SECONDARY FORESTS OF THE HIMALAYA WITH EMPHASIS ON THE NORTH-EASTERN HILL REGION OF INDIA

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RAMAKRISHNAN, P. S. & KUSHWAHA, S. P. S. 2001. **Secondary forests of the Himalaya with emphasis on the north-eastern hill region of India.** Secondary forests form a major component of the forest types in the Central Himalayan region and in the north-eastern hills of India. Deforestation in these areas is largely due to external pressures of timber extraction for industrial use. When large-scale deforestation from outside the region is superimposed upon the demands of the local communities for food, fodder and fuelwood, the previously balanced use of forest resources, including the management of swidden fallow secondary forests, becomes impaired. Understanding the local linkages between ecological and social processes is important in order to design strategies for the sustainable management of secondary forests in the region where traditional societies live. A particular approach suggested is to benefit from the sociocultural heritage related to keystone species such as *Alnus nepalensis*. The traditions around these and related species and their particular ecological attributes allow for the design of adaptive management strategies to resolve problems with both environmental and sociocultural dimensions. In designing such an adaptive management plan that could be operationalised at the landscape level where both natural and human-managed agro-ecosystems are well integrated, designing appropriate institutions at the local level is important for ensuring community participation.

Key words: North-east India - Himalaya - secondary forests - swidden agriculture - large-scale logging

RAMAKRISHNAN, P. S. & KUSHWAHA, S. P. S. 2001. **Hutan sekunder di Himalaya dengan penekanan di kawasan timur laut berbukit di India.** Hutan sekunder merupakan komponen utama hutan di kawasan Himalaya Tengah dan di bukit timur laut India. Pembasmian hutan di kawasan ini sebahagian besarnya disebabkan oleh tekanan luaran daripada pengekstrakan balak untuk kegunaan industri. Pembasmian hutan secara besar-besaran di luar kawasan ini ditambah pula dengan permintaan penduduk tempatan untuk makanan, kawasan ragutan dan kayu api, menyebabkan penggunaan sumber hutan yang seimbang sebelum ini, termasuk pengurusan hutan sekunder bekas ladang, terganggu. Memahami kaitan tempatan antara proses ekologi dan sosial adalah penting untuk merangka strategi ke arah pengurusan hutan sekunder secara mapan di kawasan ini, yang merupakan tempat tinggal masyarakat tradisional. Pendekatan khusus yang dicadangkan ialah mendapatkan faedah daripada warisan sosio-budaya yang berkaitan dengan spesies teras seperti *Alnus nepalensis.* Tradisi di sekitar spesies teras ini dan juga spesies lain yang berkaitan, serta ciri-ciri ekologi tertentunya, membolehkan strategi pengurusan menyesuai dirangka untuk menyelesaikan kedua-dua masalah alam sekitar dan sosio-budaya. Dalam merangka rancangan pengurusan menyesuai seperti itu yang dapat beroperasi pada peringkat landskap yang melibatkan integrasi padu ekosistem-tani semula jadi dan yang diuruskan oleh manusia, suatu institusi yang sesuai perlu dirangka untuk memastikan penyertaan penduduk.

Introduction

In the Himalayan region, a variety of natural and human-managed ecosystems are placed in a highly heterogeneous eco-sociological landscape, undergoing many changes, both in space and time. Most of the natural forests are now secondary successional types. The livelihood concerns of the heterogeneous traditional mountain societies living close to nature and natural resources are directly or indirectly dependent upon these forest resources. The forests supply non-timber forest products (NTFP), but they also provide a variety of other functions in multi-species complex agro-ecosystems. These agro-ecosystems include examples from swidden agriculture (locally called '*jhum*') in the north-eastern hill region right up to high energy input modern systems (Ramakrishnan 1998). The dependence of rural communities and society at large on secondary forests in India is often under-emphasised. Secondary forests are defined here as "forests regenerating largely through natural processes after significant human disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites" (Chokkalingam *et al.* 2000).

Much of the forest in the western and Central Himalayan region of India has been lost and the forest cover here is less than 20% of the total land area. The total forest cover is higher than 30% in the eastern region and exceeds 60% in Arunachal Pradesh (National Remote Sensing Agency 1983, Tiwari *et al.* 1985, Ramakrishnan *et al.* 1996a). Recent remote sensing analysis provides some estimates of the forest cover in these mountains, but our understanding of the extent of secondary forest remains only conjectural. It is obvious, however, that much of the forest cover is in some secondary stage, except in very remote areas. These secondary forests are all constantly being impacted upon by humans, and are as important to local communities as the relatively undisturbed climax vegetation. Understanding the interactions and interplay of factors that have resulted in the present mountain landscape as it exists today is crucial for designing strategies for the sustainable livelihoods of the traditional societies living here and for the long-term sustainable development of the mountain regions.

Secondary forests and ecological processes in the Central Himalayan region

Information that is available on the secondary forests of the Himalayan region as a whole is rather descriptive and largely based on Puri (1960). There are very few comprehensive ecosystem level analyses done on secondary forests (e.g. Singh & Singh 1985, Ramakrishnan *et al.* 1994a, 1996a). Here we describe briefly the secondary forest types of the Central Himalayan region, followed by what is known for the north-eastern hill region.

Cedrus deodara-dominated forests are distributed across the whole length of the central Himalayan region, at all elevations between 1829 m and 3658 m. This type occupies the upper coniferous belt, above the lower chir pine (*Pinus roxburghii*) zone. In the lower chir pine zone as well as in the upper coniferous zone, oak is an important late successional tree species. Chir pine- and *C. deodara*-dominated forests occupy dry belts resulting from soil erosion, landslides, avalanches, overgrazing and abandoned cultivation. Fire is an important element for all these conifer-forested zones. Scrub forest mixed with oak is distributed in the lower subtemperate regions. The trees are highly stunted due to intense lopping for fuel wood and fodder, litter removed for agriculture, and intense grazing. In extreme cases, the tree elements are completely lost leading to secondary subtemperate scrub vegetation. Further degradation of these secondary forests often results in open pastures with a large number of herbaceous species. Further down, subtropical forest degradation often leads to scrub vegetation.

