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Linking natural resource management with sustainable development of traditional mountain societies

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Abstract: Both in a biophysical sense and in terms of the human dimensions of the problems, mountains form a highly heterogeneous landscape. Largely occupied by traditional societies, those living close to nature and natural resources, these mountain societies are linked to the natural forest ecosystem and the human-managed agroecosystems through biodiversity driven traditional ecological knowledge. This knowledge base operates at varied levels of ecosystem complexity – sub-specific/species levels going right up to the landscape level complexity. This paper analyses the special features of this socio-ecological system complexity and considers various possibilities for sustainable management of natural resources, with concerns for sustainable livelihood of mountain communities.

Resumen: Las montañas conforman un paisaje muy heterogéneo tanto en sentido biofísico como en términos de las dimensiones humanas de los problemas. Ocupadas en gran medida por sociedades tradicionales, que son las que viven cerca de la naturaleza y los recursos naturales, estas sociedades de montaña están ligadas al sistema forestal natural y los agroecosistemas con manejo humano por medio de un conocimiento ecológico tradicional regido por la biodiversidad. Esta base de conocimiento opera a varios niveles de la complejidad del ecosistema – desde niveles subespecífico y específico hasta la complejidad del nivel ecosistémico. Este artículo analiza los atributos especiales de esta complejidad del sistema socioecológico y considera varias posibilidades para el manejo sostenible de los recursos naturales, basado en el interés por la provisión sostenible del sustento para las comunidades de montaña.

Resumo: Quer do ponto de vista biofisico quer em termos da dimensão humana dos problemas, as montanhas formam uma paisagem muito heterogénea. Ocupadas maioritariamente por sociedades tradicionais, vivendo perto da natureza e dos recursos naturais, estas sociedades serranas estão ligadas ao ecossistema florestal natural e aos agro-sistemas geridos pelas populações através do conhecimento da biodiversidade ecológica tradicional. Esta base de conhecimento opera a níveis variados da complexidade do ecossistema – espécies sub-específicas/níveis de espécies indo directamente até ao nível de complexidade da paisagem. Este trabalho analiza os aspectos especiais da complexidade deste sistema sócio-ecológico e considera várias possibilidades para a gestão sustentada dos recursos naturais, com respeito pelas condições de vida das comunidades serranas.

Key words: **A**groecosystems, biodiversity conservation, landscape ecology, mountain societies, natural resource management, traditional ecological knowledge.

Introduction

Mountains are also global centres of ecosystem complexity (biodiversity defined ecologically in its broadest sense – sub-specific, species, ecosystem and landscape levels). Their steep slopes and sharp gradients render their ecosystems very fragile. In the developing tropics, these fragile mountain ecosystems are being constantly exploited for the rich natural resources they contain - resources such as timber, the biodiversity that they harbour, medicinal plants from the wild, mineral resources, water resources for hydro-electric power generation, etc. Apart from the dependence of mountain societies themselves on the forests around them, to meet a variety of their daily needs, such as food, fodder, fuel wood, medicine and other non-timber forest products (Ramakrishnan *et al.* 2002), they indirectly depend on forest resources to sustain a variety of multi-species complex agro-ecosystems, ranging from shifting agriculture (swidden) systems to a variety of traditional sedentary agricultural systems, plantation systems and home gardens (Ramakrishnan 1992a).

Mountain societies in the developing world are largely dependent on land use activities linked to biodiversity for their livelihood concerns. These *'traditional societies'* (living close to nature and natural resources), are at various stages of social evolution. Being dependent on *traditional ecological knowledge* (TEK) linked with the manipulation and use of biodiversity various ways, which forms the basis for their link with nature, the varied levels of refinement depend on the level at which the society finds itself in the social evolutionary scale (Ramakrishnan 2001; Ramakrishnan *et al.* 2000). Consequently, the traditional mountain societies of the developing world view their mountain systems as socio-ecological systems, where humans form part of the ecosystem functioning (Ramakrishnan 1999).

Because of an exploitative approach from the rest of the society, the economic development of mountain societies has not received the kind of the attention it deserves from the developmental agencies. The economic well- being of the mountain societies is increasingly threatened by 'global change' in an ecological sense and by the 'globalization' of economies (Ramakrishnan 2001). This is the context in which the eco-sociological characteristics of the mountain regions in the developing tropics should be viewed for managing sustainable development linked to natural resource.

