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Poverty, biodiversity and institutions in forest-agriculture ecotones in the Western Ghats and Eastern Himalaya ranges of India

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Abstract

Forest-agricultural ecotones are defined as areas that adjoin forests and other natural habitats and that lie between forests and zones of intensive agriculture. These ecotones are critical for conservation of biodiversity and for the maintenance of livelihoods of people that inhabit these areas. Here we focus on three questions: (1) How can we make land use sustainable in forest-agriculture ecotones? (2) How can forest-agriculture ecotones contribute to conservation of biodiversity? (3) How can we improve the institutions that foster sustainability and conservation of biodiversity in forest-agriculture ecotones? We address these questions in the context of interventions to foster biodiversity and rural livelihoods made by the Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore, in the Western Ghats and the Eastern Himalayas, 2 of the 34 global hotspots of biodiversity in India. At several sites, ATREE's interventions have improved the livelihoods of several rural communities by providing increased income from non-timber forest products (NTFPs), diversification of livelihoods and enhanced agricultural production. These interventions have improved the prospects for sustainable land use in the forest-agriculture ecotones. Simultaneously, ATREE's interventions have strengthened a range of village level and regional institutions that play a critical role in the rural economy and in conservation of biodiversity. We believe that the path to sustainability in agriculture as well as maintenance of biodiversity passes through adaptive, strong and relevant institutions. The development of institutions however is severely constrained by low social and human capital and the neglect of forest-agriculture ecotones by the governmental agencies and international organizations. We argue that forest-agriculture ecotones offer a means to conserve biodiversity through alleviation of poverty and development of community-based institutions.

Keywords: Amla; Ashoka Trust for Research in Ecology and the Environment (ATREE); Biodiversity hot-spot; Lantana; Nested governance systems; Non-timber forest products (NTFPs); Self-help groups

1. Introduction

Forest-agricultural ecotones, areas that adjoin forests and other natural habitats and that lie between forests and zones of intensive agriculture, are critical both for conservation of biodiversity and for the livelihoods of people inhabiting these ecotones. Land uses within forest-agriculture ecotones are of vital importance to human societies for several reasons. First, land uses in areas close to natural habitats have a high impact on biodiversity. Second, forest-agricultural ecotones act as buffers between natural habitats and areas that are extensively used by humanity. The land uses in these areas can also affect the agricultural zones surrounding biodiversity rich areas. For example, biodiversity-friendly land use practices in these ecotones can extend the boundaries of the surrounding natural habitats and the distributional ranges of species contained in these habitats (Rosenzweig, 2003; Daily et al., 2003). Such practices can slow down or eliminate the march of intensive agriculture, which tends to degrade biodiversity and ecosystem services (Tilman et al., 2001; Jackson et al., 2005; Perrings et al.,

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2006). Third, land uses that sustain the livelihoods of local communities in forest-agricultural ecotones have the potential to transform the adversarial relationships that often exist between local communities and protected areas in tropical countries into cooperation, building partnerships between local communities and protected areas managers to foster biodiversity (Bawa, 2006). Fourth, forest-agricultural ecotones are characterized by relatively high levels of biodiversity, contributing vitally to the maintenance of traditional agricultural and agroforestry practices (Green et al., 2005). Hence, land use in such areas has an impact on rapidly eroding agro-biodiversity and traditional ecological knowledge (Brush, 1993). Finally, biodiversity-friendly land uses in forest-agriculture ecotones can help foster the development of new paradigms for conservation that are urgently needed to replace or supplement existing paradigms (Bawa et al., 2004; Bawa, 2006).

Biodiversity-rich areas in the humid tropics have been progressively confined to habitats unsuited to intensive agriculture (Huston, 1980). These marginal lands, often with harsh topography and poor soils, support marginalized human communities with low income and little social standing. Consequently, both private and public sector investments in such areas remain low, though they are critical for sustainable management of natural resources (Jha and Bawa, 2006). The heavy reliance of such communities on local ecosystems often puts these communities into conflict with those who seek to protect biodiversity (Chapin, 2004). The resolution of this conflict is critical for conservation of biodiversity and for the well being of society at large.

Here we address three questions: (1) How can we make land use sustainable in forest-agriculture ecotones? (2) How can forest-agriculture ecotones contribute to conservation of biodiversity? (3) How can we improve the institutions that foster sustainability and conservation in forest-agriculture ecotones? We address these questions in the context of work by the Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore, in the Western Ghats and the Eastern Himalaya mountain ranges, 2 of the 34 global hotspots of biodiversity in India. More information can be found at the ATREE website (ATREE, 2006).

