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Towards Adaptive Community Forest Management:
Integrating local forest knowledge with scientific forestry

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Introduction

Alleviating poverty and halting environmental degradation in fragile, agriculturally marginal areas requires environmentally sustainable and socially acceptable means of intensifying the use of renewable natural resources, including forests. The alternative is environmental degradation, increased rural poverty, and continued displacement of the rural poor to urban margins and expanding agricultural frontiers (Pichón, Uquillas, and Frechione 1999).

Unfortunately, conventional scientific approaches to resource management in such areas often fail; they are based on faulty models, limited and socially inappropriate goals, and incomplete information on basic parameters. They do not adequately address environmental complexity, heterogeneity, or the role of recurring disturbances (Finlayson and McCay 1998; Zimmerer 1994; Zimmerer and Young 1998).

To make matters worse, conventional scientific approaches to natural resource management often fail to create the local social institutions needed to encourage environmentally appropriate social behavior. Institutional failure has three aspects. First, the locally derived institutions needed to coordinate the compliance of resource users are lacking. Centrally imposed regulations for monitoring compliance, meting out sanctions, and distributing access are clumsy, and poorly adapted to local conditions. Second, the institutions that might generate information on the state of the resource are lacking. Finally, the ability of centralized resource-use controls to adapt to changing social and environmental conditions is limited; they lack resilience to social and environmental change (Berkes, Folke, and Colding 1998). Conventional scientific forestry is no exception. It requires a high level of social and spatial control, stresses industrial raw materials like pulp or sawmill timber over other forest uses, and it discourages agricultural clearings, burning, woodcutting, and grazing. It often results in institutional failure and social injustice (Pincetl 1993; Guha 1989; Peluso 1992; Bryant 1994; Vandergeest 1996; Scott 1998; Klooster 2000).

In contrast, traditional resource-management systems, often derived over time through a process of cultural learning and adaptation, are frequently successful in the task of generating appropriate local institutions (Ostrom 1990; Feeny et al. 1990). Increasingly, researchers argue for approaches that combine the strengths of observation of indigenous knowledge systems with the experimental method of scientists (DeWalt 1999; Hecht 1990) In at least some cases, the agricultural and forest-use practices of forest-dwelling people encapsulate management strategies that better address environmental complexity and flux than conventional approaches; they frequently foster the maintenance and expansion of forest cover (Alcorn 1981; Padoch and Peters 1993; Fairhead and Leach 1996; Fairhead and Leach 1998).

In a case study of two indigenous communities in highland Michoacan, Mexico, this paper examines data on forest change, woodcutting practices, social history, and a recent forest inventory and management plan prepared by a professional forester. It assesses the abilities of local knowledge and scientific forestry to lead to intensified forest management. It recommends cross-learning between scientific resource managers and local experts, participatory environmental monitoring to assess the results of different cutting techniques, and explicit management experiments to facilitate institutional learning at the community level. This kind of locally rooted *adaptive management* (Berkes, Folke, and Colding 1998) holds some promise for integrating local and scientific systems of knowledge and practice. It might help resolve the dilemma of conservative forest use in marginal regions.

Deforestation and agricultural marginality in the Lake Patzcuaro Basin

Mexico desperately needs successful strategies for forest management. Recent deforestation estimates range from 370,000 to 720,000 ha/year – a 0.8% to 2% annual rate. Proximate causes in lowland tropical forests include cattle ranching and agricultural expansion, while in highland forests pine and oak forests, causes include logging, woodcutting, forest fires, and agricultural expansion (Masera 1996; World Bank 1995; Cairns, Dirzo, and Zadroga 1995).

In long-settled regions, especially common in the highlands, people compensate for the decreasing viability of agriculture by intensifying their use of remaining forests (Klooster in press).This is the ccase in the Lake Patzcuaro Basin on the eastern end of the Purepecha region of highland central Michoacan. This is an area of common property forests and a long history of occupation by the indigenous Purepecha people (Gorenstein and Pollard 1983; Foster 1988).

Population increase this century averaged 2.7% per year (Castilleja 1992). The importance of agriculture, however, has decreased. Erratic rainfall, the absence of irrigation, frosts, windstorms, and soil constraints contribute to the initial marginality of agriculture in this region, but transportation infrastructure improvements, agricultural intensification elsewhere in Mexico, Mexican food policies that subsidize consumer purchase of maize and beans, and Mexico's entry into international trade agreements have further decreased the viability of rainfed agriculture during the past 50 years (Appendini 1998; Barkin 1990; Fox 1993b; Myhre 1998). Although maize agriculture maintains a role in rural livelihoods because of its cultural importance and household food security strategies (Mapes 1987), the area planted in maize in the Purepecha region decreased by more than half between 1969 and 1993. In certain regions where the climatic conditions are appropriate, maize fields and forests are converted to avocado orchards, but abandoned fields are a common sight in dry and frost-prone regions (Carabias et al. 1994; Chapela 1994; Garibay Orozco 1996; Paulson 1999).

Many of the activities supplementing or replacing agriculture in this region are forest-dependent. Almost 100% of rural people cook with firewood, and there are more than a thousand wood-based small enterprises. Most of these cabin industries are pottery workshops, but they also include brick making, charcoal production, bakeries, and small carpentry workshops (Masera, Masera, and Navia 1998; Reyes 1992; West 1947). Wood demand in the Purepecha region is four to seven times greater than the authorized cut and four times greater than the estimated annual growth increment (Masera, Masera, and Navia 1998). Estimates of wood demand and rates of forest growth suggest severe over-cutting in the Lake Patzcuaro basin, as well, mostly for firewood[1] (Becerra Luna, Reygadas Prado, and Moreno Sánchez 1997). According to official forest inventories in 1963 and 1990, the forested area decreased 50% in the Purepecha region over all, and 45% in the Lake Patzcuaro basin, with some counties completely deforested. Density of remaining forests also decreased (Alvarez-Icaza and Garibay 1992). Observers blame deforestation for siltation and rainfall declines that have lessened Lake Patzcuaro's size and productivity, displacing important small scale fisheries (Toledo, Alvarez-Icaza, and Avila 1992; ORCA 1997).

Travelers perceptions of deforestation and wood scarcity in this region date back more than 100 years (Brand 1951:123). In 1969, an anthropologist working in Santa Fe de la Laguna decried the uncontrolled woodcutting and timber raiding that was finishing off the forests there.

[1] But see Klooster 2000 beyond deforestation for a critique.

In 1979, George Foster, an anthropologist conducting long-term research in a pottery-making town directly across a bay from Santa Fe, wrote that "firewood has all but ceased to exist in the hills around Tzintzuntzan" (Gortaire Iturralde 1971; Foster 1988:377).

On the other hand, Toledo and others note that the ecology of the Lake Patzcuaro area remains relatively stable, erosion is moderate, and biodiversity remains astounding. This high degree of environmental conservation occurred despite proximity to Mexico City, one of the most populous cities on the planet, evidence of agriculture dating back 3,500 years, high population density at the time of Spanish conquest, and a long history of intense human occupation and culture-building (Gorenstein and Pollard 1983). Indigenous culture, environmental knowledge, production strategies, and land tenure patterns are said to conserve the Patzcuaro landscape. Furthermore, the tenure arrangements of village territories nested within the nation state provides significant scope for institutional innovation, and rural communities -- especially indigenous communities -- are sometimes able to develop robust and successful management systems drawing on extensive local knowledge. Indigenous knowledge and environmental management strategies are an important resource for sustainable development in this region, especially among Purepecha communities in the Lake Patzcuaro Basin (Alcorn and Toledo 1998; Toledo 1991; Toledo and Argueta 1992; Toledo 1990; Toledo and Barrera-Bassols 1984).