Biophysical attributes of secondary forests in the Central Himalayan region are well studied from an ecological perspective (Singh & Singh 1985). The forest cover itself is designated as good, medium and poor on the basis of a one-time analysis of the forest cover. With a total forest cover of about 34% and 25% for the Kumaon and Garhwal Himalayan region (Tiwari *et al.* 1985), good forests accounted for less than 5% of the total forest cover. It is our assumption that the remaining area represents some kind of degraded secondary forest. This is not surprising because large-scale timber extraction has occurred in the region for the last 100 years. Good mixed oak forests in the mid-elevation ranges have been converted into pine plantations, with implications for the ecological integrity of the regional landscape (Ramakrishnan *et al.* 1994a, 1996a, b, 2000). Conversion of mixed oak forests into pine stands has led to adverse impacts on soil fertility (Singh *et al.* 1984, Ramakrishnan *et al.* 1994a). The reduced level of sustainability of agro-ecosystems linked to forest quality in the landscape (Ramakrishnan *et al.* 1993, 1996b) has altered hydrological regimes. This has led to localised floods and soil erosion during the monsoon season, and less soil moisture retention in the soil profile during the long dry period outside the monsoon season (Ramakrishnan *et al.* 1998). Highly degraded scrub vegetation and weedy vegetation form an important aspect of the landscape. With *Shorea robusta* (Sal) forests at lower elevations, secondary forest degradation has resulted in open scrub vegetation.

Secondary forests and ecological processes in the north-eastern hill region

Deforestation and drivers of secondary forest formation and land degradation

Large-scale deforestation and forest degradation in the north-eastern region as a result of large-scale timber extraction for export outside the region has been ongoing for the last 100 years. In the colonial period, extraction was more intense during the two world wars. During the post-colonial phase, large-scale extraction accelerated during the first few decades following India's independence from colonial rule in 1947. This was due to an emerging demand from the lowlands, caused by a renewed emphasis on industrial activities in the country. Besides large-scale timber extraction, deforestation and secondary forest formation are also the consequence of swidden agriculture as a small-scale perturbation in 2- to 3-ha plots cleared by farmers. In more recent times, even bamboo forests have been further degraded to supply raw material for paper pulping, without any meaningful action plan for the rehabilitation of bamboo forests. The impact of large-scale extractive activities combined with shortened swidden cycle lengths on a highly fragile ecosystem in the north-eastern region is the development of degraded herbaceous weedy communities and eventually site desertification (Ramakrishnan 1992a).

The rainforests in the north-eastern hill region are fragile, having developed on leached soils with tight nutrient cycling through a surface root mat. As a consequence, large-scale deforestation has often resulted in land degradation and site desertification (Ramakrishnan 1992a). Indeed, more than half of the land area in the state of Meghalaya is now desertified. This indicates what happens when a combination of timber extraction and local population pressure leads to shortened cycle lengths of swidden agriculture. This has left a forest area of about 5% under the control of the State Forest Department.

As evident from Figure 1 and Table 1, there has been a total loss of 0.25 million ha of forests in Meghalaya between 1982 and 2000, which is 13 900 ha or about 11% per year. This was converted to non-forested, denuded, abandoned or degraded wasteland. A reduction of 90 700 ha of primary forests was noticed, while 159 200 ha of secondary forests disappeared during the past 18 years, about 8800 ha per year. The problem becomes critical due to heavy rainfall in the mountainous terrain, but also because of continued large-scale extraction of bamboo, timber, and other natural resources. The situation in Meghalaya is similar to that in the other six states of the north-eastern region, where swidden agriculture is practised.

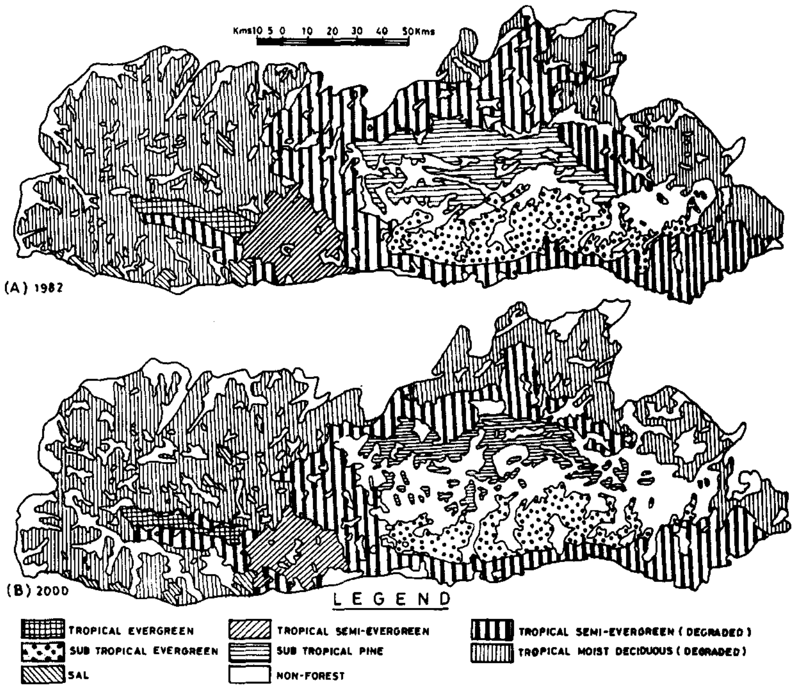

Figure 1 Remotely-sensed maps of Meghalaya State in north-east India in 1982 and 2000. Tropical evergreen and subtropical evergreen are the two climax forest types. All others except Sal (*Shorea robusta*) plantations are secondary formations.