2. Sites and people

The work reported here has been underway at a series of sites in the Western Ghats and the Eastern Himalayas. In the Western Ghats, we have worked in Biligiri Rangaswamy (BR) Hills and the adjoining Male Mahadeshwara (MM) Hills, as well as the Kanakapura Range in Karnataka state of India. The landscapes are a mosaic of forested lands managed by the state as reserved forests or wildlife sanctuaries and agricultural lands adjoining forested areas (Fig. 1). The Bilgiri Rangaswamy Temple (BRT) Wildlife Sanctuary, for example, is located in southern Karnataka, at the eastern-most edge of the Western Ghats. Because of climatic and topographic variation, the sanctuary has a range of vegetation types within its relatively small 540-km^2 area. The dry scrub forests at lower altitudes give way to woodland savanna and deciduous forests at mid-elevation. At higher altitudes, where it is wetter, one finds evergreen forests, shola forests and grasslands. The forests of BRT are home to more than 245 species of birds including 12 endemic and several endangered species (Aravind et al., 2001), 1000 species of higher plants, and 36 mammals excluding bats and rodents, and 145 species of butterflies (ATREE, 2006).

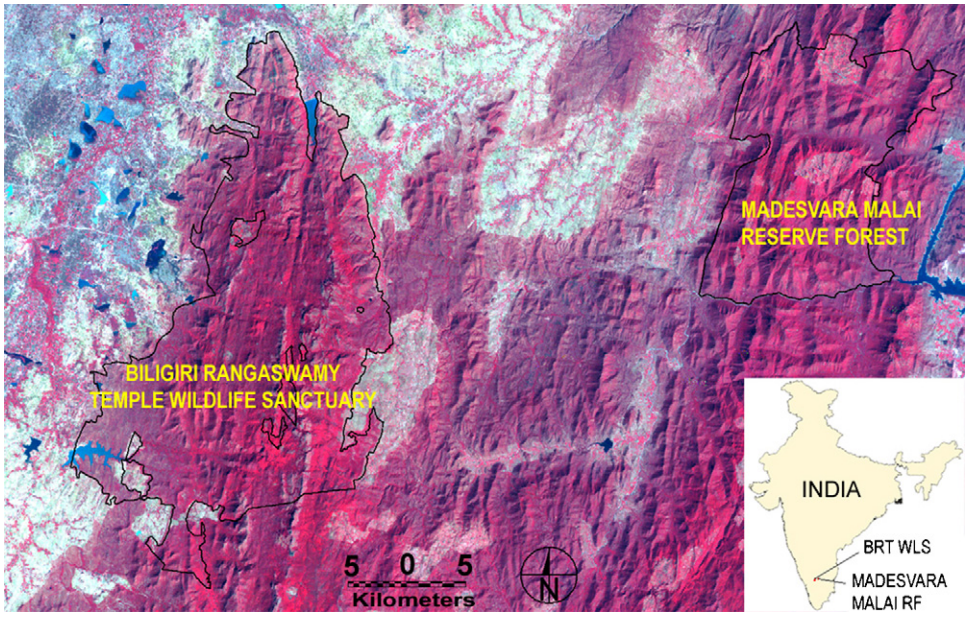

Fig. 1. False color composite of the study areas in the Western Ghats. Forests are in red color, agricultural areas in light blue and water bodies in blue.

The Eastern Himalayan sites are equally rich in biodiversity. The Darjeeling Hills and the adjoining areas of Eastern Nepal and Sikkim contain a wide array of natural habitats from sea level to 4500 m or up to the snow line, with many species of endemic and endangered plants and animals. ATREE's sites are concentrated in the temperate forests that range from 1500 to 2500 m in the 30 km^2 Senchal Wildlife Sanctuary. The sanctuary has forest dominated by oaks, maples and laurels, with many species of medicinal plants. The sanctuary also serves as a watershed for the town of Darjeeling, with a population of about 200,000 people.

The biodiversity of both the Western Ghats and the Eastern Himalayas has been under threat due to habitat loss and deforestation. For example, in the southern part of the Western Ghats, 25.6% of the forest cover was lost over a 22-year period between 1992 and 1995 (Jha et al., 2000). The rate of deforestation in the Darjeeling Hills is not known, but our personal observations over the last 40 years indicate that the rates have been equal to, if not greater than the Western Ghats.

Adjoining the forestlands are areas of traditional or low-intensity subsistence agriculture. Household land holdings are typically small, ranging from 0.3 to 1.2 ha in the hills and up to 4 ha in the plains. The areas are inhabited by an array of indigenous groups practicing subsistence agriculture. The agriculture on smallholdings is rain fed; finger millet (*Eleusine coracana*), field beans (*Dolichos lablab*), corn (*Zea mays*), tassel flower (*Amaranthus* spp.), red gram (*Cajanus cajan*), mustard (*Brassica juncea*), foxtail millet (*Setaria italica*) are sown from July to first week of August. Monsoon rains last from June to September. Crops are harvested in November. Trees grown on farmlands, generally on the perimeter of individual holdings, include gooseberry (*Phyllanthus emblica* and *P. indofischeri*), soapberry (*Sapindus laurifolia*), lemon (*Citrus limon*), papaya (*Carica papaya*), drumstick (*Moringa oleifera*), and jackfruit (*Artocarpus heterophyllus*).