Case study

Two of these communities are Santa Fe de la Laguna and San Jerónimo Purenchecuaro, which border one another on the northern shore of Lake Patzcuaro. More than 2,000 residents of San Jerónimo own a 3,000 ha territory while nearly 4,700 residents of Santa Fe own a 5,000 ha territory. Most speak Purepecha in addition to Spanish. Their common property territories range from lakeshore, at 2,040 meters above sea level to several rocky mountaintops 3,000 meters above sea level. Fragmented forests of pine and oak cover some 40% of their territories.

These communities were chosen for further study for several reasons. First, they maintain their indigenous language, self-governance structure, common property tenure arrangements, local knowledge of forest resources, and local woodcutting practices. Second, the communities maintain significant areas of forest cover but observers generally believe that wood-fueled pottery production in Santa Fe places unsustainable demands on both communities' forests. Third, a non-governmental organization, the Grupo Interdisciplinario de Tecnologia Rural

Apropiada A.C. (GIRA)[2] has been active in these communities for several years, generating data on fuelwood demand for cooking and pottery production (Masera, Masera, and Navia 1998; Masera et al. 1997b; Masera et al. 1997a; Navia and Ochoa 1998). In addition, historical data on Santa Fe is available from previous research (Brand 1951; West 1947; Gortaire Iturralde 1971; Dimas Huacúz 1982; García 1988; Zárate Hernández 1993). Fourth, leaders from both the communities have at times been interested in exploring improved forest management practices because potters from Santa Fe frequently cut pine trees in the territory of San Jerónimo without permission. Together with the two communities, GIRA requested funds from a Mexican federal program to promote community forestry and used those funds to hire a professional forester to conduct simultaneous forest inventories and management plans in the two communities (Sánchez 1998a; Sánchez 1998b). Although they have not been implemented in these communities, forest inventories such as these normally form the first step in the legal extraction of timber in Mexican forests under the conventional restrictions and prescriptions of scientific forestry.

In addition to existing sources, data for the case study comes from original research analyzing aerial photographs and conducting several months of participant observation with woodcutters and other village members over the course of two years. Together, these data afford the opportunity to analyze the abilities of local knowledge and scientific forestry to regulate the sustainable intensification of forest use in agriculturally marginal areas like this one. Since most wood demand occurs in Santa Fe, much of this research focuses on the situation there.

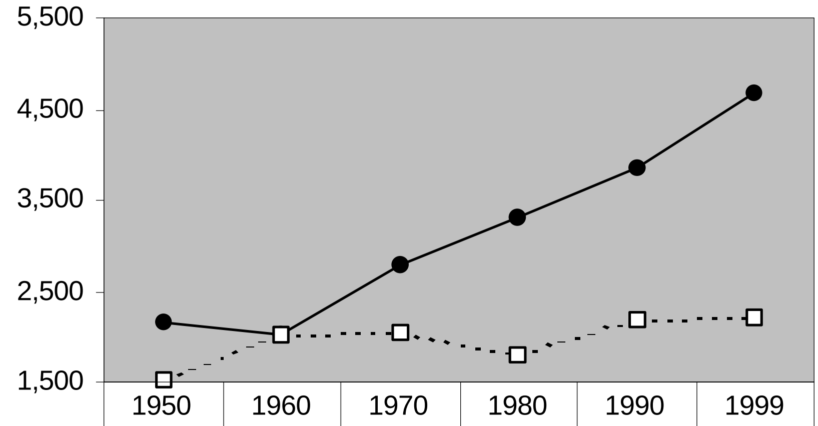
The remainder of the study is organized as follows. First, I will establish the recent patterns of population growth and productive activities. Second, I will describe a recent process of struggle over territory in Santa Fe that helps clarify the history of forest use as well as a later discussion of social barriers to resource-use restrictions. Third, I will outline recent changes to the forests of Santa Fe and San Jerónimo, including a process of pine depletion. Fourth, I will describe the local cutting practices and ethics and fifth, I will examine the proposed management plan based on scientific forestry. The discussion that follows assesses the ability of these contrasting systems to improve forest management and it considers the possibility for integration through cross-learning, participatory monitoring, and experiments in institutional adaptation.

[2] I coordinated my work with GIRA and this afforded the possibility of contributing to a longer-term process of social learning than is usually possible with independent academic research.

Productive activities

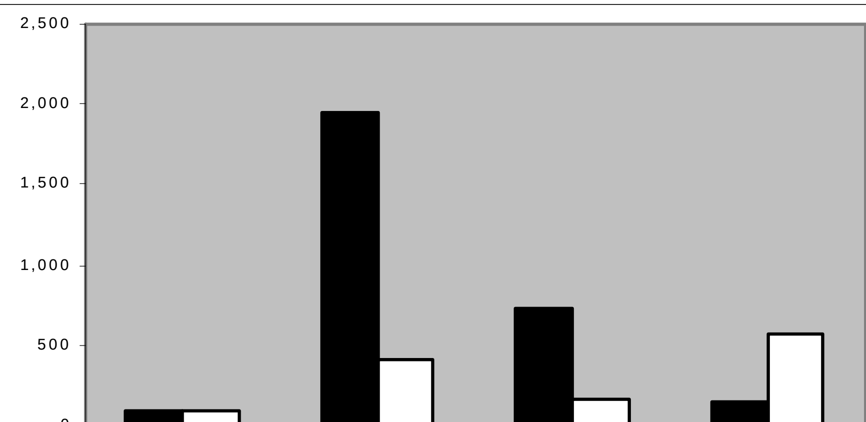
The population of San Jerónimo has been roughly stable for many years while the population of Santa Fe has doubled since 1950 (Figure 1). As is common in the Lake Patzcuaro area, the residents of these communities cobble together a rural livelihood based on off-farm labor, craft activities, and some farming (Figure 2). Comparative census data on economic activities is not available for previous decades, but interviews indicate that agriculture was previously much more important than it is now. Informants report decreased yields due to more pests, declining soil fertility, increased frequency of frosts, dry spells, and windstorms. At the same time, declining prices, increased availability of subsidized maize and tortillas, and the growth of income-generating alternatives decreased the economic viability of agriculture over time.

Residents of the case study communities have devised slightly different livelihood strategies to address the declining viability of agriculture. In San Jerónimo Purenchecuaro, villagers discovered work opportunities in the US during World War II guest worker programs. This transformed local perceptions of labor opportunities and established the necessary knowledge and social relationships for future cycles of temporary, cyclical emigration (ORCA 1997). In San Jerónimo, 17% of the working population have been out of the community for more than six months and 15% work for day wages outside of the community (Klooster 2000). In Santa Fe, community members intensified pottery production, a common supplementary productive activity in the community since the latter part of the 19th Century, or earlier (West 1947). Now, nearly 70% of working adults in Santa Fe count pottery production as their primary activity, while selling pottery employs another 20% (Klooster 2000).



	1950	1960	1970	1980	1990	1999
Santa Fe	2,162	2,014	2,781	3,308	3,862	4,685
San Jerónimo	1,537	2,011	2,045	1,788	2,180	2,199

Figure 1: Population change in Santa Fe and San Jerónimo. Source: Klooster 2000, based on Mexican national censes. Santa Fe health clinic 100% census, 1998, and San Jerónimo health clinic 100% census, 1999.



