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Indigenous ecological knowledge, biodiversity and sustainable development in the central Himalayas

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Abstract: The paper has looked at traditional systems of forestry and agricultural system management in the central himalayan region. Based on a detailed analysis of traditional ecological knowledge that is linked with biodiversity, natural and human-managed, various possibilities for sustainable management of natural resources, with concerns for sustainable livelihood of local communities have been explored for the Garhwal region in the central himalayas. It is concluded that if the development interests of local people are marginalized for a long period of time, they might adopt actions detrimental to the goal of conservation. Capitalizing on the positive dimensions of traditional knowledge and overcoming its negative dimensions through conventional science-based inputs could ease the difficult process of securing people's participation in environmental conservation together with the socio-economic development of local communities.

Resumen: En este trabajo se examinaron los sistemas tradicionales de forestería y el manejo del sistema agrícola en la región central de los Himalayas. Con base en un análisis detallado del conocimiento ecológico tradicional ligado a la biodiversidad, tanto la natural como la sometida a manejo humano, se han explorado varias posibilidades para el manejo sostenible de los recursos naturales, con miras en el interés en la provisión sostenible de sustento para las comunidades locales en la región Grahwal de los Himalayas centrales. Se concluye que si los intereses en el desarrollo de los pobladores locales son marginalizados por largos periodos, éstos pueden adoptar acciones que van en detrimento de la meta de la conservación. La capitalización de las dimensiones positivas del conocimiento tradicional y la superación de sus dimensiones negativas a través de aportaciones basadas en la ciencia convencional, podrían facilitar el difícil proceso de asegurar la participación de la gente en la conservación ambiental a la par del desarrollo socioeconómico de las comunidades locales.

Resumo: O artigo debruça-se sobre os sistemas de silvicultura tradicionais e os sistemas de gestão agrícola na região central dos Himalaias. Com base na análise detalhada do conhecimento ecológico tradicional que está ligado à biodiversidade, natural ou de gestão humana, várias posibilidades para a gestão sustentada dos recursos naturais, com preocupação para a qualidade de vida das comunidades locais foram exploradas para a região do Grahwal nos Himalaias centrais. Concluiu-se que se os interesses de desenvolvimento das populações locais

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forem marginalizados por um longo período, elas podem adoptar acções que são detrimentais para os objectivos da conservação. Capitalizar nas dimensões positivas do cohecimento tradicional e ultrapasar a sua dimensão negativa através de inputs de base científica podem facilitar o processo difícil de garantir a participação da população na conservação ambiental juntamente com o desenvolvimento sócio-económico das comunidades locais.

Key words: Biodiversity, natural resource management, rehabilitation ecology, sustainable livelihood, traditional knowledge and technology.

Introduction

The Himalayan mountain system covers only 18% of the geographical area of India, but accounts for more than 50% of India's forest cover and for 40% of the species endemic to the Indian subcontinent. Himalayan resources and ecosystem services are critical, not only for the sustainable livelihood of 115 million mountain people, but also for a much larger population inhabiting the adjoining Indo-Gangetic plains. Depletion of forest cover, biodiversity and terrestrial carbon stock, declining farm productivity, increasing hydrological imbalance and soil erosion are interconnected problems and the root-causes of the poor economy of the hill people and threaten global environmental benefits from the Himalayas (Chipika & Kowero 2000; Hamilton 1987; Hurni 1999; Ives & Messerli 1989; Myers 1990; Ramakrishnan *et al.* 1996).

Until the 1970s, environmental conservation and rural development were, by and large, treated as independent sectors. The poor results brought by the sectoral approach catalyzed efforts towards the integrated approach, which targets the resolution of environmental and socio-economic problems simultaneously. Though knowledge of the principles and potential advantages of this approach has improved considerably in recent years, there are gaps in knowledge and serious problems in putting the theory to practice (Antunes & Santos 1999; Bellamy & Johnson 2000; Jenssen & Goldsworthy 1996; Lunde & Iremonger 2000).

A simplistic view of integrated management would be to identify 'key' interventions [analogous to the concept of keystone species (Paine 1969; Walker 1991)] enabling environmental and socio-economic benefits simultaneously. There are two divergent approaches to the characterization of the problem-complex (multiple interlinked problems) or key interventions to overcome the problem-complex: (a) building on the ways in which nature, resources and livelihood have been viewed by the indigenous/traditional communities, which has been referred to as the 'internal perspective' approach (Hurni 2000) or as the indigenous knowledge-based approach or the bottom-up approach; and (b) the conventional scientific approach, or global economic and environmental world-view, referred to as the 'external perspective' approach (Hurni 2000), or top-down approach. Indigenous knowledge is an integral dimension of all societies but is more intact in areas, such as high-altitude remote Himalayan villages, where inaccessibility and isolation have acted as barriers to outside forces for a long period of time. In this article, we discuss some aspects of indigenous knowledge-based resource uses of management practices and changes therein, and of the scope for integrating indigenous knowledge and conventional ecological science for resolving biodiversity/environmental conservation-development conflicts, within the context of the Himalayan mountain systems.

