Increasing population and declining biological resources in the context of global change and globalization

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In the context of over-consumption of natural resources in the name of development and rapid industrialization by a small section of the human population that is rapidly growing, the world is currently faced with a variety of environmental uncertainties. ‘Global change’ covering a whole variety of ecological issues, and ‘globalization’ in an economic sense, are two major phenomena that are responsible for these uncertainties. There is increasing evidence to suggest that the developing countries more than the developed, particularly the marginalized traditional (those living close to nature and natural resources) societies would be the worst sufferers. In order to cope with this problem in a situation where the traditional societies have to cope with rapidly depleting biodiversity on which they are dependant for their livelihood, there is an urgent need to explore additional pathways for sustainable management of natural resources and societal development. Such pathways should be based on a landscape management strategy, that takes into consideration the rich traditional ecological knowledge (TEK) that these societies have. This is critical because TEK is the connecting link between conservation and sustainable development. This paper explores the possibilities in this direction through a balanced approach to development, that links the ‘traditional’ with the ‘modern’, in a location-specific way.

1. Introduction

As long as the human population was very small, during the hunter-gatherer and the early settled land use phase of *Homo sapiens*, it remained integrated well within the boundaries of the ecosystem/landscape. With settlements appearing with the advent of agriculture about 10,000 yrs ago, the exploitative phase of the human population started growing rapidly. In the Indian context, migration and the intermingling of the local population with successive waves of settlement leed not only to settled agriculture in the plains of the Indian sub-continent, but also to the tribal societies taking refuge in the inaccessible upland regions during the period of cultural evolution of the sub-continent. Since then rapid exploitation of natural resources, for agriculture, deforestation by successive waves of exploitation by the Moghul and British colonizers (Gadgil and Guha 1992) and the more recent accelerated deforestation done in the name of industrialization and developmental activities, have all led to the rapid depletion of the biological resources of the country. Having decimated much of the biodiversity from the plains of India, deforestation has continued at a rapid rate from the uplands too. At the moment, much of our rich biodiversity and natural resources are confined to the upland areas, where what I call in a socio-ecological sense as ‘*traditional societies*’ (integrated well within the boundaries of the ecosystem/landscape) live; they are inclusive of *tribals*, and are referred to as such in a socio-political context.

With the growing economic divide between the developing and the developed world, a situation has arisen where a small section of the global population of a few developed nations have a hold over the global natural resource base supporting over-consumption and in the process has marginalized a substantial section of the human population living in the developing world. India with its intense population pressure is one of the worst affected. It is in this context that we need to look at three interconnected issues, namely, increasing population pressure, placed in the context of ‘global change’, an ecological phenomenon and ‘globalization’, an economic phenomenon, have to be viewed.

Keywords. Biodiversity; global change; globalization; population and land use; sustainable landscape management; traditional ecological management

2. Population growth and natural resource depletion in the Indian context

2.1 *Population pressure*

Until about the 18th century, the world population was kept under check through war, famines and diseases. The steady rise in the world population which started off at a modest rate of under 0·5% rose to about 1% during the first half of the twentieth century. After 1950, the population growth rate, particularly in developing countries, rose to over 2%, arising largely out of improved living standards and medical facilities. With greater realization of the developmental problems associated with increasing numbers, many countries have moved into the demographic transition towards lower fertility and growth rate and the world population growth rate now stands at 1·7% per year. According to one of the projections of the World Bank for the future, the net increase in population will continue to be about 92 million people per year through 2015 and will slowly decline only thereafter. One must realize that these projections rest on assumptions about future trends of fertility and mortality. The increase in world population is projected to continue overwhelmingly in the developing world. About three-fourths of the 3·2 billion increase in world population through 2025 is expected to be in the developing world. About half of the population growth during this period is expected to be in Asia, with two of the most populous countries being China and India. For a country like India, the economic and environmental consequences of this scenario are very disturbing.

The rate of urbanization in developing countries is not different from those in the developed world. What is disturbing, however, is the absolute size of the cities involved and the rate at which they are growing. The urban/rural population growth differential given in table 1 suggests that the gap in numbers between the two is becoming wider over a period of time. Besides, the number of mega cities having more than five million people is becoming alarmingly large in the developing countries.

2.2 *Population problem in India*

As in other developing countries, the problem in India centres around rapid population growth and urbanization (Kayastha 1989). The urban population of India in 1981 was 156·18 million, with an increase by about 49 million during the decade 1971–1981. With Kolkata, Mumbai and Delhi having more than ten million each, the total population of the million-plus cities would cross the 100 million mark by the turn of the century. The intense pressure on civic amenities has already contributed to the development of urban slums, with a fifth of India’s urban population living in slums.

Obviously, there have been rural to urban population flows: (i) eastward, from the northern and central states towards the industrial regions in the Damodar valley and the metropolis, Kolkata, (ii) westward towards Delhi and its industrialized neighbourhoods, (iii) further south towards the industrialized city of Bhopal, (iv) towards Maharashtra and the Mumbai metropolis in the west and (v) towards Karnataka and the fastest growing city of Bangalore in the south.

Rural to rural migration is often localized for family reasons, and for daily wage labour (Skeldon 1985). However, one of the important causative factors for rural to rural migration has been to colonize sparsely populated resource-rich areas. Migration to the Terai foot hill region of the Himalayas and to Assam illustrates such a migration. In Assam the population more than quadrupled between 1901 and 1971 from 3·5 to 15 million whereas the population of the country as a whole barely doubled over the same period (Ramakrishnan 1994). It would be appropriate here to point out that this increase is partly due to the higher growth rate and partly due to migration from outside. Tripura typically represents the dilution of tribal population over a period of time because of migratory pressures from outside the states, as compared to other tribal hill states in the region (table 2). This obviously had implications in the form of social disruptions.

This circulatory movement of people from rural to urban areas and back to rural areas occurs for supplementing their sources of livelihood, whereby the city–village network is strengthened and the villages remain remarkably resilient to urban feedback (Lambert 1962;

Table 1. Urban and rural population growth (in billions) in developed and developing countries (from Kayastha 1989).

	Developed countries			Developing countries		
Year	Urban	Rural	Total	Urban	Rural	Total
1950	0·44	0·39	0·83	0·29	1·38	1·67
1975	0·75	0·34	1·09	0·81	2·17	2·98
2000	0·99	0·28	1·27	1·96	2·89	4·85
2025	1·19	0·20	1·39	3·91	2·86	6·77

Table 2. Population structure of the north-eastern region of India (from Anonymous 1971).