The concept of a cultural mountain landscape still remains a vibrant and viable entity in the developing-country context. The mountain landscape has here a variety of natural and human-managed ecosystems, and even 'sacred groves' (sacred ecosystems) or 'sacred landscapes' protected for cultural/religious reasons. In this context, it is important to look at these ecosystem types, understand their functional attributes and learn lessons which may be relevant for managing 'cultural landscapes' as integrated socio-ecological entities in a sustainable manner. In the developing-country context, *traditional ecological knowledge* (TEK) plays a pivotal role in this (Box 1).

What is 'Global change'?

The term *'global change'* is often misunderstood and often interchanged with *'climate change'*, as if the two terms were synonymous. There is much more to 'global change' than issues related solely to climate change (Bondeau *et al.* 1997). Climate change can be viewed from two different perspectives: as a natural phenomenon caused by geological events, such as in the earlier geological history of our planet; this is beyond human control. When we talk of climate change, in the present context, we are only concerned with human-induced climate changes brought about through industrial emissions into the atmosphere and the consequent changes in the atmospheric elemental composition. Given the will to take collective global action, human-induced climate change is reversible, perhaps over the next fifty years or so. There is a whole variety of other types of changes that are interlinked, but more difficult to disentangle, or indeed to reverse. Land cover changes connected with land use and leading to *land degradation and desertification* is a global change phenomenon (UNEP 1992) which can be reversed only at great economic cost, something many developing nations can ill-afford, from a short-term perspective. *Biological invasion*, the colonization by 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 this in India (Ramakrishnan 1991). With the introduction of technolo-

Box 1. Traditional Ecological Knowledge (TEK) system prevalent among mountain societies (Ramakrishnan 2001; Ramakrishnan *et al.* 1998).

TEK with benefits accruing from it is of three kinds:

(i) *Economic* - traditional crop varieties and lesser-known plants and animals of food value; medicinal plants and the traditional medical practices that are gaining importance in the present-day context; and a variety of non-timber forest products (NTFPs) harvested from the wild.

(ii) *Ecological/Social* - manipulation of biodiversity for coping with uncertainties in the environment, which in turn determine ecosystem related processes such as aboveground and belowground biodiversity and ecosystem structure, soil water balance, soil fertility management practices related to organic residue, nutrient cycling, etc. At a species level, socially/culturally valued plant species, such as many bamboo species in the swidden system in north-east India, or the oak species in the central himalayan region, are valued for improving soil characteristics and nutrient cycling processes in the natural and human-managed ecosystems.

- The complexity of a variety of agro-ecosystems maintained by traditional societies is due to TEK-based biodiversity (sub-specific and species level---crop and associated biodiversity) management, both in space and time. This forms the basis of their ability to cope with uncertainties in the environment and maintain a sustained production level, though at a low subsistence level.
- The TEK base is often converted into traditional technologies, which has relevance for sustainable management of natural resources and improving the sustainable productivity of the system. To cite an example, in a recent attempt to develop a sustainable soil fertility management practice in the tea gardens of the western ghat mountains in southern India, keystone species of the soil ecosystem, such as native earthworm species, which is part of TEK in many traditional societies, are integrated with appropriate organic residue management. This has enabled the reduction of the input of inorganic fertilizers by as much as 30-50 percent, and thus makes the tea plantation system more sustainable.

(iii) *Ethical – Cultural, Spiritual and Religious* - The social institutions linked to biological resource management are often linked to religious myths and socio-cultural belief systems. Such a concept of 'the sacred' often has spatial dimensions and specificities. One could conceptualize a broad hierarchy of social institutions or sacred entities, i.e. *(i)* spatially diffused sacred landscape, *(ii)* spatially defined sacred landscape, *(iii)* sacred groves and *(iv)* sacred species. The topmost in this hierarchy -the diffused landscape - has institutions with the least specificity but with the greatest zone of influence. Least specificity means a lower number of prescriptions and prohibitions in terms of the practice of cultural norms. Next in this hierarchy would be spatially defined landscapes with well-defined institutional norms. The concept of sacred groves also falls in this category. Sacred species, on the other hand, stand as a class apart; however, there may be restrictions on their usage. These varied dimensions of the concept of the 'sacred' are to be found in mountain societies all over the world.