Table 1 Forest cover (ha) in 1982 and 2000 in Meghalaya

Forest Type	1982	2000	Change
Primary Forest:	362 993	272 245	(-)90 748
Tropical evergreen	34 698	31 139	(-)3 559
Tropical semi-evergreen	112 101	77 403	(-)34 698
Sal	22 242	15 125	(-)7 117
Subtropical evergreen	193 952	148 578	(-)45 374
Secondary Forest:	1 588 090	1 428 837	(-)159 253
Tropical semi-evergreen (degraded)	435 056	452 850	(+)17 794
Tropical moist Deciduous(degraded)/ abandoned shifting cultivation	966 200	854 100	(-)112 100
Subtropical pine	186 834	121 887	(-)64 947
Non-forest	291 817	541 818	(+)250 001
Total forest	1 951 083	1 701 082	(-)250 001

Forest area under swidden agriculture and swidden fallow secondary forests

The north-eastern region of India, covering about 26 million ha of hills, valleys and plateau, is ethnically and culturally very distinct from other areas of the country. The hills constitute about 70% of the land area where swidden agriculture is the chief land use. This land use was at one time in harmony with the environment due to longer *jhum* cycles. Now, the cycle has shortened to an average of four to five years (Ramakrishnan 1992a). Apart from the *jhum* system, small plantations, home gardens and valley rice cultivation are common.

The area under swidden agriculture is controversial in the absence of reliable estimates. According to the Forest Survey of India (1987), 2.7 million ha of the total forest area of 13.1 million ha has been affected by swidden agriculture. Although this works out to be about 2% of the total land area affected by swidden agriculture, this represents only what is being cultivated at a given time.

The land area coming under swidden fallow secondary forests at any given point in time is quite small because of the short agricultural cycle of four to five years. Swidden fallow secondary forests are defined as "forests regenerating largely through natural processes in woody fallows of swidden agriculture for the purposes of restoring the land for cultivation again" (Chokkalingam *et al.* 2000). Swidden fallow secondary forest development occurs only if the cycle length is more than 10 years. A cycle length of 10 to 30 years leads to the formation of a bamboo forest. Mixed broad-leaved early successional secondary forests appear only if the cycle length is longer than 30 years. Swidden cycles less than 10 years result in weedy communities. Continuous imposition of short *jhum* cycles of 5 years or 10 to 15 years have often resulted in arrested successions of weed or bamboo communities, respectively. In very remote areas, where climax forests occur and where population pressure is not high, the secondary forest regeneration in the sparsely distributed small gaps is rather rapid.

Ecology and environment of swidden fallow secondary forests

Although there may be variation in species composition in the secondary forests in different locations in the north-eastern hill region under swidden agriculture (e.g. *Dendrocalamus hamiltonii* as the predominant species in the bamboo forests of Meghalaya, compared to *Bambusa* spp. elsewhere in the region), the general ecological characteristics of the secondary forests tend to be the same all over. They start with herbaceous weedy formations during the first 8- to 10-year period, passing through bamboo forest for the next 10 to 20 years (Rao & Ramakrishnan 1989). Subsequently, they move into the early successional mixed broad-leaved forests at lower elevations, or pine and broad-leaved mixed forests at higher altitudes between 10 and 30 years. Finally, they turn into broad-leaved climax forests, which may be subtropical or subtemperate forests, depending upon the altitude. Two study sites discussed below are representative of the broad patterns present in the region (Singh & Ramakrishnan 1982, Toky & Ramakrishnan 1983a, Ramakrishnan 1992a).

The study site at lower altitude (100 m at Bunihat in the Khasi Hills of Meghalaya (26° 0' N, 91° 5' E) supports semi-evergreen broad-leaved forest (Ramakrishnan 1992a). The climate is a subtropical monsoon with an average rainfall of 2200 mm per year. Most rain falls from May to October. The average maximum and minimum temperatures are 25 °C and 12 °C for November to February and 32 °C and 23 °C for the remainder of the year. The soil is a red loamy oxisol (laterite) derived from metamorphic rocks. The surface soil has high concentrations of organic carbon and nitrogen, but, due to intense leaching, has low concentrations of cations, with a surface pH of 7 that declines to pH 5 at a depth of 40 cm.

The site at higher altitude (1500 m), at Shillong in the Khasi Hills, supports warm temperature montane forests with *Pinus kesiya*-dominated early successional forests. The mixed broad-leaved forests of the climax phase are rare. The annual average rainfall of about 1800 mm is monsoonal. The average maximum and minimum temperatures are 17 °C and 8 °C for November to February and 28 °C and 16 °C for the remainder of the year. The soil is more acidic.

Swidden agriculture linked to forest fallows

The swidden cycles may vary depending upon local population pressures, the availability of good quality fallow lands suitable for agriculture, and the site quality. Site quality is directly related to the level of land degradation from forest conversions. In very remote areas, a 60-year cycle can still be found. These fallow cycles contribute to sparsely distributed small gaps that regenerate rapidly, but also result in a highly diversified landscape mosaic. Closer to city/market centres, where population pressure is high and site quality declines, there is a gradual shift towards a bush-fallow rotational system with only a light surface burn of the available weedy herbaceous vegetation, and eventually to a variety of sedentary systems (Ramakrishnan 1992a).

At lower elevations, where swidden agriculture is practised, the vegetation is slashed during December to January. Short tree stumps are left intact and there is no below ground disturbance. Before the onset of the monsoon, towards the end of March or the beginning of April, the dried debris is burnt *in situ*. Mixtures of 6 to 13 crop species are sown together at the onset of the monsoon, and the crops are harvested sequentially starting from July and until December.

The patterns of agriculture at higher altitude sites are modified versions of the typical type outlined above. The undergrowth vegetation of the pine forests and the lower branches of the sparsely distributed pine trees alone are slashed during December and January. The slash is arranged in parallel rows and the dried slash is topped over by a thin soil layer before a slow burn in May. These slash ridges alternate with compacted furrows running along the slope. Crop mixtures are sown only on the ridges.