State	Geographical area ($km^2 \times 10^3$)	Population ($\times 10^3$)	Tribals (%)
Arunachal Pradesh	83·5	467·5	79
Assam	78·3	12911·9	–
Plains	–	12456·5	11
Hills	–	455·4	58
Manipur	22·4	1072·8	31
Meghalaya	22·5	1011·7	80
Mizoram	21·1	321·9	94
Nagaland	16·6	516·5	89
Tripura	10·5	1556·3	29

Ishwaran 1966). Such a circular flow is a mechanism for subsistence of the increasing rural population (Skeldon 1985), by extending the resource base of the village and an unavoidable outcome of the increasing population pressure on rural resources.

2.3 *Numbers versus natural resource depletion*

The impact of human beings on natural resources has often been looked upon as a direct relationship. This viewpoint follows from the biological concept of carrying capacity. However, the concept of carrying capacity cannot be applied in a simplistic way in the case of human beings since a variety of other factors such as trade, technology and consumption patterns and policy related decision making processes alter land use dynamics in drastic ways. Population pressure, at best, can be viewed as an indirect contributory factor, along with other inter-linked key drivers.

These key drivers, as is becoming more and more evident from the Indian case studies are linked to governmental policies, market forces and institutional interplay, all this being exacerbated by 'global change' and 'globalization' (Ramakrishnan 2001). Thus, the swidden (shifting agriculture) farmers of north-east India, for example, are often blamed for deforestation due to the pressure exerted on land for shifting agriculture, by the increasing local population. However, external pressures from timber extractors for industrial use of timber and the governmental policies arising subsequently could be implicated for forest resource depletion and land degradation (Ramakrishnan 1992a). Linked to policy are a variety of monetary incentives provided to promote a given land use activity, as a response to market demands. Expansion of coffee in the Kodagu district of the Western Ghat region to meet international market demands is an example of this. Forest conversions to rubber in the Kerala part of the Western Ghats is another (Ramakrishnan *et al* 2000). Closely interlinked to policy are a variety of institutions that get created over a period of time, to cope with immediate problems; the institutional interplay and inter-institutional conflicts have been shown by us to be an important factor in resource degradation under diverse socio-ecological situations – in the Nanda Devi buffer zone area in the central Himalayan region and for the sacred groves in the Kodagu region of the Western Ghats (Ramakrishnan *et al* 2000).

The implications of the differences in consumption levels between the developing and developed world is another obvious factor for resource depletion. With a consumption level, over an individual life span, which is at least 20 times greater in the developed world than in the developing countries, the *de facto* population of Europe today in terms of resource dependence is not 400 million but 8000 million (Suryakumaran 1922). Compare this with the 800 million in India. In our anxiety to curb population growth, we seem to have conveniently set aside this uncomfortable reality. Population control in developing world is critical, but is only a partial remedy to problems of resource depletion.

2.4 *Population and food security*

Agriculture is an important economic activity for a large part of the population of the developing world. In India, the green revolution, which is largely confined to a small section of rural society, for instance, has had positive repercussions in terms of general self-sufficiency in food production. But it has had its negative impacts too. Firstly, this energy intensive activity is still confined to a small sector of our predominantly agricultural society. Vast sections of our rural communities are still left out leading to wide disparities in accessing resources and in income generation arising out of effective use of natural resources with appropriate affordable technology. More and more farmers have been marginalized in spite of overall self-sufficiency in food production. This is in addition to the difficulties faced at a national level by many developing countries, including India, in gaining access to non-renewable resources like petro-based chemical fertilizers and pesticides to sustain the green revolution in the face of increasing population pressure. The larger problems of environmental degradation caused by excessive and uncontrolled use of water and chemical substances would also have to be faced. It must also not be ignored that much of the increase in agricultural production in many developing countries including India is brought about by area expansion and conversion of natural ecosystems.

A special mention of gender and poverty would be appropriate at this stage. Traditionally, women have played a key role in agricultural activities, in some form or the other. Even as agriculture employs 84% of all economically active women, the green revolution has had adverse impacts on the Indian woman (Shiva 1988; Venkateswaran 1992). From the position of being a key player in the food production system, she has been marginalized to a mere labourer.

Localized famine conditions among the more vulnerable sections of our society and in the drought-prone areas of the country are not uncommon phenomena. This is paradoxical in the context of the overall self-sufficiency in food. Famine is related to problems of distribution, lack of purchasing power due to extreme poverty and competition from those who can afford it. In essence it is a consequence of the marginalization of the already vulnerable sections of society. Within a given household, there is overwhelming evidence to suggest that women as a group are more vulnerable to poverty and its consequences than men (World Bank 1991).

A close relationship between population growth and agricultural land extension, with the latter tied directly to deforestation, has been suggested through a number of cross-country studies notwithstanding fuel wood extraction and logging operations (Billsborrow 1992). While reduction of population growth can reduce local pressures on forests and other natural resources, this relationship is by no means a simple and straightforward one. We in India are now left with a little over 10% of the total land area under closed forest cover. Our forests now are largely confined to upland areas. The most vulnerable ecosystems which are under heavy stress are those in the upland areas – the Himalayas in the north and the north-eastern hills, the Aravallis in the west, the Vindhya–Satpura ranges in central India and the Eastern and Western Ghats in the south. Growing pressures on these upland ecosystems have serious consequences not only for forest cover and biodiversity, but also for the people in the region and indeed in the sub-continent as a whole. The survival in the lowland plains is wholly dependent upon the health of the mountain ecosystem. At a local level, the worst affected are the most vulnerable sections of society which include women who have to now work harder to collect their basic needs of fodder and fuelwood.

2.5 *Population-linked social disruptions*

The migratory patterns discussed earlier namely, rural to urban, rural to rural and circulatory migration, may have serious social consequences in certain situations. The concentration of population in urban centres has already choked the natural ability of urban environments to absorb the wastes and emissions from human activities. This in turn has led to a variety of environmental hazards. A recent estimate shows that today Delhi has on its roads more vehicles than Mumbai, Kolkata and Chennai put together. Almost two-thirds of the total pollution in Delhi is from vehicles.

The circular migratory patterns whereby rural–urban or rural–rural linkages are maintained, could be viewed as strategies for coping with environmental risks. Nomadism is a lifestyle available to many rural communities dependent upon animal husbandry in the drought prone areas of Rajasthan and Gujarat. Similar is the circular migration of nomadic hill tribes between the foothills and the higher mountain ranges of the north-western and central Himalaya. Rural–rural circulatory migration, when it is from resource depleted regions to richer ones, can accelerate the process of environmental degradation. A classic example of this is seen in the north-eastern part of the country. Shifting agriculture, which till recently was sustainable because of a longer cycle of 20–30 years or more, has become unsustainable as the cycle has drastically come down to less than five years, partly because of large-scale exploitation of forest resources by industrialization and consequent land degradation. Increase in population pressure from within or through migrants is only one of the factors contributing to the break-down of the shifting agriculture system caused by the rapid shortening of the cycle. Indeed, large areas in this high rainfall region have been desertified because of pressure originating from outside the region. In the tribal areas of the north-east, the adverse consequences were ecological, social and economic (Ramakrishnan 1992a).