	Agriculture	Crafts	Commerce	Others
Santa Fe	84	1,943	724	144
San Jerónimo	91	410	152	568

Figure 2: Principal occupations in Santa Fe and San Jerónimo. Source: Original data is from the 1997 Santa Fe clinic census of 2,509 working adults, 1999 San Jerónimo clinic census of 1,221 working adults. The agriculture category includes roughly equal numbers of fishermen and farmers. In Santa Fe, the craft is pottery production while in San Jerónimo, the craft category refers to weaving figures from straw purchased outside of the community. In both communities, most of the merchants in the "Commerce" category buy the local craft for resale elsewhere. "Others" include temporary emigrants, day laborers, and professionals such as schoolteachers, most of whom work outside the communities.

The social history of struggle for land and forest in Santa Fe

For much of this century, the forests and croplands of Santa Fe de la Laguna have been the object of wood theft and land appropriation from *mestizo* neighbors from Quiroga. In the late 1930s, a group of *mestizos* established a small settlement in the community's forests in a locale known as Tzintziuameo. They sold wood to Quiroga artisans as well as fuel to Santa Fe potters. In addition, groups of woodcutters from Quiroga would often extract mule-trains loaded with Santa Fe wood (Gortaire Iturralde 1971; Dimas Huacúz 1982; García 1988). Brand (1951) notes a long history of small woodcraft industries in Quiroga, but this activity intensified in 1939, shortly after the oiling of the Mexico City-Guadalajara highway, the end of a period of rural unrest, and the rise of Mexican and international tourism. These shops sold serving trays made of solid slabs of pine (*bateas*), wood furniture, and other wood handicrafts to tourists and retailers.

Santa Fe community members remember this period as one in which they could supply themselves with kiln fuel from the pine branches and slash left in the forest by Quiroga woodcutters. Santa Fe community members dared not confront these outsiders, who they suspected of carrying weapons. In discussions of forest change, they frequently blame Quiroga woodcutters for virtually eliminating the community's fir trees, the biggest pine trees, and decimating populations of madrone.

The forests of San Jerónimo also supplied clandestinely cut wood to Quiroga markets, but due to distance and better communal vigilance in the 1960s and 1970s, they escaped the intensity of woodcutting experienced in Santa Fe. Bordered on all sides by other indigenous common property territories, San Jerónimo also escaped a history of land appropriation, unlike Santa Fe.

Quiroga farmers and cattle owners appropriated substantial areas of Santa Fe's farming and grazing land. By 1967, outsiders from Quiroga held some 16% of the community's territory (Gortaire Iturralde 1971). External appropriation of communal land had connections to internal patterns of land concentration. Large landowners relied on sharecroppers to make their land produce, and many of these sharecroppers were from outside of the community. In other cases, the land-rich rented pasturage rights to Quiroga cattle owners. Community members sometimes sold their rights to usufruct plots in order to cover debts incurred to meet financial obligations for rites and festivals,[3] and this fueled internal land concentration, and sometimes, direct alienation of communal land to outsiders through personal transactions (Dimas Huacúz 1982).

The conflict between Santa Fe and Quiroga also had a strong ethnic element, as expressed at the height of the conflict by Nestor Dimas Huacuz, a native of Santa Fe:

> Land litigation goes back to remote epochs, principally with the *mestizo* town of Quiroga, which is found to the east of the community. These people arrived after the founding of Santa Fe, and because they consider the Indian a despicable being, they have always wanted to humiliate him, looting his properties and natural resources as much as possible because they are *mestizos* (Dimas 1982:44).

Illegal cutting and communal land usurpation by outsiders continued through the 1970s and early 1980s. Under the galvanizing leadership of Elpidio Dominguez, a young community leader exposed to Marxist, indigenous rights, and other left ideologies while studying to be a school teacher, the community re-organized its traditions of internal governance, became more open to the participation of younger men with charisma and relevant training and experience, and mobilized politically in defense of indigenous culture and the specific territory of Santa Fe. After several armed confrontations, shooting deaths on both sides, and adroit political maneuvering, the community was able to recuperate much of the territory occupied by Quiroga farmers and cattle men by the mid-1980s (Dimas Huacúz 1982; Zárate Hernández 1993).

Under the leadership of Elpidio and his faction, the community adapted existing institutions to organize sweeps of the forest. The community assembly would authorize this action, and then each of the community's eight distinct neighborhoods, or *barrios*, would solicit volunteers, impose communal labor taxes (*faenas*), and organize armed brigades to go and inspect a given part of the forest. This was a novel application of the community's institutional resources; previously, the *barrios* only organized *faenas* to build and maintain roads and religious buildings.

At the height of this conflict, sweeps occurred as often as twice a month. Community members confiscated animals and cutting tools of trespassers. In 1988 interviews of wood workshops in Quiroga, woodworkers told Yuraima Garcia that pine and fir once came principally from Santa Fe, but that after 1986 they had to start getting their wood from elsewhere. She observed woodcutters selling firewood door to door in Quiroga, and one admitted cutting pine in Santa Fe. "If

[3] Contrast this insider-intellectual version of the impoverishing and dependency-creating tendencies of traditional civil-religious hierarchies with Toledo's idea that the leveling effects of a "prestige economy" are associated with environmental conservation.

the people from Santa Fe catch me they could kill me or take away my axe and burros," he told her (García 1988:50). As of 1999, wood theft had decreased to imperceptible levels

After those victories, Santa Fe's internal organization and mobilization declined due to disputes over internal land expropriations, changes to traditional structures of internal government, and a proposal to install a nuclear research reactor in Santa Fe's territory that Elpidio supported in the face of local opposition. Later, a Quiroga cattle rancher murdered Elpidio on the outskirts of Santa Fe. Nevertheless, as a result of the struggle he led, the community regained lost territory and maintains effective control over its forest.

The state of the forest

The decline of agriculture and the woodcutting carried out by woodcutters from both Quiroga and Santa Fe have had repercussions in the forest. Currently, San Jerónimo's and Santa Fe's common property territories are 40% covered in fragmented pine and oak forests, interspersed with agricultural lands and grazing lands, many showing evidence of past agricultural use, such as old plow furrows and stone fences. Aerial photographs from 1960, 1974, and 1990 show abandoned agricultural fields swallowed up beneath vigorous stands of pine and oak. These landcover changes reflect the progressive decrease in the importance of agriculture amidst household productive activities[4] (Klooster 2000).

The forest also shows the impact of woodcutting, especially for the pottery production that displaced agriculture in the portfolio of household productive activities in Santa Fe. Nearly all households in Santa Fe cook with wood. In San Jerónimo, 80% of households use firewood for cooking, and most supplement wood with gas (Masera et al. 1997b; Masera et al. 1997a). Pine firewood is a critical input for pottery production in Santa Fe. There are 600 kilns there, with 450 in use at least twice a month. Village-wide inferred demand for pine is conservatively estimated at 2,000 m^3 per year (Navia and Ochoa 1998).

Woodcutting affected the forest. Cross-sectional data from the forest surveys (Sánchez 1998a; Sánchez 1998b) reveal marked differences in forest density and pine density between Santa Fe, where woodcutting for pine is most pronounced, and San Jerónimo, where it is less pronounced. On average, San Jerónimo has 250% more pine per hectare than Santa Fe does

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[4] Qualitative comparison of other areas in these communities covered by the aerial photographs also reveals greater forest cover in 1990 than in 1974 or 1960. In addition, Dr. Helen Pollard kindly provided copies of aerial photographs from a US Air Force mapping flight of 1942 which partially cover the forests of San Jerónimo. These photographs also reveal a landscape with more distinct field margins, less forest cover, and greater forest fragmentation than at present.