Forest/wild biodiversity: impacts of interventions

Crop husbandry, animal husbandry, wild biodiversity and rural economy are subsystems of the integrated traditional resource management system. On a regional scale, the landscape can be differentiated into: *i)* settled crop-livestock mixed agriculture patches dispersed in the matrix of forests and pastures; *ii)* almost pristine areas (permanent snow area and adjoining alpine vegetation) practically impossible to access for any consumptive resource use; *iii)* the remaining areas that are used for summer grazing by transhumance communities, the Gaddis and Bakarwals, who bring livestock from the distant foothill regions and the Anwals, Tarjias and Dogpas who supervise the livestock of the local hill communities. Traditional socio-cultural mechanisms of fostering systematic and regulated use of wild plant resources seem to have evolved as a necessity to optimize economic outputs from domesticated biodiversity. All across the region, traditional management systems are characterized by practices favouring a balance in utilization and regeneration of the natural resource base, equity and social integrity to achieve the ultimate goal of sustainable livelihood within small-scale subsistence economies in highly isolated and inaccessible mountain settlements. Conventional approaches to conservation, i.e., the establishment of wildlife sanctuaries and national parks, have assumed traditional practices to be detrimental to the conservation of wild biodiversity and the functioning of ecosystems. This assumption is the root-cause of people-conservation conflicts (Gadgil *et al.* 1993; Gomez-Pompa & Kaus 1992; McNeely 1988). The nature and magnitude of these restrictions, their impacts on local livelihood and people's responses to them may vary depending upon the ecological and socio-economic and cultural contexts.

Traditional forest/wild biodiversity management

Traditionally, each village had notional territories of forests and alpine meadows and resource uses within these 'common lands' were decided by the consensus of the communities. Even though local people were aware of potential economic benefits from timber, the timber trade was never practised because they traditionally viewed the utilization of non-timber forest products and ecosystem services to be more valuable for sustainable livelihood than timber. In the traditional system, there was no restriction on the collection of wild edibles, deadwood and leaf litter (to be used as a constituent of manure applied to crop fields), partly because these resources were abundant. Lopping, grazing and utilization of forest products such as medicinal plants and bamboos (raw material for handicrafts) used to be undertaken in groups during periods fixed by the consensus of the community so as to reduce the risks of over-exploitation by individuals. Traditions such as the social sanction to market forest resource-based handicrafts, medicinal plants and nomadic grazing only by smallholders and landless people fostered equity to a significant extent. Villages rich in some resources due to comparative ecological advantages (e.g. villages close to the alpine zone are richer in summer fodder, temperate bamboos and medicinal plants than those in mid-altitude zones and those in foothills which are richer in winter fodder) allowed other villages to use their resources, more from the point of achieving social integrity than from the point of economic gains (Maikhuri *et al.* 2000a,b; Rao & Saxena 1996). Local communities traditionally allowed grazing of livestock from outside the region supervised by nomads for three reasons. First, nomads used the area not grazed by local livestock and hence did not offer any threat to local livelihood. Second, the presence of livestock brought by nomads to the areas around the villages reduced the probability of depredation of local livestock. Third, the nomads bartered essential commodities, which were not available locally and brought from the foothills with local products.

Leopards and wolves are the two major predators of livestock studied in the region. In high-altitude regions, local people view wolves as a more serious threat than snow leopards because the former is a year-round predator on domestic livestock, whereas the latter attacks mostly during extreme winters. Estimates on livestock killing by snow leopards fall within a range of 1% to 12% of total stockholding (Fox *et al.* 1988; Jackson 1991; Mallon 1991; Mishra 1997; Oli *et al.* 1994; Schaller *et al.* 1987). The assessment of killings by wolves has not received as much attention as those by snow leopards. Precise estimation of predation losses is difficult because predation as a proximate cause of livestock death is confounded with ultimate causes such as disease, malnutrition, bad weather or accidents. All assessments of livestock depredation are based on killings reported by farmers who often deliberately inflate the figures.

Livestock are less able to escape predators than wild herbivores (Nowell & Jackson 1996). Local people traditionally accepted depredation as a natural hazard. Several measures are taken to minimize this loss. First, grazing of goats, sheep, donkeys and cows is kept close to permanent settlements. Two families, by rotation in a village, assemble all livestock of the village, accompany them for grazing in areas away from crop fields in the morning and bring them back to the respective households in the evening. All animals are kept in rooms, the integral part of a dwelling. Second, robust males are selected and kept as community animals so as to enhance the escape capabilities of domesticated animals. Then only yaks, dzomo/dzo and horses are taken to distant summer grazing grounds (temporary summer settlements). Here too, animals that are more valuable are kept in encampments fenced by a 3-4 m high stonewall during nights. Graziers make fires at night as a measure to keep predators away. They have evolved abilities to sense the presence of predators in the vicinity through the abnormal behaviour of livestock. At the approach of predators, they shout and throw stones to keep them away. A few less vigorous animals are kept outside encampments during the night to reduce the attacks on more valuable animals within encampments.

Retaliatory killings of snow leopards by local people are likely only when an animal causes frequent and large-scale damage and when leopards are found guarding kills of large domestic animals (Fox & Chandawat 1988; Fox & Nurbu 1990; Oli *et al.* 1994). On the other hand, wolves are killed whenever possible. Many villages have stone-pit wolf traps. Traditionally, the community (Fox & Nurbu 1990; Mishra 1997) rewards individuals who succeed in capturing pups.

Blue sheep and snow cocks are traditional delicacies, but local people rarely go out with the intention of hunting these herbivores, partly because of religious-social-cultural norms discouraging wildlife killings (Fox & Nurbu 1990; Mallon 1991) and partly because of the great ability of these herbivores to escape. Whenever a blue sheep is captured, all families of the village share its meat. People also understand that a reduction in the population of wild herbivores might increase the frequency of attacks on livestock. Thus, there seems no immediate threat to the snow leopard's or wolf's main natural prey from traditional practices.

