Applying Ecology in the Third World: The Case of Mexico

BY ALICIA CASTILLO AND VICTOR M. TOLEDO

Ecologists and policymakers alike generally agree that ecological knowledge should be considered in setting environmental policy and that ecologists should be more involved in decisions related to the management and conservation of natural resources (e.g., Ehrlich 1989, Lubchenco et al. 1991). The essence of applied ecology is that it is "solution oriented," in contrast to pure ecology, which is "problem oriented" (Newman 1993). Applied ecology seeks solutions to practical problems and is guided, at present, by the paradigm of sustainability. Applying ecology would mean using original research in the management and conservation of natural resources. That is, it implies that scientific methods can be used to solve problems in agriculture, forestry, fisheries, wildlife management, resource extraction, and biodiversity conservation.

Despite the potential of applied ecology, there is still disagreement about the extent to which ecological science is applicable to real-world problems. This concern is intensified by the fact that, although the numbers of ecologists and journals specifically dedicated to ecological topics are growing, the main global environmental problems, such as deforestation, soil erosion, loss of biodiversity, water depletion, and species exploitation, are continuing to increase at alarming rates. For example, an analysis of the influence on management practice or policy of 50 representative articles published over the last 30 years in one prominent ecology journal, the *Journal of Applied Ecology*, showed that most of these articles lacked an indication of the practical applications of the work or of management recommendations derived from the research (Pienkowski and Watkinson 1996).

Ecology and related disciplines now confront the urgent challenge of making a relevant contribution to the wise management and conservation of Earth's resources and life support systems. Many ecologists are now taking up this challenge. For example, the publication of the Sustainable Biosphere Initiative (Lubchenco et al. 1991), which was based on an awareness of the need to link science with decision-making, constituted an important step. Another important contribution was an article by Ludwig et al. (1993), which served as the basis for a forum in *Ecological Applications* about natural resources exploitation. Among the conclusions of the forum was the importance of recognizing the limitations of ecologists' knowledge of managed systems and the difficulties involved in gaining the necessary understanding.

Based on the recognition that environmental problems are not entirely or even primarily scientific (Levin 1993), some authors (e.g., Funtowicz and Ravetz 1991, Costanza 1993) have emphasized the need to integrate science with other sources of information. These authors relate ecology's low impact on solving problems to its limited capacity to function in an interdisciplinary context. In particular, information from the social sciences and the knowledge generated by rural societies worldwide (which are commonly referred to as indigenous or traditional) have an important role to play in formulating strategies for natural resource management and conservation (Altieri and Hecht 1990, Toledo 1992, Costanza 1993). Ecological information is, therefore, only one part of the decision-making process for environmental management. Consequently, more integrative forms of ecological inquiry that analyze issues from a systems perspective, including the interactions of social systems with natural systems, are needed (Holling et al. 1998).

In this article, we consider applied ecological research in developing countries, in which natural resources are predominantly used, managed, and conserved by community-based actors. We review the situation in Mexico, using it to suggest that the perceived limits of applied ecological research are related to how knowledge is generated, communicated, and socialized by scientists and their institutions. Applied ecology, at least in Mexico, seems to better accomplish its objectives when researchers and institutions conduct research in conjunction with the social actors involved in the management of natural resources. Such sectors include government agencies, nongovernmental organizations, international agencies, and rural producers themselves—the complex array of agriculturists, cattle ranchers, forest dwellers and harvesters, hunters, gatherers, and fishermen whose lives depend directly on the appropriation of natural resources. We conclude by proposing a model that can serve as a general framework for developing more integrative forms of

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Table 1. Number of holdings and owned area in 1991 for the peasant (community-based), private, and mixed[a] sectors in rural Mexico (INEGI 1994).

Sector	Number of holdings (%)	Area ($\times 10^6$ ha) (%)
Community-based	3,040,495 (66.3)	103.3 (59.0)
Private	1,410,742 (30.8)	71.7 (40.9)
Mixed	133,912 (2.9)	0.13 (0.1)
Total	4,585,149 (100)	175.13 (100)

[a]In a mixed sector, a landowner holds both types of land tenure systems (private and communal).

applied ecological research and by emphasizing the role of communication in facilitating the use of scientific findings.

The management of natural resources in the Third World

Understanding how scientific institutions and their researchers perceive the social and economic actors in natural resource management is crucial for designing strategies for applying ecological research. Labels such as "users," "managers," "exploiters," "stakeholders," or "decision-makers" commonly found in the ecological literature oversimplify a complex reality. These terms fail to recognize specific actors who can be identified culturally, socially, and economically.

The management of ecosystems is not only an ecological event but also a social—and, therefore, an economic, cultural, and even political—phenomenon. Human appropriation of nature removes minerals, water, energy, and living beings (biomass) from ecosystems. A substantial proportion of the world's biomass is directly appropriated through rural production, including agriculture, cattle raising, fisheries, hunting, gathering, and forestry. These activities are the main human activities on Earth and the principal influences on our planet's ecology (Vitousek et al. 1986). They constitute the first step in the process by which societies organize the exchange of matter and energy with nature.