(Klooster 2000). The 1998 forest inventories also show marked differences in density across the border from Santa Fe to San Jerónimo (See Figure 3).

These forests are adjacent, occupy the same altitudinal gradients, have similar expositions, and grow on similar soils. Although available data does not eliminate the possibility of different histories of forest clearing, fire, and disease, the most obvious difference between these forests is human use; Santa Fe woodcutters use much more wood, especially pine trees for kiln fuel (Klooster 2000).

The differential effects of woodcutting over time are also visible in aerial photographs. A particularly accessible area of forest near the border with San Jerónimo, for example, was forested with large pines in the memory of 45-year old woodcutters. Aerial photographs from 1960 show a similar pattern of closely spaced crowns of pine and oak on both sides of the gully marking the border between the two communities. Photographs from 1974 and 1990, however, show no change on San Jerónimo's side of the border but a progressive thinning of Santa Fe's forest. Woodcutters confirm what the photographs reveal. Little by little they finished off the pines from that area, carrying them off mule-load by mule-load to kilns in Santa Fe, and until the early 1980s, to carpentry workshops in Quiroga. As pine became scarce near the town of Santa Fe, woodcutters extended their trips and now frequently cut in the territory of San Jerónimo (Klooster 2000).

Due to the combined influences of agricultural decline and intensified woodcutting, the forests of Santa Fe and San Jerónimo are increasing in extent, but decreasing in quality. Woodcutting for kiln fuel decreases the forest's ability to meet the demands people place on it. Furthermore, Santa Fe's woodcutting in the territory of San Jerónimo is a potential source of social conflict, like Quiroga's woodtheft in the past. These communities need a resource management strategy that harmonizes people's demand for wood with the ability of the forest to produce it.

The role of local knowledge and practice

One solution to the problem of forest mismanagement might be found in existing local cutting practices, ethics, and rules. Perhaps they could form the basis for intensified sustainable forest management, as Toledo and others have argued (Toledo 1991).

Woodcutters in Santa Fe already exercise sophisticated selection criteria that often avoids diminishing the living biomass of the forest. In Santa Fe, women and older men typically gather the dry branches from the ground, or from trees others have felled. They also find dry branches from bushes and acacia trees (*huizache*) in pastures and abandoned fields; much of the area from which they gather fuel lies outside of the tree-covered forested areas surveyed by Sanchez (1998a, 1998b). During Masera *et al*'s (1997a, 1997b) surveys, 45% of woodcutters in Santa Fe and 22% in San Jerónimo reported principally gathering dead wood.

Younger men with axes and pack animals travel farther and cut standing trees, but they also prefer deadwood because it is easier to transport, and does not require time to dry. Woodcutters therefore seek out dead or dying trees which have been burned or show signs of infestation from bark beetles or parasitic plants. In burned areas, scorched trees often bear the shallow mark of a woodcutters' axe, a test for dryness before cutting. In this way woodcutters spare the trees most likely to survive. In 1998 and 1999, roughly half of the wood I observed drying in front of houses consisted of small, dead branches and parts of burned or dead trees.

In addition to the practical considerations favoring the dry wood of dead trees over the wet and heavy wood of living trees, woodcutters in Santa Fe express, and partly practice, an ethic of woodcutting. They know which of the local oaks resprout after cutting and can survive continuous lopping for long periods of time; the forests of Santa Fe and San Jerónimo are full of trees showing evidence of lopping, resprouting, and continued vigorous growth, especially along paths and near the two towns. Woodcutters also say that cutting and gathering dry and diseased wood is better for the forest than cutting healthy trees, and that it is better to travel a little farther to find such wood than to cut near town. They also say that cutting mature trees is better than cutting young ones, which have not had a chance to grow.

Other than a ban on selling the community's wood to outsiders and a ban on cutting trees in areas of reforestation, however, there are no formal restrictions on woodcutting in Santa Fe. There are no formal or informal sanctions on Santa Fe woodcutters who flout the incipient woodcutting ethic. Woodcutters like Juan Luciano can clearly point out the kinds of mature and diseased trees proper for cutting, but he is very much aware that not everyone exercises this ethic.

> The others don't have the same concern. I think it is best to cut only the big trees. I have sons, and if they don't get a profession out of going to school, they will have to support themselves with this same firewood. Other people just come to cut any which way. They just go somewhere, cut down a small tree, the right size for just one mule-load of wood.

Woodcutters are usually in a hurry. "So we can leave soon" (*para irnos pronto*) is a frequent explanation for why woodcutters choose what and where to cut. During the dry season, it is less critical to find dry wood because even the greenest pine dries quickly. Woodcutters eager to return to town and conduct other activities often cut the 15 cm diameter living pines that are easiest to fell and split and produce approximately a mule-load of good wood. Although none of the woodcutters I accompanied admitted to cutting these young pines, numerous stumps this diameter show that the practice is common. Even in areas of reforestation, where communal rules ostensibly prohibit cutting, stumps attest to cutting for building materials and firewood.

Relationship between limited institutions and social struggle in Sta. Fe.

The dearth of internal restrictions on woodcutting relates to the social history of struggle over territory. Elpidio's movement galvanized indigenous identity in Santa Fe and focussed it on a specific territory and the territorial rights community membership entails. Community membership implies rights to land, water, clay, and forest resources. In practice, however, access to clay and firewood are the only resources with an egalitarian distribution while agricultural land and house lots are effectively private and concentrated. The right of fuelwood access is very strong. Even trees and bushes on agricultural fields are available to all community members for cutting. The history of land conflict, both with Quiroga and internally, fuels the intensity of this right.

Continued social differentiation in Santa Fe also increases the importance of forest access, especially for the poorest community members. The poorest households often enter into patron-client ties with local pottery merchants, taking out loans in exchange for the promise of future sales, selling unfinished pottery to avoid the cash outlays for glaze, or selling pottery in town, to avoid cash outlays for travel to sell elsewhere (Gortaire Iturralde 1971; Zárate Hernández 1993; Dimas Huacúz 1982). Firewood cutting is an important way to avoid money expenses in the production process, and thus decrease exposure to obligations with local pottery buyers. Furthermore, selling firewood is an important source of income for a small number of woodcutters. The right of unfettered forest access,[5] therefore, partly compensates for the concentration of wealth within Santa Fe de la Laguna. It inspires resistance to new institutions that might enforce the existing woodcutting ethic.

[5] Nancy Peluso refers to an *ethic of access* that strengthens resistance to the individual appropriation of resources, such as the fruits of certain trees (Peluso 1996).

Local knowledge is inappropriate

Moreover, even if the ethic of selecting the "mature" or dominating pine trees in a stand were enforced, this might not be the best management approach. Local knowledge draws parallels between the lifecycle of individual trees and annual crop cycles or the lifecycles of livestock; the big trees are "ripe" for harvest. It has little cognizance of longer-term processes of stand succession. Given the successional ecology of pine/oak forests, however, selective cutting of pine speeds succession to oak dominance. Pine requires more intense disturbances than oak. It does not regenerate well on the forest floor, (see Snook and Negreros 1986; Styles 1993). By removing individual pines from the midst of a stand of trees, woodcutting in Santa Fe represents a kind of low-level disturbance that gradually eliminates the species without creating the conditions for its regeneration.

