Patterns and Implications of Land Use/Cover Change

Authors: Sen, K. K., Semwal, R. L., Rana, U., Nautiyal, S., Maikhuri, R. K., et al.

Source: Mountain Research and Development, 22(1) : 56-62

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2002)022[0056:PAIOLU]2.0.CO;2

Mountain Research and Development Vol 22 No 1 Feb 2002: 56–62

K. K. Sen, R. L. Semwal, U. Rana, S. Nautiyal, R. K. Maikhuri, K. S. Rao, and K. G. Saxena

Patterns and Implications of Land Use/Cover Change

A Case Study in Pranmati Watershed (Garhwal Himalaya, India)

Land use/cover changes during the period 1963–1993 and their ecological and socioeconomic implications in Pranmati Watershed in the Indian Himalaya were analyzed on the basis of information extracted from archival records, satellite data, participatory discussions, and field measurement. Agricultural land use was practiced on 14.2% of the watershed area in 1963 compared with 18.5% in 1993. More than 50% of the agricultural expansion occurred in community forests between 1850 and 2400 m and on 20–30° slopes. The increase in area under cash crops, potato, and amaranth accompanied an 86% increase in the mean monetary value of crop produce but at the cost of abandoning the traditional crops Fagopyrum esculentum, F. tataricum, Panicum miliaceum, *and* Setaria italica. *Agricultural land use changes were such that mean manure input at the watershed scale increased by 50%, and fodder output from crops decreased by 40%, implying the increasing pressure on forests. Local forest management institutions have not been adequately empowered to respond to the growing economic aspirations of people and the increasing population pressure. Research and policy support for improvement in traditional soil fertility management practices and forest resource–based economic development opportunities for local people is needed to reduce the threat from agriculture to forest ecosystems.*

Keywords: *Land use change; agricultural expansion; socioeconomic factors; forest resources; Himalaya; India.*

Peer reviewed: *January 2001.* ***Accepted:*** *May 2001.*

Introduction

Crop–livestock mixed settled farming, the primary occupation of the local people in the central and western Himalaya, is dependent on forests to provide most of the livestock feed and forest leaf litter that is mixed with livestock excreta for use as manure (Ives and Messerli 1989). Agricultural expansion at the cost of forest cover is widespread (Singh et al 1984; Rai et al 1994; Ramakrishnan et al 1994; Thapa and Weber 1995; Schweik et al 1997). However, there are reports of tree cover improvement in the recent decades in a few villages (Gilmour and Nurse 1991; Fox 1993). Agriculture–forest–rural economy linkages have not been as comprehensively analyzed as the spatial extent of land use/cover changes. The aim of the present study was to analyze the patterns, causes, and ecological and socioeconomic implications of land use/cover changes during the 1963–1993 period in Pranmati Watershed in the Indian Himalaya.

Study area

Pranmati Watershed (30°5'–30°13'N and 79°29'–79°37'E), a segment of the upper Gangetic catchment, is located in Chamoli District and covers an area of 94 km^2. The altitude varies from 1100 to 4070 m (Figure 1). There are 13 settlements, largely confined to the area up to 2400 m. At 1600 m, the average annual rainfall is 1700 mm, and the mean monthly maximum and minimum temperatures are 25 and 11°C, respectively. The temperature decreases by about 1°C with a 180 m increase in altitude, but the area is uniform with respect to rainfall regime. Schists and gneisses dominate the parent material.

In the late 19th century, land rights were granted to farmers on cultivated terraced slopes, whereas all uncultivated lands (including alpine meadows) were registered as government reserve and protected forests. Local people were allowed to use nontimber forest resources, but the government decided on the level of use. In the 1930s, 18.5% of the forest area was classified as Village *Panchayat* (community forests), and the power to regulate the use of resources needed for subsistence within these forests was transferred to local institutions known as *Van Panchayat* (forest councils). Forest councils can impose a maximum fine of Rs 50 for violation of the rules they set. Councils need approval from the government for commercial extraction of nontimber forest resources. Agriculture and commercial timber extraction are banned on all forested lands (Rao and Saxena 1996).