In the BR Hills, the Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary covers 540 km^2 and contains approximately 2300 households of Soligas, the indigenous people of the region. The MM Hills Reserved Forests, occupying an area of 435 km^2, have a more heterogeneous population with 2380 households of Soliga and non-Soliga people. The Kanakapura range has an area of 350 km^2 and the most diverse population of the 3 sites, with approximately 1800 households of a mix of ethnic groups.

In the Eastern Himalayas, ATREE researchers have worked in five forest villages in Senchal Wildlife Sanctuary in Darjeeling Hills. The sanctuary is about 30 km^2 in size in a temperate zone with broad-leaved evergreen forest. These villages have approximately 180 households, comprising a range of ethnic groups. The land holdings are generally less than one hectare per household. Farmers grow cash crops such as vegetables and cardamom, the latter under forest canopy. Corn is occasionally grown when the land holdings exceed 0.5 ha.

Because of the remoteness of these villages and the small land holdings, livelihood options are limited and income is low (less than U.S. $2/day per household). Apart from subsistence agriculture, practiced on lands over which farmers often do not have tenure, a majority of households in the Western Ghats sites gather a range of NTFPs such as the Indian gooseberry (*P. emblica*) and other fruits as well as lichens and soapnuts, and wild honey from *Apis dorsata* and *Apis cerana* in both regions. In the Western Ghats, households have traditional rights to gather products, but in the Eastern Himalayas, collection is illegal. The villagers gather NTFPs for their own consumption as well as for sale to outsider markets. Their sale in the BRT Sanctuary and MM Hills is a well-organized activity. For instance, at these sites, the harvesters sell their produce for higher returns to government-run cooperative societies, called Large-scale Adivasi Multipurpose Societies (LAMPS).

Besides NTFPs and traditional agriculture, forests are also indirect sources of other income. Soligas are employed by the Forest Department in the maintenance of roads and various forestry operations such as clearing of weeds and control of fire. Nature-based tourism, controlled by the Forest Department, also contributes to the income of a small minority of households. Sustainability of land for these local communities thus is based on both sustainability of forest resource use and sustainability of land under agriculture.

3. Interventions

3.1. Livelihoods and agriculture

ATREE has worked with local communities to: (a) enhance income from the harvest of NTFPs through value addition, (b) diversify their livelihoods, and (c) modify agricultural practices to increase productivity. The purpose of all these interventions is to improve the well being of the people and the prospect of sustainable use of forest and land resources. An underlying assumption is that diversification of livelihoods will decrease direct dependence on forest resources.

3.1.1. Income from NTFPs

The income from NTFPs has been enhanced in two ways. First, the local communities have started to add value to harvested products by processing, packaging, and marketing them. These products include honey, pickles and jams, and herbal medicine. Ten years ago, no more than 50 kg of processed honey was sold. By contrast, Soligas sold 25 tonnes of processed honey in 2004. In the same year, the market price of unprocessed honey was Rs. 42/kg, while processed honey fetched Rs. 135/kg. A total of Rs. 308,400 (US$ 6425) was distributed as profits from the sale of processed honey among 869 households.

Second, the local communities in BR Hills have improved their share of the income generated through the

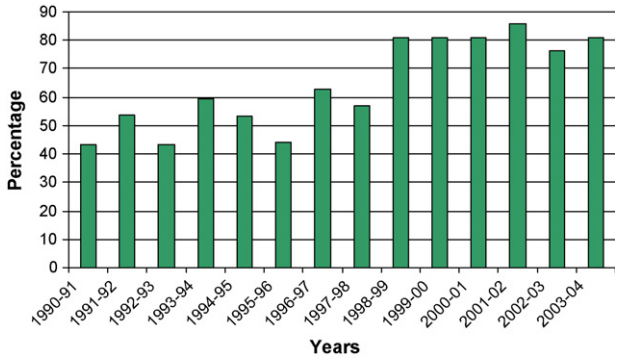

Fig. 2. Increase in sale prices of harvested unprocessed honey for years 1990–2003. Expressed as percentage of the price recovered by harvesters from LAMPS.

sale of harvested NTFPs (Fig. 2). The Soligas in BR Hills are mandated by the state to sell NTFPs collected from forests to the LAMPS. The LAMPS in turn sell the products to outside agencies, including enterprises owned and operated by the local communities. ATREE has worked with the LAMPs to ensure that the Soligas receive at least 75% of the eventual sale price of the products by the LAMPs.