Policy driven changes

The utilization of forest resources for national economic/industrial development and environmental conservation was introduced as policy goals distinct from those related to people-forest relationships. Ground actions to achieve these policy goals were coupled with actions that led to drastic changes in traditional uses of forests and wild plant diversity. The majority of village common lands were taken over by the government and notified as forest and wasteland in late nineteenth century with the implementation of the first forest policy. As at present, government forest land was stratified into: *i)* national parks where all consumptive resource uses are strictly prohibited; *ii)* wildlife sanctuaries where traditional wildlife hunting is an offence but local communities may be allowed some traditional plant resource uses free of any cost; *iii)* reserve forest where concessions to local communities are more liberal in comparison with those provided in the sanctuaries; resources can be exploited to meet the national economic/industrial raw material demands by government agencies; *iv)* community forests whose management is entrusted to local institutions such as the Forest Council (locally called Van Panchyat in the Uttranchal Himalayas) or to the traditional village headman (locally called Gaon Budha/Siem in some parts of the north-eastern Himalayas); village institutions are authorized to decide only on subsistence needs and government approval to undertake any extraction on a commercial scale and have to share benefits from any commercial extraction with the government. There were two important generic implications of changes in forest land tenure/ownership and resource-use practices imposed by policy and law: the reduction in area freely accessible to local people and emergence of a local perception that policies promote conservation or national economic development on a resource base that local people have conserved.

Grazing

Influenced by the policies promoting forest resource-based economic development, local people have also begun to give more attention to monetary benefits than to the traditional linkage between resource uses and social integrity and equity. In the Nanda Devi Biosphere Reserve, all traditional alpine meadows of a number of villages (e.g., Lata and Peng) became a part of sanctuary/national park. The unaffected villages (e.g., Malari) permitted livestock of the affected villages to graze in their territories but on payment of Rs. 20/horse or head of cattle and Rs. 4/sheep or goat. Such linkages between resource rich and poor villages did not depend on any monetary consideration in the traditional system.

Indeed, the termination or reduction of grazing rights in forests and meadows may enhance plant diversity and ecosystem functioning if the grazing pressure is intense. Long-term benefits to local communities from such enhancement may encourage them to reduce livestock holdings and switch over to alternative livelihood strategies (Fox 1993; Maikhuri *et al.* 2000b; Sharma & Shaw 1993). Such responses are likely only when the unsustainability of traditional grazing practice is demonstrated and people are compensated for economic losses due to termination/reduction of grazing rights within protected areas. There is no scientific evidence to show that traditional grazing practices always cause loss of biodiversity and ecosystem functioning (Gabriel *et al.* 1998; Ward *et al.* 1998, 2000). If the disturbances caused by traditional resource uses were moderate, diversity may decline following abandonment of these uses and the recuperation of lost diversity may be a very slow and costly process (Kotiluoto 1998; Stampfli & Zeiter 1999). Ecological impacts of traditional resource uses and management need to be scientifically evaluated before they are abandoned or modified using legal instruments.

Medicinal plants

Traditionally, medicinal plant collection was a subsidiary activity when people went away from their dwellings to graze livestock. This resource was used for local health care as well as to generate some income. The government granted permits to individuals/contractors during 1980s and started earning some revenue through this practice. Contractors, by and large, employed outside labour rather than local people, as the latter were likely to place greater stress on the extraction-regeneration balance than on maximization of profits. Local people strongly opposed this policy, partly because they did not get any direct benefits and partly because of the threat to their livelihood due to unsustainable harvesting by the outside labour. In the face of strong opposition from the people, this practice was terminated in 1988.

Wood resources

The government sanctioned felling to contractors during 1970s as a way of earning revenue from timber, as well as serving national industrial development. Foreseeing the adverse environmental impacts of commercial felling on steep slopes and the long-term consequences of such impacts as concerns the lowering of the productivity of non-timber forest products, hydrological imbalance and soil erosion, local people agitated and forced the government to withdraw fellings. This agitation (popularly referred to as the Chipko movement, i.e., 'hugging the tree' movement), which was confined to the Uttaranchal Himalayas was so effective that the government banned fellings not only in the Uttranchal hills, but also in all mountain regions of the country. The removal of dead/diseased trees in Reserve Forests started in the 1960s and continues. Government agencies can sell dead/diseased trees in Reserve Forests, but forest councils can do so only with government approval. If the market value of the proposed removal is assessed at Rs 5000 or less, the council is allowed to auction the deadwood and if more than Rs 5000, the auction is carried out by the forest department. In the latter case, 10% of income goes to the forest department as institutional charges, 36% for management of community forests jointly with the council, 18% to the district development board for district-level development projects and 36% to the revenue department for development in the concerned village. Lack of complete autonomy in mobilizing income from community forest resources is an issue in the people-government conflict.

Rural development as a component of protected-area management

In the traditional system, protection from exploitation by outsiders or insiders was a collective responsibility; each household had to contribute some mandays towards protection. Policy interventions viewed protection as enforcement rather than a social responsibility. Protection accounts for a substantial proportion of government expenditure on conservation, but as far as the people are concerned, it is an unproductive investment, as it does not directly benefit them.

Provisions of direct economic benefits to local people are being increasingly incorporated in protected-area management plans. Afforestation, mechanical soil conservation measures and supply of solar power devices, wool, improved bee-hives and spinning devices at subsidized prices to selected households, have been included in the biosphere reserve management plan. Yet, local people largely perceive the benefits far less than the losses due to enforcement. This perception seems to stem from a divergence in the development options preferred by the local people from those incorporated in management plans (Table 1), a perception which in turn is rooted in the negligible involvement of the people in reserve management planning and monitoring. Indeed, people's perceptions may not always be true when evaluated scientifically. People's preferred ways of resource uses may not necessarily fall in line with the goal of conservation and hence might need moderation (Maikhuri *et al.* 1995; 1996; 1997a,b,c; Rao *et al.* 1999; Ward *et al.* 2000), as exemplified in subsequent sections in this article.

People-wildlife conflicts

Penalties for killing wildlife imposed by protected-area managers are another key change that follows the enforcement of protected areas. Local people dislike this policy as it treats outsiders who hunt wildlife for game or economic gains the same as it does local people who resort to killing only when a wild animal turns extremely hostile. Such a policy is also viewed by local people as a way of promoting conservation at the cost of their livelihood. The involvement of local people in the surveillance of game or commercial hunting, together with interventions that keep the predators away from settlements and their resource catchments, could be a way of resolving this conflict.