Although most humans live in cities, and almost no place on Earth is free of industrial artifacts, products, and services, the portion of humanity involved in the capture of biomass is still considerable. By 1950, more than half of the human population participated in the direct appropriation of the products of nature. In 1990, the total number of people was twice that of 1950, but 45% of them were still engaged in some kind of primary production activities (FAO 1991). Approximately 95% of the agricultural population occurs in Third World countries, whereas only 5% occurs in developed nations. Consequently, human appropriation of nature is carried out mainly in nations characterized by high biological richness (Mittermeier et al. 1997), a diversity of cultures, and, ironically, high social and economic poverty and high rates of environmental depletion (UNEP 1997).

Rural producers of the contemporary world generally belong to two main contrasting and historically rooted archetypes: peasants and modern agroindustrialized producers. The ecological implications of these two main modes of appropriating nature have recently been examined (Gadgil and Guha 1993, Netting 1993, Toledo 1995). Although it is difficult to determine the exact proportion of the agricultural population corresponding to these two main types of rural producers, between 60% and 80% are still peasants or peasantlike producers. This estimate is based on the use of a key characteristic: small production units. The areas of the world in which small-scale production units clearly predominate correspond again to the Third World. In contrast, the countryside of most industrialized nations is dominated by medium and large-scale agroindustrial units (albeit with some notable exceptions, such as in Portugal, Spain, and Greece).

Statistical data show that by 1990, approximately 1.2 billion rural people were practicing agricultural activities on areas of 5 hectares or less (Toledo 1997). This figure is consistent with the last available world census of agriculture, in which more than 80% of all reported holdings were smaller than 5 hectares (Wilken 1987). Most of this

Table 2. Major ecological research institutions in Mexico.

Institution[a]	Year founded	Number of researchers[b]	Main geographical influence	Teaching programs
IE-AC	1975	106 (38)	National, with a focus on the northeast, central Mexico, and the Gulf of Mexico	Master's and doctorate in ecology and natural resources management
Ecosur	1977	104 (25)	Southeast of Mexico	Master's in natural resources and rural development and doctorate in ecology and sustainable development
IMECBio	1985	55 (0)	Sierra de Manantlán, Jalisco	Bachelor's of Engineering in natural resources
IE-UNAM	1987	54 (53)	Several regions	Master's and doctorate in ecology
IEA	1983	20 (1)	Tamaulipas State	No program is being developed

[a]Abbreviations are as follows: IE-AC, Instituto de Ecología A.C.; Ecosur, Colegio de la Frontera Sur; IMECBio, Instituto Manantlán de Ecología y Conservación de la Biodiversidad; IE-UNAM, Instituto de Ecología UNAM; IEA, Instituto de Ecología y Alimentos.
[b]Information was provided by each institution. The number in parentheses indicates the number of researchers who are members of the National System of Researchers (SNI).

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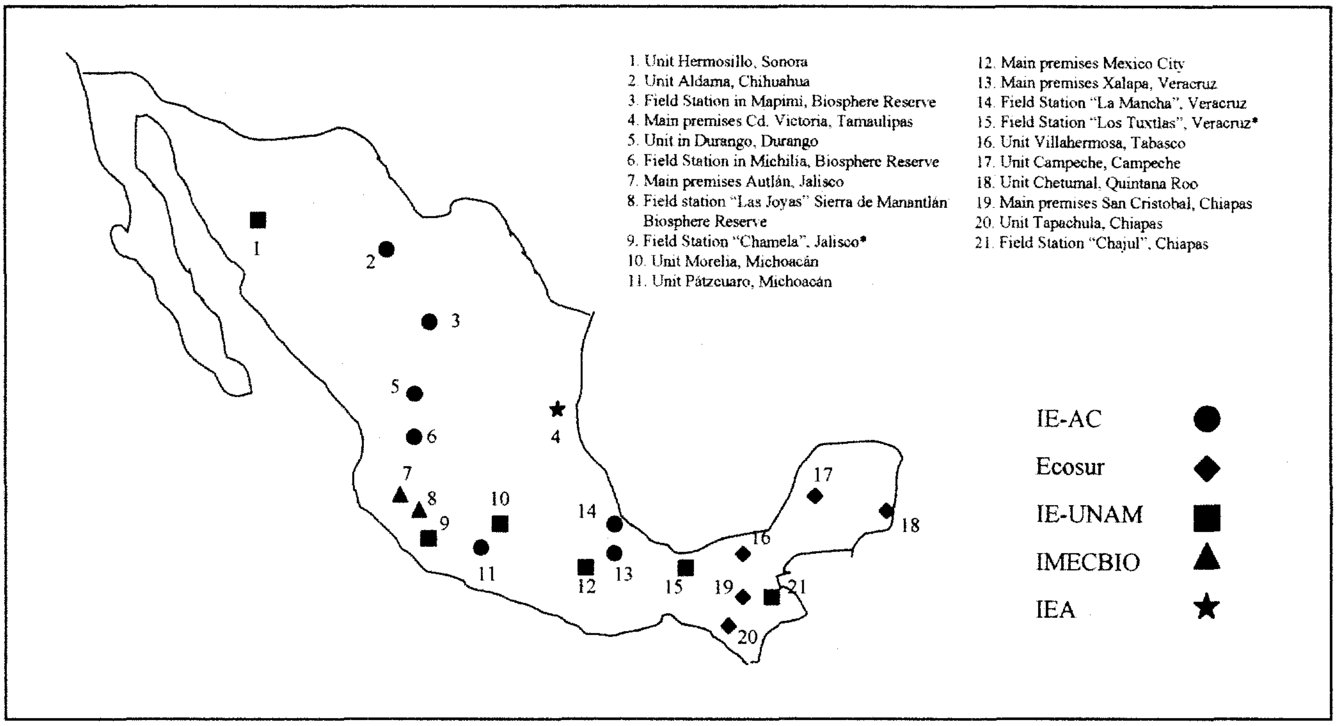

