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Towards Addressing Societal Concerns: Moving Through Genecology and Ecosystems to Socio-Ecological Systems

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ABSTRACT

Having been trained in biophysical dimensions of ecology with an ecosystem approach, the move towards a larger interdisciplinary approach with emphasis on socio-ecological systems analysis with implications to related ecological studies to societal concerns was indeed a challenging task. Having had to face with differential paradigms determining natural vs. social sciences, it was soon realized that arriving at compromises between these two knowledge streams holds the key for addressing sustainability concerns in the area of natural resource management linked with livelihood/developmental concerns of human societies ranging from the very 'traditional' to the most 'modern'. In such an effort, 'knowledge systems', particularly 'traditional ecological knowledge' (TEK) available with local communities through an experiential process was considered the key towards linking the biophysical with the socio-economic-cultural dimensions of the issues under consideration, bringing in text-book based 'formal ecological knowledge' to the extent required and appropriate depending upon what the socio-ecological situation demands. Very traditional societies living close to nature and natural resources around them may have to have TEK being brought in to a much larger degree so as to avoid social disruptions setting in, compared to the more modern societies who may need TEK only to be brought in so as to create buffering mechanisms within the socio-ecological system and thus cope up with the ill-effects arising from excessive use of energy-intensive technologies. In other words, community participatory approaches based on a value system that they understand and appreciate and therefore can participate in the process of conservation linked sustainable development is the key to combat environmental uncertainties, arising on one hand from ecological 'global change' and on the other economic 'globalization'. This is an emerging area of study in which I have had the privilege of getting involved towards understanding socio-ecological system structure and functions, the inspiration for which came from my teacher, late Professor R. Misra who always encouraged me to move away from the trodden path; and to a great measure from very traditional societies who have always valued their closeness to 'nature', and which formed the basis of their cultural identity. This paper is a summary of what I have been able to do when I moved into the realm of 'socio-ecological systems analysis', in the early 1970s, from an 'ecosystem analysis' approach which I pursued for the first two decades of my ecological researches.

Key Words: Knowledge Systems, Socio-Ecological Systems, Traditional Ecological Knowledge

INTRODUCTION

At the very outset, I wish to express my deep sense of respect and gratitude, which I always carry along with me, to my respected late Professor R. Misra, who initiated me into the interdisciplinary area of studies in Ecological Sciences, for what I am today! Professor Misra, indeed, remains a source of inspiration to me till date, in spite of a whole range of transformation has taken roots over a period of time moving from biophysical dimensions of ecology, getting more and more involved with very many attempts towards integrating the biophysical with the social, economic and cultural dimensions, so as to put in nature-culture centric viewpoint of ecology.

Having been initiated into this interdisciplinary study area from the biophysical angle, I have had a great sense of satisfaction to have worked in the area of ecotypes (ecological races at the sub-specific level adapted to contrasting environmental conditions), also referred to as 'genecology', and having published a whole set of papers in the area of edaphic ecotypes - ecological races adapted to differential edaphic situations (for example, Ramakrishnan 1965, 1971). It was a gradual evolutionary experience for me when some of the studies on ecotypes got extended into looking at differential adaptation of plant populations to seasonal changes in climatic events, such as photoperiodic differential responses of summer ecotypes as distinct from the winter ecotypes in species such as *Chenopodium album* (Ramakrishnan and Kapoor 1974). My initial training in genecology had inter-disciplinary dimensions at the biophysical level.

As a logical process in my personal evolution, what I did at the intra-specific level studies, based on my initial training under late Professor R. Misra, lead me to look at the intra-specific (Ramakrishnan 1970) and inter-specific nutrient-linked competitive relationships existing at the level of closely related species such as that of *Argemone* living in the same area (Ramakrishnan and Gupta 1972, Ramakrishnan and Jeet 1972). With the encouragement and the needed impetus coming from my respected Professor R. Misra to whom I turned to for his acceptance, all along in these formative years starting with the late 1950s to early 1970; this traditional viewpoint of ecology seen through the biophysical lens still holds good to date, for the vast majority of ecologists, a viewpoint no doubt is important.

However, there is an increasing realization today than ever before that community-centric ecological perceptions have to be integrated into the text-book centric biophysical perceptions of ecological sciences. In other words, what one is talking about is a socio-ecological systems approach to address issues linked with environmental conservation and linked sustainable livelihood/development issues. This is the context in which follows the discussion on socio-ecological systems approaches to sustainability concerns linked with rapidly accelerating environmental uncertainties, an area of study that is gaining more and more importance in the context of rapidly emerging 'global change' in an ecological sense (climate change and global warming, land use-cover change, biodiversity depletion and biological invasion) (Bondeau et al. 1997) and economic 'globalization' (Dragun and Tisdell 1999, Ramakrishnan 1999).

What is being argued here in the following pages is that the emerging problems cannot be adequately well addressed without having community participation based on a value system that they understand and therefore participate in the process leading to conservation-linked sustainable development. It is further argued here that such an approach towards addressing sustainability concerns has, therefore to be based on appropriately linking text-book based 'formal ecological knowledge' (FEK) with 'traditional ecological knowledge' (TEK) to arrive at solutions that are community-centric, a viewpoint that dawned on me early on when I got involved with the traditional ethnic societies living in the north-eastern hill region, in the early 1970s, and got reinforced early on, based on a decade of initial observations (Ramakrishnan 1984). Over a period of time, the implications of the value of knowledge systems as an important basis for human security, not only at the local level, but also on regional and global levels, became apparent, as human societies whether they be 'traditional' or modern always wish to relate with a cultural identity that is nature-culture centric (Ramakrishnan 2009).

ON THE ISSUE OF INTERDISCIPLINARITY

Coming from a biophysical background on ecological studies in a landscape context of the Indo-Gangetic alluvial plains of northern Indian region, as I tried to make the studies relevant to north-eastern hill region, the limitations of text-book based knowledge alone in finding solution to conservation linked livelihood concerns of the traditional societies (those living close to nature and rich natural resources around) became apparent. It became apparent that interdisciplinarity has to go beyond the biophysical dimensions of the problem, and get into the social, economic and cultural dimensions of the issues involved with the issues centred around the traditional societies living in the region. The linked complications were that one had to deal with the few hundred ethnic groups with their own languages, music and dance forms, and therefore with distinctive cultural heritage systems, and therefore a rich diversity in traditional wisdom, with the embedded TEK. This was the context in which interdisciplinary approaches that linked natural science with its social dimensions became critical to get a good grasp of the problems at the ground level where traditional societies had all along had a marginalized existence, which was getting exacerbated over time and space.

What has to be emphasized at this point is that one needs to make a clear distinction between inter-disciplianarity from multidisciplinarity. My efforts in the early 1970s, to work along with a distinguished social scientist in a joint initiative, in the north-east Indian context, had to be given up very soon, because of the paradigm differences between the biophysical and the social sciences. Struggling for integration of the natural with the social dimensions of the problems linked with the issue of landscape management in the context of shifting agriculture and a whole range of other traditional land use practices in the biodiversity-rich forested landscape, I eventually narrowed down to TEK as the most powerful tool for linking the biophysical with the social dimensions of the problems. In other words, the former approach could have lead to multidisciplinary approach, which is distinct from interdisciplinarity which was the real aim that was achieved by using TEK as the connecting link between the two streams of sciences. As illustrated through Figure 1, I was eventually able to weave through these two sets of boxes (the biophysical and the social) through all the scalar dimensions ranging from a plot-level family land use initiative all the way through to the landscape-level initiatives on a regional scale in which one or more of ethnic societies may be involved. The ultimate objective was to arrive at ecological conservation linked livelihood/development of the traditional societies on a sustainable basis, a set of failed efforts for over a century, right from the colonial times (Ramakrishnan 1992a). Indeed, as discussed below we could convert our research efforts in the region into a developmental initiative in the State of Nagaland, eventually, through what came to be known as the NEPED (Nagaland Environmental Protection and Economic Develop-ment) initiative.

Having said all this, I would hasten to add that with the experiences gained, working with social science disciplines as part of a team effort is difficult but not impossible to achieve; what is required is the ability to find a mid-point between these two – natural and social science paradigms that have evolved independent of each other, to enable make real integration possible at a mid-point!

KNOWLEDGE SYSTEMS: THE CONCEPTUAL FRAMEWORK

Here we are dealing with two aspects of ecological knowledge: (i) the formal knowledge - that is text-book based ecological knowledge derived by the scientific community, going through a hypothetico-deductive process; (ii) the traditional knowledge - that is available with local communities which has just started receiving adequate attention from the scientific community; this knowledge base accumulated by traditional societies on the basis of an experiential process is all the time being refined and adapted to changing socio-ecological situations, both in space and time.