gies for rapid and mass transport of men and materials, the problem of biological invasion on a global scale becomes an increasingly serious problem. This again is difficult to control, once it has occurred. Apart from the economics involved, there are ecological and social problems that stand in the way of the control of biological invasion. Linked to all this is *biodiversity depletion,* another serious global change issue (May 1992) that is totally irreversible. Biodiversity once lost can never be recovered, as we see from the accelerated large-scale human-induced extinction of species. The impact of global change on the generally more fragile socio-ecological systems of mountains in the developing tropics is likely to be felt more than in situations elsewhere in the region where the societies are economically more developed (Ramakrishnan 1992a; Ramakrishnan *et al.* 1994b, 1996). The sustainable development of traditional mountain societies has to be viewed in this context.

Traditional agroecosystems

A wide range of complex agro-ecosystem types with biodiversity comparable to that of the natural ecosystems exists in the tropics. Classifying complex agricultural systems and relating them to a gradient in management intensification is a difficult task. However, a grouping based loosely on the intensity of land use and management provides a useful framework for discussing the relationship between agro-ecosystem complexity and function (Fig. 1).

Through a number of recent studies on agro-ecosystems, a large body of evidence is accumulating to suggest that biodiversity within them plays an increasing role in determining agro-ecosystem stability and resilience (Swift *et al.* 1996; Sala *et al.* 1999). A common perception of agro-ecosystems is that their composition is deficient in biodiversity and their structure and function impaired under human management. This is a limited view based on perceptions arising from agricultural management of the northern hemisphere. Such a perception of agriculture is also becoming more and more evident in the developing world, under the impact of the 'green revolution'. The rich diversity in agro-ecosystem types that existed not long ago is being lost rapidly, as well as crop diversity at the specific and sub-specific levels. Along with this, we also run the risk of losing the rich traditional ecological knowledge and technologies developed by these traditional societies on the basis of empirical knowledge accumulated by them over a long period of time, a knowledge-base centred around the use of crop and associated biodiversity in a variety of ways to strengthen the internal processes that determine the stability and resilience of these systems. The emphasis here is not so much on high production, but more on coping with uncertainties in the environment (system resilience), under the somewhat unfavourable ecological situations in which they operate.

Pathways for agroecosystem development

The agro-ecosystem typologies by themselves are significant from a cultural perspective, since

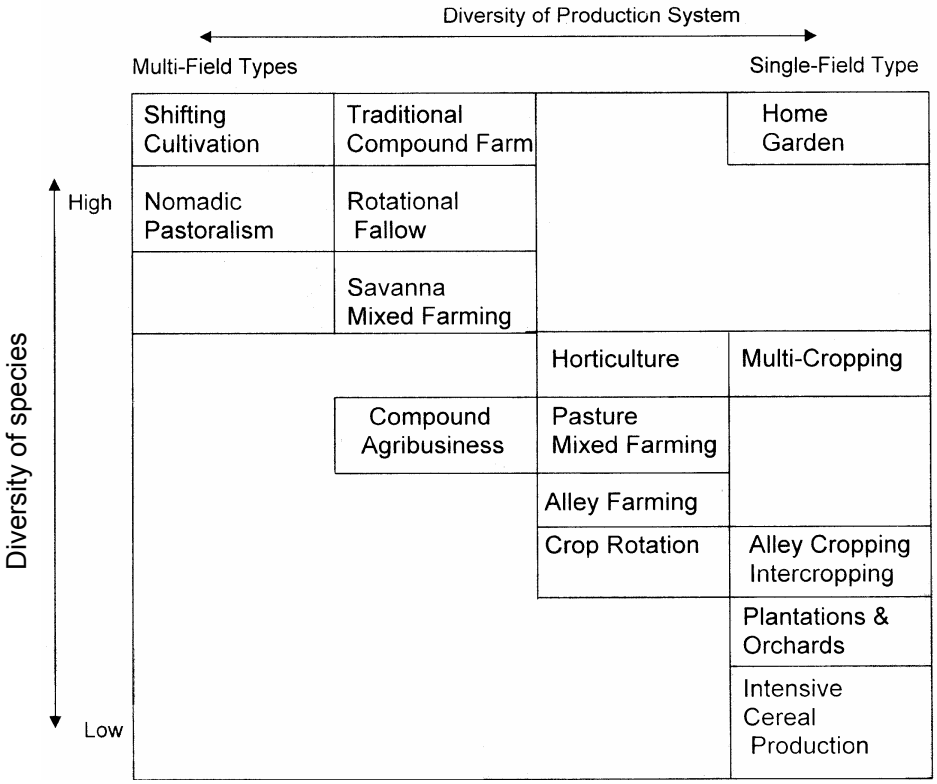

Fig. 1. Broad agro-ecosystem typologies linked to species richness (x - axis) and agro-ecosystem complexity (Swift & Ingram 1996).