Figure 1. Location of the main campuses (premises) and facilities of the five main institutions of ecological research in Mexico: IE-AC, Instituto de Ecología A.C. (part of the National Council of Science and Technology); Ecosur, Colegio de la Frontera Sur (part of the National Council of Science and Technology); IMECBio, Instituto Manantlán de Ecología y Conservación de la Biodiversidad (part of the University of Guadalajara); IE-UNAM, Instituto de Ecología UNAM (part of the National Autonomous University of Mexico); and IEA, Instituto de Ecología y Alimentos (part of the Autonomous University of Tamaulipas). The Chamela (9) and Los Tuxtlas (15) field stations are actually part of the Institute of Biology of UNAM, but many researchers at IE-UNAM have carried out investigations in these sites.

peasant population carries out its production activities not as socially isolated households but as family units belonging to specific village communities. These family units represent community-based resource management systems; such management systems are the norm in Egypt, Tanzania, Vietnam, Indonesia, Perú, Bolivia, Colombia, and, especially, Mexico, India, and China.

Given this context, applied ecologists and their institutions in the Third World must recognize the importance of small-scale, community-based producers as target audiences to promote the effective, practical use of new scientific knowledge. These producers generally belong to some of the approximately 6000 indigenous cultures (Toledo in press) that, through long periods of time, have constructed complex systems of knowledge about their environments. Consequently, ecological research must be planned according to the information demands, cultural characteristics, and productive bottlenecks of these rural producers, not only at the country scale but also, and especially, on regional, micro-regional, and local scales.

The case of Mexico

Mexico is one of the main centers of biodiversity of the world. It is the fifth-most biologically rich nation, after Brazil, Colombia, Australia, and Indonesia (Mittermeier et al. 1997). The biological diversity of Mexico results from its topographic and climatic variation, which creates a rich mosaic of habitats. Six well-defined terrestrial ecological regions can be distinguished: humid and sub-humid tropical lowlands, humid and sub-humid temperate mountains, deserts, and wetlands (Toledo and Ordoñez 1993). This diversity of environments and a wealth of natural resources were undoubtedly decisive factors in making Mexico the birthplace of major early civilizations of Mesoamerica. Contemporary rural Mexico is still, after many centuries of social change, an agrarian nation that is dominated by indigenous, or Indian-derived, peasants. In addition to the mestizos, or Spanish-speaking producers, there are 54 main indigenous groups speaking 240 languages and dialects (Grimes 1988). These indigenous groups live in nearly all of the main natural habitats of the country.

Community-based systems of resource management are of great importance in Mexico. Approximately 30,000 peasant communities manage more than 100 million hectares, corresponding to 60% of the country's productive land area. In addition, 7000–9000 communities manage approximately 70% of Mexican forests (Bray 1995). These peasant units are embodied in two forms of community-based corporate ownership that are currently rec-

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Table 4. Number of applied ecological projects[a] carried out in Mexican research institutions.[b]

Area of concern	IE-AC (45)	Ecosur (52)	IMECBio (46)	IE-UNAM (105)	IEA (18)	Subtotal (46)	Other 11 institutions[d]	Total
	Number of applied projects[c]							
Agriculture	0	8	7	5	3	23	9	32
Livestock production	0	1	3	0	0	4	1	5
Forestry and agroforestry	0	4	12	8	3	27	13	40
Fishing and aquaculture	0	0	0	0	0	0	1	1
Wildlife management	4	9	1	0	0	14	5	19
Conservation	8	10	3	9	5	35	22	57
Landscape modeling	2	2	0	2	1	7	6	13
Ethnoecological rescue	0	3	4	1	0	8	4	12
Ecological restoration	0	0	0	2	0	2	2	4
Total applied projects	14	37	30	27	12	120	63	183
Ratio of applied to total projects	31.1	71.1	65.2	25.7	66.6	45.1	—	—