Though it has been argued that the frequency of livestock killings has increased in the recent past because of an increase in the livestock population (Mishra 1997), the possibility of an increase in the predator population following strict conservation measures implemented since 1972 cannot be completely ruled out. Protected-area management does have a provison of cash compensation for livestock killed by wildlife, which is indeed an advantage to local people conferred by the conventional conservation approaches. However, the available funds are too low to compensate for the losses and the procedure too complex to be understood by the community (Maikhuri *et al.* 2000b; Mishra 1997; Rao *et al.* 2002). The policy of compensation also contributed to an erosion of the traditional institutions concerned with depredation. The enhancement of traditional practices to protect livestock from wildlife depredation is likely to be a more effective way of resolving wildlife-people conflicts in developing countries than providing cash compensation.

Table 1. People's perceptions of development options in the Nanda Devi Biosphere Reserve, central Himalayas (after Maikhuri *et al.* 2000b).

Development options	% of total responses	
	Villages near to core zone	Villages away to core zone
Increase in crop yields:		
by expanding farm holdings	2	2
by using chemical fertilizers	14	12
Improvement in livestock productivity:		
by increasing fodder productivity of degraded forest lands	94	82
by replacing traditional breeds with high yielding breeds	8	8
Income from timber of dead trees in community forests	96	92
Improvement in margins of profits from local products:		
by local cooperative societies	18	12
by value addition locally	18	12
by protective government policies	98	98
Opening of core zone for tourism	98	96
Plantation of coniferous trees by Reserve Authority	24	12
Replacement of traditional beehives by ones provided by Reserve Authority	4	8
Replacement of traditional looms, beehives, by new devices and supply of solar power panels provided by Reserve Authority	6	4

Traditional agriculture and emerging changes

Traditional settled farming systems in the central Himalayas are characterised by: *i)* cultivation of three crops in two years in low-altitude villages and one crop per year in high-altitude villages; *ii)* community decision on the period of fallowing (the village is divided into two halves termed Mulla and Malla Sar, each household owns at least one plot in each Sar, and a Sar is fallowed during one winter-crop season over a period of two years) but independent household decisions on choice of crop and management practices; *iii)* exclusive use of organic manure derived from livestock excreta mixed with forest leaf litter; *iv)* exchange of seeds without any monetary considerations; *v)* use of local cultivars. Traditional agriculture has undergone prominent changes in the recent past in many segments of the Himalayas. Though there is no perceptible change in cropping intensity, the area under agriculture and crop diversity and husbandry practices have changed. *Echinochloa frumentacea*, *Glycine max*, *Setaria italica* and *Pennisetum typhoides* at lower altitudes and *Hordeum vulgare* at higher altitudes, have been abandoned, while the area under cash crops *Solanum tuberosum* (potato) and *Phaseolus* species has substantially increased (Appendix I). These changes have accompanied substantial improvements in the local economy, but at significant environmental cost. The expansion of potato, the by-products of which do not have any fodder value, implies a lower production of fodder from private farms and thereby greater pressure on forest use. Further, soil erosion from potato fields could be 6-8 times higher than that from traditional staple food crops (Table 2), despite of an organic manure input which is 2-4 times higher in the former as compared to the latter. Larger quantities of manure input imply more removal of litter from forests and hence risks of deterioration in forest ecosystem services (Maikhuri *et al.* 2000b; Sen *et al.* 1997). A change such as the cultivation of medicinal plants (which used to be harvested from the wild and many of which are recognized as rare and endangered species), an indigenous knowledge-based response, falls in line with the goal of conservation. On the other hand, changes like the loss of traditional lesser-known crops and cultivars and the negative environmental implications of potato cultivation do not serve the goal of conservation.

Traditional water management and changes therein

Traditionally, the upland people have capitalized on sub-surface water sources and small rainfed rivulets (Table 3). Sub-surface flows were the preferred sources of potable water. This preference to sub-surface water necessitated conservation of forests around sources. While drinking water sources were used and managed separately by lower and higher caste groups, there used to be a unified canal irrigation system for the entire village (Saxena *et al.* 1994). Though a huge quantity of water is available from snow-fed rivers, people rarely used it for two reasons: (a) the water flow is too fast to be managed with the traditional capacity and (b) river water contains a much higher content of coarse particles and is cooler, properties considered undesirable for drinking or irrigation purposes. The traditional concerns of water management thus centered around minimum energy or material inputs for purification, storage and canalization of water, minimal interference with natural

Table 2. Soil loss from different crop fields and terrace slope in the Pranmati watershed of the central Himalayas (after Sen *et al.* 1997).

Crop	Soil loss from terrace slope ($t\ ha^{-1}\ yr^{-1}$)					
	Low (<2^0)		Medium (2-6^0)		High (6-10^0)	
	1993	1994	1993	1994	1993	1994
Eleusine coracana	0.658	0.089	1.199	0.386	6.037	0.525
Amaranthus paniculatus	0.517	0.372	1.462	0.437	13.435	1.475
Echinocloa frumentacea	0.536	0.093	1.213	0.310	7.578	0.652
Oryza sativa	0.300	0.334	2.950	0.429	8.122	1.050
Solanum tuberosum	0.606	0.327	7.653	1.812	64.400	3.758

Table 3. Traditional water management systems in the central Himalayas.