Methodology

Human and livestock population

Data on human population in 1963 and 1993 were compiled from village records. Livestock holdings were not registered. Interviews were held with 20% of the holdings, selected randomly in each village, to enumerate current livestock holdings as well as holdings in and around 1963, as recalled by elderly family members.

Physical and land use/cover patterns

Thematic details in the Survey of India topographical map (1:50,000) enabled mapping of altitude, slope, aspect, and 4 classes of land use/cover (agriculture, forest, alpine meadows, and riverbed) as of 1963. Land use/cover in 1993 was mapped using visual interpreta-

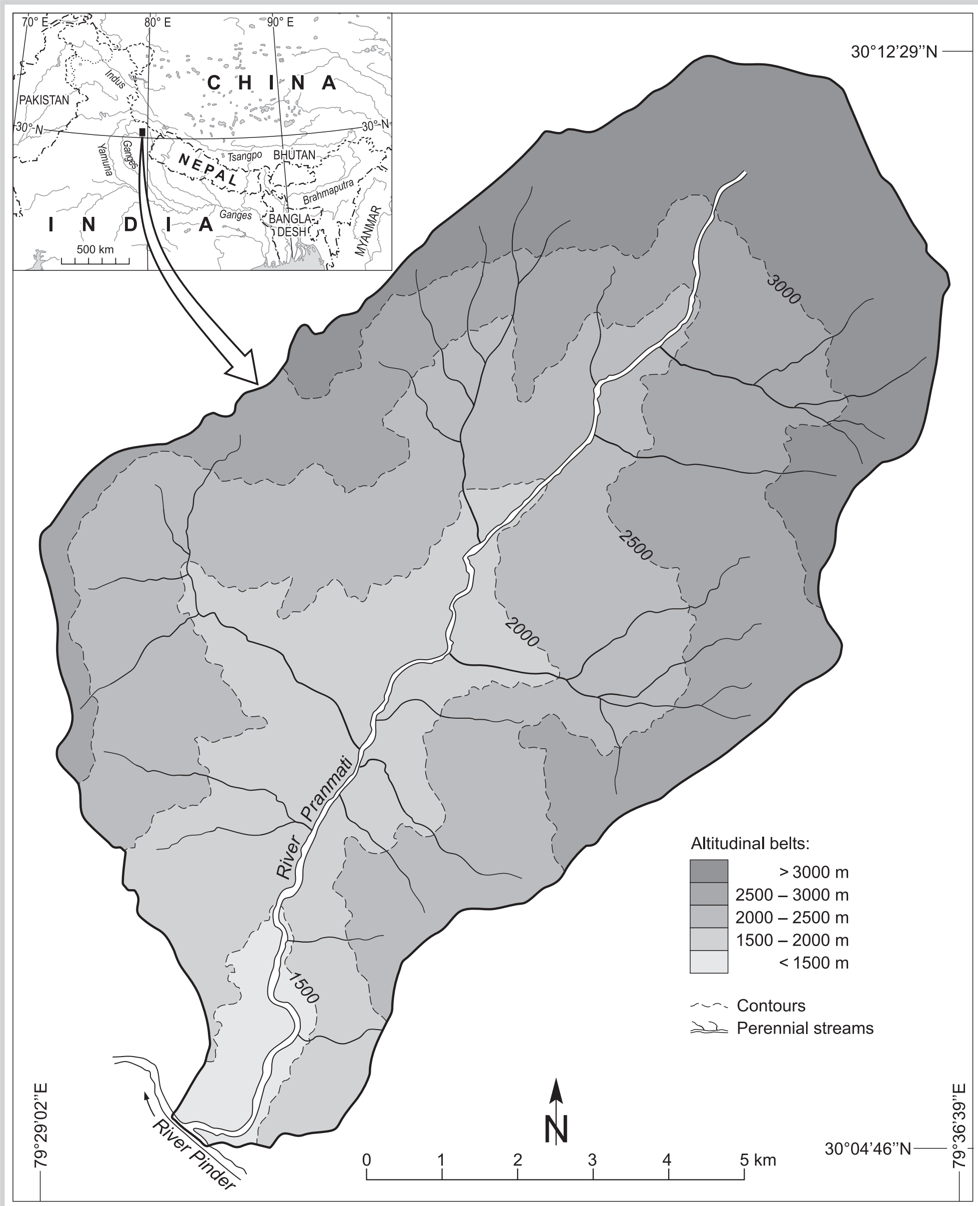

FIGURE 1 Location of Pranmati Watershed, showing the Pranmati River (locally known as the *Gad*), important streams, contour lines (at 500 m intervals) and altitudinal belts. (Map by K.S. Rao)