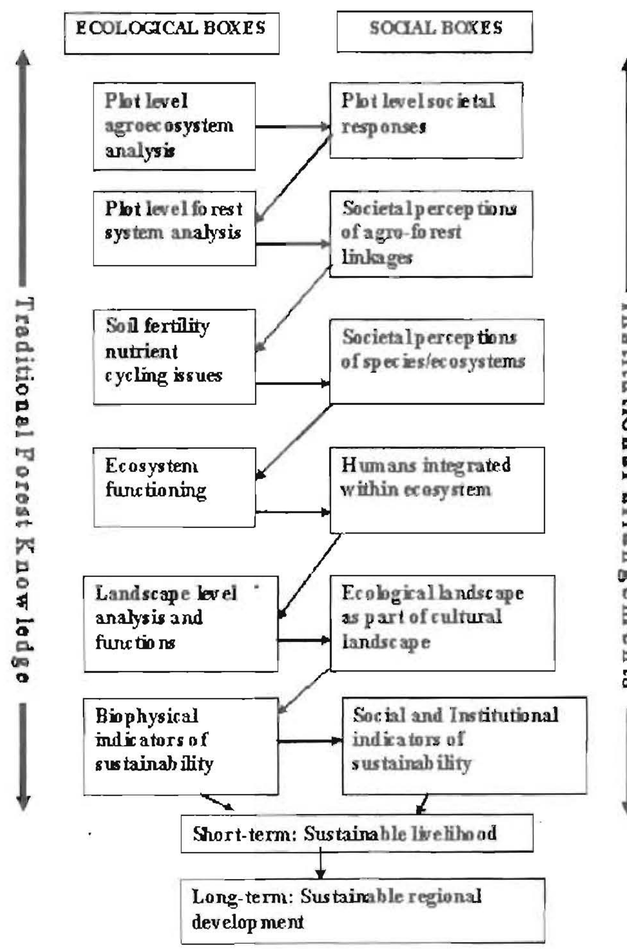

Figure 1. Traditional Ecological Knowledge (TEK) as the connecting link between ecological and social processes, at varied scalar dimensions – plot, ecosystem to cultural landscape levels, with implications for natural resource conservation linked sustainable livelihood/development of traditional societies.

Formal Ecological Knowledge

Traditionally ecologists have largely been concerned with understanding biophysical principles underlying ecosystem organization and functions. 'Formal knowledge', derived through a hypothetico-deductive process, proved a bio-physically limited viewpoint of understanding of ecosystem processes, though there have been gradual shifts occurring in the perceptions gained over a period of time - from studies based on trophic dynamism that is producer-controlled with research emphasis on well protected pristine ecosystems, to one that is consumer-controlled, that eventually leads to the recognition of disturbance being seen as a driving force in the evolution of ecological systems. The recognition of perturbation as an integral component of ecosystem functioning (Figure 2) has implications, for our understanding of population dynamics, successional processes, energy flow, nutrient cycling, biomass and production functions, etc., relevant for natural resource management. In spite of all these developments in our understanding of ecosystem dynamics, there is an increasing realization today than ever before that there is a worldwide crisis in resource management; it has been maintained by many that sustainability is neither a realistic goal nor a useful concept for ecosystem and natural resource management (Holling et al. 1998).

Traditional Ecological Knowledge

Traditional societies, based on their accumulated wisdom have evolved their own knowledge base linked to biodiversity in all its scalar dimensions (sub-specific, species and ecosystems and landscapes), linking conservation with their sustainable livelihood concerns. Based on a value system that they cherish (intangible cultural values – Ramakrishnan 2008b), they seek tangible benefits from the natural and human-managed ecosystems placed within the landscape.

On the basis of the current knowledge status, one could look at TEK not only from the point of tangible economic benefits that communities could derive using the available biodiversity around them, but also intangible benefits, which is oftentimes given the status of the 'sacred' (Ramakrishnan et al. 1998). TEK linked with biodiversity in all its scalar dimensions can be broadly classified into: (i) ethnobiological – aspects dealing with medicinal species and lesser-known species of food value; (ii) that links ecological processes, at the species, ecosystem and landscape levels with social processes right from family, village, village clusters and regional levels; and (iii) ethical/cultural with intangible

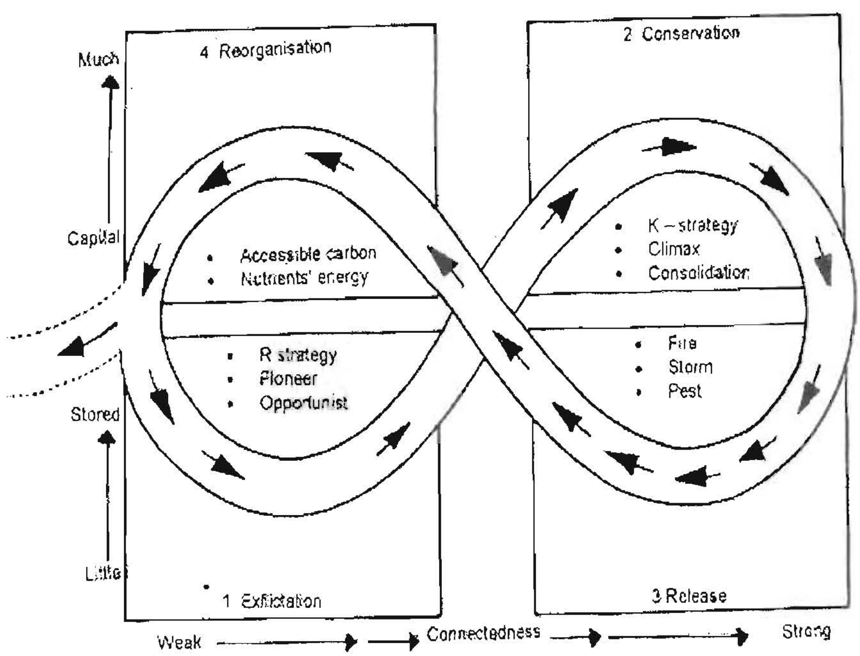

Figure 2 Interconnectedness of the four major phases and the flow of events of ecosystem organization and function. The arrows indicate the speed at which recovery of the system occurs after a perturbation, starting with the 'release' phase of flow; closeness of the arrows indicate rapid change. Y - axis is the amount accumulated capital of carbon and nutrients; X - axis shows the degree of connectedness between variables within the system. The exit room the cycle is indicated on the left, where a flip is likely into a less or more productive and organized system (from Holling 1995)

values that they treasure (Ramakrishnan 2008b), often times with tangible implications (what may be viewed as socially valued species, ecosystems and landscapes with tangible economic benefits linked to them (Ramakrishnan 2008a, c).

Of the three categories of TEK-linked biodiversity issues listed above, ethnobiological aspects have always received considerable attention (Berlin 1992) in the context of conserving and making use of traditional medicinal plants (Valiathan 1998, UNESCO 1999) and/or lesser-known plant species of food value (National Academy of Sciences 1975, 1979), two important resources of India, and the tropical world in general.

TEK: The Basis for Linking Ecological with Social Processes

Socio-ecological Value at the Species Level

Species Level Interconnections in Traditional Agriculture

Traditional societies maintain a variety of complex multi-species agroecosystems, operated under varied levels of intensification. Ranging from casually managed shifting agricultural systems, through a whole variety rotational fallows, agroforestry systems, compound farms, traditional cash cropping systems, crop rotation systems, etc. maintained at the middle intensity levels, leading to the modern high energy input agriculture, we are dealing with over a hundred typologies. The complexity of these agroecosystems are due to TEK-based biodiversity (sub-specific and species level crop and associated biodiversity) management, both in space and time.

It is not only the mere presence of biodiversity and the functional role it has for many of these traditional systems of agriculture that is significant here, but the manner in which traditional societies manipulate this biodiversity for altering ecosystem functional attributes and landscape integrity. In the shifting agricultural hills of north-eastern India, a mixed cropping system involving up to 5-45 species, the number of species declines drastically with shortening of the agricultural cycle. The farmer also shifts his emphasis from cereals under a long 30-year agriculture cycle, to tuber and vegetable crops under a shorter 5-year cycle; this shift is to emphasize upon nutrient-use efficient species under shorter cycles. Even on the same slope, the nutrient-use efficient crops are emphasized on the top of the slope and the less efficient ones are largely placed towards the base of the slope. This indeed is an elegant example of adaptation towards optimization of resource use and risk coverage, through manipulation of biodiversity, by the humans within the ecosystem.

