scale. Technology transfer should not be confused with experimentation or applied research. Otherwise, the technology is likely to be unsuccessful and the adopters might become unwilling to try other innovations.

Second, technology is transferred most effectively by direct people-to-people actions. People who are to adapt and apply the technology need to learn it directly from people who have experience applying it. Successful technology transfers seldom are based solely on media presentations, such as pamphlets, books, radio programs, or films. Rather, personal interactions are essential. Media presentations, however, can help motivate the personal interaction, supplement technology transfer efforts, and support subsequent applications of the technology (3).

Third, the technology transfer agents must be well-qualified and able to communicate effectively to people who are capable of receiving and applying the technology. Agency personnel who are themselves learning the technology for the first time as they try to transfer it are often a cause of failure. Thus, development assistance agencies need to employ substantial numbers of experienced technical personnel.

A more significant constraint is the lack of indigenous capacity to continue the technology transfer beyond the boundaries of development assistance projects. Thus, the task for development assistance agencies is to enable local organizations to build an effective system of transfer agents who use personal contact to reassure people about the appropriateness of an innovation and who provide the information needed for a fair trial.

Fourth, in addition to transfer agents and capable recipients, "facilitators" or "middlemen" are needed. These people must understand the technology transfer process, especially the market for the technology and its products and the political, social, and economic constraints and opportunities affecting the other actors. Because technology transfer is usually a long-term process, subject to mistakes and setbacks, it needs advocates to help the new technologies compete with established ways of using resources. Thus, facilitators must maintain their roles throughout the transfer process.

The permanent staff of development assistance agencies could act as facilitators. Too often, however, they are rotated to other parts of the agency before the technology transfer process is complete. An alternative is for the development assistance agencies to locate and work with facilitators among the indigenous tropical people (31).

Fifth, users and transfer agents should be involved in choosing, planning, and implementing the technology transfer so it meets actual needs and is appropriate for the situation. For example, women are most directly affected by community forestry projects but are usually excluded from problem identification and project planning efforts (1).

Sixth, all parties involved must feel that they are "winners" and must, in fact, be winners. Each actor's interests should be identified at the start of the technology transfer process so they can be addressed. Early in the transfer process, the potential users must be shown the merits of an innovation (34). Many ideas that outsiders think will solve development problems may not seem beneficial to the people who are directly affected by them. For example, village woodlots may be supported by local women who otherwise must walk far to collect each day's fuel but resisted by local men

who may view them as an unprofitable use of land and by herders who may view them as an intrusion on grazing land.

For technologies designed to produce items or services for sale, the intended adopters usually must have information on markets in order to anticipate benefits. With reforestation or forest product technologies, the information can be obtained through demonstration projects, surveys, and market research. Where education and research technologies are being transferred, it is necessary to determine who will reward the educator or researcher for using the new technologies.

Seventh, the participants must be aware of subsequent steps in the transfer process and the relationship between their actions and those steps. This requires early definition and communication of roles for each person involved. A well articulated strategy must be devised. Of course, this strategy must be flexible, since it is planned at the time in the transfer process when least is known about how it will work. In particular, plans must be made to disseminate the technology beyond the pilot project.

Eighth, demonstrations of the technology should take place under conditions similar to conditions that will exist subsequently. Pilot projects should not be made unrealistically easy by being given unrealistic levels of funds or other inputs, being located where there are few socioeconomic or institutional constraints, or being provided with artificial markets.

Finally, the initial commitment of resources should be sufficient to carry the technology transfer until it is self-supporting. A transfer is self-supporting when the techniques have been adapted to local conditions and are being adopted spontaneously by organizations or individuals.

Opportunities to Improve Technology Transfer

In agriculture, development assistance agencies have had impressive technology transfer successes. Yet, relatively little has been done in the forestry sector. The need for international assistance in development of forest resources has been realized only recently, but there are already some indications that the level of such assistance is leveling off (29). The assistance agencies' major opportunities, then, lie more in increasing the likelihood of technology transfer success than in increasing the number of projects.