It is important to mention that honey is one of the most valuable non-timber forest products. Increases in income from other products have not matched the increases from honey. There are several reasons for this, some of which are discussed in the subsequent section.

3.1.2. Diversification of livelihoods

ATREE's interventions have focused on the development of new micro-enterprises based on a range of agricultural products. Here we highlight one unusual class of micro-enterprise based on an invasive species. *Lantana camara*, a native of South America, is a highly invasive woody species that has now spread into most of India. Putting this weed to use in livelihood enhancement is an ongoing 'experiment' in the MM Hills led by Dr. R. Uma Shaanker of ATREE and the University of Agricultural Sciences, Bangalore. The use of Lantana in is also linked to the recent decline in wild populations of bamboo (Uma Shaanker and Ganeshaiah, 1998), thereby helping conserve bamboos. Traditional bamboo artisans in the MM Hills make baskets out of split bamboo for carrying agricultural produce to markets. Bamboo poles are cut from the surrounding forests that are managed by the Forest Department. Bamboo populations have been declining in the region for decades due to a combination of fire and competition from Lantana. As a result, the number of artisans has declined and they have started taking on other menial jobs.

Lantana stems have been used by other forest-dependent communities in adjacent states to make baskets for over 100 years due to the decline in bamboo in these regions. However, in the MM Hills there was no knowledge of such use of a substitute for bamboo. A few artisans from MM Hills were trained by tribals to make baskets out of Lantana in the neighboring state of Andhra Pradesh in 2003. After artisans were trained in the use of Lantana stems to build furniture, more than 150 families started the use of Lantana in the next 2 years. Out of this group, 71 artisans are women. Monthly income for these artisans has increased by 300%. Rural and urban market dynamics driving Lantana furniture sales have been complex, but sales have been sustained with minimal market intervention. ATREE's current emphasis is on building production capacity and ensuring quality of products among the network of artisans. It is critical that we focus on improving these capacities as urban-market linkages could increase demand beyond what can be sustained at current capacity. Scaling up such natural product-based enterprise, while simultaneously ensuring positive conservation outcomes with adequate community participation, is a complex challenge.

It is well known that the commercial use of natural products has often led to their decline. Such a decline in Lantana could have a negative impact on the livelihood strategies of the poor artisans now dependent on the resource. However, since Lantana is abundant throughout South India and is a highly competitive and adaptable species, there is little expectation of a decline in the near future. We estimate that currently artisans are using less than 10% of the annual productivity of the species.

In the Eastern Himalayas, a similar effort is the ongoing work centered in the villages adjoining the Senchel Wildlife Sanctuary (SWS) in Darjeeling district, led by Suman Rai. The intervention seeks to introduce a positive feedback on the native invasive mallingo bamboo (*Arundinaria mallingo*) by promoting its profitable extraction from the wild. Here it is seen as an opportunity to improve the livelihoods of local communities who weave baskets by linking them to potential buyers, in this case, the tea estates in the area.

Mallingo is considered an invasive species of the runner bamboo type. It has invaded a significant portion of the deforested parts of the SWS. The mallingo weavers of Rambi village have been weaving simple baskets (doko) which they sell in the local village markets. In order to ensure sustainable livelihoods of local mallingo craftsmen, ATREE has established market links with tea plantations where there is a continuous demand for tea-plucking baskets. ATREE is working in collaboration with the local community of mallingo weavers, the Eco-Development Committee (EDC) of Rambi village, and officials of the Forest Department, to ensure that this initiative is sustainable. The Forest Department has identified 5–10 ha of mallingo forest for potential commercial harvest, and weavers have already begun supplying plucking baskets to the tea estates. A socioeconomic survey of weaver households will be conducted that will enable an assessment of the impact of the program on their livelihoods.

Two other villages have also approached ATREE for support in initiating the same activities in their areas. The regulated harvesting of mallingo, linking sustainable livelihoods of local mallingo craftsmen with positive

conservation benefits, is now being developed into a separate project. The project will integrate natural and social sciences to study mallingo occurrence, and its regeneration and utilization potential.

3.1.3. Agriculture

Most of the agricultural practices followed by Soliga tribal farmers in BRT Wildlife Sanctuary are adapted from the shifting-agriculture systems that they practiced for centuries in the area before being settled in 1972. Soliga farmers in the BRT own or lease 1–4 acres of land per household. They grow a diversity of crops such as finger millet, maize, red gram, mustard, amaranths, castor, field beans, banana and other useful plants. Forty percent of farmers grow shade-coffee under residual forest trees. Agriculture is adapted to the subsistence needs of farm families. Current agriculture practices are low in input and generate low yield. Soil quality is low due to erosion on sloping farmlands. Farmers work under the constant threat of wildlife damage to crops.