[a]The number of applied projects dealing with different productive and conservation issues was obtained from the list of research projects reported by each institution in the 1998 Mexican directory of organizations involved in environmental conservation (FMCN 1998).
[b]IE-AC, Instituto de Ecología A.C.; Ecosur, Colegio de la Frontera Sur; IMECBio, Instituto Manantlán de Ecología y Conservación de la Biodiversidad; IE-UNAM, Instituto de Ecología UNAM; IEA, Instituto de Ecología y Alimentos.
[c]Numbers in parentheses indicate the total number of research projects reported by the institutions.
[d]No total number of projects is given for the other 11 institutions carrying out ecological research because many of these projects are in areas other than ecology.

or in areas such as agriculture and forestry. The field of plant ecology has been particularly well developed in Mexico, especially during the last two decades (Martínez-Ramos 1994).

Information needs. Mexico's natural resources have suffered a dramatic depletion as a consequence of the activities of rural producers (Table 3). This decline in the quality of the natural resource base is reflected in stagnant agricultural, livestock, forestry, and fisheries production. In fact, Mexico is now a net importer of corn, sorghum, beans, milk, and other foodstuffs. Thus, as Table 3 shows, numerous environmental problems affect Mexico's natural resources, to which applied ecological research could contribute solutions.

The response of Mexican research institutions. Attempts to close the gap between scientific research and environmental problems in Mexico have been carried out by research institutions for several decades. For example, INIREB aimed to integrate basic and applied research with resource management and education; although it has been dissolved, its innovative approach is still influential in the work of important research groups in Mexico (see Gómez-Pompa and Giddings 1986). And in recent times, applied ecologists have been studying ways to solve some of the main ecological problems found at the rural community level (see boxes on pages 71–73 for examples).

To examine the extent to which research institutions in Mexico have responded to the need to solve environmental problems, we evaluated the involvement of the five main ecological research institutions and another 11 research groups in applied ecological projects (Table 4). The analysis shows that nearly half of the projects carried out by the five main institutions can be considered applied research. The actual proportion may be smaller, however, because a significant proportion (29%) of the projects are classified under conservation, which includes basic as well as applied research. In addition, the analysis showed that the 11 research groups (especially those at the Natural History Institute of Chiapas and the Department of Management and Conservation of Natural Resources [PROTROPICO] of the Autonomous University of Yucatan) play a significant role in applied ecology research in Mexico, accounting for approximately one-third of the total number of applied projects.

This analysis also showed that most applied projects focused on conservation, forestry, and agriculture. Relatively few dealt with livestock production, even though this activity is a major cause of deforestation and land-use change in the tropical lowlands of Mexico (Masera et al. 1997). Only four projects overall were related to restoration ecology, which indicates the poor consideration that Mexican institutions are still giving to this field. The almost complete lack of interest in aquatic ecosystems may be due to the fact that the institutions examined focus their research on terrestrial habitats.

The comparison of the five institutions reveals a range of institutional responses to the need to solve practical problems. Three institutions have an applied orientation (Ecosur, IMECBio, and IEA), and two have a more basic orientation (IE-AC and IE-UNAM). It appears that institutions with a local or regional interest develop more applied types of projects, whereas those not having a clear local focus get more involved in basic scientific subjects.

Another factor that appears to play a part in the decision about institutional research emphasis is the system of academic rewards. Like most academic scientists, ecolo-

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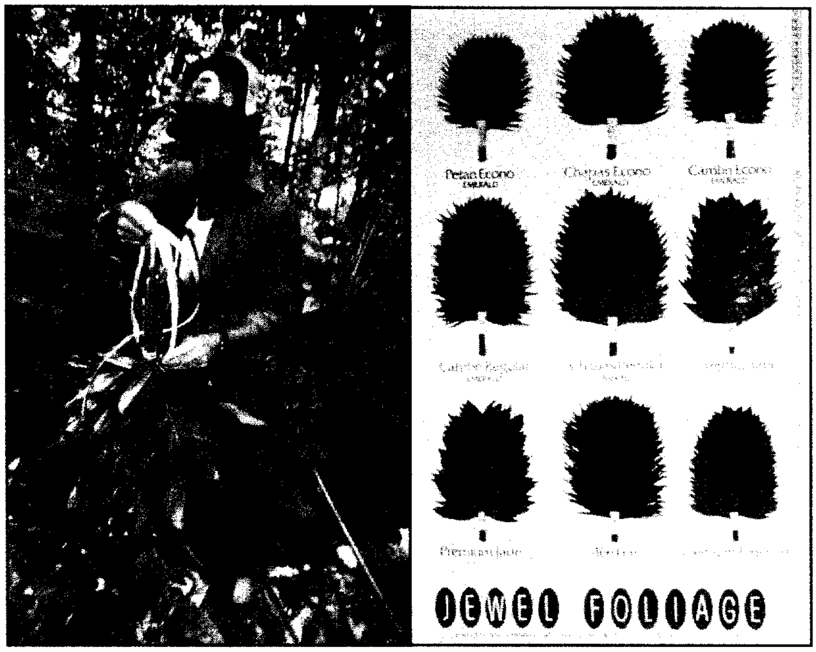
Harvest of tropical nontimber products