ecological, socio-economic and cultural dimensions determine societal preferences. In a developing-country context, many of these forest-linked agro-ecosystems are under intense outside anthropogenic pressures. Therefore, they need to be redeveloped to ensure an improved productivity. In order to ensure this, the pathway for agricultural development needs to be based on a value system that the society has in the socio-ecological context in which it operates. There are three possible options (Swift *et al*. 1996).

Incremental pathway

This pathway suggests that the TEK available with the local communities should form the basis for ensuring community participation in agro-ecosystem redevelopment (Box 1). Thus, for example, swidden agriculture, which is still prevalent in the tropical mountains of Asia, Africa and South America and has become untenable for a variety of reasons, has defied a solution despite attempts to work out an alternative. This system of land use, as well as many other traditional agricultural systems in operation that are casually managed or at low intensity management levels, needs to be redeveloped through incremental, rather than quantum change, based on TEK; drastic measures may not find acceptance by the local communities. Thus, one may have to consider a short-term compromise that may be constrained because of ecological, economic, social and/or cultural reasons, apart from a more ideal and perhaps desirable long-term strategy. The most comprehensive study on the 'incremental pathway' as a route for agricultural development is available through the case study on the shifting agricultural system in north-eastern India, the conclusions of which have wider applications for this widely practised land use system prevalent throughout Asia, Africa and Latin America (Box 2). To elaborate one of the critical components in this developmental pathway, one needs to consider strengthening the now weak tree component of the swidden system (Ramakrishnan 1992a). Thus, for example, a socially valued and ecologically significant keystone species such as the Nepalese alder (*Alnus nepalensis*) is extensively used by tribal societies for soil fertility management. This early successional tree species in the north-eastern hill region, which is traditionally preserved in the slash and burn plots, conserves up to about 120 kg nitrogen ha^{-1} yr^{-1}, thus ensuring sustainability over a very short five year swidden cycle (the length of the forest fallow period between two successive cropping phases). The introduction of the Nepalese alder into the system under a five year cycle would not only fix nitrogen in the soil through root nodules, but also add nitrogen-rich litter to the soil, its mineralization and the consequent biological build-up of soil fertility. We have shown that species like the Nepalese alder, which are socially valued, are also ecologically significant keystone species, and as such are a basis for community participation in agricultural and natural ecosystem management (Ramakrishnan *et al.* 1998). These considerations formed the basis for a decentralized village development plan in one of the north-eastern hill states of India, a unique experiment for a redeveloped swidden system, rather than a replacement for it (Box 2).

The contour pathway

This pathway seeks to acknowledge and work with the ecological forces that provide the base on which the system must be built, while acknowledging the social, economic and cultural requirements of the farming communities. Working with nature, rather than dominating it, this approach would involve active planning with the character of the background ecosystem fully in mind. Many agro-ecosystem types in the 'low' and 'middle' intensity management categories will come under scrutiny on this pathway. A whole variety of agroforestry and alley cropping systems, for example, come under the 'contour pathway'. A variety of attempts are now being emphasized to develop agroforestry models based on the TEK of local communities, thus affirming the social dimensions of the problem.

Modern agriculture

Modern agriculture, which demands very heavy energy subsidies in the form of inorganic fertilizers and pesticides and which stands apart as an artificial monoculture entity from the rest of the landscape, is a pathway which has limited value in the developing-country context; it could at best be confined to valley lands only.

Mountain agriculture in the developed world is largely high-energy input terraced agriculture, which has already been responsible for a variety of soil pollution problems and has lead to a concern for alternative models for sustainable agriculture. There is an increasing interest now, more than ever before, in creating buffering mechanisms that may help in over-coming the ill-effects arising from

Box 2. TEK-based sustainable management of the swidden-affected land use system in north-east India.