Under these circumstances, which are probably common to millions of farmers in forest-fringe areas in the tropics, we are working with farm families to introduce simple 'organic' technologies to increase yields, diversify the farms, retain and build capacity in the preparation of organic composts, cultivation of fruit trees and conservation of soil and water. Introducing these technologies depends on a strategy of using on-farm trials for low-risk interventions and field-station trials for high-risk interventions. Low-risk interventions include the use of contour row-sowing to replace broadcast sowing, improved access to traditional varieties of seeds, and composting practices. The relatively high-risk interventions are to incorporate locally grafted high-yielding amla and related fruit trees, selection of high-yielding local crop varieties, and crop rotation. Amla is one of the most frequently used of the Ayurvedic herbs, and it is now being used in many commercially available soaps and cosmetics. It is the fruit of the tree, *P. emblica*, which occurs naturally in the area. Our interventions aim to strengthen on-farm capacities and improve on traditional technologies, integrating research whenever possible to combine learning from the experience.

On-farm trials using row cropping showed a 30% increase in yields due to broadcast sowing on 21 farms (Fig. 3). However, yield variation among plots using either sowing method was high, ranging from 100 to 1250 kg/acre. This points to a high degree of variation in soil fertility, and possibly to local varietal variation, suggesting a potential to raise yields considerably by improving practices and improving quality of soils. Seeds of traditional varieties have been sourced, and systems put in place to store and distribute them. Seed storage systems use traditional knowledge borrowed from farmers elsewhere in the state. Thirteen thousand seedlings of 16 tree species preferred by Soliga farmers were grown and distributed for planting along farm bunds. The project has helped farmers to build

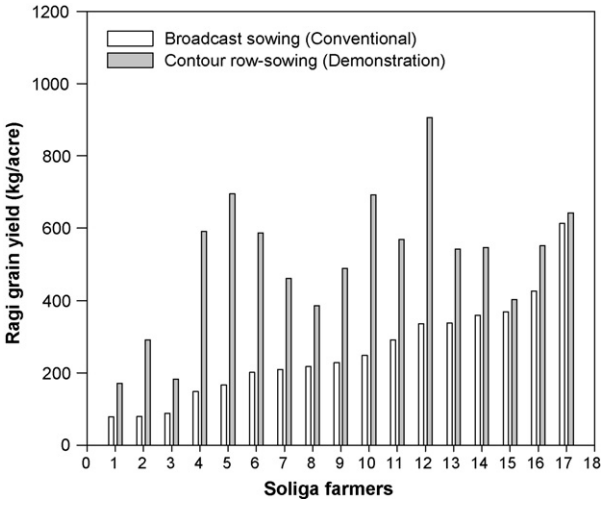

Fig. 3. Difference of finger millet (ragi) yield in conventional and demonstration methods of sowing in BRT wildlife sanctuary based on trials on 17 farms.

bunds for control of soil and water erosion. In some villages, more than 60% of farmers have opted for putting these bunds on their agricultural land. Nursery technologies to improve quality of seedlings are experimentally evaluated at the field station, before being put into operation. We are building on-farm capacity to improve composting systems. Rather than introduce high-yielding grafted trees from non-local sources, we are experimenting with grafting locally available tree scions and rootstocks for select species with medicinal and nutritive value. Using local individuals reduces the risk of disease/pest introduction and the uncertain impacts of gene flow from introduced individuals. Small farm size means there is little space available for trees, so it is critical that farmers have access to early- and high-yielding grafted trees. ATREE continues to experiment with complementary methods to diffuse farmer-friendly technologies, to achieve the twin goals of livelihood support and ecological sustainability.

3.2. Institutions

Addressing livelihood needs in any context requires scale-dependent, robust and democratic institutions. In these forest-agriculture ecotones, we continue to strengthen existing institutions, but also search for new institutional models and associations that will serve the various objectives of strengthening livelihoods and conservation concerns. We will briefly discuss role and scope for these various institutions and their relative strengths and weaknesses. For more analytical reviews, please refer to Lele et al. (1997) and Shanker et al. (2005).

3.2.1. LAMPS

The Large scale Adivasi Multipurpose Societies have a cooperative structure. Each taluk (county) has a LAMPS. It is chaired by the local Forest Department official and its

member secretary is an official from the Cooperative Department. The harvesters of NFTPS are individual members who elect a board of directors; however, the board has no decision-making power. Most of the power is vested in the Forest Department officials and the secretary. The efficacy of this institution is dependent on having honest government officials. Harvesters having usufruct rights must sell to the LAMPS, for a price that fluctuates from year to year based on the market.

Part of our effort of strengthening existing institutions has been directed toward LAMPS reform. This is being conducted at various levels. At the level of the community, ATREE has conducted 35–40 information-sharing meetings in individual Soliga settlements, where the people have been made aware of the trends in benefits accruing to them from the LAMPS over the past 10 years.