The Apatanis of Arunachal Pradesh, who practice an ecologically efficient form of wet rice cultivation have evolved practices by which rice varieties are determined according to nutrient status at a given location (Kumar and Ramakrishnan 1990). Since the whole system is largely dependant upon recycling of village waste resources for soil fertility maintenance, through an elaborate waste water recycling system, it is obvious that fertility levels would be higher in the plots closer to the village, rather than farther away. Closer to the village, they emphasize upon a pure crop of nutrient uptake/use efficient rice cultivar. Since this variety of rice takes longer time for crop maturation, here they are able to combine pisciculture in such a way to synchronize simultaneous harvest of both the crop and the fish together. Further, in this nutrient rich environment, combining rice with fish culture makes much sense, in terms of resource use. Rice cultivars with shorter time period required for crop maturity are placed in plots farther away from the village; here pisciculture is absent. Short-duration cultivars away from the village also is, to some extent, an insurance against predatory wild animals. A good example of synchrony between nutritional physiology of crop varieties and soil nutrient status, for optimizing production.

Combining mixed cropping strategies in space and time with traditional weed management strategies, shifting agricultural farmer of north-east India ensures effective check on nutrient loss during the cropping phase. They practice weed management rather than weed control. Even the pulled out weeds are put back into the system. The traditional weed management practices, where about 20% of the weed biomass is left *in situ*, undisturbed in the plot by the shifting agriculture farmer, is also a practice common to the Mayan agriculture in Mexico, with implications for nutrient conservation and agroecosystem sustainability. Indeed, this 20% weed biomass left on the plot does not compete with the crops, and at the same time conserve nutrients loss from the plot, through hydrological processes. This is the cut-off point when the weed becomes a non-weed in the cropping system. What is referred to as the '*non-weed concept*' of the traditional farmer in the context of the Mayan agricultural practice and as 'weed management' rather than 'weed control' practices of the traditional shifting agriculturists, apparently looks like an incomplete weeding. But this TEK-based technology that contributes towards sustainable resource use (soil water and fertility).

The concept of ecological keystone is part of TEK, and is the end product of a social selection process, spread over a time scale too. Thus, in many areas in north-east India where the shifting agricultural cycle has come down to less than 5 years, and the landscape is highly degraded, a legume crop of lesser known food value, *Flemingia vestita*, is socially valued and used both in space and time under a 2-5 year rotational fallow system or sedentary system of agriculture. By fixing 250 kg. of nitrogen per hectare per year, this keystone species ensures sustainability of these low-input agroecosystems, under conditions of extreme pressure on the land and low soil fertility.

Species Level Interconnections in Natural Ecosystems

There is a greater realization now that tree species in a forest ecosystem, for example, which are socially valued often, have keystone value in the ecosystem. However, the role of socially selected ecological keystone species within natural forest ecosystems in conserving and enhancing biodiversity, and indeed in manipulating ecosystem function, is a critical area which has not been adequately explored. Keystone species play a crucial role in biodiversity conservation, through key functions that they perform in an ecosystem; often they are also socially or culturally valued. Therefore, they could be used for not only managing pristine ecosystems, but also for building up biodiversity in both natural and human-managed ecosystems, through appropriately conceived rehabilitation strategies that will ensure people's participation. Though the information on this interphase area between ecological and social processes is limited, the following examples will illustrate the kind of future opportunities.

In the successional forests of north-eastern hills of India, a variety of socially selected species are also ecologically significant keystone species. Nepalese alder (*Alnus nepalensis*), a nitrogen fixing species (fixing up to about 125 kg N ha^{-1} yr^{-1}) and many bamboo species (*Dendrocalamus hamiltoni, Bambusa tulda, and B. khasiana*) with the ability to conserve nitrogen, phosphorus and potassium in the early successional shifting agricultural fallows play a key role, both in space and time, in determining forest successional processes. Such an interphase between ecological and social processes are critical for natural resource management with community participation, and for biodiversity management in the context of 'global change', research areas which have only just started receiving attention. Such keystone species could occur also within the sacred groves, ecosystem patches maintained by traditional societies, for cultural and/or religious reasons (see the discussion below). Thus, species like *Englehardtia spicata, Echinocarpus dasycarpus, Sysygium cuminii and Drimycarpus racemosus*, as in highly infertile soils of the Mawsmai sacred grove in Cherrapunji in north-east India, conserve high levels of nitrogen, phosphorus and potassium, as much as about one-third of what is conserved in this dense rainforest ecosystem.

Such socially valued 'sacred' tree species are to be found in a variety of other situations too, in the global context (Ramakrishnan et al. 1998); in Cameroon, species such as *Ficus* sp., *Acacia albida, Prosopis africana*, etc. are sacred (Michaloud and Dury 1998); Oak species are traditionally considered sacred by Celts, Slavs and Germans, the Romans' northern barbarian neighbors of olden times, this species being regarded as the most divine tree (Hughes and Chandran 1998). Natives of Iran worship sacred trees by attaching textile, chains, locks, etc. to the trees (Khaneghah 1998). However, the ecological values linked with these socially valued species remain largely obscure, for want of information in this area of study.

Socially Valued Ecosystems

The socially valued ecosystems (the sacred groves) with a range of socio-ecological dimensions: (i) traditional agricultural systems that meet with the livelihood needs of traditional societies; (ii) they may be specially conserved and rigorously protected ecosystems of socio-cultural value; and/or (iii) to which one could also put in ecological value, particularly in the contemporary context of rapid land use conversions and linked land degradation all around.

Socially Valued Human-managed Ecosystems

With 'traditional societies' living in natural resource rich regions of the tropical world, being dependent upon biodiversity and being part of the ecosystem functioning, the natural resources contained therein are critical for their livelihood requirements. In such a context, socio-cultural dimensions have crucial role in determining ecosystem properties, with implications for their sustainable management. Shifting agriculture, which represents a complex set of sub-systems within, is indicative of this linkage between food security of traditional societies and their efforts towards conserving their cultural identity. What is worth noting weeding. But this TEK-based technology that contributes towards sustainable resource use (soil water and fertility).

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Box 1. Spiritual dimensions of shifting agriculture: Propitiating Nature (UNESCO 1983, Ramakrishnan 1992a, Schmidt-Vogt 1999)

Traditionally being animistic in their religious beliefs, shifting agricultural farmers consider themselves to be part of nature and natural resources around, and therefore look and view natural phenomena with respect and reverence. As an expression of their respect and reverence for nature, they tend to have a set of rules, rituals and taboos, interpreted through the village elder or the priest, with impacts that may be positive, or that may cause disaster. Indeed, these traditional societies tend to have a shifting agricultural calendar right from the stage of slashing and burning of the forest, through seeding and sequential harvesting of the of the yield/s from their mixed cropping system. The work related calendar is linked with socio-cultural festivals and ceremonies – the expressions of which may vary depending upon the ethnicity and locale of the given ethnic group, but the psychological basis remains. A few examples of these culture-lined expressions are:

- In the Garo hills of Meghalaya, in north-eastern region of India, for eg., the Garo community believe that the first Garo to settle on their land was 'Bone Nirepa' and Jane Nitepa, who started jhum, with blessings from their deity Misipa.
- The animistic Wanchos of Arunachal Pradesh in India, like many other ethnic groups in the region, traditionally sacrifice cocks, pigs, buffalos, and even the socially treasured 'Mithuns' to propitiate the spirits of nature, on different occasions, for a bumper crop.
- Baigas of Madhya Pradesh, consider that using a plough implies tearing the breast of the mother earth. Therefore, direct dibbling of seeds after slash and burn is done without ploughing the land, like many others.
- For the Lua (Lavu'a) of the northern Thailand, spirits grant protection through the village priest – they believe in ancestral spirits, house spirits, field spirits, and the spirit 'Chao Ti' for the protection of the land, all of whom are propitiated before slash and burn operation.
- Karens of Thailand with a strong attachment to their territory, are concerned about the 'Crop Grandmother' sitting on the half-burnt stumps in the jhum plots, which forms the basis for them to protect the stumps from damage till the harvest is over. They worship the lord of the 'land and water', to help rice grow and to call back the 'soul of rice' at harvest time.
- Sharing the belief on the sacredness of rice along with the Karen's, the Akha tribe in northern Thailand refer to the totality of Akha myths, traditions, customs and ceremonies as 'Akhazang', and expect all Akhas to carry this tradition forward; those who do not follow the code of conduct are expected to leave .
- For the Meo hill tribe in northern Thailand, it is the ancestral spirits prevent the people from abandoning shifting agriculture.
- The tradition of maintaining a sacred grove for each village, with many religious ceremonies performed within the groves during the year, in order to propitiate natural elements, is indicative of the sacredness attached to them, by different tribes of north-east India. It is another matter that many of these traditions are getting eroded, due to modern influences on the society. The Mawsmai sacred grove in Cherrapunji and Mawphlong grove nearer to Shillong in Meghalaya are two examples of relatively well protected sacred groves in the region.
- The Buddhist Dai (T'ai) tribe of Xishuangbanna in Yunnan Province in southwest China, a shifting agricultural country, have many holy hills, 'Nong Ban' and 'Nong Meng', belonging to a village or a cluster of villages, and they are spread over a large area, forming hundreds of small or large forested reserves.