3. ‘Global change’ and ‘globalization’

Since the impact of ‘global change’ as an ecological phenomenon and ‘globalization’ as an economic phenomenon as well as the closely linked policy decisions and institutional arrangements are key drivers of natural resource degradation, the environmental uncertainties linked to these have to be reconciled.

3.1 *Global change*

With the advent of the industrial revolution and the subsequent rapid industrialization of the western world, wanton destruction of nature and its resources set in. Having decimated much of the natural resources of the European countries, the attention then shifted to the exploitation of the natural resources of tropical regions. The period of political colonization of Asia and Africa, which lasted up to the first half of the 20th century, was characterized by exploitation of the rich natural resource base of the tropical and sub-tropical regions of the world, for the development of the then rapidly industrializing western Europe. This period also saw colonization of the Americas and the Australian region by European settlers, at the expense of the indigenous people of these regions. With sparsely settled human populations and large geographical areas rich in natural resources available at the disposal of these settlers of the ‘new world’, industrialization of the temperate world occurred rapidly. With the setting in of the process of political de-colonization, many of the already impoverished countries, with a heavy load of foreign debt and rapidly expanding human populations resorted to further exploiting natural resources. This had to be done to earn foreign exchange, to catch up with the process of their own industrialization and feed the rapidly increasing human population. The consequences of this process of land use and land cover change is there for all of us to see. Large-scale deforestation and biological resource depletion from a variety of habitats caused through anthropogenic activities, leading to biodiversity loss on an unprecedented scale witnessed simultaneously rapid urbanization and pollution related impacts on air, water and soil. The sum total of the impact of all these anthropogenic activities is now commonly referred to as ‘global change’, which has started receiving much attention from a very large section of the international scientific community, through a number of research initiatives.

The term ‘global change’ is a term that is often misunderstood and often inter-changed with the term ‘climate change’, as if they were synonymous (Ramakrishnan 2001). There is much more to ‘global change’ than mere climate change related issues. Climate change, in the present context, refers only to human-induced changes that are being brought about through industrial emissions into the atmosphere and the consequent changes in the atmospheric elemental composition, rather than a natural phenomenon. Given the will to take collective global action, the human-induced climate change is indeed reversible, even if it takes the next 50 years. There are other changes that are more difficult to reverse for a variety of reasons. Land use linked land cover changes leading to land degradation and desertification is a global change phenomenon which can be reversed if only at a great economic cost, which many developing nations can ill-afford, from a short-term perspective. Biological invasion, the colonization of exotic species in an alien environment, is a phenomenon which has played havoc in the past and still continues to do so; water hyacinth in our water bodies or *Lantana* invasion on the land are examples of such an invasion of India. With the introduction of technologies for rapid and mass transport of men and materials, the problem of biological invasion on a global scale is more and more becoming a serious problem. This again is difficult to be controlled, once it has occurred. Apart from the economics, there are ecological and social problems that stand in the way of control of biological invasion. Biodiversity depletion is another serious global change that is totally irreversible. Biodiversity once lost cannot be recovered, as we see from the accelerated large-scale human-induced extinction of species.

Global change of an unprecedented scale creates a whole variety of environmental uncertainties, impacting upon natural and human-managed ecosystems. The challenge before the scientific community is therefore to cope with these uncertainties and maintain the desirable ecosystem resilience. It is now well recognized that biodiversity in an ecosystem contributes towards coping with uncertainties. Therefore, managing and indeed enhancing biodiversity in both natural and human-managed ecosystems has become significant.

3.2 *Globalization*

With the Uruguay round of GATT and the subsequent establishment of WTO (World Trade Organization) as part of a global economic platform and the world tending to become unipolar due to the dismantling of the Soviet Union, a new era in the world economy has emerged commonly referred to as ‘globalization’. This process aims at a greater level of integration of national economies, as part of a larger global economic order, for an efficient and equitable organization of humans on this planet. Whilst there is hope that the impact of this process will by and large be positive, there is skepticism about the wisdom of this process coming from different quarters, particularly from the developing world.

The traditional view on trade liberalization is based on the principle of a comparative advantage, which suggests that producers with a comparative advantage in production of certain goods will specialize and expand their production at the expense of others with higher cost of production of the same goods; this in turn will lead to more consumption, production and income. This emanates from a world view which assumes that natural resources are inexhaustible. The relationship between increased consumption by an increasing section of the population and environmental degradation seems to be an obvious consequence, viewed from the present day context of the great divide that already prevails between the rich and poor nations. On the other hand, those who argue for trade liberalization and globalization of economies, argue that increased incomes would enable higher spending on improved environmental quality.

The process of trade liberalization and globalization which has been put in place, is perhaps a *fait accompli*. The impact of globalization is still a matter of debate, with economists taking different positions in this regard. Those who argue in favour of it take the position that all countries would gain from this process. The poorer countries are viewed as being able to pull themselves out of the poverty trap, because of greater access to the markets of the rich countries. The contrary view point takes the position that globalization may create a whole range of opportunities and benefits for many and may even improve the environmental quality in some situations, but the impacts may not be uniform. The argument is based on the fact that socio-ecological and institutional settings differ widely amongst nations (Dragun and Tisdell 1999). With such a diversity between nations of the world, developing countries, particularly those already under stress from ecological fragility and social disruptions may be at a greater risk, as a consequence of globalization. Given the diversity in viewpoints, what seems to emerge from these discussions is the pressing need for analysis of policy initiatives in a wide range of settings.

The following conclusions seem to emerge on socio-ecological issues of concern to us. Global level generalizations are difficult in view of the great diversity in ecological, social and economic systems. A differential impact between the developing and the developed world could be expected. By and large, it may benefit many countries in terms of GNP, but differential outcomes could be expected for different sections of societies within a given nation/region. This is particularly true for the developing world, where social problems are already very acute with the intense population pressure and a vast section still living below the poverty line. Absence of basic endowments like food security despite self-sufficiency in food production at the national level, access to basic educational, health and hygiene, etc. are some of the specific issues linked to poverty. The danger of an increasing divide between the rich and the poor in the immediate future is very real.