tion of the Standard Geocoded False Color Composite of Indian Remote Sensing Satellite data (1:50,000). Five classes—agriculture, open and closed forests (crown cover <30% and >30%, respectively), alpine meadows, and riverbeds—were delineated. Twenty locations in each class distributed across the watershed were visited to evaluate the accuracy of interpretation. An accuracy of 100% was achieved in the identification of agriculture, forests, alpine meadows, and riverbeds, by contrast with 90% in distinguishing open from closed forests. The boundaries of community, protected, and reserve forests were extracted from government records. All thematic maps were digitized and registered on polyconic projection and spatiotemporal dynamics of land use/cover, elucidated through overlay operations using Arc/Info software in a PC environment.

Cropping patterns, manure input, and yield

Individual cropwise area, inputs, and outputs were not available in village records nor could they be interpreted from satellite data. Based on watershed surveys, 3 elevation zones, 1100–1850 m, 1850–2400 m, and 2400–2600 m, with different cropping patterns were identified. In 20 holdings randomly selected in each zone, the area under different crops/fallow was measured. Manure input and yield of edible and fodder components were estimated in 20 random fields for each crop in each zone during the period 1993–1994 following Semwal and Maikhuri (1996). In addition to measurements, elders in the households were asked to quantify cropwise area, input, and yields in traditional measurement units that were converted to metric units. The insignificant difference ($P > 0.05$) between interview-based values and measurements during 1993–1994 confirmed the high degree of reliability among farmers in recalling past scenarios. Farmers were unable to recall crop/fallow area, manure, and yields in absolute terms in 1963 but could quantify relative changes during the 1963–1993 period. They responded to interviews with enthusiasm, partly because the research was part of a larger project for promoting resource management interventions based on indigenous knowledge and local priorities. Pooled data for a given elevation zone and the whole watershed area are presented.

Results

Human and livestock population

During the period 1963–1993, the number of households increased from 670 to 1890, the human population from 4760 to 10,551, the cattle population from 4590 to 12,948, sheep–goats from 4757 to 7733, and mules from 377 to 502. The increase in the number of households (182%) was higher than that of the human population (122%). Cattle showed the highest rate of population growth (182%), followed by sheep–goats (66%) and mules (33%).

Land use/cover

Agriculture accounted for 14.2% of the total watershed area, reserve forests for 13.7%, protected forests for 43.1%, community forests for 15.6%, and alpine meadows for 11.9% in 1963, compared with 18.5, 13.5, 41.4, 13.0, and 12.1%, respectively, in 1993. Thus agricultural land use expanded at an average annual rate of 0.14% of the total watershed area, or 1.03% over the agricultural area existing in 1963. More than 50% of the agricultural expansion occurred in community forests, between 1850 and 2400 m on 20–30° slopes. Agricultural expansion in reserve forests was negligible in comparison with that in protected and community forests (Table 1). In 1993, open forests covered 25% of the area of reserve forests, in contrast with 14.7% of community forests and 9.6% of protected forests. The rate of change from closed to open forests could not be estimated because forest area was not classified into open and closed classes in 1963 data. Agricultural expansion was more frequent in patches devoid of any significant tree cover (Figure 2).

Cropping patterns

Two crops were harvested, one during the summer rainy season (May–October) and the other during the winter season (November–April), but a substantial area was fallowed during the winter season. During the period 1963–1993, the area under potato and amaranth increased at the cost of complete abandonment of 2 buckwheat crops (*Fagopyrum esculentum* and *F. tataricum*) and hog millet and reduction in the area under barnyard and finger millet during the rainy summer cropping season. Foxtail millet used to be raised as a minor crop mixed with paddy but is not grown now. None of the winter crops was completely abandoned, but wheat and mustard replaced a significant area under barley (Table 2).

TABLE 1 Disaggregation of agricultural land use expansion from 1963 to 1993 according to elevation, slope, aspect, and forest classes in Pranmati Watershed.