Name of traditional system	Technical features	Management features
Gools	Water from rainfed small rivers called Gaad or rivulets called Gadhera is diverted to agricultural fields through a network of channels enabling flow along gravity. Points of stable perennial flow are identified on the natural course. If the flow is slow or sources dry up for some time in the lean season, a small storage tank is constructed. The tank is desilted almost every year.	A hamlet or village was the operational management unit for water management. Distribution of irrigation water and responsibilities of maintenance of tank/ channels among households were decided by a selected group of elders constituting the 'Pani Panchayat (Water Council)'. Usually, a group of 3-4 households is identified for repairing canals in the face breeches or obstruction to water flow due to accumulation of stones in the stretches lying outside private farmlands. These households are rotated on an annual basis and are compensated by food grains or money by the remaining households.
Choyas	Tiny seasonal seepages, very close to farm fields discharging water insufficient for canalization are called Choyas. The flow is diverted towards a terrace. Whenever water accumulates, the excess, if any, flows to the terrace below. Farm field connected.	This system is an environmental opportunity for a few households and not for the entire village. It is managed independently by the concerned household(s).
Dhara	Dharas are believed to be undergorund water channels that get exposed usually on lower or mid-slopes. Water recharge and flow are adequate enough to yield a perennial clear and perpetual water thread. A small shallow tank is usually dug and lined with locally available stones/slates below the point of exposure. Water directly from the exposed source is used for drinking and cooking and from the tank for other household purposes. This tank is often connected to another unlined tank below used for retting fiber plants like *Grewia, Cannabis* and *Urtica.*	By and large, drinking water sources of lower caste people were in more difficult terrain and away from dwellings, compared to those of higher caste people. Sources are managed collectively by the concerned caste groups.

hydrological processes and minimal risk of damage to life and cultivated land from overland flow.

The traditional systems became ineffective in most cases when irrigation and drinking water supply were provided as government service facilities. People did benefit, in that water was provided as a free commodity, but the benefit could not be sustained for long. An analysis of a cluster of villages showed that the area under irrigated farming declined in more than 50% of the villages between 1971-81 (Rao & Saxena 1994). This failure has largely been because of the inappropriateness of the water harvesting and distribution technologies, which were introduced, and of the management institutions (Kothyari *et al.* 1991).

Traditional knowledge-based ecosystem rehabilitation strategies

Out of the 59-million ha total geographical area of the Indian Himalayas, 7.3 million ha are degraded community lands and 13.5 million ha degraded government forest lands. In many villages, per capita cultivated land is lower than per capita degraded forestland. Though numerous land rehabilitation projects have been implemented since the 1970s, the impact has, by and large, been poor because of inappropriate technologies and because of the callous or negative attitudes of the local people. In mountain regions, active participation by local people is a prerequisite to the success of any rehabilitation effort. One way of securing people's participation would be to formulate a rehabilitation strategy which addresses the people's needs/priorities and to complement/supplement indigenous knowledge /informal institutions with conventional scientific knowledge/formal institutions. A comparative and concise account of successful land rehabilitation achieved in a high-altitude village and a low-altitude village (Tables 4 & 5) is presented in the following sections.

Table 4. People's preferences for rehabilitation of degraded lands. Total number of respondents 70. People's preferences were sought before initiation of the project (after Rao *et al.* 1999).

Land use option	% of the respondents supporting land use option
Treatments/inputs	
Plantation of trees	8
Plantation of bamboo (*Thamnocalamus spathiflorus)*	58
Cultivation of medicinal plants	
Aconitum heterophyllum	34
Allium stracheyi	34
Angelica glauca	34
Carum carvi	34
Nardostachys grandiflora	17
Orachis latifolia	9
Picrorhiza kurrooa	34
Podophyllum hexandrum	17
Rheum australe	34
Saussurea lappa	9
Swertia chirayta	9
Tanacetum tomentosum	34
Thalictrum foliosum	17
Introduction of both bamboo and medicinal species	27
Protection from grazing	100
Soil management/organic manuring	100
Decision making	
By formal village institutions	Nil
By entire village community informally	100
People's contribution	
Voluntary labour	Nil
Farm yard manure	95
Propagules/seedlings/saplings from community forest	98
Reinvestment of a portion of returns for replication of the rehabilitation model	95

People's perceptions

At both locations, people were more concerned about immediate tangible benefits from rehabilitation than about indirect/intangible benefits (soil conservation, hydrological balance, carbon sequestration and biodiversity conservation, the prime national and global concern; they were aware of all these aspects, except for carbon sequestration). Over 90% of the respondents did not prefer exclusive tree plantation, which has been a common intervention for rehabilitation by government

Table 5. People's preferences for rehabilitation of degraded community lands (after Maikhuri *et al.* 1997a,b).

	% of total response*
Treatments/inputs	
Afforestation	
Coniferous species	2
Local multipurpose broad-leaved species	6
Agroforestry	
Local multipurpose trees + cash crops	87
Local multipurpose trees + staple food crops	5
Agriculture	nil
Water management	64
Proper terracing	58
Organic manuring	98
Inorganic fertilizers	8
Decision making	
By formal institutions	7
By entire village community informally	87
By other means	6
People's contribution	
Voluntary labour	nil
Organic manure	nil
Social fencing	98
Seedlings/saplings from private farmland	98
Seeds of cash crops	98
Reinvestment of a portion of returns for replication of the rehabilitation model	92

*Total number of respondents: 219

agencies. The reasons for this dislike of exclusive tree plantation were:

(a) Coniferous timber species, viz., *Pinus roxburghii*, *P. wallichiana, Cupressus torulosa* and *Cedrus deodara* were planted on a large scale in degraded forestlands. The choice of coniferous species was based on their well-known silviculture, their non-palatability, which is advantageous in natural protection from grazing and their ability to establish themselves in poor soil conditions. Coniferous species are not highly valued in respect of leaf litter, fuel wood and minor timber required in bulk quantities to sustain traditional livelihood. There is evidence to show that coniferous forests may not render as favourable a hydrological balance and slope stability as broad-leaved forests (Singh *et al.* 1992), but local people did not perceive this of the service dimension ecosystem.