It is even harder to predict the impact of globalization on ecological issues (Ramakrishnan 2001). Deforestation and natural resource depletion could occur, with much of what is conserved being chiefly confined to nature and biosphere reserves, or some form of protected areas placed in a monotonous, mono-cultural landscape of crop fields of high yielding crop varieties supported through high technology interventions such as biotechnology. This would also mean that many of the traditional production systems that harbour crop biodiversity will be out-competed by homogenization of agricultural practices. Whilst energy intensive agriculture is better sustainable in temperate climatic conditions, the experience of declining production, associated with rapid land degradation recognized in recent times, in the case of the green revolution agriculture of Punjab and Haryana, has become a matter of concern for the long-term sustainability of such systems in the tropics. Perhaps the soils developed under tropical climate demands land use diversification through such practices as agroforestry and social forestry systems to ensure landscape integrity; this seems to be much more critical for the tropics than for the temperate world. Pollution problems could get aggravated in the resource-poor developing countries in the immediate future, with long-term impacts arising from them.

The rate at which natural resources are used up for the growth of world economy outstrips the rapid growth of population. While developed countries of the world use up a large chunk of the world's natural resources for supporting a much smaller population, population pressure is the bane of the developing world, despite the highly restricted per capita demand on resources in the developing regions of the world. It is important to recognize that generally larger family size in developing countries is considered a means to ensure risk coverage arising out of extreme poverty. Therefore, a holistic approach encompassing sustainable livelihood/development, education and empowerment and family planning measures is crucial to tackle the problem. The problem of coping with the twin problems of population and resource depletion has to be viewed in this context.

4. Socio-ecology of biological resource rich areas

4.1 *Ecological diversity linked to cultural diversity*

Having decimated much of our biological resources in the plains of India, we are now left with pockets of biodiversity concentrated in remote and relatively inaccessible areas of the mountains. These are the areas in which much of our 'traditional' societies (societies that live close to nature and natural resources) also live. These traditional societies are largely comprised of, what are often referred to as 'tribal' societies, in a socio-political context. In an anthropological sense, it denotes certain categories of perliterate cultures, though the term covers a wide range of forms of societal organization and levels of techno-economic development (Dube 1998). However, since many rural hill societies (e.g. Kumaon and Garhwal) more or less fit into this category in an socio-anthropological and ecological sense, the term 'traditional' is more appropriate. These traditional societies, during the period of social evolution in the Indian sub-continent were pushed into more remote and biologically rich hill areas. It is reasonable to assume that this process of migration of traditional societies into the upland areas also coincided with the gradual depletion of biodiversity in the plains of the country, the livelihood concerns of these society being driven by biodiversity (Ramakrishnan 1992a, 1994). It is in this context that ecological-cultural linkages have to be viewed.

Of the 2800 culturally distinct communities living in India, tribals belong to over 600 ethnic communities, belonging to equally diverse linguistic groups (Dube 1998) and constitute over 8·5% of the total population. They are largely concentrated in the north-eastern hill region, central India, the ghat region of southern India, with lesser distribution in many other parts of the country (Sinha 1993). However, if we look at the picture in a broader context of 'traditional mountain societies', we are dealing with a much larger proportion (about 25%) of the total population. The cultural diversity amongst these traditional societies could be gauged when we see that a small region like the north-eastern hill area alone has over a hundred different tribes, with their own distinct cultural identity in terms of language, music, dance forms, etc.

In this context, if we look at the ecological zones of the country, we have on one extreme, the dense tropical evergreen forest in the Western Ghat region in southern

India, various deciduous forest types in the Eastern Ghats, central Indian uplands and in the western and central Himalayan foot hills. The Himalayan region itself is ecologically very diverse. Ranging from the dry desert conditions of the Ladakh region in the extreme north-west, moving on to dry deciduous forests as one moves towards the central Himalaya, leading to extremely fragile rain forests of the north-east along the longitudinal gradient, the Himalayan region have a range of ecosystem types. Over an altitudinal gradient, one comes across a whole variety of other ecosystem types ranging from sub-tropical forests, moving on to temperate conifer/broad leaved forests, reaching up to alpine meadows. Such a high ecological diversity is matched by rich cultural diversity, ranging from the typical predominantly Indo-Aryan hill societies of Jammu and Kashmir, except for the mongoloid population at the higher reaches of the mountains, with increasing degrees of mongoloid traits appearing as one moves along eastwards, with a large complex of tribal societies of south-east Asian origin in the extreme north-eastern region. This complex interaction at a socio-cultural level has led to the evolution of a whole complex of traditional ecological knowledge (TEK), with socio-ecological imprints on them, that are location-specific in many respects. TEK, indeed is a connecting link between ecological and social processes influencing natural resources linked with traditional societies (Ramakrishnan 2001). The challenge before us, therefore, is to understand the complexity in TEK arising out of the interaction between ecological diversity and social diversity and at the same time be able to make generalizations that could cut across socio-ecological specificities.

5. Traditional ecological knowledge in the socio-ecological context

Traditional societies have accumulated a whole lot of empirical knowledge on the basis of their experience dealing with nature and natural resources. This traditional wisdom is based on the intrinsic realization that man and nature form part of an indivisible whole and therefore should live in partnership with each other. This ecocentric view of traditional societies is widely reflected in their attitudes towards plants, animals, rivers and the earth. This reverential attitude concretized itself in iconography and imagery of sculptural forms – a way of transmitting the timeless truths of man–nature ethics (Vatsayan 1993).

Indeed, in recent years, one of the concerns of ethnobiologists and those concerned with sustainable development has been to evaluate ethnobiological information of value derived from the natural environment in which traditional societies live. Such an evaluation has become important in the context of rapidly depleting biodiversity due to a variety of human activities adversely impacting upon the natural resource base. The benefits of ethnobiological significance could be varied: (i) Economic – traditional crop varieties and lesser known plants and animals of food value and medicinal plants, harvested from the wild, (ii) Ecological/social – manipulation of biodiversity for coping with uncertainties in the environment and in the present day context of ‘global change’, for controlling soil water regimes and hydrology, soil fertility management through soil biological processes and for efficient organic residue management, (iii) Ethical – considerations reflected in the cultural, spiritual and religious belief systems centred around the concept of the sacred species, sacred groves and sacred landscapes (Ramakrishnan 2000a).