Other kinds of disturbance are frequent, however, especially fires and agricultural abandonment. These do create the exposed mineral soils and high light-intensity conditions favoring the regeneration of pine. The effects of these disturbance patterns are also evident in the forest, and partly reflected in the statistic of oak dominance in Santa Fe. The least-disturbed stands are on slopes infrequently traversed by cigarette-smoking woodcutters, and partly insulated from forest fires by moister conditions and greater distance from the agricultural areas where many fires start. These stands are oak-dominated.[6] Furthermore, there have been sporadically successful reforestation efforts with pine, and these are now the pine-dominated stands closest to Santa Fe. Similarly, pine enrichment through reforestation on the Santa Fe side of the San Jerónimo/Santa Fe border are reflected in higher figures for that species than would otherwise be expected in those areas.

Human impacts on the forests of Santa Fe are multiple and complex. Some are purposeful and others inadvertent. And their interpretation is complicated by history, patterns of disturbance, and spatial variation. Nevertheless, current practices of woodcutting do appear to reduce the availability of pine. Woodcutter recollections and observations, cross-sectional data, and time series data of increasing pine scarcity seem to corroborate this. If the local system of woodcutting is currently inadequate, can Santa Fe woodcutters develop a superior alternative on their own? This seems unlikely because of difficulties monitoring the forest response to their actions.

[6] Oak-dominated, old growth-like stands were subject to selective cutting by Quiroga woodcutters seeking large pines for *bateas*, however.

Monitoring limits evolution of the local knowledge system

In Santa Fe, there is a great deal of knowledge about the forest. Many woodcutters know Purepecha names for trees, which correspond closely to the Linnean system of species names. They know the burning and construction qualities of different kinds of wood. Many are also intimately familiar with their territory, which is thick with Purepecha place names absent from any paper map. Collectively, they also have memory of the forest's history of fire, disease, and agricultural clearing.[7] Woodcutters are also clearly aware that they are traveling farther to find pine that they did in the past, and they recognize the border of San Jerónimo when they cross it. So why have Santa Fe woodcutter been unable to develop a more appropriate knowledge system to inform their woodcutting practices?

Santa Fe woodcutters face great difficulties monitoring the forests' response to their woodcutting techniques. First, the time scale of forest response to woodcutting is not conducive to woodcutter learning. The successional cycle of pine oak forests takes more than a century, and it is very rare that oral histories can transmit sufficiently detailed information on forest history or past woodcutting practices. Individual woodcutters can not know the history of fire and disease and agricultural clearing that also shape the forest their woodcutting affects (see Balee 1993). Second, woodcutters' actions are spatially disbursed and they overlap. This makes it difficult to trace the effects of one's own actions over time, or to know what other woodcutters have been doing in a given plot of forest.[8] Finally, people have increased mobility these days. They spend a smaller part of their lives in the forest, and intersperse woodcutting and livestock herding activities in the forest with long absences for schooling, work in Mexican cities, and emigration to the US. The learning context of woodcutter's forest management knowledge is very different from that of a small-scale farmer, exercising relative autonomy over a given plot, with greater ability to directly experiment with different crops and cropping patterns and weeding styles, and with the ability to see the results of such tinkering within a year or two.

Local forest knowledge and cutting practices, therefore, provide a poor foundation on which to base intensified forest use. Monitoring presents particular difficulties.

[7] Individually, though, their estimates of the length of time a given field was abandoned are often several decades different from what aerial photographs reveal.

[8] Furthermore, the appropriate management unit is bigger than the woodlot. Ultimately, forest sustainability occurs at the landscape level, which ought to maintain a mosaic of stand ages and compositions.

Scientific forestry

Another potential method of harmonizing wood demands with the forest's production potential is found in scientific forestry. The management plans recently prepared for Santa Fe and San Jerónimo measure stand volume and growth rates, quantify a sustainable cut, and use aerial photographs to map the information (Figure 3). The plan calls for the application of the Mexican Method of Managing Irregular Forests (*Método Mexicano de Ordenación de Bosques Irregulares*), which seeks to maintain permanent forest cover, regularize the distribution of age-classes, and allow low-intensity harvests.

Figure 3: Tree volume by stand in San Jerónimo and Santa Fe (removed)

In Santa Fe, for example, it divides the forest up into 5 blocks of 3 to 7 management units each (*rodales*), and returns to each block every five years. Depending on the characteristics of the stands within each management unit, foresters implementing the method would select dominated, damaged, burned, and diseased trees for elimination, so that the stand accumulates biomass more efficiently over time. Once the stand is dominated by large trees that no longer grow efficiently and prohibit pine regeneration, the plan calls for partial clear cuts (*aclareo mediante selección*). These maintain 1/3 to 2/3 of the original tree cover, with surviving trees selected for good form and even spacing for efficient growth. In areas of moderate slope, the partial clearcuts can be sufficiently intense to allow regeneration through seedfall. Moderately intense cuts such as these maintain a regular distribution of age classes among stands and a diversity of species within stands (Sánchez 1998a; Sánchez 1998b).

The scientific forestry model must overcome several hurdles to better contribute to resource management in communities like Santa Fe, however. First, it requires extreme social and spatial control, but the same right of unfettered forest access that complicates enforcing the woodcutting ethic generates rapid internal resistance to spatial restrictions. In 1999, for example, communal authorities responded to official pressures to reforest by fencing in an area of abandoned agricultural lands now used for grazing. The fenced-off area intercepted a well-worn path. Woodcutters refused to walk around the fenced area and demanded the installation of a gate. Despite repeated admonitions and cajoling on the part of communal authorities, however, woodcutters consistently failed to close the gate after they passed through. Cattle entered and trampled the pine and cedar seedlings.

Second, to better meet the needs of rural woodcutters, scientific forestry must overcome a bias towards industrial production of pine saw logs. Volume estimates, for example, come from methods focussed on sawmill-sized timber. They ignore or poorly estimate deadwood, branches, bushes, and small-diameter trees, but Santa Fe woodcutters seek deadwood throughout the forest. They cut branches and resprouting oaks and make use of many other species besides pine.

Third, and most critically, scientific forestry is also a very limited form of environmental knowledge. The case of oak growth rates is the clearest example. In highland Mexico, forester's growth rates for pine come from *in situ* measurements of the spacing of growth rings, but oaks are not believed to produce reliable rings at this latitude. A common, but arbitrary surrogate for annual growth is 2.5% of volume, which follows the practice of professional foresters managing forests for the production of pine (see Becerra Luna, Reygadas Prado, and Moreno Sánchez 1997). There is little evidence to support this convention, however, especially considering the ability of many oaks to resprout and survive lopping.[9] Scientific forestry, therefore, lacks reliable data on a basic parameter of forest management.[10]

A fourth limitation of scientific forestry as normally practiced in Mexico, comes from the lack of explicit attention to monitoring the forests' response to logging treatments. Sanchez' (1998a, 1998b) plans for San Jerónimo and Santa Fe, for example, do not contain provisions for monitoring plots or follow-up visits to logged areas, for example. There is no single section or subsection of the 65-page document devoted to monitoring. Instead, monitoring is assumed to occur in the subsecuent studies required for adjustments to the main plan or for yearly cutting permits. Information on volume, species composition, growth rates, and projected extraction rates are reported only to the level of the management unit, however, and these can reach 300 ha or larger, so this information often lacks spatial precision. The stand-level effects of logging treatments are not systematically monitored. Information on cutting intensities, the presence of disturbances such as forest fires, disease outbreaks or other disturbances that might complicate analysis of the forests' response to cutting is not routinely collected or accessibly archived. Long-term monitoring presumably occurs in the course of repeating forest management plans every 10 or 20 years. After that, completely new studies would be required. In practice, foresters

[9] Personal communication from Rafael Sanchez Concha, a professional forester working in central western Mexico and author of the management plans for San Jerónimo and Santa Fe.
[10] The dearth of information on growth rates for harvested and accompanying species is even more pronounced in tropical forests, where diversity is higher and Western management experience with homologous species much shorter.

rarely consult data from previous studies,[11] which frequently used different inventory methods and cutting prescriptions. Older studies are distributed among government offices and private forestry firms and very difficult to find. When they are found, they do not contain information on the precise application of cutting prescriptions. This information typically gets lost in government offices of state and regional capitals. The monitoring that does occur is done by expert foresters, and little communication of results occurs. Finally, conventional forestry in Mexico monitors compliance through a federal environmental enforcement agency, but the goal of this monitoring is the meting out of sanctions to offenders, not the self-assessment of institutional fit.