(b) Income is a major local concern, but the policy does not provide for timber extraction for monetary benefits, in view of the risks of soil erosion and hydrological imbalance by tree cutting and associated disturbances in the fragile Himalayan landscape.

(c) Local people were involved merely as labourers because their wages were much lower than those of the outside labour force. It was assumed that the traditional knowledge and experiences of the local people would not confer any technical or practical advantage.

(d) It was assumed that selected species could withstand all sorts of soil stresses and hence there was a lack of any basal improvement in soil physico-chemical properties in plantation programmes.

(e) Seedlings/saplings were raised in centralized nurseries and damage during the course of transport led to the transplanting of unhealthy individuals (Rao & Saxena 1994; Saxena *et al.* 1993).

At high altitude, the planting of temperate bamboo (*Thamnocalamus spathiflorus,* locally referred to as Ringal) was the most common choice, followed by the cultivation of medicinal plants, while at low altitude, people stressed multipurpose tree-cash crop integrated agroforestry (Table 6). The choice of these species was based on their economic potential, comparative ecological advantages and some indigenous knowledge of their husbandry.

Decision-making by the entire village community rather than a few elected individuals suggested that people had lost faith in formal institutions and intended to rejuvenate traditional consensus decisions. Even though they were assured that all benefits from the proposed rehabilitated site would go to the community, none of the respondents agreed to voluntary labour. They suggested that their contribution would be in terms of social fencing (the community would ensure that the treated area was protected from grazing through their traditional regulatory mechanisms), supply of seeds and seedlings/saplings from the community forests and farmyard manure.

Moderation of people's perceptions

An analysis of people's perceptions revealed strengths and weaknesses of the indigenous knowledge and provided scope for overcoming the weaknesses. The challenge was how people's perceptions and priorities could be integrated with national/global priorities. In the high-altitude village, the following points were gathered from the existing scientific knowledge and from a rapid ecological survey of the regional landscape. These aspects were either altogether unknown or, their implications were not properly understood by the people:

(a) The people were not aware of the biological peculiarity of *Thamnocalamus spathiflorus*, viz., its gregarious flowering and low productivity for 3-4 years after flowering. As bamboo flowering is unpredictable, pure plantation of this species would be risky.

(b) *T. spathiflorus* and many medicinal species were regenerating in shaded and moist microhabitats in *Q. leucotrichophora-Aesculus indica-Juglans regia* mixed forests. Local people valued these tree species for their multipurpose products. Bamboo and medicinal species requested for plantation were thus likely to survive the continued growth of tree canopy. Apart from a range of products, planting of trees in degraded lands could bring in micro-environmental changes facilitating natural regeneration of medicinal plants and temperate bamboo. A shortfall in grass fodder production was expected with the development of tree canopy because most palatable grasses grew in open habitats. This shortfall was likely to be compensated by income from bamboo, medicinal plants and tree products.

(c) The cultivation of medicinal species was a risky proposition because of the poor agronomic and ecological knowledge pertaining to them.

(d) Medicinal species, being tender herbs, would require intense weeding and soil management for success in degraded sites. Since private farm fields had better soil fertility and were partly abandoned, cultivation of these species would be more advantageous in abandoned fields. Rehabilitation should serve primarily the purpose of producing propagules and secondarily economic needs.

(e) Bamboo could be planted only through vegetative means, as its seeds were not available, whereas both seed and vegetative propagation options were available for medicinal plants. Mortality in a stressed environment was less likely with vegetative propagation than with sexual reproduction.

(f) Continuous harvest of bamboo, medicinal species and grass fodder was likely to aggravate nutrient stress in a recovering site because all these species had root systems confined to surface soil. Trees with fast decomposing litter although they may not offer a large number of immediate tangible benefits, would draw nutrients from deeper soils and enrich the surface soil. This in turn would enhance productivity of products preferred by the people. The nitrogen-fixing trees *Alnus nepalensis* and *Alnus nitida* were more suitable from the point of view of enabling of a rapid recovery in soil fertility.

When the above points were discussed with the people, they agreed to the planting of the tree species *Aesculus indica, Quercus leucotrichophora* and *Juglans regia,* along with medicinal plants and bamboo. *Alnus* species, though desirable from the point of soil fertility recovery, were not acceptable because of the insignificant direct benefits over a short-term period.

Water stress was perceived as a problem only in the low-altitude village. People felt that while canal-based irrigation introduced by conventional agencies cannot be sustained in the long run, it was practically impossible to establish the traditional system in the changed socio-economic and ecological conditions. Based on an ecological survey of the landscape, it was felt that the crops preferred by the local people for cultivation would need only life-saving irrigation and not flood irrigation, for which the canal system was designed. Because of large-scale land degradation in the past, the run-off around and within degraded lands was quite high. People accepted the proposal to establish simple water-harvesting tanks for collecting run-off and to recycle the stored water following traditional irrigation practice (Kothyari *et al.* 1991).

Outcome

Tree biomass

At the high-altitude site, the bamboo *T. spathiflorus* showed significantly higher aboveground biomass accumulation over a period of 7 years, followed by the tree *A. indica.* There was no significant difference in biomass accumulation by *Q. leucotrichophora* and *J. regia* (Table 6). Because of a more favourable temperature and larger quantities of manure applied primarily for crops, tree biomass even after 5 years was better at the lower altitude site, and more so in the irrigated treatment (Maikhuri *et al.* 2000a).

Soil fertility recovery and carbon sequestration

There was a significant improvement in the water-holding capacity and fertility status of the soil over a period of 5 and 7 years after land rehabilitation in Banswara and Khaljhuni, representing lower and higher altitude sites, respectively (Table 7). Rehabilitation also implied a higher level of carbon sequestration as a result of organic

Table 6. Growth after 7 years of plantation of tree and bamboo species in a high-altitude village (Khaljhuni, Almora district) rehabilitated site of the central Himalayas (after Rao *et al.* 1999).