After the clear-cutting and burning of the swidden fallow secondary forest, the ecosystem loses its ability to hold nutrients, previously concentrated in the biomass (Ramakrishnan & Toky 1981, Ramakrishnan 1992a). Much ash is blown away by strong winds during the dry months of March and April. Large losses also occur through the volatilisation of carbon and nitrogen during the burn so that there is a reduction in the quantity of these elements in the surface soil layers. These losses continue during the early cropping phase. In contrast, available phosphorus and cations are added to the soil during the burn. Nutrient losses through runoff and leaching also occur during the early monsoon, particularly before the crop cover is established. The total losses through runoff and leaching can be considerable during one cropping season, particularly under a short swidden cycle. The losses are impressive when calculated for a 30-year period (Ramakrishnan 1992a).

Ecology of swidden fallow secondary forests

The soil nutrient budget shows qualitative and quantitative differences between short and long *jhum* cycles (Ramakrishnan 1992a). The quantitative differences are directly related to the biomass build-up during the fallow phase and the consequent slash load and ash release during the burn. Herbaceous communities of up to about five years generally have more phosphorous. *Dendrocalamus hamilitonii* of 10 to 25 years of age has more potassium (Toky & Ramakrishnan 1983b), so that different quantities of these elements are released in ash under short and long *jhum* cycles. Fallows dominated by *Mikania micrantha* also conserve potassium under short cycles. Thus, the qualitative differences in the nutrients after slash and burn are related to the vegetation structure of the fallow phase. There is an increased proportional release of calcium and magnesium when agricultural cycles are long (60 years) or after the clearing of virgin forest, as in Arunachal Pradesh in north-eastern India. To conclude, nutrient levels are generally poor under short cycles, and increase with the lengthening of the fallow cycles. However, some of the keystone species present within the fallow system contribute towards concentrating specific nutrients such as potassium, for example, *D. hamilitonii.*

During a nitrogen budget analysis of the inter-connected swidden fallow systems under cycles of 15, 10 and 5 years, Mishra & Ramakrishnan (1984) showed that a shortening of the swidden cycle lowers the nitrogen content of the soil. Nitrogen loss under a 15-year cycle may be high because of the large quantities built up in soil and vegetation after a longer fallow re-growth phase. During one cropping phase, the agro-ecosystem loses about 600 kg ha^{-1} of nitrogen (the difference between the soil nitrogen capital before and after one cropping). If the plot was under a 5-year cycle at the time of this study and during the previous 20 years (for which period the land use history was known), the system had lost 1.28×10^3 kg ha^{-1} of nitrogen from its initial capital of between 7.68×10^3 and 6.40×10^3 kg ha^{-1}. While 10- or 15-year *jhum* cycles are long enough to restore the original nitrogen status in the soil before the next cropping, it seems unlikely that the 600 kg ha^{-1} of nitrogen lost during one cropping can be restored under a 5-year cycle. One of the important disadvantages of a 5-year cycle lies in the reduced nitrogen capital (Ramakrishnan 1992a). Increased frequency of fire and cropping with too short a fallow phase thus results in rapid site degradation, and arrested succession at the weed stage, with substantial invasion of exotics as the ultimate consequence.

Bamboos form an important component of the secondary succession of many tropical rain forests (Whitmore 1975), including those of north-eastern India. Many of the species such as *Dendrocalamus hamiltonii* and *Neohouzeaua dulloa* decline after 25 to 30 years of fallow (Rao & Ramakrishnan 1987). We have shown that species such as *Bambusa tulda*, *Bambusa khasiana* and *N. dulloa* store much more nitrogen, phosphorous and potassium in their biomass than other species in the community (Rao & Ramakrishnan 1989). *Dendrocalamus hamiltonii* accumulate potassium in the forest fallows (Toky & Ramakrishnan 1983b). Thus, the bamboos play a critical role in conserving these major nutrients in slash-and-burn agriculture.

When a forest is converted to farmland, perturbations due to fire, the introduction of crop species, weeding and other disturbances during crop harvest all result in a large reduction in the number of the species. During secondary succession, the number of species increases gradually (Toky & Ramakrishnan 1983a). A remarkably linear relation was observed during the first 15 to 20 years of succession with respect to species diversity and such processes as litter production and net primary productivity (Ramakrishnan 1992a). The change in community structure was very marked at the lower altitude, from the initial weedy herbs, to a bamboo forest and, finally, to a mixed broad-leaved forest. At the higher altitude, this change in community structure was less marked, because the slash and burn was not as complete as at the lower altitude, since only the branches of the sparsely distributed pine trees and the ground vegetation were slashed. Growth of pines is retarded as recovery is slow, although fire favours pine seedling regeneration leading to arrested succession. In the absence of frequent perturbations at higher altitudes, the pine-mixed forest should normally be the next stage in the succession.

With the rapid transfer of nutrients from the soil to the vegetation during the early phase of the fallow, rapid depletion of nutrients occurs in the soil even though losses by leaching and runoff are greatly reduced (Figures 2 and 3). It is only after about 10 years of fallow that the net transfer of nutrients back to the soil through litter fall becomes important and soil fertility recovers (Ramakrishnan 1992a). This is one of the reasons why a 10-year cycle for slash-and-burn agriculture is considered to be the shortest possible for the stability of the *jhum* system, unless the fallow has an accelerated re-growth with species such as the introduced *Alnus nepalensis* and other fast growing early successional secondary forest trees which improve soil fertility by the rapid recycling of nutrients with a fast turnover of leaves (Ramakrishnan *et al.* 1982).

The mineral nutrient content of the biomass increases during the first 20 years of fallow (Toky & Ramakrishnan 1983b), with faster rates of nutrient cycling at lower elevations compared to the higher elevations. With an early successional (secondary) warm temperate pine (*Pinus kesiya*) forest (Ramakrishnan 1992a, Mishra & Ramakrishnan 1983a) at higher altitudes, the higher soil acidity and resinous pine litter (Das & Ramakrishnan 1985) all contribute to lower nutrient-cycling rates during the forest fallow (Mishra & Ramakrishnan 1983b), compared to the rates at lower elevations. For this reason, the forest farmers merely cut off the lower branches of the sparse pine trees for agriculture, rather than clearfelling as at lower altitudes.