contemporary context of modernism, unfortunately have declined in numbers, and those still surviving often are highly disturbed through human activities. In any case, there are still very many surviving, often times at varied levels of protection; in a country like India, there are a whole range of estimates on the number of surviving sacred groves; what is reported for a tiny state of Kerala in southern India, having around 5000 groves covering about 39,100 ha (Pushpangadan et al. 1998) is indicative of the extent of distribution of such groves in the Indian context, let alone what is available elsewhere in the global context (Ramakrishnan et al. 1998).

Being a consequence of the intangible values attached to forested ecosystems, sacred groves elegant examples rich biological diversity linked with cultural diversity. With an estimated over 40,000 endogamous groups, and with an estimated 37,000 more structured around the Hindu caste system, the cultural diversity in the Indian context is mind-boggling, which has implications for a rich heritage of such protected ecosystems (Malhotra 1988, Malhotra et al. 2000). What is given here (Box 2) is just illustrative of the rich cultural diversity linked biodiversity at the ecosystem level, in the Indian context, whilst a global analysis of this concept is given elsewhere (Ramakrishnan et al. 1998).

Socially Valued Cultural Landscapes

Awe-inspiring Distant Natural Landscape Formations

It is not difficult to visualize natural landscape units such as the imposing mountain systems that are worshiped by diverse communities all over the world, as the next logical step in linking cultural diversity with natural landscape level diversity. Awe-inspiring as they are, mountains seem to personify power, and the attendant sacredness, being seen to be of a high order – in all its splendors and with the most impressive features, distant and yet over-whelming (Box 3)

Unique Natural Sacred Landscapes

At yet another level, a variety of more specific natural sites where humans live as part of the given cultural landscape, and often times with intangible values linked to them. These may be also in the form of water bodies, caves, or sites of worship (Box 4).

Unique Living Cultural Landscapes

Moving beyond the hunter gather phase, it is possible to visualize a whole range of traditional agricultural typologies with natural and a whole range of human-managed traditional agricultural systems, ranging from shifting agriculture to the modern. These human-managed ecosystems along with natural ecosystem types together form distinctive 'cultural landscape' units sculptured by the humans living in the area. Some of these cultural landscapes carved out by traditional societies may be unique in a socio-ecological sense that they could be seen as possible world heritage sites too (e.g., as given in Box 5).

TEK at the Landscape Level and Sustainability Concerns

Manipulations at this level done by traditional societies have been able to ensure overall integrity of the interconnected ecosystems. Thus for example, the Apatani tribe in north-east India, discussed above, have evolved elaborate wet rice cultivation systems that are adapted to gradients in soil fertility and water availability, linked with traditional management options possible within the landscape. Thus, widening plots by digging adjacent higher forested ground, down to an irrigable level, and creating a saucer-shaped valley system over a period of time, seems to be a successful response to population increase and new market opportunities. The Apatanis living in the valleys and exclusively practicing wet rice cultivation, depend upon the forest ecosystem available with the socially lesser developed tribe, the Sulungs living in the neighboring hill slopes and who manage their forest resources for hunting/gathering and shifting agriculture. Such a landscape management is also done by many other traditional hill societies in south-east Asia too, such as the Tara'n Dayaks of West Kalimantan in Indonesia, and many in the Western Ghats of southern India. Many of these rural communities, establish forest reserves or economically valuable 'tree gardens' (home gardens), within the forest-agriculture landscape. In regions where the whole or part of the landscape is viewed as a common property resource, the community even formulate rules about the use of the resources within, with implications for sustainability.

A similar dynamic adaptation of land use technology has occurred in the context of deforestation and linked limitations in availability of organic residues in the landscape, particularly around urban centres such as Shillong township at higher elevations of Meghalaya in north-east India. This example is also indicative of the dynamic adaptation of traditional slash and burn agriculture of the region to rotational farming leading to more sedentary land use practices. Indeed, the TEK linked with shifting agriculture has indeed been a dynamic system, with TEK evolving over

Box 2. Cultural diversity and sacred groves in the Indian context (Ramakrishnan 2008a)

With its roots in animistic belief systems of traditional societies, sacred groves as a representative ecosystem sample with socio-ecological connotations is widespread both among the most traditional upland societies, and the less traditional rural communities living in the Indian plains, but with appropriate transformations that happened over time and space.

Amongst many traditional tribal societies who are largely located in uplands, the concept of sacred groves is still largely based around animistic beliefs; this often is in spite of the advent of in the context of north-eastern hill areas of India.

Elsewhere, in the country, it may be linked with the Hindu/Buddhist/Jain belief systems which have always been religions that have remained nature-centric.

- Advent of Islam and Christianity denounced and decreed against Paganism; in spite of this, in a traditional Islamic society like that in Afghanistan, sacred groves became a part of historical and geographical tradition of the people, with over 150 sacred groves being now controlled by local communities (Zaman, 1988)
- For the Hindu sages, right from antiquity, *'Aranya'*, the sacred forest is a place of wisdom and peace. '*Tapovana'* for the monks is a forest for meditation and spiritual enlightenment. By linking forests to Gods and Goddésses, the Indian tradition of conservation is sanctified through spirituality.
- In Meghalaya, each village is suggested to have had a sacred grove attached to it. In a small area around Cherrapunji alone, there are over 20 reasonably well protected sacred groves locally known *'law Kyntang'*.
- Mawsmai village sacred grove close to Cherrapunji called *'Phyllaw u Blui'*, is well protected and stands out prominently in a highly desertified and balded landscape, in spite of an annual average rainfall of 12 m. this area receives, which in an exceptional year may go up to 24 m. as in the year 1974! Traditionally, removal of even dead wood from these groves was prohibited, though many of the traditional religious ceremonies, with offerings of goats and poultry have been abandoned in recent times. This is indicative of declining cultural traditions even amongst many tribal communities in India.
- The Munda tribes of Bihar are linked with the Buddhist philosophy of maintaining '*Sarnath*' - the dear parks maintained by them are seen as a pilgrimage center where Buddha gave his first sermon. With a grove for each village, permission is granted by the priest for cutting a tree only through sacrifice to please tree gods.
- The groves of the Bishnois in Rajasthan, enriched with the sacred tree *'khejari'* (*Prosopis cineraria*), an ecological keystone species of the arid region, along with the sacred animal, the blackbuck (*Antilope cervicapra*), is a tradition going back to 1731, when the agents of Maharaja of Jodhpur wanted to cut trees for timber. The locals lead by a woman Amrita Devi and other Bishnois laid down their lives defending their trees. Locally called '*Oran'*, each village protects the grove around. The Bishnoi sect itself was founded in 1486 by Lord Jambeshwarji, based on 29 percepts to which Bishnois are to adhere; 29 forms the basis for the name of the sect itself (locally, Bis = 20; Noi = 9).
- With a rich tradition of sacred groves, and dedicated to gods and goddesses or to ancestral spirits, the groves in Kerala are often identifiable through a given socio-culturally valued ecological keystone tree species. Offerings in the form of animal sacrifices are performed on a stone slab installed at the base of the tree. Many of the groves have a temple that is the focal point for elaborate religious rituals, with traditional dance and music that may vary from place to place.Those owned by traditional tribal societies living in the hills are dedicated to 'Vanadevatha', the Goddess of the forest; other village groves are often referred to as *'Ayyappan kavu'*, *'Bagavathi kavu'*, or *'Amman kavu'*, the gods and goddesses of the Hindu pantheon. *'Sarpa kavu'*, are dedicated to the snake gods, perhaps an animistic tradition that is still prevalent.
- In Maharashtra state, groves are maintained for village deities; they may be lined with ancestors too, being located in burial ground areas too.
- Along the coastal areas of the country, mangroves also receive protection from the local people, dedicated to forest gods and goddesses.