Applied ecological research can contribute to the sustainable harvest of wild populations of trees and the optimal cultivation of several nontimber products. The sustainable use of nontimber products represents a productive option for local people living in or near tropical forests. It allows resources to be appropriated while maintaining the integrity of forest ecosystems. In Mexico, thousands of peasants extract vanilla, chicle, allspice, edible fruits, wild fauna, and especially palm leaves of the genus *Chamaedorea* from tropical forests. These palm leaves (and even entire plants) are used as ornamental houseplants and in floral displays, mainly in the United States and Europe.

However, in recent years, an increase in the numbers of people extracting palms, the breakage of leaves and branches during cutting, and forest destruction are putting important palm populations in danger (Oyama 1992). Consequently, several groups have tried to devise strategies to allow both the conservation of *Chamaedorea* palms and the improvement of rural peoples' quality of life. For example, at the "Sierra de Santa Marta" Biosphere Reserve, a nongovernmental organization and a group of researchers are studying the ecology of *Chamaedorea* palms and working with peasants to develop ways to cultivate the palms (Ramírez 1997). This initiative has also benefited from the information derived from the Instituto de Ecología, Universidad Nacional Autónoma de México, whose investigators have carried out extensive research into the evolutionary biology and population dynamics of *Chamaedorea*, thus confirming the links between basic and applied ecology. Similar collaborative projects are being carried out at the Instituto de Ecología y Alimentos with the rural communities of the El Cielo Biosphere Reserve (Trejo et al. 1999).



A collector of "palma xate" (common name of palms of the genus* Chamaedorea*) in Monte Tinta, Oaxaca, Mexico, and a US catalogue offering a variety of palm leaves for sale. Photos: Fulvio Eccardi.

gists in Mexico are confronted with reward structures that emphasize the importance of basic research. The main system of economic incentives in the country is the National System of Researchers (SNI), which is administered by the Ministry of Education to give grants to scientists according to their scientific production (as measured in terms of articles published in refereed international journals). Because the economic benefits obtained from SNI constitute a significant portion of the salaries of Mexican researchers, these scientists tend to focus on producing scientific papers rather than on communicating useful information to nonscientific sectors or participating in other practical activities. Ecologists are, therefore, confronted with a system that values the generation of new scientific knowledge over its social use. Indeed, our analysis (Tables 2 and 4) revealed that the Mexican institution with the highest number of researchers belonging to SNI is also the institution that is the least involved in applied ecology projects (IE-UNAM). Conversely, the research institutions developing more applied projects have the fewest researchers accepted into SNI. Thus, researchers at institutions responding directly to the country's problems seem to be receiving less personal economic incentives than those involved mainly in basic ecological research.

In addition to examining general trends in applied research, it is also worthwhile to look at particular features of the institutions that have high applied interests. For example, the main research aim of IMECBio is to generate knowledge that can be used to solve environmental problems in the area of the Sierra de Manantlán Biosphere Reserve. The main motivators of the research activities are the social demands of the rural communities and the environmental problems of the area (Jardel et al. 1996). Apart from the research groups, IMECBio has two specialized groups—the environmental education and the community development teams—that link the generation of scientific knowledge with its practical use. The environmental educators disseminate information about the reserve and