5.1 *Ethnobiology*

The economic considerations such as the traditional value of biota as a source of food, lesser known uses in traditional medicine or as non-timber forest product (NTFP), in an ethno-biological sense are important from the point of sustainable livelihood concerns of societies (Ramakrishnan 2000a, 2001). These are also well documented (National Academy of Sciences 1975; Jain 1991; Berlin 1992; Hladik *et al* 1993). Many of the crop species are cultivated, as part of multi-species complex agroecosystems by traditional societies (Swift *et al* 1996) and medicinal plants are cultivated as part of a cash cropping system (Ramakrishnan *et al* 2000). What is, however, significant about sustainable management of natural resources is TEK operating at the process level, linking the ecological with the social. Therefore, the emphasis here is on these process level socio-ecological linkages.

In India alone at least 76 species of animals – 16 invertebrates and 60 vertebrates, are known to be part of tribal medicine. Over 9500 wild plants are recognized to be of ethnobotanical value of which over 7500 are used in medicine, 3900 as edibles, 500 for fibre, 400 as fodder and 300 plants are used as pesticides with many of them having potential for commercial exploitation (Ministry of Environment and Forests 1994). With such a rich tradition in India and equally diverse systems elsewhere in the tropical world, the opportunities to develop them for building the local economy are immense.

5.2 *Interconnections between ecological and social processes*

5.2a *Socio-ecological system complexity*: The traditional approach to the role of biodiversity in ecosystem functioning, humans are often kept out of the definition of the ecosystem boundary. 'Traditional societies' living in natural resource rich regions of the tropical world, being dependent upon this resource for their livelihood requirements, still function as an integral part of the functioning of the ecosystem. In such a context, the role of biodiversity in ecosystem functioning will change drastically. The social, economic and cultural dimensions of the humans would also play a crucial role in determining ecosystem properties. Such a shift in our understanding of the relationships between the ecological and social processes would also have its implications for the sustainable management of natural resources with peoples' participation in developing countries.

The concept of the village as an ecosystem amongst traditional tribal societies, with all its ramifications involving agriculture, animal husbandry and the domestic sector enmeshed with the forest and forest-related activities such as hunting and gathering of food, fodder, fuelwood and medicinal plant collection, as also the forest-linked traditional farming practices such as shifting agriculture and a variety of other complex agricultural systems are examples of humans integrated within the ecosystem boundaries and for evaluating the role of biodiversity in ecosystem function in a broader context (Ramakrishnan 1992; Swift *et al* 1996). This implies that conserving biodiversity is crucial for immediate survival.

The way in which traditional societies perceive and manipulate biodiversity around them in the landscape, both in space and time is important to ensure ecosystem stability and resilience, in the context of global change. These societies have evolved ecologically sound biotechnologies, based on the empirical knowledge accumulated over a period of time, to deal with land use management issues such as soil fertility and soil water regimes (figure 1). Capitalizing upon this knowledge base and adapting it to contemporary situations through input of modern science and technology is now being seen as critical for managing natural resources sustainably. Peoples' participation has become even more important in the context of 'global change' (Ramakrishnan *et al* 1996). Many of these ecologically sound ethnobiological knowledge of traditional societies is often embedded in their belief system through culture and religion (Ramakrishnan *et al* 1998). At the rate at which 'global change' is occurring, a major proportion of all species on earth will be lost over the next century and yet it is these species we need to build a secure future (Raven 1995). There is an increasing realization that in many ecological/social situations, TEK should be an integral part of a holistic and cost-effective approach to sustainable development; hence the greater emphasis on the ecological/social component.

5.2b *Traditional multi-species complex agroecosystems*: Process level relationships operate at the individual species, population, ecosystem and landscape levels (figure 2). One of the earliest attempts to move in this direction is that of Conklin (1954) who distinguished two distinct swidden systems whilst dealing with Hanunoo forest farmers in the Philippines – (i) the 'partial' and the integral types, the former being migrants from outside and using swidden as a simple means of producing a crop and (ii) the 'integral' which reflects the traditional, year-round, community-wide, largely self-contained and ritually sanctioned way of life. Subsequently, Kunstadter and Chapman (1978) have attempted a classification of the swidden systems in Thailand on the basis of the use of resources and the relationships between cultivation and fallow periods in these agroecosystem types. These authors have further elaborated this typology for north-east India, taking into consideration ecological, socio-economic and cultural dimensions (Ramakrishnan 1992a).

Indeed, traditional societies maintain a variety of complex multi-species agroecosystems, operating under varied levels of intensification (figure 3). Ranging from

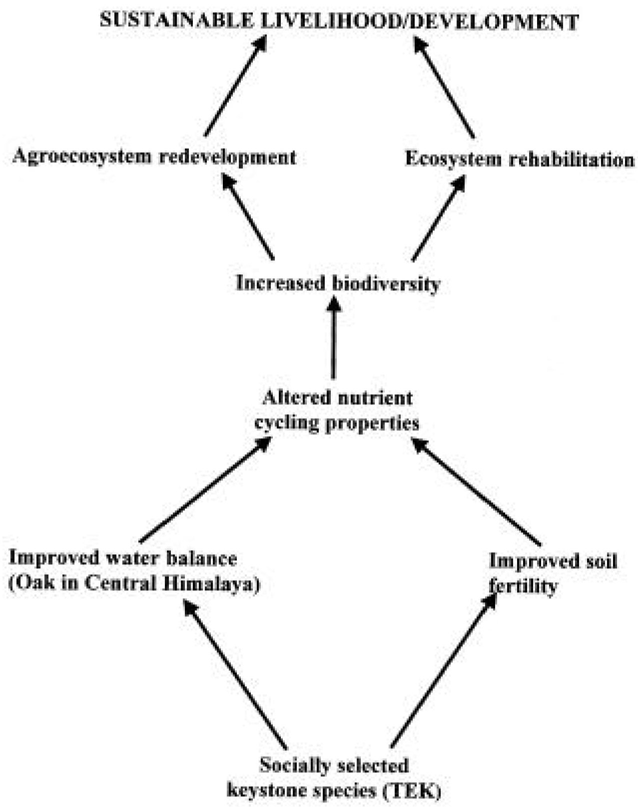

Figure 1. TEK centred around the socially selected keystone species, *Quercus* spp, acting as a trigger for soil fertility recovery and water resource mobilization and thus towards rehabilitation of the degraded mountain landscape in the central Himalaya (from: Ramakrishnan 2000c).

casually managed shifting agricultural systems through a whole variety of rotational fallows, agroforestry systems, compound farms, traditional cash cropping systems, crop rotation systems, etc. at the middle intensity levels, leading to modern high input agriculture, we are dealing with over a hundred typologies. The complexity of these agroecosystems are due to biodiversity (sub-specific and species level-crop and associated biodiversity) both in space and time.