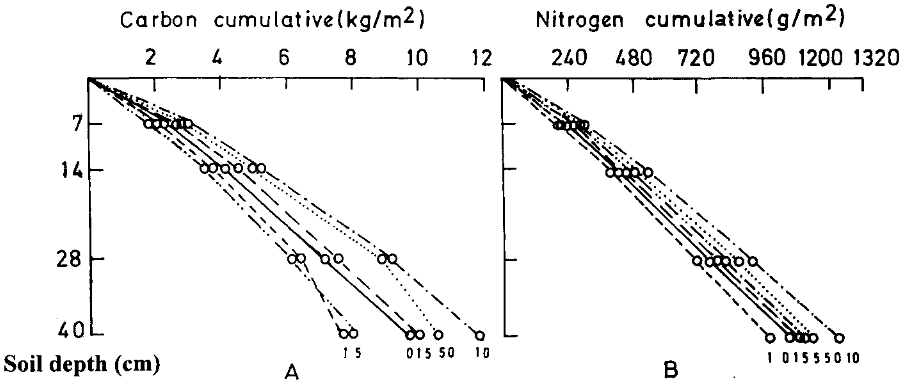

Figure 2 Changes in cumulative quantity of carbon (A) and nitrogen (B) within a soil column of 40-cm depth under 0-, 1-, 5-, 10-, 15- and 50-year old *jhum* fallows (after Ramakrishnan & Toky 1981)

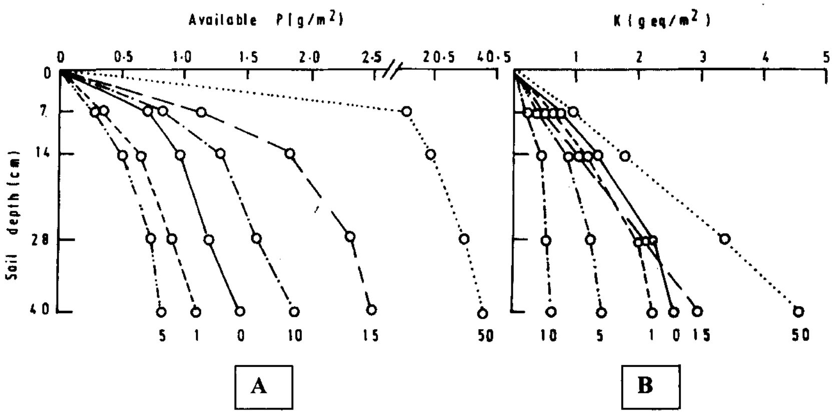

Figure 3 Changes in cumulative quantity of available phosphorus (A) and potassium (B) within a soil column of 40-cm depth under 0-, 1-, 5-, 10-, 15- and 50-y-old *jhum* fallows (after Ramakrishnan & Toky 1981)

Eco-physiological attributes of swidden fallow secondary forests

Rapid change in the secondary successional fallow environment is reflected in the declining light availability for the shoot system and the changes in the nutrient distribution in the soil profile, as one moves from an early to a late successional fallow environment. This is reflected in evolutionary adaptive differences in shoot and root architecture of early versus late successional trees (Ramakrishnan 1986, 1992a, Ramakrishnan *et al.* 1982). Early successional secondary forest tree species attain a narrow crown form with rapid extension growth from the main axis, a faster rate of branch production of different orders, a rapid extension of the first-order branches at the expense of the others, stronger correlative growth inhibition with apical control over the growth of the branches beneath, and branch orientation. This enables the early successional species to grow fast, capitalising upon the high light availability in a transient environment. Conversely, the contribution of the second-order branches is more for the late successional secondary forest trees. These have a brief period for branch production and growth, but a wider angle of branch placement. This leads to broader crowns, which enable better leaf display under a low light regime in the canopy. The early successional species have a higher rate of leaf production, faster turnover rate, and the consequent larger proportion of younger leaves to older ones, compared to the late successional trees. This enables the former category to be opportunistic in their strategy for light capture and faster photosynthesis, compared to the conservative strategy of late successional species.

The early versus late successional secondary forest trees also differ significantly in their root architecture and the consequent ability to exploit different profiles of the soil. With the rapid accumulation of nutrients in the surface layers of the soil after the clearcutting of a forest, the early successional species, with a largely surface-feeding root profile distribution, again exhibit an exploitative or opportunistic strategy towards nutrient uptake. With nutrient depletion in a late successional soil environment and its more uniform distribution in the soil profile, the late successional trees have a better developed root system with more uniform distribution down the profile (conservative strategy).

From the point of forest management and the rehabilitation of degraded ecosystems, such a tree architectural analysis helps in determining the complementarity of species in a mixed forestry programme (Ramakrishnan 1992b, Ramakrishnan *et al.* 1994a, b). Also, such an understanding of the eco-physiological and morphometric analysis of tree species has implications for identifying compatible tree species for fallow management under swidden agriculture and for developing appropriate agroforestry system models that could stabilise secondary forest vegetation itself, through assisted fallow recovery (Rao & Ramakrishnan 1989).

Institutional interplay

The disjunction that exists between the biophysical and the social processes, persistent throughout the history of institutional development in the Himalaya, is to be blamed for the problems identified in the previous sections. An understanding of institutional interplay throughout history should provide clues as to how land use-related institutions can be reorganised. Ecosystem properties, such as energy and material stocks and flows, the temporal and spatial variability of those resources, and the complex and dynamic ways in which the underlying processes relate to one another, with perturbations playing an important role, have important implications for these institutional reorganisations (Pritchard Jr. *et al.* 1998).