There has been tremendous variation in benefits accruing to NFTP harvesters both among LAMPS and within individual LAMPS, among years. A recent resolution raises the proportion of returns to collectors to 75% in two of three LAMPS. One of our goals is to ensure that all three LAMPS fix a 75% return policy.

ATREE held a directors' training to make them aware of the powers and responsibilities of their position, and the role they could play in bringing about reforms in the LAMPS' functioning. A very positive outcome of the recent general body meetings held in two of the three LAMPS has been a policy decision to raise the proportion of returns to the collectors to 75%, which is a marked improvement on the earlier figure.

3.2.2. Non-governmental organizations

To strengthen our work, to learn from others and share our knowledge, we actively collaborate with local non-governmental organizations (NGOs). At BRT, we have forged a long-term partnership with Vivekananda Girijana Kalyana Kendra (VGKK). VGKK works on health and education of tribal people, while we complement their work on forest conservation related issues. We have strengthened the capacity of VGKK in development of micro-enterprises and marketing. Other inputs include the establishment of banks and tree-based farming.

A key component of capacity building has been participatory resource monitoring by the Soligas. Both VGKK and LAMP are involved in participatory resource mapping, which involves monitoring by the Soligas together with the members of the enterprise team. The resources that are monitored are those harvested by the members of the LAMPS, primarily amla and honey.

In a sense Soligas have always monitored harvested resources to determine what, how and when to harvest. The purpose of the participatory resource monitoring is to keep track of resources over time and space, and monitor not only available stocks, but also regenerative capacity and potential threats to resources. The participatory monitoring at BRT sanctuary has evolved over time from the initial effort that involved Soligas and the researchers to Soligas and the enterprise unit. Until 2005 the participatory monitoring was done by the harvesters in association with the Soligas managing the enterprise unit. The monitoring has focused on two products: amla (*Pyhyllanthus emblica*) and honey bees (*A. dorsata*). Groups of five to seven people estimate the amount of fruits or the number of colonies available in the areas from where they are likely to harvest the products. Records also kept of the amount harvested. Researchers also estimate production and extraction levels from the transects in the study areas. Our data indicate that the two methods yield similar estimates. Participatory monitoring is voluntary and has been inbuilt into the management of enterprises run by the Soligas. Continuation of the participatory monitoring will depend upon the perceived benefits of such monitoring by the Soligas. These benefits in turn will be contingent upon the linkage between economic gains from harvest of NTFPs and sustained access to NTFPs. In 2006, the state imposed a ban on the harvest of NTFPs in the BRT wildlife Sanctuary as the sanctuary was 'upgraded' to a tiger reserve. The Soligas are opposing this infringement of their usufruct rights, and it is uncertain if the ban will be continued.

3.2.3. Self-help groups and federations

ATREE adopted the self-help group (SHG) model in order to establish community-owned conservation-oriented micro-enterprises. The SHGs typically consist of 5–15 members. These members receive micro-credit and sometime technical inputs from others. These groups receive no matching grants from ATREE, but rely entirely on funds mobilized from among the individuals in the group. The SHGs become more stable institutions when more than 30 are federated and are registered as a legal entity. Stability of these federated institutions is reflected in links with formal lending organizations such as scheduled banks. At one site, ATREE has formed 55 women's SHGs, consisting of 630 families from 25 villages. Total savings are over Rs. 485,000 (US$ 11,000). Most of these women belong to households where the annual income is less than $300/year.

Two main foci of this program are economic stability and empowerment of women, creating micro-finance facilities in the villages themselves and reducing dependence on moneylenders. SHG leaders are undergoing training on sustainable NTFP harvesting methods, and entrepreneurship skills. We are looking at ways to link the SHG groups or the federations of SHGs to enterprises that have neutral or positive outcomes for the environment. Livelihood-based enterprises have been linked to SHG institutions by other NGOs, but there is as yet no serious attempt to link and build capacities to run 'green' enterprises in this area of India.

3.2.4. Community organizations

It is important to work with community networks and organizations to strengthen their capacities in issues related to environmental governance. The Soliga Abhivrudhi Sangha (SAS) is a community-based organization that primarily

works to guard the rights of the tribals and to ensure that government-allocated funds for tribal development are shared 'equitably' among the members of the community. SAS continues to support ATREE's SHG activities among the Soligas and facilitates the strategic training of LAMPS members in its area. We are planning a strategy to formally link the SHG federation with SAS in one of our sites to ensure long-term sustainability. However, SAS needs focused capacity building in facilitating such SHG federations.