For improving the system of land use and resource management in north-eastern India, the following strategies were suggested by Ramakrishnan and his co-workers (Ramakrishnan 1992a)

- Wide variations in cropping and yield patterns under jhum practised by over a hundred tribes under diverse ecological situations, where transfer of technology from one tribe/area to another alone could improve swidden, valley land and home garden agro-ecosystems.
- Maintain a swidden system with a cycle length of minimum ten years (this cycle length was found critical for sustainability), which was found to be sustainable when this land use was evaluated using ecological, social and economic currencies. Strengthen shorter swidden cycles through TEK and agroforestry inputs based on tree biology, following the *'incremental pathway'* for agricultural development.
- Use culturally valued tree species which improves soil fertility, such as the Nepalese alder (*Alnus nepalensis*), bamboo species that conserve N, P and/or K, or traditional lesser-known food-crop legume species, such as *Flemingia vestita*, for speedy recovery of the fallow phase.
- Condense the time-span of forest succession and accelerate restoration of degraded lands based on the basis of tree biology or appropriate traditional technologies like water harvesting systems.
- Improve animal husbandry and other components of the village ecosystem through appropriate eco-friendly technologies.
- Strengthen conservation measures through the revival of the concept of the 'sacred', such as sacred groves and landscapes.
- Ensure community participation through appropriate institutional arrangements based on the traditional value system.

The Nagaland experiment in the north-east hill region has the following salient features (after NEPED & IRRR 1999):

- Involving all the 1200 villages of the State of Nagaland, with 200 experimental plots in farmers' fields for redeveloped agroforestry systems, the experiment covers about 5500 ha of replicated test plots. Local adaptations and innovations for soil and water management are emphasized in local testing of plot results in 870 villages.
- Locally identified edible legume cover crop is cultivated as part of the jhum cropping phase of about 3-4 years, in mixtures as well as a pure cropping system.
- Traditional technologies based on Nepalese alder (*Alnus nepalensis*) trees and a variety of locally identified edible legume cover crops form part of the swidden system. Ten fast-growing tree species for poles and fuelwood and twenty tree species of value for timber have been identified and introduced into swidden plots to strengthen the system, in consultation with local communities.
- Traditional rainwater harvesting systems and erosion control measures are incorporated into the redeveloped swidden practices, where appropriate.
- Mixed tree plantations in the jhum plots were shown to be superior to monocultures and these are recommended.
- Introduction of non-traditional crops, strengthening of home gardens, mixed tree plantation practices in swidden fallows are some of the other initiatives through community participation.
- VDBs (Village Development Boards) constituted on the basis of the local value system is the institutional vehicle for land use linked landscape development.

modern agriculture. One of the possibilities to have evoked much interest in the developed world is to look at organic residue management in the soil and thus reduce the dependence on inorganic fertilizers as far as possible.

Sustainable forestry

Much of the natural forest ecosystem in the developing mountain systems has degraded to secondary formations (Ramakrishnan 2001) and

conversions to a greater or lesser extent in both the developed and developing worlds have also been to plantation forestry. Conversion to plantations essentially implies replacing a species-rich natural ecosystem by the species-poor monoculture of trees. Many of these plantations require intensive management with a variety of external subsidies, and therefore, the long-term sustainability of such conversions, both in ecological and economic terms, often remains uncertain. Sylvicultural aspects that maximize economic returns have formed an important basis for forestry practices in the developed world, and until recent times in the developing world, too. Mixed plantation forestry practices have only begun to receive attention in recent times.

However, it is increasingly recognized that natural forest management and the rehabilitation of degraded natural systems demand that attention be given to ecological, socio-economic and even cultural dimensions, and the interactions between all these (Fig. 2). This complexity is even more critical in a developing-country context, where a large chunk of the human population is directly dependent on forests not only for timber but also for non-timber forest products (NTFPs). As discussed earlier, resource flow in the form of nutrients and organic residues also determines the sustainability of mountain agriculture, particularly in the tropics where agriculture is dependent on resource recycling from the forests.