Of all the traditional agroforestry systems, a special mention should be made of the concept of 'home gardens' in the tropics, variously termed as kitchen gardens or forest gardens, with structural variations, functional differences and spatial complexity. They show much variation in their structural and functional attributes depending upon the ecological and social settings in which they occur. Imitating a natural forest with a highly stratified and compacted set of economically important trees, shrubs and herbs in small plots of 0·5 to 2 ha, these gardens could have over a hundred species (Millat-e-Mustafa 1998). The farmer is able to obtain many of his requirements such as food products, firewood, spices, ornamentals and medicinal plants from this system, all

Figure 2. Descriptive and process linked TEK at the ecosystem/landscape level understanding of the anthropological, social, socio-economic and cultural dimensions of ecological functions (from: Ramakrishnan 2000c).

the year round. Detailed economic and energy output/input analysis done on the north-east Indian systems (Ramakrishnan 1992a) suggest that these systems are indeed very efficient.

Under declining soil fertility and site degradation, as in Cherrapunji in north-east India, the shift from shifting agriculture to home gardens could be viewed as a human response based on TEK (Ramakrishnan 1992a). This is contrary to suggestions that home gardens are confined only to more fertile soils (Millat-e-Mustafa 1998). Indeed, TEK-based changes in garden diversity, structure and management have been reported (Gliessman 1990) from the upland central region of Mexico, as a response to industrialization and population increase. Such adaptations are a response to labour constraints, available off-farm employment opportunities and insurance against possible loss of outside income.

However, we need to know much more on the organization and functioning of these unique human-managed ecosystems. In the Indian context, home gardens provide a window for introducing family-based cash crop economy in areas where traditional societies live, the reason being that large-scale cash-crop plantations will encourage a migrant labour force, which is often resisted by local people. TEK will play a crucial role in building such a redeveloped system, with community participation. In their effort to adapt to 'global change', this strategy appears to work, since the developmental process has to be based on a value system that the society is able to relate with.

5.2c *Agro-ecosystem biodiversity manipulations*: It is not only the mere presence of biodiversity and the functional role it has for tribal humans that is significant, but the manner in which the traditional societies manipulate this biodiversity for ecosystem functional attributes and landscape integrity are interesting. In the shifting agricultural hills of north-eastern India, for example, the number of species in a mixed cropping system declines drastically with shortening of the agricultural cycle (Ramakrishnan 1992a). 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 the use of species which use nutrient efficiently 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. Through mixed cropping involving a large number of species in space and time and traditional weed management strategies, shifting the agricultural farmer of north-east

India ensures effective check on nutrient loss during the cropping phase. The traditional weed management practice, where about 20% of the weed biomass is left undisturbed in the plot by the shifting agriculture farmer is also a practice common to Mayan agriculture in Mexico, with implications for agroecosystem sustainability (Altieri and Liebman 1988).

Ecosystem/landscape level manipulations also are known, whereby traditional societies have been able to ensure integrity of the systems at these levels. The Apatani tribe in north-east India has 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 (Ramakrishnan 1992a). Widening plots by digging adjacent higher ground down to an irrigable level seems to be a successful response to population increase and new market opportunities, as also demonstrated for the Tara'n Dayaks of West Kalimantan in Indonesia (Brookefield and Padoch 1994).

The lessons learnt from such manipulations of biodiversity done both in space and time, as an adaptation to a variety of 'global change' related issues – population pressure, land degradation, biological invasion and climatic uncertainties, are important for biodiversity management in resource rich regions of the tropics (Ramakrishnan *et al* 1996) and indeed for designing strategies for agroecosystem redevelopment (Swift *et al* 1996).

5.2d *Pathways for agroecosystem redevelopment*: The high-energy intensive 'modern agriculture' pathway has come to stay. However, additional pathways for sustainable agriculture are available, but they still remain underexplored. The two additional pathways available are centred around building upon the TEK that is embedded in the traditional multi-species complex agroecosystems that are maintained by traditional societies, who also happen to be the custodians of the rich agroecosystem biodiversity. The TEK centred around cropping patterns both in space and time is based on: (i) optimizing production often along a nutrient gradient where it occurs, (ii) synchrony in nutrient release from the soil and uptake by the crop, (iii) efficient recycling of biomass residues, and (iv) weed management rather than weed control. The objective here is to strengthen internal processes within the agroecosystem, rather than depending on external energy subsidies for relative stability and resilience within the system (Gliessman 1990; Ramakrishnan 1992a; Woomer and Swift 1994; Altieri and Liebman 1988). These agroecosystems can be organized along a gradient in the

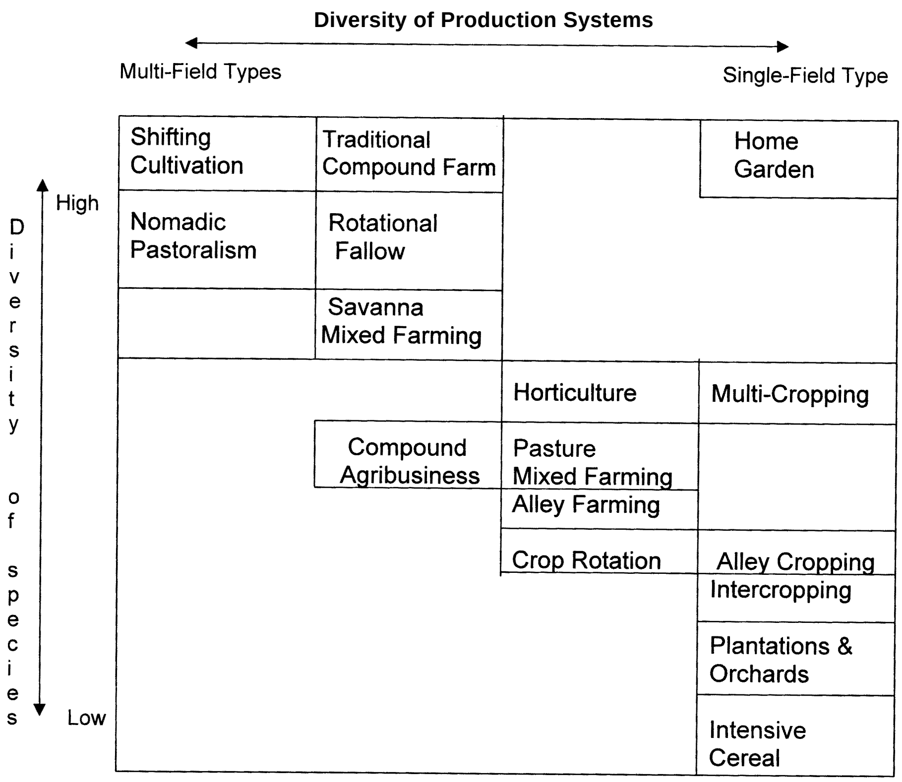

Figure 3. Broad agroecosystem typologies linked to species richness and agroecosystem complexity (from: Swift and Ingram 1996).