Box 3. Awe-inspiring unique natural formations (Ramakrishnan 1998, Berbaum 2001)

- Standing out very prominently from its surroundings, and worshipped by the Hindus and Buddhists of the Asian region, and tucked away in the folds of the Himalaya, the symmetrical Mount Kailas rises above the Tibetan plateau, and is the legendary Mount Meru or Sumeru, the 'Mandala' of the Buddhists (the cosmic axis around which the axis of the Universe is organized for both Buddhists and the Hindus). For Hindus, it is the dwelling place of Lord Shiva, one of the three forms of the supreme deity who is also seen as the carrier of the majestic river Ganga, personified as a Goddess. Buddhists compare Kailas to the legendry mount Meru, and see it as a '*Mandala*'. As the source of sacred rivers, Indus, Sutlej, Brahmaputra and Ganges, flowing like the spokes of an eternal wheel. Buddhists see Kailas as the abode of the deity, 'Demchog', embodiment of the masculine compassion and feminine wisdom.
- For the Hindus in Bali, Indonesia, the mountain, Gunung Agung is sacred because, it is seen as representing the axis around which the Universe is organized.
- Mount Everest: Straddles the border areas of Nepal and China, the highest peak in the world and is an object of worship for people in the region; Tibetans reverentially call it 'Chomolungma', the mother Goddess of the Earth; in Nepal it is known as 'Sagarmatha' (mother of the Universe).
- Mount Kanchendzonga, the second tallest speak, next only to Mount Everest in the Himalayas, is deeply venerated; this peak and the land below is suggested to have been blessed by Padmasambhava, an incarnate of Buddha; Arising from this belief, the Yoksum area, known as 'Demojong' for the Tibetan Buddhists, located , in West Sikkim is seen to be sacred. Believed to have a large number of hidden treasures ('*ter*') of spiritual value embedded within the land and water bodies, to be slowly revealed at appropriate times only, this entire landscape is to be conserved with least human disturbances imposed on this landscape.
- Nanda Devi is the abode of Parvati of the Hindu Goddess, with its majestic peaks, which also includes the entire basin down below that includes the sacred Hemkund lake that is revered by the Sikh and the Hindu communities alike. With many fairs and festivals all the year around, and a major one every twelfth year, one could see many of the local devotees moving in a ritualistic procession to worship Nanda Devi, the Goddess, during the festival season. This part of the Nanda Devi Biosphere Reserve is a UNESCO-recognized world heritage site.
- Japanese, through their ritual ascent of the Mount Fuji are said to attain peace and enlightenment through meditation and transformation, as they gather inner strength to help each other.
- For the Maoris of New Zealand, the mountains are sacred. Maori mythology holds that all life forms came from the sky and the earth, and humans are linked to the mountains. The sacred mountains of Tongariro, Ruapehu and Ngauruhoe, donated to the government by the indigenous community way back in 1888, now stands protected as a National Park.
- According to the local belief of the Kikuyu tribe, Ngai, the Creator of all things dwells on Kirinyaga, a high point in Mount Kenya. East Africans traditionally bury their dead facing the sacred peaks of Kilimanjaro/Mount Kenya.
- Mount Olympus, a trans-national cultural heritage of Europe, the highest peak in Greece is symbolic of the European cultural heritage. In spite of repeated attempts to pollute its environs, in the name of development, Europeans from all walks of life have resisted many attempts to 'develop' the area as a tourist resort.

both in space and time. The shift towards a variety of rotational fallow systems, leading to sedentary farming practices (Figure 3), involving a keystone crop species such as a leguminous nitrogen fixer like *Flemingia vestita* (a lesser-known plant with small tubers that are of food value, particularly for use during the lean winter months) is indicative of TEK being adaptive in both space and time. Indeed, the landscape structure and functions in such an evolving situation is unique indeed, with Pine plantations as the tree cover, and with an acidic low-fertility soil which demands appropriate amelioration, which is provided by the nitrogen-fixing legume that fixes up to 250 kg. ha^{-1} yr^{-1}.

Knowledge Systems-Linked Landscape Developmental Pathways

Biodiversity, no doubt, contributes in a variety of ways towards ecosystem functioning, such as production, decomposition, nutrient cycling dynamics, and thus towards stability and resilience of the system. Working towards community participatory agriculture develop-

Box 4. Unique natural sites of worship (Hay-Edie and Hadley 1988, Bagri and Gupta 2001)

- The larger diffused cultural landscape region of Garhwal mountain region of the Central Himalaya, with humans living as part of the cultural landscape, discussed in detail elsewhere, with all its beauty, traced by the sacred river Ganga and its tributaries, with a series of temples of worship located at sites all along the route traced by the river system, and embellished through religious fairs and festivals, form a sacred land of religious/cultural tourism, for the people living in the entire Indian region.
- The Demajong cultural landscape of Sikkim for those following the Tibetan Budhhist philosophy, which is also discussed in detail elsewhere, with the sacred land, river and lakes of the Yoksum region are not to be drastically altered in any manner. Large-scale perturbations to the landscape system is suggested to end up in calamity for the Sikkim region as a whole.
- The Sikh religious shrine Hemkunt Sahib in Garhwal Himalaya, along with the lake of the same name surrounded by seven snow covered peaks, and at an altitude of about 4300 m. is a revered by the Sikhs; it is believed that this site finds a place in the Sikh religious text – the 'Guru Granth Sahib'. This forms the basis for conservation of this religious landscape and the linked religious tourism.
- The conserved holy forested hill of Tirumala of the southern India, the site for the ancient Vaishnavite temple of Tirupathi Balaji is a famous pilgrimage site for the Hindus of the Indian subcontinent..
- Ibusuki and Kyushu sacred woods in Japan is a place of worship for 'Kami' – the nature spirit, found in trees, rocks and streams.
- Ethiopia, the source of the Blue Nile river considered a holy site along with Abay, the stream flowing down to Lake Tana, another sacred site, by the Ethiopian orthodox church,
- Bear Bute High Ridge: Sacred for a few thousand native American Indians of Souh Dakota, USA, this natural feature is a source of vision and quests, spiritual power and knowledge.
- Lake Guata Vita is a sacred site for the indigenous Muisca people of Columbia.

Box 5. Examples of living cultural landscapes sculptured by traditional societies that links with conservation with sustainable livelihood concerns (Ramakrishnan 2008a,c)

Rice Terraces, Philippine: Over 2000 year old high rice terraces of the Ifugaos of the Philippine Cordillas managed all along in a sustainable way forms the basis for ensuring sacred cultural traditions and the delicate ecological balance – a landscape of great beauty and eco-cultural harmony.

The Ziro valley land which is the abode for the Apatani ethnic group of Arunachal Pradesh is another cultural landscape which merits recognition under this category, for its unique forest management system/s linked with wet rice agricultural system in a biophysical sense. With a traditional agricultural system based on internal recycling of resources and labour energy coming from the village itself as the input, this rice-fish based system is comparable to the 'green revolution' agriculture of Haryana and Punjab, but has an ecological efficiency (energy output/input ratio) of around 50-60 units compared to 0.5 unit for modern Indian agriculture and 0.1 unit for the more modern industrial agriculture of USA and Japan, and therefore merits recognition as a FAO world heritage site under its GIAHS (Globally Important Agricultural Heritage System) category.

An interesting dimension to the forestry based activities of the Apatanis, with institutional arrangements for their management, is the layers of forests maintained by them around the Apatani valley – a layer of community managed bamboo forest (this is apart from the family- or village-centred bamboo gardens that they often have), another of Pine plantation, a third one of *Castanopsis*, and a fourth towards the extreme peripheral portion being a mixed broad-leaved forest. This is a very unique feature of forestry management of the Apatanis, suggestive of the high degree of self-sufficiency and sustainable management of natural resources within a limited landscape valley area to which they are confined.