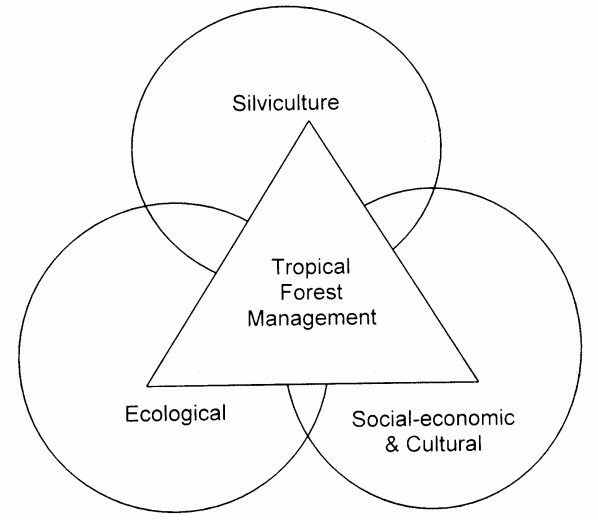

Fig. 2. Interdisciplinary interactions called for in tropical forest management and conservation (Ramakrishnan 1992b).

There is also a wider recognition throughout the globe and across disciplines that regions of ecological prudence exhibit a symbiotic relationship between biophyscial ecosystems and social systems, with strong cultural interconnections between the two. This makes explicits that culture and environment are complementary, and in various stages of evolution. The concept of *'cultural landscapes'* (*'sacred landscapes'*) is an outcome of this recognition by traditional societies, wherein they modify nature, actively maintaining it in a diverse and productive state, based on locally evolved TEK. The concepts of 'sacred species', 'sacred grove' (sacred ecosystem) and 'sacred landscape' represent various stages in social selection (Box 1). The concept of sacred mountains is worldwide. The guiding principles that regulate the use of natural resources are embedded in the codified and often non-codified institutions that they have evolved (Ramakrishnan *et al.* 1998). These sacred institutions were originally intended to boost social solidarity rather than to promote environmental consciousness *per se,* but the conservation values, *ipso-facto*, are also upheld. However, in some of the sacred landscapes such as the 'Demajong landscape', sacred for the Tibetan Buddhists of the Sikkim region of the eastern himalayas, traditional institutional arrangements differentiate between permissible small-scale perturbations and large-scale perturbations that are not permissible (Ramakrishnan *et al.* 1998).

We have many lessons to learn from the way sacred landscapes are sustained through traditional institutions in the developing tropics. Sacred groves, as representative samples of protected natural ecosystems, could form the basis for the rehabilitation of degraded ecosystems generally. A culturally valued tree species often also happens to be an ecologically significant keystone species in the ecosystem, with the ability to support much-associated biodiversity. All these socio-ecological linkages that traditional mountain societies in the developing world, still have and that have already been lost in the developed world (Messerli & Ives 1997; Price & Butt 2000; Ramakrishnan *et al.* 1998) and remain to be rediscovered, could form important elements for sustainable forestry management and the rehabilitation of degraded landscapes.

Sustainable mountain landscape management

There are many lessons to be learnt from traditional societies as concerns sustainable landscape management. Understanding adaptive social evolution of the land use practices of these societies could be an important basis for designing strategies for landscape management in the mountains of the developing world, with a view to contending with environmental uncertainties arising from 'global change' (Ramakrishnan 2000). Realizing that biodiversity and ecosystem complexity do contribute in a variety of ways to ecosystem functions, and that agro-ecosystem does harbour a great deal of crop biodiversity valuable for general human welfare, it is reasonable that we adopt a mosaic of natural ecosystems coexisting with a wide variety of agro-ecosystem models derived from all the three pathways. Such an approach is important even in order to sustain the more widespread 'modern agriculture' in the mountains of the developed world. The relative apportionment of land to the three pathways for agricultural development should be determined by socio-ecological factors. Under better soil fertility conditions, such as in mountain situations with extensive valley lands and gentle slopes, where high-energy input could be sustained, the emphasis could be more on 'modern agriculture', but combined with agroforestry/foresty to buffer the ill-effects arising from intensive farming practices. On the other hand, where traditional mountain societies are involved, as in the developing-country context, the emphasis may have to be more or less on either the 'contour' or 'incremental' pathways, even as part of a short-term strategy for the sustainable management of mountain resources. For obvious reasons, the overall emphasis in the mountains has to remain on sustainable forestry practices. The bottom line should be managing the mountains for a highly diversified landscape, as a means of coping with the obvious fragility of the mountain ecosystem.