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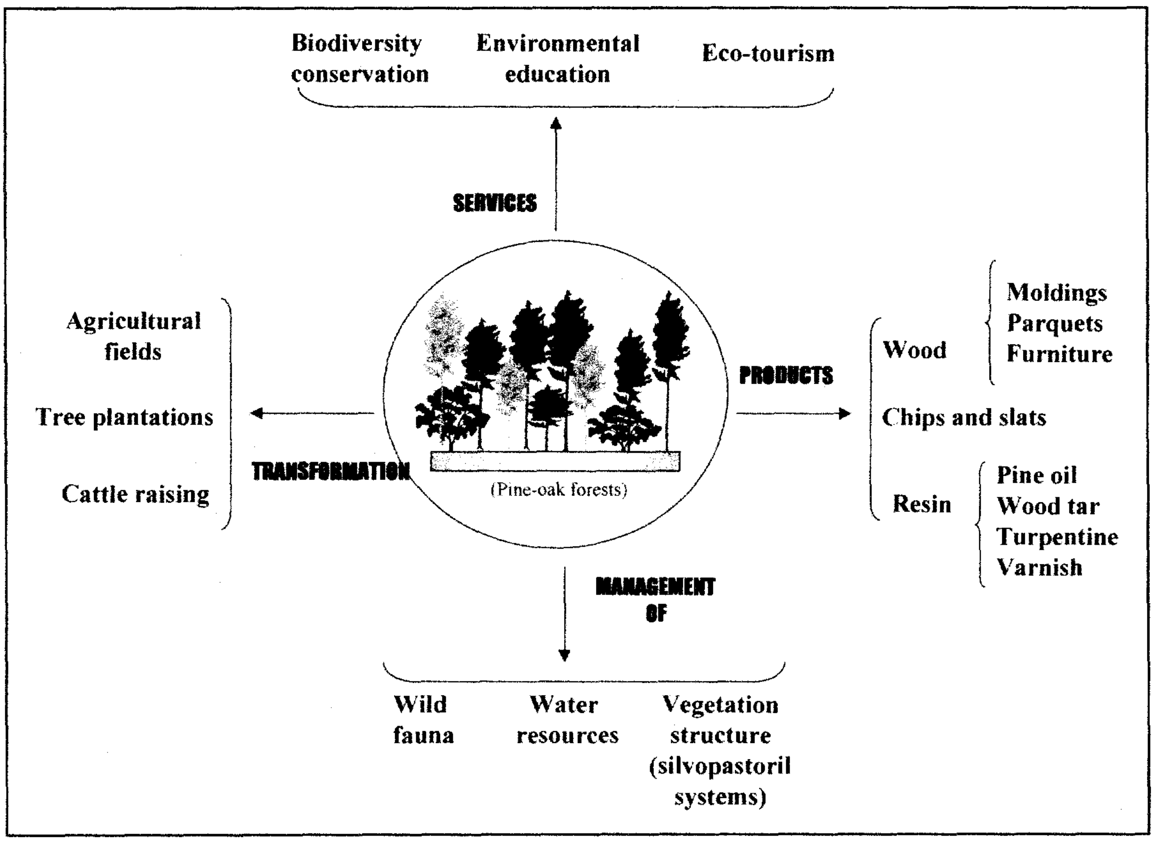
Community-based sustainable forest management

Approximately 70% of Mexican forests are under the dominion of peasant communities, making Mexico the country with the largest experiment in community-based forestry in the world (Bray 1995). These community-owned areas were for many years exploited by private and state companies, with no benefits to local people. During the last two decades, however, peasant communities have been reappropriating their own resources. Today, over 500 ejidos and comunidades have come together to form the National Union of Forest Community Organizations, which is demanding economic incentives, technical assistance, and scientific information to achieve sustainable forest management. Many communities have successfully combined scientific information with administrative efficiency and a strong social organization. Examples can be found in the states of Oaxaca, Quintana Roo, Durango, and Michoacán.

A crucial aspect of these experiences has been the application of landscape models and the use of technology, such as Geographic Information Systems, for land-use planning on a rural community scale. The indigenous community of Nuevo San Juan Parangaricutiro, in Michoacán, provides an example. This community, which is nationally and internationally known for its holistic management of forests (Alvarez-Icaza 1993), asked researchers at the Instituto de Ecología, Universidad Nacional Autónoma de México, to develop a project that includes biodiversity and land conservation, diversified production, and sustainability. Both scientific information and peasant knowledge have been integrated to formulate a management plan that directs the use of forests and natural resources (Bocco and Toledo 1997). The scientific knowledge produced has been used in biological inventories, wildlife management, ecotourism, environmental education, and improving water management for alternative crops in Nuevo San Juan Parangaricutiro (Bocco et al. 1998).



Multi-use management of forested land by the indigenous community of Nuevo San Juan Parangaricutiro, Michoacán. A diversity of products and services can be obtained from the forest ecosystem.

its ecological relevance among human communities within and near the reserve. The community development workers carry out mainly extension work, including providing technical advice and implementing production projects such as community forest management or extraction of the grass "otate" (*Otatea acuminata*) for basket production. It is through the work of both teams that IMECBio establishes a dialogue with the communities obtaining information about their knowledge, views, needs, and concerns. This information influences

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Searching for sustainable coffee in Mexico

Mexico is fourth in the world in terms of volume of coffee produced and fifth in terms of area devoted to coffee cultivation. The total number of coffee producers is estimated at approximately 200,000, 90% of whom work in small holdings (less than 5 hectares). Most of the producers with small holdings are indigenous producers that belong to one of the 28 ethnic groups who maintain multilayered and shaded coffee agroforests (Moguel and Toledo 1999). Shade coffee systems, especially those within dense natural vegetation, have been found to maintain high levels of biodiversity and acceptable standards of soil and water conservation while producing coffee and other products for the market. Since the mid-1970s, researchers at several Mexican institutions have studied shade coffee systems, in the process facilitating their transformation into ecologically sound plantations. These studies were initiated in the former Instituto Nacional de Investigaciones sobre Recursos Bioticos, with emphasis on the ecophysiology of the coffee agroecosystem. Research has since been extended into such subjects as evaluation of biodiversity, soil enhancement, biological pest control, waste recycling, analysis of the shade structure (canopy), and ecological design of polycultures.