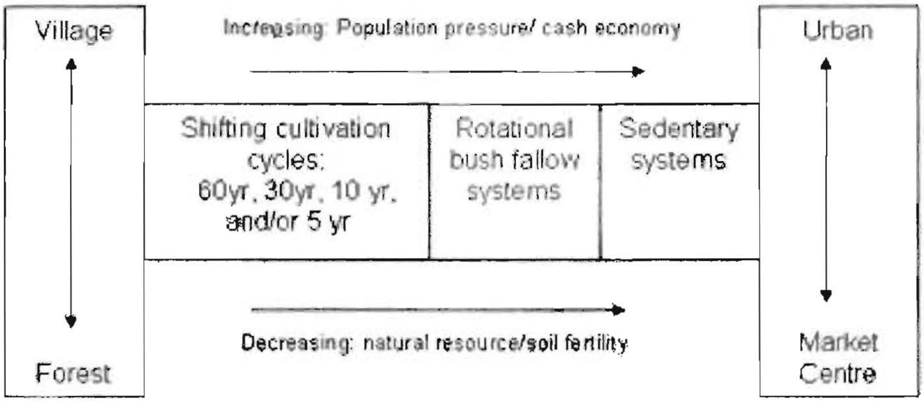

Figure 3. Evolution in TEK linked with agroecosystem in the landscape, as land use changes in response to population pressure, land degradation and available linkages to market economy closer to an urban landscape (Ramakrishnan 2008c)

ment possibilities, Swift et al. (1996) considered three distinct sustainable agricultural development pathways that is based on linking different proportionalities of TEK with the text-book based formal knowledge. Such an approach is extendable to cover integrated sustainable landscape management too (Figure 4). Incremental pathway is all about an incremental build-up largely using TEK, whilst the what is referred to as 'auto-route' (based on the simile that to cross a mountain you can use an environmental friendly long route of going around the mountain; or alternatively have a short and less environment-friendly approach by having a highway drilled through the mountain to reach the other side faster, a simile linked with energy-intensive modern land management technologies). In between the two comes the 'contour pathway' wherein the TEK and formal knowledge inputs are adjusted more or less to an equal proportion, depending upon the ecological contours, e.g., for dealing with sustainability concerns of very many settled farming practices whether they be in a hilly terrain as in the Central Himalayan region or in the rural landscape of the Indo-Gangetic alluvial plains of India.

Incremental Pathway

When one is dealing with traditional societies, in the Indian contexgt who constitute a substantial section of the human population in the developing tropics (in the Indian context, e.g., they form 1/3 of the total human population) who have a rich TEK base; therefore, the obvious choice to build upon this rich TEK base step by step, bringing in FEK based technology only to the minimal extent needed to build hybrid technologies – the *'incremental pathway'*.

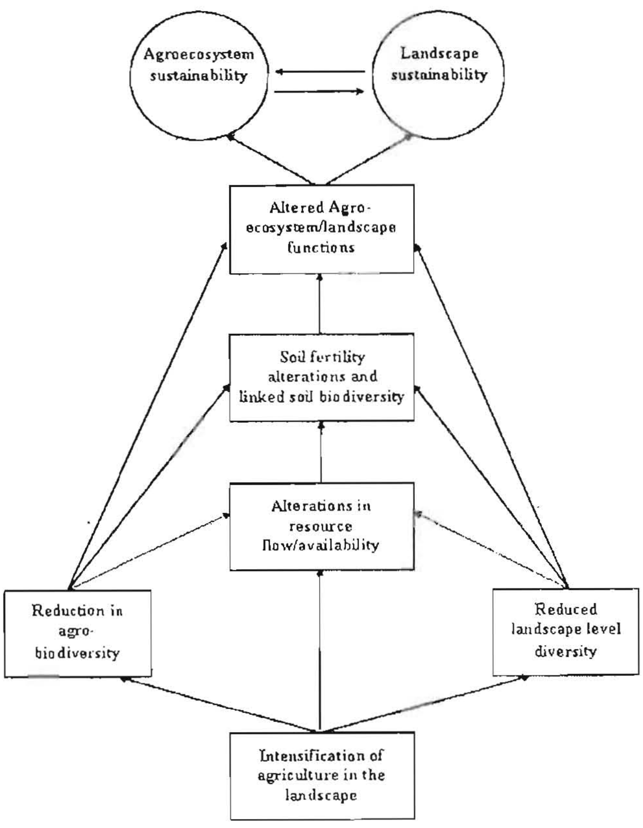

Figure 4. Intensification of agriculture, biodiversity changes, changing resource flow, aboveground biodiversity impacting upon belowground biodiversity and linked soil fertility alterations in soil fertility levels, altered agroecosystem/ landscape functions with sustainability implications (adapted from Swift and Anderson 1993),

Building upon some of the general principles evolved on the basis of over two decades of research, a few generalized principle for jhum redevelopment was formulated in the early 1990s (Ramakrishnan 1992a), which formed the basis for the subsequent redevelopment initiative taken up later for the State of Nagaland, through sustainable fallow management based on agroforestry principles, but without drastically departing from their traditional practices.

The developmental initiative implemented for the State of Nagaland in north-east India towards sustainable fallow management based on agroforestry principles, without drastically departing from their traditional practices (the NEPED project that was steered through the India-Canada Environmental Facility by me) was aimed at a redeveloped jhum, based on the value systems cherished by the people of the region. This project aimed at building upon the available TEK and bring in modern science only to the minimal extent that the situations demanded. Community participation was ensured not only through TEK at the natural resource management level, but also by rejuvenating traditional ways of institution building at the village level along with modern elective processes put in place in recent times. Such a short-term strategy for development was aimed to empower the Naga society, so that they can gradually move towards developing their own strategies by such an empowered society for a long-term land use development plan, at the appropriate time.

To elaborate one of the components in this developmental pathway, a keystone species such as the Nepalese alder (*Alnus nepalensis*) is extensively used by tribal societies for soil fertility management (Mishra and Ramakrishnan 1984). This early successional tree species in the north-eastern hill region, which is traditionally conserved in the slash and burn plots conserve up to about 120 kg nitrogen ha^{-1} yr^{-1}. We have shown that under one cropping cycle, the system loses something like 600 kg nitrogen ha^{-1} in one year of cropping. Under short agricultural cycles of 5 to 6 years, not more than 300 kg ha^{-1} of soil nitrogen alone is put back into the system during the 5-year period. Introduction of Nepalese alder into the plot could recover all the 600 kg N during a five year period. Recovery of all the 600 kg would otherwise require a minimum of 10 years of recovery period through natural processes of forest succession. In other words, introduction of Nepalese alder into the system under a 5-year agricultural cycle could stabilize the system, with adequate nutrient recovery. Apart from nitrogen fixation, the production of nitrogen-rich leaf litter and mineralization also contributes to biological build-up of soil fertility. Thus, this species could be used for fallow management with community participation, since the people can identify themselves with a value system that they understand and appreciate, and therefore participate in the process of development.

These considerations formed the basis for a decentralized village development plan in one of the north-eastern hill states of India. Over a thousand villages in the state of Nagaland have been organized into Village Development Boards (VDBs), with the specific purpose of rural development in mind. The VDBs were established taking into consideration the traditional village organization of the given cultural group; however, all of the VDBs had the same function, namely rural development. Using this institutional mechanism, the highly distorted shifting agricultural system, which indeed is basically an agroforestry system, but now operating at subsistence or below subsistence level, is being redeveloped, by strengthening the tree component that has been weakened due to extreme deforestation in the region (NEPED and IRRR 1999). The entire basis for this incremental build up is the rich traditional ecological knowledge base of these hill societies (Box 6). The project implementation by the Nagaland Government officials through Village Development Boards created by the Government of Nagaland and being implemented now aims at augmenting the traditional system of agriculture rather than attempting to radically change it. The Nepalese alder-based agroforestry systems, with planting of trees done both in space and time (during the cropping and fallow phases of shifting agriculture) and maintained for hundreds of years, by some of the local tribes like the 'Angamis' formed the impetus for this initiative.

Reliance being placed on participatory testing rather than being transplanted into the field site by the extension agents, about a dozen tree species are being tested in over 200 test plots. Currently it is estimated that the agroforestry technology is being tested in 5500 ha of replicated test plots. Farmers have adopted this, for local-based testing in 870 villages, covering a total area of 33,000 ha (38 ha per village x 870 villages); in these plots, local adaptations and innovations for activities such as soil and water management are emphasized.

To summarize the range of objectives that were in the back of the mind of diverse stakeholders which were achieved to some degree, they are very many: (i) sustainable traditional agricultural development with

Box 6. Shifting Agriculture (Jhum) Landscape and Sustainable Development for North-eastern India (from Ramakrishnan 1992a).