Sustainability - a series of compromises

Sustainable development tends to have different connotations according to the context in which it is used and the disciplinary background of the one who is trying to define the concept. Theoreticians have often tried to make a distinction between 'ecological sustainability' as distinct from 'social sustainability', as if ecological paradigms were divorced from the human dimensions. It is well recognized that conservation and sustainable development represent two sides of the same coin, and are closely interlinked with one another, in the sense that one cannot be achieved at the expense of the other. From a human point of view, such an integrated approach demands that basic human needs be satisfied in an equitable manner, that social, cultural and biological diversity be maintained or indeed promoted, as would be the ecological integrity of the system as a whole. It is in this context that the entire question of the evaluation of sustainable development should be viewed. Development in an economic sense is very often evaluated through a unified measure such as the GNP, though economists amongst themselves may not agree on a common definition for 'development', which is essentially a process that can differ depending upon the ultimate objective/s. Planners and administrators and funding agencies often ask that a unified currency akin to the GNP be identified for the evaluation of sustainable development, little realizing that 'sustainable development' as a process has larger ramifications than mere economic development. Our understanding of the ecological processes that could form the basis for sustainable use of a given ecosystem are far from adequate. Add to this, the social dimension, and we are left groping in the dark. It is in this context that a number of diverse currencies are necessary to measure sustainable development; in all my studies, starting from the early 1970s, working in the north-eastern hills and in the himalayan and western ghat mountain regions of India, I have always argued for compromises that are location-specific, between ecological and social measures (Ramakrishnan 1998a).

The sustainable development of local communities, the effective management of natural resources with regard to conserving biodiversity (Ramakrishnan *et al.* 1996) and the rehabilitation of degraded/altered ecosystems (Ramakrishnan *et al.* 1994a) are all closely interlinked with one another. As already indicated, ecological issues are tied up with social, economic, anthropological and

cultural dimensions, since the guiding principles of sustainable land use management and development cut across these very disciplinary realms, with obvious trade-offs.

Currencies for evaluation

Sustainability cannot be measured using a single currency. A number of different currencies, ecological, economic and social, need to be reconciled in any evaluation of the sustainable development of a landscape unit (Ramakrishnan 1993, 1995). We are all used to the economic evaluation of 'development' that attaches monetary values and uses monetary input/output analyses, and the efficiency accruing therefrom, as the currency. In the same sense, perhaps, it may be appropriate to use energy input/output analysis, for energy efficiency can be viewed as an ecological currency. The argument here could be that the less one is dependent on external energy subsidies, the better will be the ecological sustainability of the resource management practice. If one were to use a single social currency for evaluation of sustainable development, I would wager on 'equity' as a principle that could be evaluated using economic developmental criteria. This argument is based upon the belief that if 'economic equity' considerations are taken care of, it may not be too difficult to ensure 'social equity'. I do realize that there are problems in this line of argument, but this is a compromise that one makes, particularly realizing that it is too difficult to measure equity in a simple way. Of course, one needs to arrive at compromises between these three units of measurement.

Indicators for monitoring

How does one monitor sustainable development? We need a variety of indicators. The indicators of sustainable development are varied; therefore, here again, compromises are called for (Gupta *et al.* 2001). Monitoring and evaluation have to be done using a number of different indicators that may be ecological, economic, social and even cultural (1993, 1995). Basically, these indicators add up to the 'value system' that a given society desires to have. At least, as part of a short-term strategy, economic feasibility should be an important consideration.

Ecological indicators may be: land use and land cover changes, biomass quality and quantity, water quality and quantity, and soil fertility; energy management becomes the key measure for achieving the best in terms of the desired objectives. *Land use and cover change:* By sequential monitoring of land use and land cover changes using a variety of technologies such as remote sensing, aerial photography and ground truth measurement, one could get a reasonable estimate of land quality; any conclusion that suggests land degradation in the long run is obviously not sustainable. *Biomass quality and quantity:* The quality of biomass generated on the land (biodiversity), and the quantity of biomass generated through rehabilitation measures of a given ecosystem, are equally important indicators. We need quality and quantity of biomass for multiple uses, for ecosystem integrity as well as sustainable use by humans. *Water quality and quantity:* Any land use and cover change, and indeed any land-based human activity, if unsustainable, may be reflected in ground-water recharge and the water quality. Monitoring this through sequential recharge characteristics of the system and/or monitoring water quality in rivers, ponds and lakes in the area would immediately give an idea as to the sustainability of a given developmental pathway chosen for that landscape. *Soil fertility:* Sustainable management of soil fertility implies the effectiveness with which one is able to maintain soil fertility by strengthening internal biological processes within an ecosystem, within the soil profile and above the soil, and thus minimize energy subsidies through inorganic fertilizers. The less the energy subsidy, the more sustainable the soil fertility management becomes.