The history of the development of the present institutional arrangements in the Nanda Devi buffer zone secondary forest area is illustrative of the *ad hoc* manner in which they were created without due consideration for natural resource management (Ramakrishnan *et al.* 2000). Traditionally, when resources were unlimited, and vested interest in them was perhaps minimal, the land and resource use-related institutional arrangements were often informal and not codified, but designed for the shared use of resources by local communities. However, in 1865, when the forest land (uncultivated land including forests, pastures and snow-clad peaks) was declared as the colonial government's public property, local people were allowed traditional forest-use rights for the purposes of cultivation, and private land-use rights were also granted. In 1920, by introducing the concept of reserve forests under the total control of the Forest Department, more restrictions were imposed on the collection of NTFPs from the forest. The government also had to introduce the concept of civil forest to allow local community use. Civil forests were assigned closer to settlements, but with land rights vested in the revenue department of the government. These forests were of poorer quality and degraded further with time, because of the dual control and use.

With the recognition of the area as a wildlife sanctuary in 1939, more restrictions were imposed on forest use. On the other hand, the opening up of the area for tourism became a new source of income for the people. The governmental response to the increasing resentment against restrictions was the creation of another institution called community forests, locally called the *panchayat* forests. The ownership of these *panchayat* forests rested with the revenue department, the managerial rights with the local communities. This inter-institutional interplay contributed to forest-related conflicts which could not be resolved. When large-scale timber extraction for industrial use from the Central Himalayan region started causing land degradation, eventually impinging upon their livelihood concerns, the villagers responded by hugging the trees to prevent their felling.

The conversion of the Nanda Devi wildlife sanctuary in 1982, and its further elevation to a biosphere reserve in 1988 and its recognition as a world heritage site in 1992, all led to more restrictions on forest use rights, and the complete exclusion of tourism. The institutional arrangements became *ad hoc* to calm down the rising disenchantment of the local communities with the decision-making process, rather than being based on local traditions and knowledge system linked to natural resource use. Indeed, this is a typical way in which natural resource management decisions are made in the north-eastern Himalaya and in the Western Ghat region of India. Alternative options can be visualised where local level institutional arrangements are revamped to harmonise ecological systems with local social systems.

The objective of a revision of the institutional arrangements should be to avoid conflicting interests to the greatest extent possible. Further, institutions should contribute towards community empowerment and their fuller participation. For instance, in Nagaland, one of the north-eastern hill states of India, over a thousand villages have organised into Village Development Boards (VDBs). The Naga communities are culturally heterogeneous and linguistically distinct tribal groups.

In spite of the existence of a variety of other elected bodies at the village level and at higher levels, VDBs were created to implement village level development. The VDBs are constituted on the basis of a traditional value system that each one of these tribal groups understands. The entire village, with adequate representation for gender, participates in the decision-making process. Linkages with the already existing institutions, both governmental and non-governmental, involving key individuals such as the village headman, are taken care of. This helps to harmonise the functioning of the VDB system with others already in place and operating at different hierarchical levels. A bottom-up approach is a central facet of this initiative.

The entire objective in this effort of institution-building was to find a solution to the highly distorted problem of swidden agriculture in Nagaland, as elsewhere in the entire north-eastern region (Ramakrishnan 1992a). The local agroforestry system is now operating at subsistence or below subsistence level. It is now being redeveloped with concerns for biodiversity, by strengthening the tree component that has been weakened due to extreme deforestation in the region. The basis for this redevelopment is the rich traditional ecological knowledge base of the hill societies. The project implementation by the Nagaland Government officials through the VDBs (Anonymous 1980, Faminow 1999) focused on augmenting traditional agriculture, rather than attempting to radically change it. The existing practice of planting Nepalese alder trees, maintained for hundreds of years by some of the local tribes like the *Angamis* (Gokhale *et al.* 1985, Ramakrishnan 1992a), formed the impetus for this initiative. This planting is done both during the cropping and fallow phases of swidden agriculture.

One of the issues that experts have all along tried to grapple with is the obvious mismatch between biophysical/ecological boundaries and the institutional jurisdiction (Pritchard Jr. *et al.* 1998). In institution-building, ecological considerations constitute only a small component, largely centred on rights and opportunities. Ecological considerations are only one of the important components of a whole variety of social, economic and cultural dimensions taken as an integrated whole. Dealing with natural resources involves conflict resolution and requires built-in flexibility in institutions as a mechanism for conflict resolution. This implies that the ultimate choices in institution-building have much more to do with social rather than biophysical considerations. In the ultimate analysis, environmental decision-making has to be based on participatory research that recognises traditional value systems.

Social, economic and cultural dimensions of secondary forests

Understanding the linkage between the ecological and social processes is indeed the basis for sustainable forestry management in the developing tropics. In such an integrated approach to management, the socio-economic and sociocultural issues and the traditional knowledge of the local communities need to be reconciled (Ramakrishnan *et al.* 1996b, 1998).

Secondary forest and sociocultural aspects

Linking ecological and social processes is crucial to appreciating the relationship between biodiversity and ecosystem functioning, and to utilising this relationship for human welfare through the sustainable management of resources. The linkages could operate at the process level or at the ecosystem/landscape level (Ramakrishnan *et al.* 1994a).

The role of keystone species found in swidden fallow secondary forests for conserving and enhancing biodiversity and indeed for manipulating the ecosystem function is critical and an example of process-level linkage, which has not been adequately explored. Keystone species play a crucial role in biodiversity conservation, through the key functions that they perform in an ecosystem. Therefore, they could be used not only for managing pristine ecosystems (Ramakrishnan 1992a, b), but also for building up biodiversity in both natural and human-managed ecosystems, through appropriately conceived rehabilitation strategies (Ramakrishnan *et al.* 1994a).