3.2.5. Government organizations

The State Forest Departments (FD) have the overall legal responsibility for the management of biodiversity within forest lands. However, through 'eco-development' programs, the FD has intervened in the development of surrounding agricultural lands, with mixed outcomes to conservation. ATREE's interventions have been largely in the provision of ecological and socioeconomic information to the FDs. ATREE has also brought together various stakeholders with the FD and other departments such as the Departments of Cooperative Societies and Rural Development, to resolve management issues and address tenurial issues and capacity-building needs. More recently, the FD has sought ATREE's inputs to the development of a conservation management plan for the BRT sanctuary.

Overall, ATREE's interventions have enhanced the role of institutions in mobilizing and steering local communities towards the path of sustainability in three ways. First, ATREE has facilitated the formation of new institutions such as self-help groups. Second, ATREE has built the capacity of institutions such as LAMPS, SHGs, and community-based organizations. ATREE has also provided training to forest guards and more recently scientific inputs to the draft management plan of the BRT Wildlife Sanctuary. Third, ATREE has brought together government and NGOs to develop conservation and management plan. ATREE's work with institutions has led to the NGOs playing a greater role in sustainable management of resources during the last 10 years than in the prior 50 years.

4. Interventions and sustainability

We define sustainability in terms of the ability of the present generations to use biodiversity and land resources without compromising the ability of the future generations to use such resources. Sustainability is hard to measure, but we outline below some parameters that we use to measure the effect of our interventions on progress towards sustainability.

Our interventions are designed to positively influence biodiversity, livelihoods, institutions, including governance and policy. We are monitoring biodiversity at two levels: at the level of the ecosystem by evaluating changes in forest cover, biomass, and species composition, and at the level of species by monitoring changes in populations of extracted species. At the ecosystem level, we have used remotely sensed imagery to detect changes in biomass from the middle of 1970s to 2000. Our unpublished results show an overall increase in biomass inside the sanctuary. We are in the process of determining if the increase is due to regeneration in degraded areas or spread of invasive species or both. Although we cannot attribute the increase to our interventions because we did not begin our work until the late 1990s, we wish to emphasize that the monitoring at the landscape level is an integral part of our program. More recently, we have also established ten 1-ha plots in deciduous and scrub forest where all individuals of woody species greater than 1 cm dbh are marked and monitored. At the species level, we have intensively monitored the populations of amla and *A. dorsata* for 10 years. Results of our monitoring are routinely conveyed to the soligas and the state forest department.

We have not detected significant changes in either of these two very intensively harvested species. We are aware that a number of factors other than extraction of NTFPs could influence changes in biodiversity. These factors include fires, invasive species, and other human impacts. Any positive association between interventions and biodiversity changes will require careful analysis and long-term studies, and we have long-term monitoring systems in place. There is evidence that in areas where participatory monitoring has been practiced, people's awareness about negative impacts of extraction has increased (Setty et. al., in preparation). In these sites, destructive harvesting practices such as cutting of main branches have been reduced.

Participatory monitoring on the other hand remains to be institutionalized. Although Soligas are willing to undertake systematic monitoring, uncertainty over rights to harvest products remains a major hurdle. The real value of monitoring lies not only in the initiation of participatory resource monitoring, but also the training of LAMPS directors in monitoring. At the very least, there is now realization among the communities and their institutions, as well as in the state forest departments, that monitoring at various levels and by a variety of stakeholders is a critical component of ecosystem and land management.

It has been suggested that increasing commercialization of non-timber forest products could result in their greater exploitation. Such a possibility at our sites is minimized by monitoring protocols in place, and just as importantly, by the presence of other stakeholders such as the FD and other agencies.

The impact of agricultural interventions on biodiversity can be roughly assessed by the amount of time spent engaging in eco-friendly activities that enhance livelihoods. Activities such as sowing of row crops introduction of trees on agricultural land and growing vegetables in greenhouse-like polyhouses all take time, leaving less time to extract products from the forest. More importantly, agricultural interventions promote diversification of livelihoods options that are not based on extraction of wild resources. In one of the villages in the Eastern Himalayas, charcoal making from

the wood collected from forests, previously practiced by several households, has completely ceased.

Sustainability in the use of natural resources may also be fostered by interventions designed to enhance rural income and an institutional framework for conservation. ATREE's activities have clearly had a positive impact on income. While we do not know the impact of increased income on the use of natural resources at our sites at this time, we do know that poverty often contributes to the degradation of the environment (World Commission on Environment and Development, 1987; Durning, 1989; Cleaver and Schreiber, 1994; Ekbom and Bojö, 1999).

Institutions are key to eventual sustainability along ecological, economic and social dimensions. Institutions established or strengthened by ATREE have positively contributed to either ecosystem management or diversification of livelihoods and increase in rural incomes. However, nested institutions that operate on different spatial scales are critical for achieving sustainability. A major unfinished task for ATREE is the linkage of village level institutions with regional and state level institutions.