Nevertheless, scientific forestry –and forest ecology more generally – has the potential to make substantial contributions toward monitoring the impact of different kinds of woodcutting interventions, including those prescribed by conventional management plans or experimental hybrid systems. Techniques might include long-term monitoring plots, repeat photography, data from remote sensing, and more careful reporting of harvest data and follow-up visits to logging sites.

Discussion: the possibility of integration

Integration needed

Sustainable development in forests requires management systems based on adequate knowledge of the resource and an institutional framework able to encourage forest users' compliance with restrictions and prescriptions for action. Local indigenous knowledge and traditional management practices in Santa Fe lack these characteristics. Existing ethics and rules lack internal enforcement, and in any case, they lack a theory of stand or landscape management and promote selection criteria that lead to stands dominated by less-desireable species. Conventional scientific resource management also fails to provide these characteristics. It has little to say about management techniques for the kinds of non-lumber wood that woodcutters require, and it doesn't even provide a reliable parameter on growth rates for the species woodcutters prefer for cooking fuel. The greatest failure of scientific forestry, however, is poor institutional fit. It assumes a single actor with perfect control over rotating areas of cut, and has no mechanism to adapt such restrictions to the multiple-actor environment of a village composed of hundreds of woodcutting households (Table 1 highlights these differences).

[11] The forests of San Jerónimo and Santa Fe had not been logged in recent times; no previous plans existed.

Table 1: A summary comparison of management goals and characteristics of scientific forestry and local practice in Santa Fe de la Laguna.

	Scientific Forestry	Local Knowledge and Practice
View of ecology	Succession	Agricultural cycles
Species focus	Pine trunks	Pine, oak, others. Branches. Dead wood.
Selection within stands	Removal of dominated individuals. Removal of diseased, damaged, imperfect or dying individuals Save most "fit" for seed	Removal of dominating individuals. Removal of "dry" individuals (fire-damaged, diseased, dead and dying trees) Harvest "mature" so that young can grow
Stand renewal	Clear focus of management. Partial clearcuts to create conditions for pine regeneration.	Inadvertent management. Fires, insect damage, and agricultural abandonment create conditions for pine regeneration.
Knowledge of resource	Aerial photos Vegetation sampling Maps Management plan	Walking and seeing
Communication	Writing, maps, photographs	Memory, oral history
Monitoring	Comparisons to management plan	Personal experience
In situ Experimen-tation	Inadvertent and unaware	Inadvertent and unaware
Institutional monitoring	none	Community assemblies Woodcutters' observations of others' behavior
Equity	Not an issue	A central concern. Ethic of access.
Space	Tight control, zoning, view from above	Freedom of movement, view from the path
Power	Concentrated in foresters and the state	Dispersed among woodcutters

Neither resource management system provides appropriate suggestions for how woodcutters should modify their behavior. Neither one provides an institutional framework able to bring about behavioral changes. Neither one provides a ready-made set of monitoring tools or strategies. Although individually, neither scientific forestry nor the traditional woodcutting practice and ethics of these indigenous people are adequate for sustainable forest management, there is potential for integration. The greatest hurdle for local forest management systems, for example, is the difficulty in systematically monitoring and reporting forest response to people's actions. The techniques of scientific forestry and forest ecology, however, provide a basis for monitoring and reporting. The main barrier for scientific resource management, on the other hand, is lack of institutional fit, and this is where local knowledge and practice is strongest.

Integration through adaptive management

As has been argued by a small group of scholars for some time now, an integrated system might better facilitate the sustainable use of natural resources like forests (Hecht 1990; DeWalt 1999). Berkes, Folke, and Colding (1998) provide one of the more advanced proposals for the integration of scientific and local management systems. They call for adaptive management, which emphasizes the opportunity for environmental feedback to shape policy. It is a process through which people learn about the potentials of natural populations to sustain harvesting mainly through experience with management itself, rather than through basic research or the development of general ecological theory (Walters 1986).

> Adaptive management is a relatively new approach in resource management science, but its common-sense logic that emphasizes learning by doing and its elimination of the barrier between research and management resemble traditional resource management systems. Both rely on feedback and learning, and on the progressive accumulation of knowledge, often over many generations in the case of traditional systems. Adaptive management has the advantage of systematic experimentation and the incorporation of scientific research into the overall management scheme (Berkes and Folke 1998 p. 11).

Unlike conventional systems, adaptive management explicitly considers social learning and institutional evolution. Under conventional resource management systems, social learning occurs in lurches following crisis. Crisis usually relates to a loss of ecosystem resilience due to the suppression of disturbance, the homogenization of an ecosystem under management guidelines, and the increasing brittleness of social institutions, like industries and management bureaucracies. Sometimes crisis results in a renewal of the management system, sometimes not (Finlayson and McCay 1998; Gunderson, Holling, and Light 1995).

An alternative, adaptive management system should learn to manage by change, not simply react to it. This requires active monitoring designed to achieve understanding and to identify remedial response (Gunderson, Holling, and Light 1995: 9). A typical weakness of conventional scientific resource management is the way it ignores the local knowledge of resource users. The quotidian environmental knowledge of such people has great value, especially for monitoring (Pálsson 1998). But monitoring will also benefit from the tools of scientific resource management. Monitoring enables social learning (Figure 4 provides an heuristic model of adaptive management.)