In the sacred grove forests of Cherrapunji in Meghalaya, a substantial proportion of nitrogen, phosphorus and potassium conservation within the ecosystem is determined by four dominant tree species: *Englehardtia spicata, Echinocarpus dasycarpus, Sysygium cuminii* and *Drimycarpus racemosus.* These keystone species contribute towards supporting biodiversity in these relict forests through their nutrient-cycling role in ecosystem function and are often protected by local people for religious and cultural reasons. Other keystone species such as Nepalese alder (*A. nepalensis*), found in the secondary forests of north-east India conserve up to about 120 kg of nitrogen a year through nitrogen fixation, and many bamboo species (*D. hamiltonii, B. tulda* and *B. khasiana*) conserve nitrogen, phosphorus and potassium in their biomass (Ramakrishnan 1992a).

Manipulating keystone species is a simple way of managing a whole variety of biodiversity in the ecosystem. These species are significant in rehabilitation ecology, and ensure community participation since they can be related to a value system (Ramakrishnan *et al.* 1994a). If manipulating keystone species is supported by a broader ecosystem or landscape-level linkage, for instance, water management (Kothyari *et al.* 1991, Ramakrishnan 1992a, Ramakrishnan *et al.* 2000), the changes initiated in secondary forests may have broader consequences. This is even more so because influencing water management triggers a variety of additional ecosystem and landscape-level changes (Ramakrishnan *et al.* 1994a, 2000), such as altered soil biological processes, improved soil fertility arising out of these changes, and improved aboveground and belowground biodiversity.

Secondary forests and socio-economy

In the temperate forest zones of the Himalayan region as a whole, the Forest Department has converted mixed broad-leaved forested areas into economically rewarding pine plantations. The related large-scale depletion of biodiversity arising out of these monoculture pine plantations has had serious economic consequences for the local communities. For instance, several oak (*Quercus* spp.) keystone species yield good fodder, fuel wood and timber. They also ensure water balance within the soil. These species are highly valued by local people in the Central Himalayan region and elsewhere, playing a key role in nutrient cycling and conservation. This value is recognised in folk music, dance, literature and poetry. A lot of resources flow from the forest ecosystem into a variety of human-managed agro-ecosystems under traditional management. A comparative analysis of oak- versus pine litter-based agriculture suggests that many of these traditional agricultural practices are being threatened, without any viable alternatives available (Ramakrishnan 1992a; Ramakrishnan *et al.* 1994b, 1996a, 1996b, 1998). This has had its adverse impact on the livelihood concerns of the local communities and the quality of life. The large-scale conversion of mixed oak forests to pine plantations by foresters over the last hundred years in mid-elevation ranges of the Central Himalaya led to the *Chipko* tree-hugging movement (Ramakrishnan *et al.* 1998). These species that are socially valued by the community could play a key role in the rehabilitation of degraded systems.

A second example is the impact of bamboo harvesting for paper pulp. Bamboos are culturally valued species of secondary forests and are used for house construction, water transportation, household utensils and artistic expression. Ecologically speaking, bamboos are valuable as conservators of essential N, P and K nutrients essential for the swidden systems of north-east India. The harvesting of these species for pulp deprives communities of a valuable secondary forest resource.

Secondary forests directly influence the quality of life of local communities in the swidden-based north-east India situation. Swidden, being an agroforestry system operating both in time and space, is closely linked to fallow management practices. We have done detailed socio-economic and ecological evaluation of swidden operating under different fallow lengths, using money and energy as currencies for input/output evaluation (Table 2); this is apart from other currencies like, for instance, soil fertility and water quality. All these analyses suggest that longer swidden fallows with secondary bamboo/bamboo mixed broad-leaved secondary forests are required for sustainable swidden systems to operate (Ramakrishnan 1992a). The longer secondary forest fallow phases ensure that the key elements such as nitrogen, phosphorus and potassium are sufficiently conserved with the secondary forest phase to be used for swidden. The major constraint to having long fallow cycles is linked with large-scale deforestation and site desertification. This could be remedied only through a major forest rehabilitation initiative with heavy economic inputs and more innovative approaches (Ramakrishnan 1994). However, as part of a short-term strategy, the only way the benefits of a long fallow can be ensured is through assisted secondary succession, through the introduction of tree species such as the Nepalese alder, which is now being attempted in the Nagaland experiment discussed above.

Table 2 Ecological (energy) and economic efficiencies of swidden linked to fallow re-growth (from Ramakrishnan 1992a)

Fallow length	Input	Output	Output/ input ratio
30-year fallow cycle[1]	2616 (1665)	5886 (56 766)	2.13 (34.1)
10-year fallow cycle[2]	1830 (1181)	3354 (56 601)	1.83 (47.9)
5-year fallow cycle[3]	896 (510)	1690 (23 858)	1.80 (46.7)

Values in parentheses are energy values in MJ
[1] Broad-leaved mixed bamboo forest
[2] Bamboo forest and herbaceous vegetation
[3] Herbaceous vegetation

Elsewhere, in the buffer zone area of the Nanda Devi biosphere reserve, NTFP generation is an important concern of the local people. The extraction of dead wood and medicinal plants form important NTFP-related economic activities. Tourism and expeditions have traditionally been other means of earning cash income for local communities, and all of the above offer opportunities for further elaboration and development (Ramakrishnan *et al.* 2000).

Landscape management

Climax forests in these mountains form only a small proportion of the total landscape in the entire Himalayan region and the north-eastern hill areas. Much of the forest cover is secondary. A substantial component of the landscape is degraded weedy communities including exotic invasive weeds. It is in this context that adaptive landscape management becomes important. The Nagaland experiment towards developing alternative fallow management systems as a solution to the short-cycle swidden system is an interesting case.

The most obvious way of landscape management with sustainability concerns is through a whole series of iterative process analyses (Figure 4). The starting point in this is a plot-level analysis of ecological issues along with family-level responses leading to decision-making at that micro level. This interactive shift between the ecological and social boxes would then eventually lead to ecosystem level analysis, and landscape-level understanding of the linkages. The bottom line in such an analysis should be developing a short-term strategy for sustainable livelihood of local forest dwellers and a long-term regional development plan.