- For improving the system of land use and resource management in north-eastern India, the following strategies suggested by this author, and his coworkers are based on a multidisciplinary analysis. Many of these proposals have already been put into practice.
- With wide variations in cropping and yield patterns under jhum practiced by over a hundred tribes under diverse ecological situations, where transfer of technology from one tribe/area to another alone could improve the jhum, valley land and home garden ecosystems. Thus, for example, emphasis on potato at higher elevations compared to rice at lower elevations has led to a manifold increase in economic yield despite low fertility of the more acid soils at higher elevations.
- Maintain a jhum cycle of minimum 10 years (this cycle length was found critical for sustainability), when jhum was evaluated using money, energy, soil fertility biomass productivity, biodiversity, and water quality, as currencies) by greater emphasis on other land use systems such as the traditional valley cultivation or home gardens.
- Where jhum cycle length cannot be increased beyond the five- year period that is prevalent in the region, redesign and strengthen this agroforestry system incorporating ecological insights on tree architecture (e.g. the canopy form of tree should be compatible with crop species at ground level so as to permit sufficient light penetration and provide fast recycling of nutrients through fast leaf turnover rates). Local perceptions are extremely important in tree selection, for introduction into the cropping and fallow phases of jhum, as is being done in a major initiative in the state of Nagaland in north-east India.
- Improve the nitrogen economy of jhum at the cropping and fallow phases by introduction of nitrogen-fixing legumes and non-legumes. A species such as the Nepalese alder (Alnus nepalensis) is readily taken in because it is based on the principle of adaptation of traditional knowledge to meet modern needs. Another such example is the lesser known food crop legume Flemingia vestita, traditionally used by tribals as an important species when jhum cycles decline below 5 years.
- Some of the important bamboo species, highly valued by the tribals, can concentrate and conserve important nutrient elements such as N, P and K. They could also be used as windbreaks to check wind-blow loss of ash and nutrient losses in water.
- Speed up fallow regeneration after jhum by introducing fast growing native shrubs an and trees – socially valued species with ecological keystone value, as noted above can easily be identified through community interaction, as we have shown through our research analyses.
- Condense the time-span of forest succession and accelerate restoration of degraded lands based on an understanding of tree growth strategies and architecture from the FEK angle at the same time taking on board social values attached to species as noted above, which could then be the basis for having the right species mix, over space and time.
- Improve animal husbandry through improved breeds of swine and poultry.
- Redevelop village ecosystems through the introduction of appropriate technology to relieve drudgery and improve energy efficiency (cooking stoves, agricultural implements, biogas generation, small hydroelectric projects, etc.). Promote crafts such as smithying and products based on leather, bamboo and other woods.
- Strengthen conservation measures based upon the traditional knowledge and value system with which the tribal communities could identify, e.g., the revival of the sacred grove concept based on cultural tradition which enabled each village to have a protected forest once upon a time although few are now left.
- In the ultimate analysis, have an integrated approach for land use development in a given ecological/cultural landscape; base short-term sustainable livelihood strategy on building upon traditional knowledge and technology; long-term sustainable development plan should based on larger ecologic/economic considerations should gradually built up to avoid social disruptions.

improved economic returns per unit area; (ii) improved forest cover in the landscape; (iii) contribute towards carbon sequestration to deal with climate change, an aspect that is now being emphasized system; (iv) dynamic conservation TEK available in the region for use by posterity; (v) sustainable soil fertility and soil water management; (vi) though aimed at sustainable agriculture to start with, it ended up with sustainable landscape management in a holistic sense; and (vi) ensure dynamic conservation of the cultural identity of over three dozen ethnic groups living in the region.

The Auto-route:

On the other extreme, are modern societies involved in mono-culture 'green revolution' agriculture and/or plantation systems in a landscape largely devoid of biodiversity, sustaining production through excessive fertilizer application. Obviously what one is seeking for is to *'buffer and improve soil health'* through sustainable organic residue management, with concerns for enhanced biodiversity at both above- and belowground levels. Herein, the revived and adapted TEK-based input is restricted to the minimal extent that is necessary to ensure sustainability of the system, by reducing external energy subsidies to the extent desirable, at the same time ensuring increased quality production.

The 'FBO' (Fertilisation Bio-organique Dans les Plantations de the) or 'Bioorganic Fertilization for Plantations') in-situ soil fertility management techno-

Box 7. The FBO technology for buffering intensively managed modern agricultural systems (from: Senapati et al. 2002)

- As part of a systems analysis, a variety of cultured earthworms along with a mixture of high and low quality organic materials in specified proportions, and application procedures are determined for a given situation. The specialty of the capsule is autoregulation of the synchrony of plant demand and soil supply of nutrients through regulated mobilisation and immobilisation. The capsular implementation is carried out only inside the designed 'fertilization units' to minimize physical disturbance and for high efficiency. In situ use of resources within the prevailing cropping system allows flexibility, to decide upon the components, combinations, proportion, placement and application schedule compatable with site conditions.
- Earthworm technology that incorporate organic residues into the soil to stimulate the activities of existing or introduced soil inhabiting earthworms is 'in-soil' technology. FBO prefers this for long term system sustainability and effectiveness. Success of this technology depends upon the choice of suitable species, the provision of appropriate organic supplies to feed the worms and the maintenance of a minimum diversity in the whole invertebrate communities. Replenishment of the lost eathworm diversity under intensive land use, demands careful selection of existing and eliminated species for rebuilding the community suitable to takeover their role from a threshold level.
- Large-scale production units are laid out, for efficient use of space and to meet the demand for direct 'in-soil' earthworm management. Depending on variable culture conditions it has been quantified that the inoculated population may multiply 10 to 30 times within a span of about three months, at a minimal cost of about about Rs. 200 for a kilogram of live worms, for use in adjoining fields.
- Locally available organic residues are selected for soil amendment along with earthworm species from the reference native systems, in case their population is below a threshold level. Composition of species and their functional proportion depend on the location specificity and soil status. The emphasis is on effective use of local resources and thus minimize labour, expense and time.
- FBO' technology package is not equivalent to any single process like vermi-composting, mulching, chemical fertilization, soil replacement, hormone spray etc. etc.. nor even combinition of some of them.
- Experimental plot level analysis show tea growth, upto 75% to 260% enhancement in intermediate profit over the conventional system within a period of 6 months to one year; this is apart from improved soil physical-chemical and biological qualities for which economic cost of evaluation is not available at present. The overall biological status improved by more than 200% along with about 60% improvement in pysico-chemical soil characteristics, over the control the control plots under conventional management.
- Maintaining a minimal functional diversity, this technology does not favour an exaggerated development of a single species that accumulate large biogenic structures and result in severe problems of soil compaction. Application of too much and too little of organic matter without monitoring of quality, quantity and placement is linked to the functional integrity of the system. Inoculation of alien species of earthworms should be weighed against the future implications for biotic community interactions within the soil, and the consequent issues of system sustainability.

logy standardized by a group of Indian and French scientists, as part of an ongoing international initiative on tropical soil biology and fertility (TSBF), looked at land degradation issues in the tea garden plantations of Karnataka, Western Ghats of southern India (Box 7). This technology, patented between the Indian and French scientists involving the tea garden managers, has now gone up to the Chinese shores. Here, one could visualize the situation where socially valued species with ecological keystone value for nutrient conservation and release through organic leaf litter residues forms the basis for organic residue management for soil fertility build-up, and enhanced soil biodiversity, without even knowing what is in that diversity since it is difficult to catalogue the same, which then is monitored through using earthworm species of ecological keystone value within the soil sub-system; in other words, appropriately identified organic residue management for sustainable soil fertility build-up makes it possible to have a substantial reduction in inorganic fertilizer application by 30 to 50% (Senapati et al. 2002).

The end results achieved arising from this developmental initiative could be seen to have had the following dimensions: (i) increased tree cover in the landscape context, with emphasis on traditionally valued tree species coming into the plantation landscape as a whole; (ii) improved yield of tea with better quality for the leaves arising from increased use of organic residues for improved soil ferity; (iii) overall improvement in aboveground biodiversity with implications for improved belowground biodiversity too and of course (iv) overall sustainability of the landscape system as a whole.

The Contour Pathway

In between the above two pathways, under many diverse landscape situations, with largely reduced biodiversity, and rapidly degrading landscape, there is the necessity to develop agroforestry system models bringing in an appropriate mix of TEK and FEK based inputs in tree species selection; this principle could be also be the basis for bringing trees into the landscape as a whole to ensure sustainability of the natural ecosystems in order to ensure sustainability of the landscape as a whole. Working with nature, rather than dominating it, this approach would involve active planning with the nature of the background ecosystem fully in mind. Many land use systems in the 'low' and 'middle' intensity management categories will come under scrutiny under this pathway. In brief, the objective here is to have an appropriately reconstructed sustainable landscape with improved overall biodiversity – the *contour pathway*, which as the term suggests is towards building up models that fit into the ecological contours of the given situation. Increasing the organic residue levels in order to improve the physical qualities of the soil, moisture and nutrient retention abilities of the landscape system as a whole, the primary objective here not to replace intensively managed human-managed ecosystems within the landscape, but to but to improve the ecosystem/landscape functions appropriately by bringing in heterogeneity in the landscape system by bringing in appropriately selected locally available species that would sustain both natural and human-managed ecosystems within the given landscape unit (Box 8).