Terrain feature	% of Total extension
Elevation zone (m)	
1100–1850	3.7
1850–2400	69.5
2400–2600	26.8
Slope class (°)	
<20	31.0
20–30	53.2
>30	15.8
Aspect	
Northwest	13.8
West	23.5
East	15.8
Southeast	28.5
Southwest	14.3
South	4.1
Forest type	
Reserve Forest	5.6
Community Forest	59.6
Protected Forest	34.8

Manure input and agronomic and fodder yield

Potatoes received the highest manure input (21–38 tons/ha). This was not applied at all to finger millet and varied from 2 to 17 tons/ha in other crops. Potato and buckwheat did not have any fodder value. Amaranth, mustard, and pulses yielded lower quantities of fodder (0.2–1.2 tons/ha) compared with cereals and millets (3.0–4.2 tons/ha). The mean annual manure input increased by 10, 50, and 93%, fodder output declined by 14, 36, and 87%, and the monetary value of crop yields increased by 58, 88, and 110% in the 1100–1850, 1850–2400, and 2400–2600 m elevation zones, respectively, from 1963 to 1993 (Table 3). At the watershed scale, manure input increased by 50%, fodder output from farmland decreased by 40%, and the monetary value of crop produce increased by 86%.

FIGURE 2 Trees in forests are heavily lopped, resulting in conversion of dense to open forests over time. The photo shows heavily lopped oak trees (*Quercus leucotrichophora*) and expansion of cultivation in an open area. (Photo by K. K. Sen)

TABLE 2 Relative area under different crops/fallow (% of total area in a given season) in 1963 and 1993 in 3 elevation zones in Pranmati Watershed. Area values in 1963 and 1993 in a given zone are significantly ($P < 0.05$, Mann–Whitney rank test) different if followed by different letters within parentheses. NG = not grown. The scientific names of the crops are given below the table.

Crops/fallow[a]	1100–1850 m Zone		1850–2400 m Zone		2400–2600 m Zone	
	% Area in 1963	% Area in 1993	% Area in 1963	% Area in 1993	% Area in 1963	% Area in 1993
Rainy season crops						
Amaranth	5(a)	10(b)	18(a)	28(b)	30	NG
Barnyard millet	20(a)	9(b)	10(a)	5(b)	NG	NG
Buckwheat (F.e.)	2	NG	4	NG	11	NG
Buckwheat (F.t.)	NG	NG	13	NG	14	NG
Finger millet[b]	35(a)	30(a)	24(a)	9(b)	NG	NG
Hog millet	10	NG	NG	NG	5	NG
Horse gram	1(a)	1(a)	8	NG	NG	NG
Paddy[c]	26(a)	30(a)	5(a)	7(a)	NG	NG
Potato	1(a)	20(b)	18(a)	51(b)	40(a)	100(b)
Winter season crops						
Barley	15(a)	7(b)	8(a)	3(b)	18	NG
Lentil	5(a)	4(a)	2(a)	1(a)	NG	NG
Naked barley	6(a)	2(a)	22(a)	15(b)	22	NG
Mustard	15(a)	20(b)	18(a)	27(b)	NG	20
Wheat	19(a)	27(b)	10(a)	16(a)	NG	NG
Fallow	40(a)	40(a)	40(a)	38(a)	60(a)	80(b)

[a]Amaranth, *Amaranthus paniculatus*; barnyard millet, *Enchinochola frumentacea*; buckwheat (F.e.), *Fagopyrum esculentum*; buckwheat (F.t.), *Fagopyrum tataricum*; finger millet, *Eleusine coracana*; hog millet, *Panicum miliaceum*; horse gram, *Macrotyloma uniflorum*; paddy, *Oryza sativa*; potato, *Solanum tuberosum*; barley, *Hordeum vulgare*; lentil, *Lens esculenta*; naked barley, *Hordeum himalayens*; mustard, *Brassica campestris*; wheat, *Triticum aestivum*.

[b]Pulses viz., soybean (*Glycine soja*), black gram (*Vigna mungo*), and rice bean (*Vigna angularis*) are grown as minor crops mixed with finger millet.