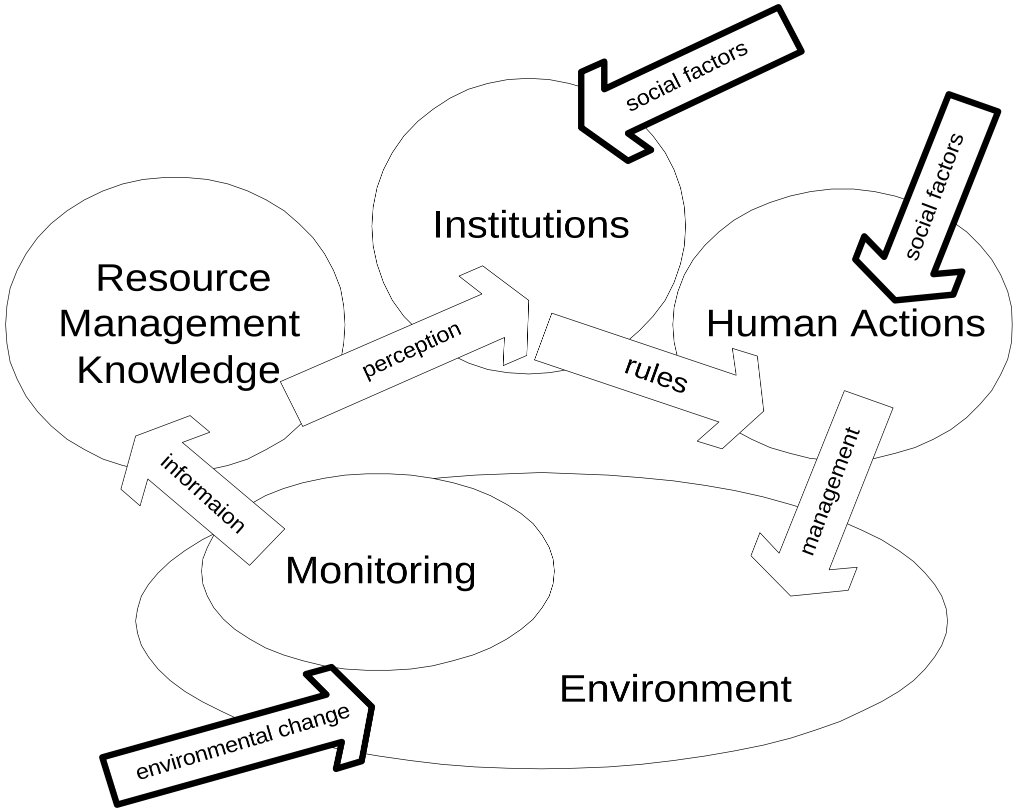

Figure 4: An heuristic model of adaptive management

Community forestry provides a partial model

The integrated system implicit in Mexican community forestry sometimes approaches this model. It partly integrates the institutional capacity and adaptability of forest-owning communities with the resource measuring, mapping, and spatial management strengths of scientific forestry. In Mexico, community forestry refers to the community-based commercialization and management of forest resources through logging under the tenets and controls of scientific forestry and state regulation. Some of the most promising experiences with forest management in Latin America so far come from the hundreds of communities which have been able to integrate scientific forestry into their traditional common property management traditions, logging in accordance with sustainable management plans, restoring productivity to damaged zones, reforesting abandoned agricultural areas, patrolling forest territories to prevent illegal cutting, and implementing the necessary restrictions of sustainable forestry fairly and effectively. Community forest management provides some of Latin America's must impressive examples of sustainable development (Bray 1998; Klooster 1999; Merino 1997; World Bank 1995).

Mexican community forestry provides examples of success in fostering the adaptation of scientific resource management to local goals through appropriate institutional crafting at the community level. Where it works, communities have been able to develop locally appropriate and flexible institutions governing forestry. They are able to apply some aspects of local forest management knowledge and goals while resolving the dilemma of poor institutional fit between local realities and centrally imposed rules (Klooster 2000). By providing room for local adaptation, it sometimes resolves the problems of institutional fit that often plagues conventional scientific resource management (Berkes and Folke 1998; see Scott 1998), and which accompanied past approaches to forestry in Mexico (Klooster 1996; Bray and Wexler 1996; World Bank 1995). Some of the most successful communities implement permanent monitoring plots and use GIS and other sophisticated data management systems. They are at the cutting edge of Mexican scientific forestry, and maintain the flexible, experimental, and self-aware approach of adaptive management.

In Mexico's inhabited and intensely used forests, community forestry plays an important role in forest conservation and restoration (Jaffee 1997; Klooster 1999). However, the Mexican model of community forestry is currently limited to the commercial production of sawmill-quality logs and only a minority of Mexican communities own the kind of commercial-quality forests able to support the model. Furthermore, the model depends on conventional forestry science while mostly excluding local forest knowledge and management goals. Finally, the model relies on a centralized, highly structured form of organization, while most rural Mexican communities organize their use of common property forests at the household level. If the model is to inform forest-use intensification strategies in areas of commercially-marginal forests, it must address the sustainable harvest of firewood and craft inputs, seek synergies between scientific approaches and local knowledge, and foster the generation of locally-appropriate institutions governing community members' use of the forest.

Towards adaptive community forestry

Such an, integrated, adaptive management approach requires better communication between villagers and foresters, participatory monitoring, and systematic experiments in institutional adaptation. In the context of communities like Santa Fe and San Jerónimo, this could be accomplished with relatively simple techniques and a small number of outside facilitators and collaborators.

Communicating management goals and forest knowledge between local Purepecha forest experts and university trained managers such as foresters and ecologists could initiate and accompany the adaptive management process. Transects, or "walking workshops," for example[12], could facilitate communication about the local goals of forest management and the character of indigenous forest management knowledge. These would involve a facilitator and a core of local vegetation experts, especially older men and women. In a transect through different vegetation types, including abandoned fields and areas of recent forest fires, they could identify trees with Purepecha and Spanish names, comment on their firewood and other uses, whether the species is more or less common than in the past, the species' requirements for regeneration, and the best way to harvest the species. Collections made during this process could be identified by botanists familiar with the local vegetation, and local knowledge compared to the botanical literature.

Professional foresters, ecologists, and botanists would accompany the local experts on some of these transects, but they should not dominate conversations, in accord with the objectives and philosophy of participatory rural appraisal methodologies.[13] Once the extent of local forest knowledge is clear, however, these resource management professionals could discuss and contrast their understanding of forest succession, technical approaches to selecting trees for felling, the philosophy of rotational cutting, and engage in more general conversations about forest management.

Adaptive management will also require systematic monitoring, data gathering, and appropriate ways of reporting data to gatherings of villagers and village leaders. Otherwise, resource users and managers can only guess at the results of the iterative social and environmental experimentation inherent to management practice. Monitoring should be participatory. If it remains the purview of expert resource managers, woodcutters will be denied a chance to participate in the interpretation of results and they will be less likely to undertake institutional change.

[12] This section on potential adaptive management techniques is clearly speculative, but it has benefitted from discussions with foresters, especially Rafael Sanchez Concha, NGO practitioners from GIRA, and – most importantly – village members and authorities from San Jerónimo and Santa Fe.

[13] The philosophy, goals, and methods of Participatory Rural Appraisal for forestry is described in Chambers 1983; Chambers 1997; Schoonmaker Freudenberger 1994; Oltheten 1995.

Test plots should be established to monitor forest growth and forest response to woodcutting. In particular, they should establish local growth rates of oaks, and forest response to different styles of woodcutting and fallowing. Although results from many of the monitoring experiments will not be obvious for many years, they also provide an arena for continued conversations and learning between community members, foresters, and ecologists.

Various modern technologies can facilitate communication and participatory interpretation of results. Repeat photography from eye-level, perhaps making use of the Global Positioning System, could serve as a valuable conversation stimulator in the field, and it could also facilitate communication with community assemblies about succession and the effects of woodcutters' selection criteria. Similarly, remote sensing is increasingly appropriate for participatory monitoring of change and persistence in forest cover, and it could also facilitate communication in village gatherings.

Villagers could take aerial photos and appropriate projections of satellite images with them on the walking workshops to discuss forest type and forest change. They could also gather Purepecha place names and locate them on the images. This would help to demystify the spatial data presentation of scientific forestry. Eventually, Geographic Information Systems might also play a role in forest monitoring and communication about the results of management.

Adaptive management relies on experimentation, and this includes institutional experimentation, in which communities adapt existing institutional resources to solve management problems, and evaluate whether they work. Elpidio made use of Santa Fe's institutional resources in the struggle against Quiroga; in a novel application of existing institutional resources, the *barrios* used the *faena* to organize the brigades that patrolled the forest and kept Quiroga woodcutters at bay. Under his leadership, the community also adapted those institutional structures to successfully reforest several areas near town.