Finally, at the policy level, ATREE's interventions have started to motivate changes in the state's governance and policies. Specific examples include stakeholder meetings with participation of state agencies to discuss management issues, reduction in lease fees for collection of NTFPs by rural communities, and the incorporation of research and monitoring protocols proposed by ATREE researchers in the draft management plans of the state Forest Department for BRT Wildlife Sanctuary.

5. Concluding remarks

Turning to our three original questions, how then can we achieve sustainability in land use in forest-agriculture ecotones? ATREE has worked on the premise that livelihoods in many of the areas where we have worked depend directly on continuity of ecosystem services, including the provision of NTFPs, water, soils, pollinators and pest controls from surrounding forests, even though the details of these relationships are very difficult to document. Ecosystem services can be sustained in three ways. First, local impacts on ecosystem services can be minimized, through reduction of the harvest of ecosystem products with diversification of livelihoods. Second, agriculture that uses improved traditional practices and incorporates local diversity can actually enhance ecosystem services. Such practices are found to be economically efficient and also enjoy acceptance by farmers in these ecotones (Purushothaman, 2005). Third, local communities in forest-agriculture ecotones can be provided economic incentives such as direct payments (Ferraro and Kiss, 2002) for the maintenance of ecosystem services (see below).

The second question we posed was: How can forest-agriculture ecotones contribute to conservation of biodiversity? It must be answered in two parts. The biological answer is to promote land use practices that foster biological diversity, thereby extending the habitats of at least some wild species. This offers the challenge of documenting the distribution of wild species and the impact of land use practices on their habitats and ecological responses. The social answer is also challenging. The challenge lies in the opportunity costs to local communities of conserving biodiversity that has global benefits. Even for crop genetic diversity, where the benefits to the global community are more obvious than conservation of biodiversity at the community and landscape levels (Jackson et al., this volume), there are few successful models that compensate farmers for maintaining high diversity. For wild biodiversity, approaches focused on enhancement of livelihoods have met with limited success (World Resources, 2005). More recently, direct compensation models for conservation of biodiversity have been proposed, often as alternatives to the kinds of smaller-scale livelihood enhancement measures described in this paper (Ferraro and Kiss, 2002; Ferraro and Simpson, 2005). However, the two approaches may in fact complement each other. Experience and success with direct payments has been limited, as has been observed by its proponents (Pascual and Perrings, this volume) and the demands made by such approaches on institutional, legal and social frameworks are daunting in the short to medium term. A combination of direct payments with livelihood enhancements may offer a more realistic option as a set of incentives for biodiversity conservation.

The third question, regarding the improvement of institutions that foster sustainability and conservation of biodiversity in forest-agriculture ecotones, is critical to both human and biotic communities (Dietz et al., 2003). We have primarily worked at the scale of local and regional institutions. Although we know that multiple institutions operating at different spatial scales are required to conserve biodiversity, local institutions hold the key to success in the management of common property resources. Such institutions cannot function without true representativeness, adequate information, and the ability to enforce rules and resolve conflict (Dietz et al., 2003). Even in a democratic country such as India, despite long-standing emphasis on decentralized governing bodies, many village level institutions lack representativeness (Lele, 2004). In our experience, they also lack information, capacity and power to intervene. The lack of power stems partly from the uncertain tenure rights of local communities and their institutions over ecosystem resources, and the consequent dominance of state institutions that purportedly retain complete control of resources. The resulting asymmetries in institutional influence relegate local institutions to a minor role in the management of resources. ATREE has therefore focused on strengthening local institutions through structural reforms, the provision of information, and capacity building. At all sites we still have long way to go in developing the nested governance systems that will be critical to meet the challenges of sustainability.

We envision nested rather than parallel institutions at the local scale. One scenario is that local federations and community organizations be nested under the Panchayat (elected village governing council). These local bodies are empowered by the constitution of India to make plans for economic development and social justice within their geographical jurisdiction (Talwar, 2006). We must address the challenge of making these linkages work between conservation-oriented organizations and networks within the Panchayat to ensure long-term sustainability of outcomes.

Overall, our experience indicates that sound institutions at multiple scales hold the key to sustainable management of natural resources. Institutions in forest-agriculture ecotones face severe challenges. First, apart from natural resources such as biodiversity, land and water, the institutions must also manage agricultural resources that are necessary for productive and sustainable agriculture. Second, institutions in remote areas where most forest-agriculture ecotones occur often command inadequate capacity and infrastructure systems for effective governance. Third, forest-agriculture ecotones often span multiple landscapes spread over hundreds of square kilometers with complex interlinkages. Effective management of such landscapes requires functional, nested institutions. The fashioning of such institutions will be an indispensable element of sustainable development in forest-agricultural ecotones.

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