Realising, therefore, that biodiversity (in all its dimensions, from the sub-specific, species and functional groups up to ecosystem level complexities) does contribute in a variety of ways to ecosystem/landscape functions (Gliessman

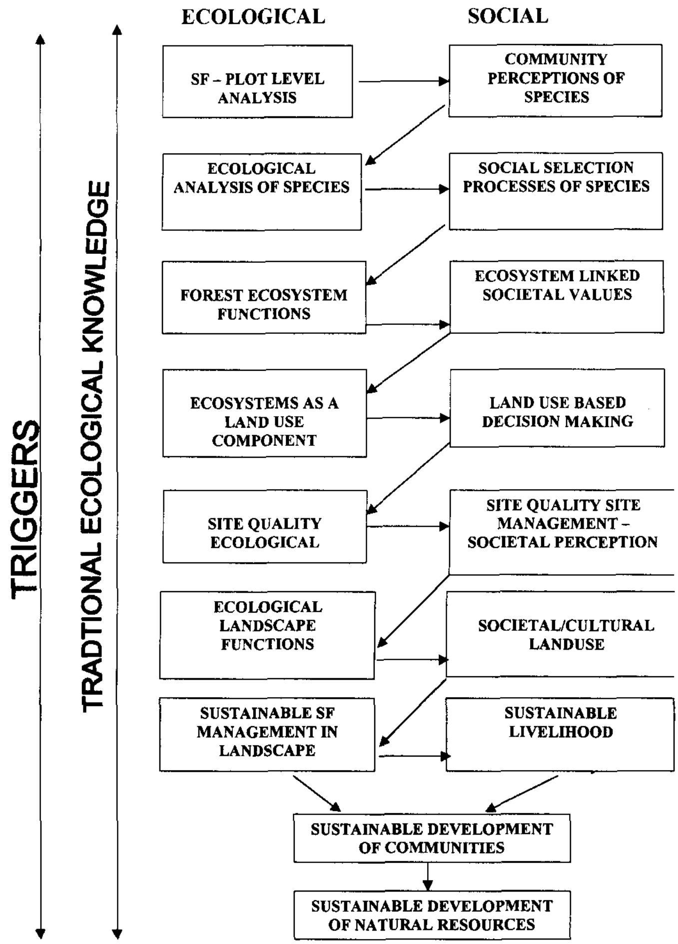

Figure 4 Methodological approaches towards effective linkages between ecological and social processes that would contribute towards better management of secondary forests with concerns for the sustainable livelihood/development of rural populations in the tropics

1990, Ramakrishnan 1992a) and that agro-ecosystems do harbour a great deal of biodiversity valuable for human welfare (Pimental *et al.* 1992), it is reasonable that we go in for a mosaic of natural ecosystems coexisting with a wide variety of agro-ecosystem models derived through all possible pathways.

In the north-eastern Indian context, we need to consider a variety of tree species as part of assisted succession, to re-build the fallow phase (as in the Nagaland initiative), through an incremental pathway for agro-ecosystem redevelopment (Ramakrishnan *et al.* 1996b). Redeveloped valley rice cultivation and redeveloped home gardens, two land use systems already prevalent in the area (Ramakrishnan 1992a) should be effectively integrated with a whole variety of forested ecosystems at various stages of successional development, along with protected climax forests.

Such a highly diversified landscape unit is likely to have a wide range of ecological niches conducive to enhancing biodiversity and, at the same time, to ensuring the sustainability of the managed landscape itself. Perturbations, whether they develop intrinsically or are a result of extrinsic factors such as fuel wood extraction by humans or extreme natural events, are an essential element for ecosystem functioning. It is critical for landscape management to keep the impacts of perturbations low, both in terms of intensity and frequency. Such an approach will provide an appropriate mix of human-managed ecosystems, along with natural ecosystem types (of secondary and climax phases). Thus, in north-east India, a whole variety of swidden fallow secondary forest systems (bamboo forests and other mixed broad-leaved forests at lower elevations, pine and mixed forest systems at higher elevations) should coexist with climax forests and traditional multi-species complex agricultural systems, to ensure ecosystem/landscape-level integrity (Ramakrishnan 1992a). The concept of protected sacred landscape units are indicative of the approaches adopted traditionally by the local people in the region to ensure ecosystem/landscape-level integrity (Ramakrishnan *et al.* 1998).

Conclusion

Large-scale deforestation and land degradation in the Himalayan region has led to significant reduction in forest cover. Much of the remaining forest cover is secondary though we do not have reliable data on the actual extent. We do have adequate knowledge on forest ecosystem functioning in a biophysical sense although only for a limited number of landscapes. We have only limited knowledge of a whole variety of human-managed ecosystems that are closely linked to secondary forest ecosystems. Traditional mountain societies are an integral part of the functioning of forest ecosystems, now largely a variety of secondary types that are under increasing human pressure. We need a better understanding of the linkages between biophysical and social processes. In order to have this understanding, we need to consider new and emerging ecological paradigms that effectively link ecological processes with social processes. We need a new breed of scientists who have the ability to move back and forth between the ecological and the social dimensions of the problem (Figure 4). The concept of sustainability is a useful one to build up the necessary linkages between natural and social sciences, using adaptive and innovative methodologies.

Traditionally, ecologists have viewed secondary forests from a limited, biophysical viewpoint only. The characteristics of secondary forests and fallow recovery processes depend upon a variety of factors, such as land use history and competing forest uses and extraction. Inadequate fallow vegetation recovery is influenced by competing resource use, which affects not only the structural and functional attributes of the secondary forest ecosystem, but also the social and economic values of current and future regenerating forest. Better regulation of competing extractive uses and assisted fallow recovery incorporating a variety of keystone species should be encouraged for both landscape rehabilitation and sustainable development among the region's poor rural farming population. This discussion, based on case studies from the Himalayan region, also suggests that we need to take a more integrated approach to the study of secondary forests for effective management of the remaining natural resources, and indeed for the rehabilitation of degraded ecological systems. Only then will we be able to take on board the concerns for a better quality of life for the mountain societies in the tropics, and thus ensure community participation in forestry management.

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