Indian woman harvesting coffee in a traditional shade plantation. Photo: Fulvio Eccardi.

Today, Mexico is the world's main exporter of shade organic coffee (accounting for one-fifth of the total volume). A substantial part of this production is performed by indigenous communities of Chiapas, Oaxaca, and other states. In 1996, more than 11,500 organic producers were registered by the National Coordination of Coffee Organizations (CNOC), an organization for small coffee growers in Mexico. CNOC is promoting the creation of ecologically and socially sound coffee agroforests among its approximately 75,000 affiliated producers.

IMECBio's research, enhancing the possibilities of its application.

Other initiatives follow similar approaches. Ecosur, like IMECBio, emphasizes the establishment of links between ecological research and environmental and development problems—in this case, of the complex and conflict-prone southern border region of Mexico. In addition to research and teaching, one of their main areas of interest is a program aimed at linking academic work with the regional social sectors. Through projects dealing with productive activities, health, women's participation in rural development, and biodiversity conservation, Ecosur promotes communication between scientists and local social sectors and the permanent exchange of information, technologies, and research experience. These examples represent a science that responds effectively to social demands. There remains a need, however, to support this type of experience within the Mexican academic context and to spread the approaches used by IMECBio and Ecosur to the rest of the scientific ecological community.

The Ecological Information System: toward integrative ecological science

Mexican ecological science needs to continue generating basic and applied knowledge, but at the same time it needs to create more opportunities for fruitful interaction with the rest of Mexican society, in particular with those sectors involved directly in ecosystem management. In this context, it should be noted that in Mexico, mechanisms that could link the work of social organizations (both governmental and nongovernmental) with academic institutions are weak. Although the groups have become better networked in recent years, no organizational structure exists to facilitate the exchange of information and experiences. New institutional structures should be developed in Mexico that can make ecological information more accessible to decision-makers. Given the absence of a governmental policy on applied science, Mexican research institutions have the responsibility to establish mechanisms that facilitate public access to their information and expertise.

One model that can help to integrate ecological research with the rural use, management, and conservation of ecosystems and their resources is the Ecological Information System (EIS). This approach is based on the concept of the Agricultural Information System (AIS), which was formulated by agricultural researchers to organize the related tasks of research and extension with the activities of farmers. The AIS recognizes the need to have a flow of information in all directions among researchers, extension agents, and farmers to underpin the use of scientific infor-

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mation by agricultural producers (Röling 1990). The EIS includes three main sectors: ecologists, change agents (environmental educators, communicators, and other professionals), and rural producers (peasants, forestry workers, hunters, gatherers, and fishermen). The linkages among these three sectors are shown in Figure 2. The components of the EIS are the people and institutions that generate, transfer, receive, and feed back information. The EIS facilitates the integration of scientific research with the practices and knowledge of the principal managers of natural resources: the rural producers. The promotion of interactions and the exchange of information between these sectors can enhance the creation of alternative technologies for managing natural resources.

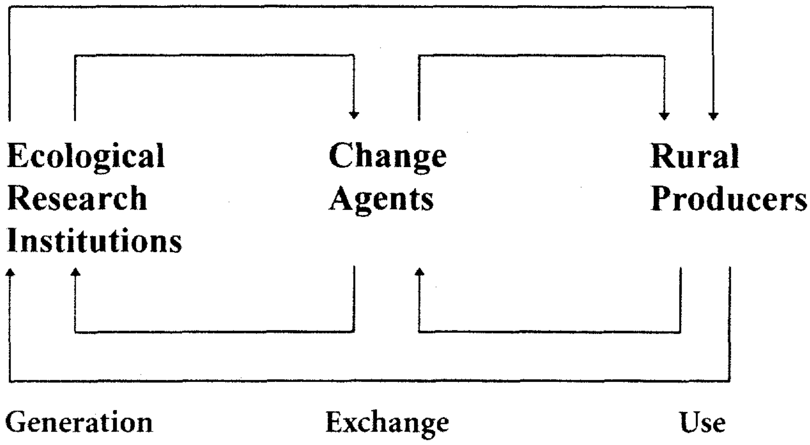

Figure 2. The Ecological Information System. The arrows indicate flows of information between the sectors. The research sector on the left corresponds to the main generators of knowledge; the rural producers on the right represent the main (potential) users of information within the system. Change agents function as intermediate links between the other two sectors. The generation, exchange, and use of knowledge can occur in all three sectors.

The exchange of information would imply, however, that scientific institutions are receptive to the establishment of two-way processes of communication with nonscientific sectors, in particular with rural producers. As has been recognized in agricultural development, farmers are far more likely to use scientific findings if they have been involved in the research process. This concept is the guiding principle of a worldwide movement that is generally known as "farmer participatory research," which is based on the recognition that many farmers engage in their own research (e.g., see Okali et al. 1994). Similar perspectives can be found in the new fields of agroecology (Altieri and Hecht 1990) and ethnoecology (Toledo 1992). Studies in these areas can provide important insights for enhancing the interaction between the outcomes of ecology and the problems and needs of rural producers.