Species / Aboveground biomass (kg plant^{-1})	*Aesculus indica*	*Juglans regia*	*Quercus leucotrichophora*	*Thamnocalamus spathiflorus*
Bole/Main stems	8.1 ± 1.1	2.8 ± 0.7	3.2 ± 0.6	25.6 ± 0.8
Branches	2.6 ± 0.3	1.1 ± 0.3	0.8 ± 0.1	8.1 ± 0.5
Leaves	1.1 ± 0.2	1.2 ± 0.5	1.5 ± 0.3	10.6 ± 0.8
Total	11.8 ± 1.2	5.1 ± 1.0	5.5 ± 0.5	44.3 ± 1.8

Table 7. Soil physico-chemical characteristics (mean ± standard deviation) before rehabilitation and 7 years after rehabilitation in a low-altitude village (Banswara, Chamoli district) and a high-altitude village (Khaljhuni, Almora district) in central Himalayas (after Rao *et al.* 1999).

Characteristics	Banswara		Khaljhuni	
	Before rehabilitation	After rehabilitation	Before rehabilitation	After rehabilitation
pH	6.6 ± 0.9	6.2 ± 0.8	5.8 ± 0.04	6.1 ± 0.04
Water-holding capacity	26.2 ± 6.0	46.7 ± 4.1	27.5 ± 4.2	35.6 ± 3.6
Carbon (%)	0.94 ± 0.2	1.76 ± 0.2	1.7 ± 0.7	2.9 ± 0.7
Nitrogen (%)	0.15 ± 0.05	0.28 ± 0.07	0.15 ± 0.02	0.21 ± 0.09

matter in the soil and woody biomass build-up (Table 8).

Economic viability

The NPV of investment was recovered over a period of 7 years (Tables 9 and 10). Local participation was economically advantageous in that costs for the mechanical measures of protection, centralized nurseries and transportation could be saved. Indeed, any strategy combining local economic concerns and national/global environmental concerns will be more costly (US$ 305 per ha in the present case, as compared to US$ 160-190 per ha the exclusive tree plantation programmes implemented by the government (Maikhuri *et al.* 1997a,b; Saxena *et al.* 1993), but investment in the former is more secure. One way of meeting the huge investment required for the rehabilitation of vast areas would be to establish model plots with government/donor funding, on the condition that a portion of the income from the treated plot would be invested for replication and participatory approaches for further improvement.

Table 8. Carbon sequestration rate (t ha^{-1} yr^{-1}) in soil and vegetation after rehabilitation in a low-altitude village (Banswara, Chamoli district, over a period of 5 years) and a high-altitude village (Khaljhuni, Almora district, over a period of 7 years) in the central Himalayas (after Maikhuri *et al.* 2000a and Rao *et al.* 1999).

Characteristics	Carbon sequestration	
	Banswara	Khaljhuni
Soil (0-15 cm)	2.2	3.4
Tree bole/bamboo culm	0.9	4.3
Total	3.1	7.7

Off-site benefits

The availability of fodder, medicinal plants and bamboo from the rehabilitated site close to the dwellings could save on the average 48 man-days of labour per year in the high-altitude village

Table 9. Monetary costs and benefits (Rs ha^{-1}; net present value at discount rate of 12%) of land rehabilitation over a period of 7 years in a high-altitude village (Khaljhuni, Almora district) of the central Himalayas (after Rao *et al.* 1999).

Costs / benefits	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
COSTS								
Land preparation	1335	-	-	-	-	-	-	1335
Plantation	5363	-	-	-	-	-	-	5363
Maintenance	2780	493	473	343	307	274	245	4915
Total cost	9478	493	473	343	307	274	245	11613
BENEFITS								
Fodder	1607	1674	1495	1336	1193	1065	815	9185
Bamboo	-	-	-	268	738	852	951	2809
Medicinal products	-	-	214	304	77	94	387	1076
Total benefits	1607	1674	1709	1908	2008	2011	2153	13070
Net return								1457

Table 10. Monetary costs and benefits (Rs ha^{-1}) of land rehabilitation over a period of 5 years in a low-altitude village (Banswara, Chamoli district) of the central Himalayas (after Maikhuri *et al.* 1997b).

Cost/Benefit	Year 1	Year 2	Year 3	Year 4	Year 5	Total
COSTS						
Tools and implements	500	300	200	300	400	1700
Water harvesting tank (material cost)	7478	250	100	-	50	7878
Labour	12584	11300	10700	10550	9500	54634
Other costs (including transport, maintenance)	2400	700	500	-	-	3600
Total cost	22962	12550	11500	10850	9950	67812
BENEFITS						
Wood and fodder	900	1400	3000	4100	6500	15900
Agronomic yield	20670	22070	22570	22870	23055	111235
Total benefits	21570	23470	25570	26970	29555	127135
Net return over a period of 5 years						59323

which, otherwise, would have been spent in collecting from distant forests (Rao *et al.* 1999). This saving of labour must have been diverted towards other productive activities, but we could not quantify it. Further availability of these products from degraded lands implies less pressure on forests and thereby fewer threats to the conservation of wild biodiversity and ecosystem service. Initiatives, following the rehabilitation treatment, in the cultivation of medicinal plants on private farmland, although involving only 3 farmers, can also be viewed as an off-site benefit.

The lessons learnt

Unfavourable site conditions and poor soil seed bank are the key problems for the restoration of degraded lands on steep slopes (Andreas & Michaela 1999; Ramakrishnan 1992). Plantation and reseeding together with mechanical and biological amendments of the soil become essential steps to accelerate the process of ecological restoration. The introduction of 'nurse species' or 'keystone species' would be the most desired course of action from the point of accelerating the natural recovery processes, but will be appreciated by the people only when they can satisfy their immediate needs. Further, limited ecological knowledge of traditionally valued species limits the scope for identifying keystone species (Kettler 1996; Ramakrishnan 1992). Despite this limitation, as shown from this study, there is scope for building successful rehabilitation strategies on indigenous knowledge, supplemented/ complemented with existing scientific knowledge and institutional support (Altieri & Masera 1993; DeWalt 1994).