Coordination of Development Assistance Agencies

Many organizations attempt to help tropical nations develop forest resources, but these efforts are poorly coordinated. The causes of tropical forest degradation are so complex that no single assistance agency is likely to be able to create sufficient conditions for the forests to be sustained. To do that the various capabilities of all the development assistance agencies are needed. However, it is unlikely that these capabilities will be applied at the right places at the right times simply by chance.

The need for improved coordination was stressed in the report of the U.S. Interagency Task Force on Tropical Forests. In section 118 of the Foreign Assistance Act, Congress has given AID a specific mandate to improve coordination of forestry and natural resource development assistance in tropical nations. But the needed coordination does not occur because of the structure, staffing, and management of development assistance bureaucracies. In the tropical countries, these organizations are generally too understaffed to manage their own programs sensitively and have no incentives to coordinate and collaborate with others (42).

In theory, long range strategies and coordination should be administered by agencies of the tropical nations. In practice, when funding is from foreign or international donor agencies, decisions to implement projects are often made without reference to a long-term resource development strategy or to how the project compares with alternative investments. Because the availability of the donor funds usually cannot be separated from a specific project (41), the

immediate need to maximize foreign donor funding interferes with the longer term need to coordinate donor efforts.

One way to get around these bureaucratic constraints is to establish ad hoc international organizations with no programs or policies to promote other than 1) design of long-term strategies for technology transfer to effect sustainable resource development, and 2) coordination of assistance agencies' contributions to carrying out those strategies. Coordinated Development in Africa (CDA) is such an ad hoc organization that seems to be gaining the political influence and the technical expertise necessary to make this approach work. Its efforts are directed to designing long-term strategies. Whether the coordination necessary to follow such strategies will be politically feasible remains to be demonstrated.

Need for Professionals

Another major constraint on successful technology transfer is misidentification of resource development problems. This results from a lack of public participation in planning technology transfers and from a too-narrow technical approach to project planning (19). While the need for participant planning and interdisciplinary technical inputs is widely recognized, it is too seldom realized. To a large extent this is because of the shortage of technically experienced personnel in development assistance agencies' offices in the tropical countries (42).

Chronic understaffing means that people in charge must spend nearly all their time doing bureaucratic functions. Technical inputs are then left almost entirely to contractors. This means the agency staff must make decisions about technical matters which they are often not qualified to decide.

One opportunity to overcome the shortage of professionals is to encourage experts who work for U.S. Federal agencies to take temporary assignments in development assistance agencies (44). This probably cannot be done effectively without increasing some budgets, however. Supporting U.S. nationals overseas is more expensive than supporting them domestically, and their absence would disrupt the programs of their regular agencies. Public Law 85-795 enables domestic agencies to assign personnel to international development organizations, but it is seldom used.

Technology Transfer Timing and Followup

Technology transfer, especially where the emphasis is on building the capacity of local institutions to select, adapt, apply, and disseminate technical innovations, is a long-term process. Periods of 10 to 20 years are typically needed before progress can be measured in terms of product or income. Yet, short development project planning and funding cycles often mean that projects must be evaluated at the end of 2 to 5 years to determine whether funding is to continue. At this stage, a technology transfer project is barely under way and should be expected to have revealed problems and be experiencing setbacks. Thus, the function of an evaluation should be to develop information on how to deal with these. However, this important function is compromised if participants in the evaluation fear that a seemingly negative evaluation will lead to premature termination (42).

Once a technology transfer appears to have become self supporting on a local level, continuing technical support is often necessary. Unforeseen problems will arise during the technology's diffusion, and these may be beyond the technical capacity of the local institutions. Regional centers of technical expertise that offer continuing education to technicians, technology managers, and technology transfer facilitators, and that disseminate further innovations and improvements in technologies, could help solve this problem. This has proven successful with remote-sensing technology transfer projects sponsored by development assistance agencies in Africa (7).

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