Change agents. The EIS model recognizes the need to have change agents as intermediate links (Havelock 1986) that transform, transfer, and exchange information between the sectors involved in the use, management, and conservation of natural resources. In Mexico, the role of change agents has been filled by nongovernmental organizations that link and facilitate dialogue between social sectors. Approximately 150 nongovernmental organizations are currently implementing environmental projects in Mexico (FMCN 1998). The training of change agents varies; some have professional backgrounds in a scientific discipline such as biology or agricultural science, and some are technicians trained in agronomy, animal husbandry, irrigation engineering, or related areas. Members of governmental agencies promoting the exchange of information between sectors to solve problems can also be considered change agents.

At the rural producers level, change agents can also be identified in the role of "peasant promoters." These people participate in a social movement that acknowledges that, at the rural community level, the most effective communication is between peasants. Peasant promoters primarily contribute to the design and diffusion of sustainable ways of managing natural resources through experimenting with and sharing technological innovations developed though contact with other peasants. Peasant promoters also serve as links between rural producers and other sectors. Peasant promoter training programs carried out with the support of national nongovernmental organizations and international agencies have been developed in several parts of Mexico and in Central America (García-Campos et al. 1997).

The change agent model can provide an effective way by which ecological research institutions can communicate and interact more efficiently with other actors in society. Change agent teams from each organization would help scientists to communicate with nonscientists, including disseminating scientific findings to different social sectors that could use the knowledge and making scientific information accessible to wider audiences. Information accessibility is important because in many cases, a scientific solution to a problem may exist but is overlooked because it is not presented in a useful form (Pitelka and Pitelka 1993). Other tasks include transforming scientific findings to

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meet the needs of different sectors (i.e., re-creating the information to make it understandable and usable for lay audiences) and promoting the feedback of information from users to researchers.

Communication would be the main instrument of these teams, and they would therefore need to receive training in communication skills. Because the teams would be dealing with scientific information and would need to understand the way in which both natural and social scientists work, team members would need to come from diverse scientific and technical backgrounds. Qualifications and experience in interdisciplinary and intersectoral work would be especially relevant. Although it may seem difficult to develop such teams, Ecosur is already developing a similar idea. At present, a 12-member team is involved in Ecosur's "Linkage with Social Sectors" program. Three members of the team work at planning, designing, and implementing the general program for the entire institution, and the rest are "linkage technicians," who work to solve specific problems (Rodolfo Mondragón, Ecosur, personal communication).

EIS in action. The main advantage of the EIS model is that it enables the work of the sectors to be visualized as a whole rather than as individual parts. This perspective facilitates the identification of weaknesses in the access and use of information to solve problems. EIS can serve as a framework to encourage the formation of networks of people and institutions for a common purpose. The more structured and organized the sectors are with respect to each other, the greater the efficiency with which the information system functions. The model can also be used to examine the interactions between sectors in a given situation—for example, in relation to the work of an organization involved in environmental management. In this context, a case study of IMECBio has shown that there is a close relationship between the work of this research institution and the synergetic functioning of the EIS (Castillo in press).

Toward a new scientific approach in the Third World

The establishment of efficient communication between research institutions and the sectors directly involved in the management of ecosystems will not, by itself, lead to improved ecosystem management and solutions to environmental problems. Solutions will be found only through new approaches to policy setting and decision making that consider what the different social sectors have to say. Governmental bodies, nongovernmental organizations, international agencies that fund research and action projects, research institutions, and rural producers all need to network and collaborate in the search for solutions.

Particularly in the context of Third World countries, a change is needed in the way in which scientific activities are organized and evaluated. It is important to promote a science that, in addition to nurturing humans' understanding of the natural world (which is of extreme importance in both cultural and utilitarian terms), also contributes more directly to solving problems. This approach to science should originate from the recognition that the function of science is not limited to the production of new knowledge but also includes its transmission, exchange, and use. The challenge of promoting this new approach to science involves whole institutions more than individual efforts. In the last decade, some ecologists have asked the scientific community to change the academic reward system to promote communication with wider audiences. Such was the message of a recent letter by several internationally recognized ecologists (Bazzaz et al. 1998), who referred strongly to the relevant role of individual ecologists. It is essential to start thinking in terms of accomplishment of goals by institutions, particularly regarding the fulfillment of their social responsibility. For science to have a relevant impact on the way human societies relate to ecosystems, institutional mechanisms must be developed that allow the participation of all professional scientists—those generating the knowledge and those working on its transformation, transmission, exchange, and use. The environmental crisis is in grave need of solutions, and society as a whole—especially ecologists and their institutions—must keep reacting and responding to the urgent calls from the world's reality.

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