Several areas of past reforestation in Santa Fe and San Jerónimo are now dense stands of 15cm diameter pine trees. These stands will benefit from a well-managed thinning cut that produces building posts and firewood for community use, and those thinning cuts could be experiments to discover appropriate institutional forms of organized, intensified, forest management. They would help the community learn which of its organizational traditions are most useful for stand control, for coordinating woodcutting in specific places, and perhaps for distributing the fruits of the collective reforestation efforts begun nearly 20 years ago. With the participation of a professional forester indicating which trees to fell, thinning cuts could simultaneously provide another arena for discussing and testing different selection criteria.

Through these participatory monitoring activities and management experiments, the communities and collaborating foresters and ecologists will learn about each other's management goals, knowledge, and techniques. They will learn to evaluate what kinds of cutting guidelines and management practices are both effective and socially appropriate. In the process, and more importantly, the communities will establish an iterative process of management and learning about the social and environmental effects of management.

Barriers to change

In Santa Fe and San Jerónimo, the biggest barrier to experiments with this kind of integrated, adaptive management option comes from the lack of local urgency to address forest issues. This, in turn, is partly related to regional forest policy and the lack of community boundary enforcement.[14] The internal social differentiation and the conflation of Santa Fe identity with unrestricted rights to forest access raise important barriers to change. In open-ended interviews, however, most woodcutters and village authorities expressed the belief that this could be overcome if, and only if, there were a general agreement to impose cutting fallows or other restrictions, arrived at by consensus in the village general assembly. During the period of Elpidio's leadership, an external threat galvanized the community to take collective action in the defense of common property territory. Currently, problems from pine scarcity are not sufficiently intense to motivate villagers to participate in the collective action required for adaptive management experiments.

There are two main reasons for this. First, the costs of inaction[15] are hidden by the porosity of borders. Santa Fe woodcutter's ability to leave their territory and cut elsewhere partly drowns the feedback from the environment. At the same time, it removes incentive for action. It is easier to walk farther in search of wood than it is to organize neighbors, or spend valuable time participating with an NGO's attempt to conduct management experiments. Second, the benefits of change are far from obvious. Neither the local cutting ethic nor scientific forestry provide a clear and compelling vision of what might be gained from change.

[14] Because of past reforestation and the pine recovery following forest fires and agricultural abandonment, there might also be room for woodcutters to "muddle through" with existing cutting practices without immediate, change-galvanizing crisis.

[15] For the full development of the role of cost-benefit analysis in collective action leading to institutional change see (Ostrom 1990).

Regional forest policy reinforces these two barriers to change. A perception of drastic deforestation prevails among urban voters and policy makers in this region, and this leads to restrictive forest policies including a logging ban within the Lake Patzcuaro Basin.[16] This precludes experiments with the community forestry route to intensifying forest use. The situation reduces incentives for San Jerónimo and communities like it to protect their borders. They have no way to make productive use of the forest, so why should they risk conflict with a neighbor? It also makes it even more difficult for community leaders and members in Santa Fe to imagine better forest management options than the status quo.

As Alcorn and Toledo argue (1998), common property territories like Santa Fe and San Jerónimo provide an arena for institutional crafting. They are tenurial shells, sufficiently insulated from the rest of society to allow groups of resource users to generate appropriate institutions. This research points out that the framework in which these tenurial shells are nested affects the possibility and direction of institutional changes. Limited state support for boundary protection and the lack of legal avenues for community forestry diminish the chances of institutional innovation within communities like Santa Fe and San Jerónimo.

Outside intervention could change that dynamic. Adaptive environmental management of the kind described here will require a participatory process of social learning involving personnel experienced in participatory techniques. At least initially these will be outside catalyzers from NGOs or government agencies. Hurdles include the current time frame of academic researchers, NGOs, and funding agencies, and the demands and rotation of community leaders. The global environmental services provided by forest protection could offset some of these costs (Klooster and Masera under review). Successful examples of adaptive environmental management could change perceptions of the potential benefits of change for villagers as well as policy makers.

Conclusion

There is an acute need for alternative resource management strategies in areas of marginal agriculture. This is especially true for forests, which are increasingly a source of fuel, nontimber forest products, and raw materials for craft industries as the viability of agriculture decreases. In the neighboring indigenous communities of Santa Fe de la Laguna and San

[16] The ban allows salvage logging of trees killed by fire or threatened by disease, but this serves to maintain the power of professional foresters, the forest bureaucracy, and sawmill owners. These actors frequently collude to gain access to timber resources, allowing outbreaks of disease to spread, responding slowly to forest fires, and possibly even setting fires. Sawmill operators get access to trees, foresters and bureaucrats get payoffs, but forest-owning

Jerónimo Purenchécuaro, pottery production creates livelihood opportunities that agriculture no longer provides. The resulting intense woodcutting for kiln fuel creates wood scarcity, however. These communities, and other like them, will benefit from forest management systems enabling the sustainable intensification of forest use.

Local woodcutters have a great deal of knowledge about the forest and they can express a woodcutting ethic, but this has not been sufficient for successful forest management. A professional forester recently prepared forest management plans for these communities. In the context of a common property territory, numerous indigenous woodcutting households, and poor fit with the kinds of wood needed for pottery production and cooking, however, scientific forestry does not provide an adequate basis for the sustainable intensification of forest use, either.

Adaptive management (Berkes, Folke, and Colding 1998) calls for the integration of these kinds of knowledge in a flexible system in which management is considered to be a series of systematic experiments. Similar to the situation in successful traditional resource management systems, adaptive managers iteratively adjust their behavior in accord with careful and constant monitoring of both social and environmental aspects of the system. In communities like Santa Fe, however, one of the greatest failures of local knowledge comes from difficulties in monitoring and communicating the results of woodcutting techniques. Conventional scientific forestry and affine professions, however, provide a suite of monitoring tools that could contribute to an integrated, adaptive, management system.

The worst hurdle for conventional scientific forest management, on the other hand, is the poor institutional fit between foresters' restrictions and forest users' social structures and customs. Adaptive management eliminates this stark separation between expert resource managers and disempowered resource users. It pays greater attention to the social side of resource management systems, including institutional fit. In integrated adaptive management, traditional systems such as those found in Santa Fe are a source of institutional capacity for the flexible implementation of resource management restrictions and prescriptions.

Adaptive management, therefore, potentially integrates local forest knowledge and traditional self-organization with the monitoring and data communication abilities of scientific forest management. In Mexican communities like Santa Fe and San Jerónimo, creating an

communities receive small benefit from their forest. Policy does not provide forest management opportunities and incentives to forest-owning communities. See Alvarez-Icaza and Garibay 1992; Garibay Orozco 1996).

adaptive management system involves at least three functions. First, it requires better communication and cross-learning between university-trained resource managers and local experts, perhaps through participatory resource appraisal exercises. Second, participatory monitoring and appropriate data reporting should enable resource users to assess the impact of different woodcutting techniques and learn from the successes and failures of management. Third, through experiments in institutional design, village communities could discover socially appropriate ways of coordinating users' behavior to cut in prescribed ways.

There are several barriers blocking these kinds of steps towards an integrated, adaptive management system, however. Current forest policies inhibit productive use of forests; they deny incentives to develop alternative systems. State support for enforcing the boundaries of common property territories is limited; it is easier for woodcutters to seek wood in a neighbor's territory than to engage in experiments to improve management at home. The state, therefore, has a role in creating a framework within which adaptive resource management policies might evolve.[17] Actors such as NGOs could also play an important part by collaborating with resource-owning communities in the discovery of viable paths towards the adaptive resource management systems urgently needed to meet human needs in agriculturaly marginal, environmentally fragile areas.

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[17] Part of this role will include the spatial dynamics of sustainable forest use at the landscape scale.

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