The Emerging Lessons

Whilst dealing with traditional societies, we are concerned with conserving cultural diversity that they cherish in the context of biodiversity to which they are closely linked with. Valuing tangible benefits in the context of the intangible values that they wish to conserve has to be the basis for the sustainable management/development with concerns for the socio-ecological system integrity, whilst one deals with biodiversity conservation linked sustainable livelihood/development issues. Conservation linked sustainable development of modern societies on the other hand has to based on some small component of TEK, rediscovered, if need be, through a historical evaluation what they had sometimes in the past. In between many others may need to have a developmental philosophy that may lie something in between. In the ultimate analysis, we all should aim at having appropriately constructed cultural landscapes that helps to bring humans as close to nature as feasible.

A value system based approach for restoration/reconstruction of natural cultural landscapes is the key to address sustainability concerns, in the rapidly changing global scenarios, in the context of socio-ecologic 'global change' and economic 'globalization'. Intensification of agriculture (cf. Figure 5) is closely connected with declining natural and human-managed biodiversity, leading to reduced resource flow from aboveground to belowground system, with implication for sustainable soil fertility management; this in turn would lead to altered land use functions, with implications for sustaining natural and human-managed ecosystems and indeed landscape systems.

Box 8. Building Agroforestry/social Forestry Based Models Through 'Contour Pathway'

A whole variety of landscapes with agroforestry and alley cropping models, for example, would come under the 'contour pathway'. Sloping Agricultural Land Technology (SALT). developed by the Mindano Baptist Rural Life Centre in the southern part of the Phillippines, for mountain agricultural landscape is one of them. It is based on the planting of annual and perennial crops in 3-5 bands between double rows of nitrogen fixing trees and shrubs planted on contours for soil conservation. The objective here was to establish a stable ecosystem that would check soil erosion, ameliorate the chemical and physical properties of the soil and lead to increase in the income of the farmers. Whilst these objectives were realized in the initial experimental phase, attempts are now being made to introduce this technology in other situations in Asia (Pratap and Watson, 1994).

The agroforestry based cardamom plantations with Nepalese Alder (*Alnus nepalensis*) as a cover crop is one of the elegant examples of a community based traditional agroforestry system that has evolved gradually, developed through the 'contour pathway, and now popular in the Sikkim Himalayas (Sharma 2006).

There also exist a whole range of agroforesty system models, ranging from rotational agroforestry systems to sedentary systems elsewhere in the Himalayan region, with no alternatives in place, that are amenable to the 'contour pathway' (Rao et al. 2002). Many agricultural systems that are rapidly breaking down in the rural plains of India would also be amenable to be developed through the 'contour pathway' (Singh et al., 1994). Also, very many diverse traditional agroforesty systems existing in the rural plains of India are now breaking down due to loss of the tree component. It is critical that the redeveloped models have to fit into the ecological contours, and has to be in tune with locally available resource base on which these agricultural are dependant.

Indeed, many of the traditional agroforestry system models of the rural plains of India are rapidly breaking down in the absence of the tree component as part of the agroforesty systems; indeed, often the entire landscape itself is depleted to tree cover. Here, building agroforestry models (Singh et al., 1994), to suit to the given socio-ecological contours offer a range of possibilities for reconstructions based on community values, and fitted appropriately into the given socio-ecological contours. Mâny such land use systems, also common elsewhere in the developing tropics, and coming under low- and/or middle intensity landscape management category, they too are amerable to the 'contour pathway' for addressing sustainability concerns.

Humans, obviously, are one of the key drivers in determining the final outcome – sustainability or otherwise of landscape functions, with implications for human wellbeing in a larger sense – tangible benefits along with the linked intangible values that they seek to have as an integral part of 'nature'.

It is therefore heartening to see now IUFRO coming with 'Traditional Forest Knowledge' programme for sustainable forestry, IGBP/IHDP coming with the initiative on 'Knowledge Systems, Societal Learning and Sustainability Concerns' to cope with 'global change' to cope with rapidly emerging environmental uncertainties, and FAO coming with 'Globally Important Agricultural Heritage Systems' that has implications for sustainable agriculture. Therefore, it is satisfying for me to see that what was started by me as a loner in early 1970s is now rapidly gaining wider acceptance and international credibility, for this important area of ecology and sustainability science.

In the ultimate analysis, when I reflect upon what has transpired within my research-linked life span of over five decades, trying to move from trying to understand ecosystem functions to socio-ecological system functions, I owe a lot to my revered late Professor R. Misra, and dedicate this keynote article to him, on the occasion of his birth centenary.

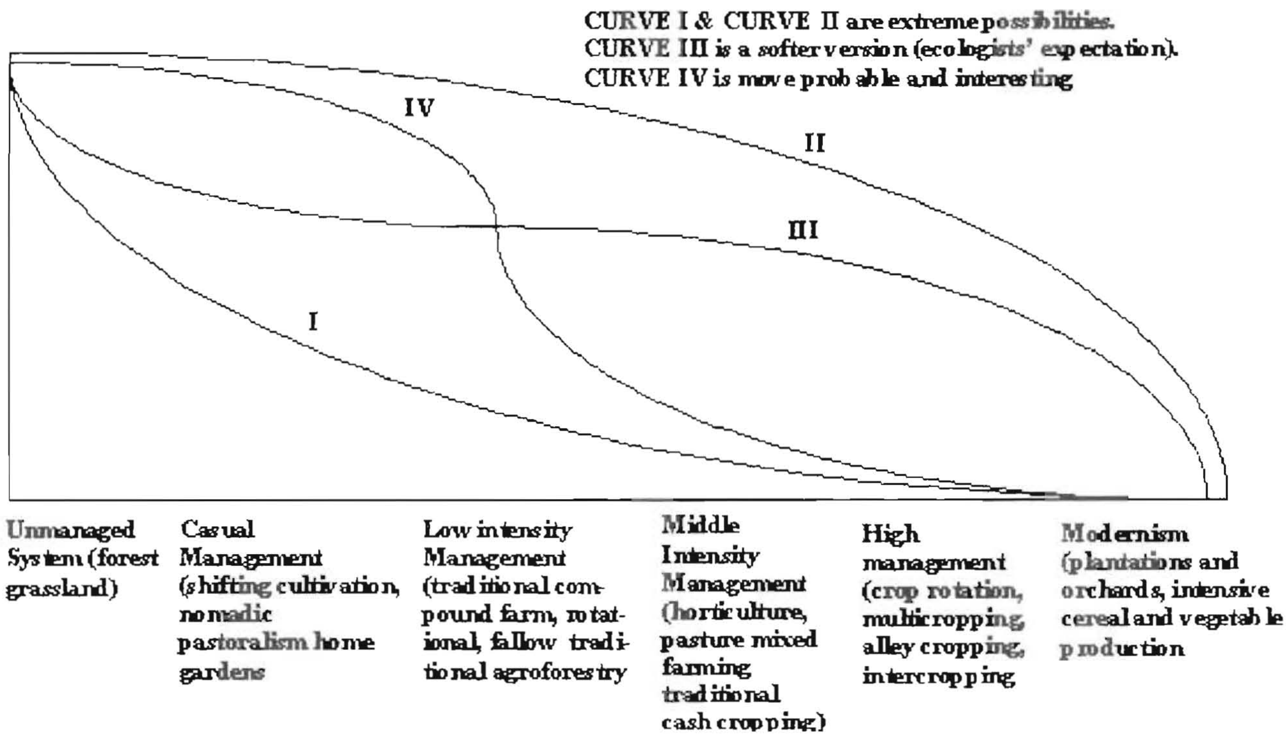

Figure 5. Biodiversity changes (four patterns) as related to agroecosystem types and intensity of management. Curve I and Curve II represent two extreme possibilities that seem to be unlikely. Curve III is a softer version the ecologists' expectations, whilst Curve IV seems to be more likely and is the most interesting from the viewpoint of agrobiodiversity conservation (from: Swift, M.J. et al. 1996).

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