Economic indicators are very much standardized in the already prevalent developmental paradigm. Monetary output/input analysis, capital savings or asset accumulation, and dependency ratio are some of the measures adopted for economic evaluation. On a macro-scale, the GNP is a unified indicator of the national developmental level. The question often arises whether one can have a unified indicator such as the GNP that can also be used for sustainable development the answer is an obvious 'no', for reasons we have discussed earlier.

Add the social dimensions to all this and evaluation becomes more complex. In a social

sense, 'quality of life' is a composite indicator, which is difficult to monitor, and even more difficult to reconcile with the sub-units contained within. More easily measurable social indicators are health and hygiene, nutrition, food security, morbidity symptoms, education status, etc. An indicator that is difficult to quantify, such as societal empowerment, and the less tangible ones in the area of socio-cultural values, are even more difficult to evaluate.

We have not considered so far, the institutional arrangements that are to be made in order to ensure peoples' participation, an essential requirement for 'sustainable development'. The organization of local communities through a bottom-up approach would ensure that each household take part in the decision-making process at the lowest level in the hierarchy. A local-level institutional framework should consider the following aspects: *(a)* identification and strengthening of local-level institutions that are already available, such as those existing in the north-eastern region, *(b)* the representative nature of these bodies and the extent to which individual family interests are taken care of, *(c)* their role in decision making right from the project formulation stage through different levels of implementation, *(d)* flexibility in function so as to take care of the interests of all sections of the society, *(e)* education and human resource development that these institutions have been able to trigger, particularly for weaker and vulnerable sections of the society, *(f)* ability of these institutions to stand on their own through empowerment in terms of capability building.

Ecologically speaking, Traditional Ecological Knowledge (TDK) evolved by traditional societies, on the basis of trial and error and their intuitive experiences, becomes important; these societies need to be incorporated into the identified developmental pathways to ensure community participation. As part of a short-term strategy for development, even socio-cultural dimensions should be taken on board. Thus, for example, traditional societies of north-east India based on the shifting agriculture (locally called 'jhum') have a 12-month calendar of socio-cultural events linked to this land use system, which must be considered if community participation in the developmental process is to be ensured.

Conclusions

Where do we stand in the context of the concepts that we have analyzed here? Landscape is the appropriate basic unit for the basis of any sustainable development plan, since the ecosystem types within the landscape form a closely-knit interacting system. If it is a well-defined watershed, as viewed currently by developmental agencies, it is even better. Sustainability has to be considered within a temporal framework. A long-term strategy for sustainability has to be reconciled with a short-term strategy necessitated by ecological, social and cultural constraints. In the ultimate analysis, sustainable development is indeed a series of compromises; the compromises should be made, keeping in view the twin objectives of better quality of life for the humans while maintaining environmental quality without any obvious degradation of the natural resource base.

The basic determinant in all these, is the societal perceptions and demands, with compromises made between different stakeholders of the society. The question as to the basis for compromises between different currencies/indicators is often raised. The basis for compromises has to emerge from the society, based upon its perception of the economic needs and the ecological resource stock that is available. The best way to approach sustainable development is through a thorough understanding of the linkages between the ecological and social processes, viewing the issues involved at different scalar dimensions. Thus, for land use decisions, on an ecological plane, a plot level analysis, which leads through the ecosystem level and eventually reaches the landscape level analysis becomes most obvious. A similar set of units, on the social scale, would be a family, a village and a cluster of villages in a given ecological landscape. This would ensure that the end-product is sustainable livelihood as a short -term strategy, leading to sustainable development of the region as part of a long-term strategy, through a participatory and interactive analytical framework. In other words, communities themselves form the arbiter for arriving at the required compromises (Ramakrishnan 1998b) that they understand and appreciate and therefore, are able to participate in a process of development based on a value system they cherish.

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