There are two major problems in scaling out or up the elements of indigenous knowledge found effective on a small/local scale. First, ecological and socio-economic problems and prospects in the Himalayas are so diverse that interventions found appropriate in one region might not hold true in other regions. Second, although researchers have stressed the importance of flexibility, adaptability and an objective analysis of indigenous knowledge for reconciling the conflicts among different stakeholders (Holling & Meffe 1996; Ramakrishnan 1992; Ramakrishnan *et al.* 2000), these elements need to be properly accounted in policies and implementation programmes.

Incremental improvement in traditional agroforestry systems

Managing tree lopping practices

Productivity of both crop and tree components in traditional rainfed agroforestry systems in the central himalayas is limited by water and nutrient stress (Maikhuri *et al.* 1997a,b, 2000a). Local farmers believe that the yield-depressing effects of trees always outweighs their yield-enhancing effects, but maintain trees for fodder and fuel wood near dwellings during lean winter periods (Maikhuri *et al.* 1997a,b). As two food crops are harvested in a year, lopping seems an essential management in the regulation of tree-crop competition for optimizing multiple benefits from the system. Even though farmers are aware of a reduction in crop yields during the rainy season due to the tree canopy, they do not practise lopping during the rainy season for two reasons. First, the policy provides for the free utilization of non-timber forest products, which are abundant during the rainy season in the government forests (Rao *et al.* 1999). Second, they believe that lopping during the rainy season, although it may enable higher crop yields, will be detrimental to tree vigour. Farmers usually lop all branches of farm trees during the winter season because green fodder and fuel wood are scarce in forests at this time of the year. Tree lopping may result in an increase in PAR, day temperature and availability of water and nutrients to understory crops. The magnitude of these changes and their impacts on crop yields would depend upon the lopping intensity and ecophysiological attributes of trees and crops growing in association. Experimental trials showed that removal of 25% of the branches during the winter season was too low to result in any significant change in the yields of any of the crops except lentil. An almost linear increase in agronomic and by-product yields in all crops between 25% and 75% lopping rates, but insignificant difference in yields between 75% and full lopping (100%) treatments, suggests that lopping of >75% branches would not confer any advantage in terms of enhanced crop yields to farmers. As lopping and leaf fall in most of the tree species occurred during the winter season, winter crops showed a lower reduction in yields as compared to rainy-season crops when all tree species had the densest canopy. Lopping will certainly affect the tree growth. Availability of products from trees will depend on the magnitude of compensatory growth following lopping. Thus, the loss of crop yields may not be significant if 25% of the branches are retained (Semwal *et al.* 2002). Such a practice might also improve tree vigour in traditional agroforestry systems and reduce pressure on forests.

Soil fertility management

Traditionally, leaf litter from forests is used as bedding material in cattle-sheds and a litter-cattle excreta mixture is used as manure in the crop fields. An intensive survey of variation in yield in relation to forest type showed higher yields in oak dominated landscapes as compared to pine dominated ones (Ghosh *et al.* 1997). This formed the basis of a short-term experiment to test whether oak forest based manure will enable higher yields than pine based manure. The concentration of nutrients was higher and the C/N ratio and moisture content lower in oak manure as compared to pine manure, but the polyphenol concentration was almost the same (Table 11). The experiment carried out in a poor soil showed yields in oak manure treatment to be 15% higher than that in pine manure treatment (Table 12). Thus, there is scope for improving productivity in traditional agriculture by managing manure quality (Semwal *et al.* 2003; Woomer & Swift 1994).

Table 11. Important characteristics (mean ± standard deviation, n = 5) of oak-based and pine-based organic manure. Mean values of the two manure types are significantly (P<0.05) different if followed by a different superscript letter.

Characteristics	Manure type	
	Oak	Pine
Moisture (%)	226.21 ± 19.21[a]	303.50 ± 20.50[b]
Carbon (%)	24.66 ± 0.58[a]	33.33 ± 0.58[b]
Nitrogen (%)	1.40 ± 0.03[a]	1.16 ± 0.03[b]
Cellulose (%)	12.33 ± 0.57[a]	17.00 ± 2.64[b]
Lignin (%)	14.01 ± 1.05[a]	17.33 ± 0.29[b]
Polyphenol (%)	0.32 ± 0.04[a]	0.37 ± 0.03[b]
C/N	17.68 ± 1.25[a]	28.73 ± 0.48[b]
Lignin / N	10.04 ± 0.71[a]	14.94 ± 0.25[b]
Polyphenol + Lignin/ Nirtogen	10.26 ± 0.72[a]	15.26 ± 0.25[b]

Table 12. Biomass production (mean ± standard deviation, g m^{-2}) by wheat crop treated with oak-based and pine-based manure. The two treatments are significantly (P<0.05) different for all paramaeters.

Component	Manure type	
	Oak-based	Pine-based
Grain	58.5 ± 3.8	46.7 ± 2.7
Straw	108.8 ± 12.1	81.7 ± 5.6
Roots	8.5 ± 0.6	7.3 ± 0.1
Total	175.8 ± 11.6	135.7 ± 9.8

Conclusions

Though conservation and socio-economic development of local communities are complementary and equally important tasks, stress has been laid on achieving conservation through legal enforcement. If the development interests of local people are marginalized for a long period of time, they might adopt actions detrimental to the goal of conservation. Capitalizing on the positive dimensions of traditional knowledge and overcoming its negative dimensions through conventional science-based inputs could ease the difficult process of securing people's participation in environmental conservation together with the socio-economic development of local communities.

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