intensity of their management. In the ‘middle intensity’ management range come a whole variety of agroforestry systems that are adapted to specific ecological situations and could be developed further to follow the ecological contours – the ‘contour pathway’. Very often, one may have to build upon traditional systems in a step by step manner, this approach often being necessitated due to ecological/social/cultural constraints under which traditional societies function – the ‘incremental pathway’ (Swift *et al* 1996). The objective in all these TEK-based redevelopmental efforts is to maximize productions with concern for *in situ* conservation of agro-biodiversity. Based on the efforts of this author, there is a major initiative in the state of Nagaland, towards a redeveloped shifting agriculture based on TEK, operating through the state government with support from the India–Canada Environment Facility (NEPED–IIRR 1999) 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 spread out in 5500 ha of replicated test plots in 870 villages, covering a total area of 33,000 ha (38 ha per village × 870 villages). In these plots, local adaptations and innovations for activities such as soil and water management are emphasized. Though an interesting developmental experiment to find a solution to the vexed problem of jhum which has defied solution for over a hundred year, many corrective measures may have to be incorporated to address the perceived deficiencies as this effort progresses.

6. Socially valued keystone species for agroecosystem/forest ecosystem management

The role of socially selected ecologically significant 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 not only for managing pristine ecosystems (Ramakrishnan 1992a), but also for building up biodiversity in both natural and human-managed ecosystems through appropriately conceived rehabilitation strategies (Wali 1992; Lamb and Tomlinson 1994) that will ensure people’s participation (Ramakrishnan *et al* 1994a, b). Though the information on this interphase area between ecological and social processes is limited, the following will illustrate the kind of future opportunities.

In many areas in north-east India where the shifting agricultural cycle has come down to less than 5 years with the landscape getting highly degraded, a specially valued legume crop of lesser known food value, *Flemingia vestita* is used both in space and time under a 1–2 year rotational fallow system or sedentary system of agriculture (figure 4). By fixing 250 kg of nitrogen per hectare per year, this keystone species ensures sustainability of these low-input agroecosystems with altered cropping patterns, under conditions of extreme pressure on the land and low soil fertility (Ramakrishnan 1992a).

In the successional forests of the north-eastern hills of India, a variety of socially selected species are also ecologically significant keystone species (Ramakrishnan 1992a). Nepalese alder (*Alnus nepalensis*), a nitrogen fixing species, 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 agriculture linked forest successional processes. Such an interphase between ecological and social processes is critical for biodiversity management in the context of ‘global change’ (Ramakrishnan *et al* 1996) and has only just started receiving attention. Such keystone species could occur also within the sacred groves maintained by traditional societies (e.g.

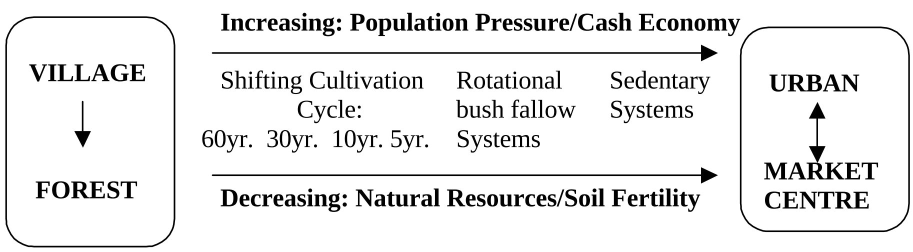

Figure 4. The land use changes as related to population pressure, land degradation and available linkages to a market economy. These pressures decline as one moves away from the urban center in north-east Indian uplands. Note that the swidden system is replaced by rotational fallow system leading to sedentary farming when one moves closer to the urban center (adapted from: Ramakrishnan 1992a).

Englehardtia spicata, *Echinocarpus dasycarpus*, *Syzygium cuminii* and *Drimycarpus racemosus*) that conserve high levels of nitrogen, phosphorus and potassium in highly infertile soils within a sacred grove in northeast India. Manipulating these keystone species is an effective way of managing biodiversity with people's participation within ecosystems and during rehabilitation of degraded ecological systems.

At a landscape level manipulation, many traditional societies such as the Tara'n Dayaks of west Kalimantan, Indonesia (Brookfield and Padoch 1993) and others elsewhere (Ramakrishnan *et al* 1994a) establish forest reserves within the forest–agriculture landscape and formulate rules about the use of the resources within, with implications for sustainability. In the ultimate analysis, linking silviculture with ecological considerations in the context of the socio-economical needs of the societies will determine the success obtained in tropical forest management (Ramakrishnan 1992b).

7. Conserving the sacred: Species to landscape level interconnections

Many traditional societies all over the world maintain protected refugia of the natural ecosystem in a given region as 'sacred groves'. A variety of cultural beliefs and practices associated with them have provided a 'social fencing' for these relict ecosystems now often occurring as part of a derelict landscape, otherwise heavily impacted by humans (Ramakrishnan *et al* 1998). Many such groves exist all over the tropics; the ones that occurred in Europe, however, have all disappeared due to industrialization.

'Sacred landscapes', with a set of interacting ecological systems – both natural and human-made, with village ecosystems integrated within – are an extension of the sacred grove (ecosystem) concept. The sacred landscape of the Ganga river system of the central Himalayan Garhwal region in India, a whole variety of landscapes sacred to the Buddhists in the eastern Himalaya and the south and south-east Asian region (Ramakrishnan *et al* 1998) and many sacred mountains such as the holy hills of the Dai tribe who inhabit the Xishuangbann in Yunnan province in China (Messerli and Ives 1997) are all examples of biodiversity conservation and natural resource management based on TEK. In Latin America the pre-Hispanic cultures managed complex ecotechnological systems which through an extended historical process of cultural adaptation reached a surprising degree of stability. The Mesoamerican and Andean highlands, the grazing systems involving native Camelidae in the Punas; the quite complex lacustrine agricultural systems of the Mexican 'Chinapas', the Zenu hydraulic society in the Caribbean lowlands of Colombia and the shifting agricultural systems that permitted maintenance of forest ecosystem diversity such as the Amazonian and Mayan forests of Mexico are examples of the role of indigenous cultures in sustainably managing natural resources and contributing to development and refinement of their civilizations (Monasterio 1994).

A reductionistic view of the sacred grove concept (Ramakrishnan *et al* 1998) will lead to the concept of the 'sacred species'. The species recognized in this category are either ecologically important 'keystone species' or have economic value. There are many medicinally valued species such as the sacred Basil (*Ocimum sanctum*) or 'neem' (*Azadirachta indica*), worshipped in all traditional Hindu homes and recognized as a multi-purpose medicinal plant. This latter species has come into the limelight in recent times because of the active principle which has been successfully extracted and chemically stabilized and patented by the industrialized west for its pesticidal properties, though this species has been part of the Indian traditional systems of medicine since antiquity.

The state-of-the-art ecological knowledge on conserving this sacred cultural heritage is now synthesized (Ramakrishnan *et al* 1998), in view of the renewed interest in biodiversity conservation and seeking new paradigms for the sustainable management of natural resources. If ecology, economics and ethics are viewed as parts of an interconnected circle that stands broken at present (Bormann and Kellert 1991), we are looking for a shift in the developmental paradigm leading to the sustainability of our biosphere. Building upon TEK is one of the powerful tools that can move us in that direction. Within the sacred groves and landscapes, there exist a variety of socially valued and ecologically significant keystone species. Many of the sacred species such as *Ficus* spp. found all over Asia and Africa, *Quercus* spp. in the central Himalayan region, Nepalese alder (*Alnus nepalensis*) in the eastern Himalayan and north-eastern hill region, *Prosopis cineraria* in the arid regions of Rajasthan, found both within and outside sacred groves/landscapes are again ecologically significant keystone species performing key functions, which they either perform on their own or through the associated biodiversity that they generate. The concept of the 'sacred' species provides a basis not only for natural resource management, but also for rehabilitation of degraded ecosystems with community participation.

8. Landscape management and monitoring

In a landscape, we deal with both the natural as well as the human-managed ecosystems. The latter, as discussed earlier could have three distinct agroecosystem development pathways. All these pathways are significant, but the land apportioned to each could vary. Having more than one of these pathways is important for sustainable agriculture at a landscape level. In biodiversity rich mountain areas, we may have to emphasize more upon 'incremental' and 'contour' pathways, because of the socio-ecological conditions prevailing there but much less on modern agriculture (Ramakrishnan 2000b). On the other hand, in areas where 'green revolution' agriculture is already in place, a greater emphasis might have to be placed on agroforestry systems coming from the 'contour pathway', to counter the ill-effects of the former.

There are many lessons that one could learn from traditional societies, in terms of effective agroecosystem/landscape management itself. Learning from adaptive social evolution of TEK-linked land use practices of these societies could be an important lesson one could learn to cope with 'global change' related uncertainties. Apart from process level linkages discussed earlier, system level connections could be made using appropriate traditional technologies. Redeveloping traditional water harvesting systems, to use water as a triggering agent to alter and manage both natural and human-managed ecological systems and to trigger processes in rehabilitation ecology (Ramakrishnan 1992a, b; Ramakrishnan *et al* 1994b) illustrates the significance of system level linkages, under monsoonal climate conditions with a long dry season.

Realizing that biodiversity and ecosystem complexity do contribute in a variety of ways to ecosystem functions and that agroecosystems do harbour a great deal of biodiversity valuable for general human welfare, it is reasonable that we go in for a mosaic of natural ecosystems coexisting with a wide variety of agroecosystem models derived through all the three pathways. The relative area apportioned for each of these land use units would be determined by ecological and social location-specificities. In a landscape mosaic, agroecosystems form one, though important, of the components of a wide variety of ecosystem types. These are natural systems such as forests, grasslands and fresh water ponds or lakes, interspersed with human-managed agricultural monocropping systems such as rice, wheat or maize fields and village woodlots. A highly diversified landscape unit is likely to have a wide range of ecological niches conducive to enhancing biodiversity and at the same time ensuring sustainability of the managed landscape itself.

Viewed in this context, sustainable development has to be evaluated using three major currencies and a variety of indicators within each one of them. Monitoring and evaluation have to be done using these diverse currencies (Ramakrishnan 1992a, 1993) that may be: (i) ecological (landuse changes, biomass quality and quantity, water quality and quantity, soil fertility and energy efficiency), (ii) economic (monetary output/input analysis, capital savings or asset accumulation and dependency ratio), (iii) social (quality of life with more easily measurable indicators such as health and hygiene, nutrition, food security, morbidity symptoms; measures which are difficult to quantify such as societal empowerment and the less tangible ones in the area of social and cultural values). All these diverse currencies have been considered to arrive at a meaningful sustainable developmental strategy for the north-eastern hill areas of India (Ramakrishnan 1992a).

Further, institutional arrangements have to ensure peoples' participation, through a bottom-up approach for their organization, ensuring that each household takes part in the decision making process at the lowest level in the hierarchy and with special dispensation for the weaker and vulnerable sections of the society. The Village Development Boards (VDB) of Nagaland is a case relevant to this discussion (NEPED and IIRR 1999). Village based institutions such as the VDBs of Nagaland are formed with due representation given to each family, taking into consideration gender sensitivities and more importantly by allowing the formation of local boards based on the local value system that they have always cherished and conserved. Such village level institutions could be successfully broadened with inputs from scientists, non-governmental organizations (NGOs), and governmental agencies, as has happened with joint forest management committees that have become so successful in many regions of the Asian tropics (Ramakrishnan 1992b, Ramakrishnan *et al* 1994a, b).

The local level institutional framework, should consider the following aspects: (i) identification and strengthening of local level institutions that are already available such as those existing in the north-eastern region, (ii) the representative nature of these bodies and the extent to which individual family interests are taken care of, (iii) their role in decision making right from the project formulation stage through different levels of implementation, (iv) flexibility in function so as to take care of the interests of all sections of the society, (v) education and human resource development that these institutions have been able to trigger, particularly for weaker and vulnerable sections of society, (vi) ability of these institutions to stand on their own through empowerment in terms of capability building. These were the considerations that formed the basis for developing socio-ecological guidelines for rehabilitation of degraded ecosystems (Ramakrishnan *et al* 1994b) and sustainable livelihood for local communities in the Asian tropics (Ramakrishnan 1995). In the ultimate analysis, sustainable development is indeed a series of compromises, made both in space and time and depending upon the ecological, social, economic and cultural dimensions of the problem in hand (Ramakrishnan 1998).

The more recently evolved 'biosphere reserve' concept of UNESCO, indeed a rediscovery of the concept of the 'sacred landscape' of traditional societies dating back to antiquity, is an attempt towards such an integrated management strategy to conserve natural resources for sustainable use with inter-generational equity concerns.

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