[c]Foxtail millet (*Setaria italica*) was mixed with paddy earlier but is not grown now.

TABLE 3 Farmyard manure input, fodder yield (tons/ha), and monetary return (Rs/ha; Rs 34=US$1 in 1994–1995) across elevation zones in 1963 and 1993 in Pranmati Watershed.

	1100–1850 m		1850–2400 m		2400–2600 m	
Farmyard manure/fodder	**1963**	**1993**	**1963**	**1993**	**1963**	**1993**
Farmyard manure input						
Rainy season crops	7.3	10.0	9.2	18.3	14.3	32.0
Winter season crops	7.7	6.5	9.1	9.1	2.5	0.4
Annual input	15.0	16.5	18.3	27.4	16.8	32.4
Fodder yield						
Rainy season crops	3.5	3.1	1.7	0.9	0.2	0.0
Winter season crops	1.5	1.2	1.6	1.2	1.3	0.2
Annual yield	5.0	4.3	3.3	2.1	1.5	0.2
Monetary return						
Rainy season crops	16,088	26,168	21,903	43,305	34,191	74,250
Winter season crops	5536	7986	5983	9217	2625	3000
Annual return	21,264	34,155	27,886	52,522	36,816	77,250

Discussion

The rate of agricultural expansion observed in Pranmati Watershed (0.14% of watershed area/year) was significantly lower than the rates (0.21–1.62% of watershed area/year) observed in other Himalayan watersheds (Virgo and Subba 1994; Thapa and Weber 1995; Schweik et al 1997). Such comparisons, however, should be viewed in light of variation in the spatiotemporal scale of change analysis, mapping methodology, and ecological, socioeconomic, and policy factors influencing land use dynamics. Though all agricultural land use on forestland is illicit in the Indian Himalaya, the degree of enforcement of this policy varies. Reserve forests were not much encroached upon because they were easily accessible and frequently visited by government officials for pine resin extraction prescribed in a government working plan. Encroachment is more frequent in community and protected forests because these forests are highly inaccessible and also excluded from government working plans. Forest councils are unable to check encroachments within community forests because of several reasons:

- Councils can impose fines up to Rs 50, a negligible amount when compared with the economic benefits of agriculture.
- Councils are not empowered to utilize any forest resources on a commercial scale and are hence unable to divert attention from agriculture-based to forest-based income opportunities.
- People are not much worried about encroachment because they have the right to use forest resources in reserve and protected forests for agriculture and other subsistence needs.

Unlike some other mountain areas where policies forced or promoted cash crops (Ives and He 1996; Preston 1998; Renaud et al 1998), expansion of cash crops, potatoes, and amaranth in Pranmati Watershed seems to be an indigenous initiative driven by a sociocultural change from a subsistence to a market economy (Bjonness 1983; Nusser and Clemens 1996), the comparative ecological and economic advantages of these crops, changing food habits, and the policy of supplying food grains at subsidized prices since the 1970s (Maikhuri et al 1996). Confinement of agricultural expansion to higher altitudes (1850–2600 m) is partly because climatic conditions here are more favorable for potato and amaranth. Farmers gained substantial economic benefits by expanding cash crops, although this was done at the expense of many traditional crops and cultivars. The latter development implies that options for coping with the risks of market failure and suspension of subsidized food grain supplies were foregone.

Differing from the trend observed in Pranmati Watershed, the change from a subsistence to a market economy progressed without any significant loss of crop diversity in Chhakinal Watershed (District Kullu, Himachal Pradesh). Farmers here switched from monocropping of traditional crops with poor economic potential to mixed cropping on small plots, rather than abandoning the crops altogether (Singh et al 1997). Bhotiya farmers, a transhumant tribal community in the Nanda Devi Biosphere Reserve (Uttar Pradesh,

FIGURE 3 A heap of manure outside a livestock shed. Leaf litter from the forest is used as bedding material in such sheds, and the mixture of litter and animal excreta is used as manure in fields. Higher manure input to sustain cash crops results in more intense litter removal from forests. (Photo by K. K. Sen)

Himalaya), began cultivation of many costly medicinal plants that used to be harvested from the wild, thus generating income without any significant loss of food crop diversity (Maikhuri et al 2000).

Increase in livestock population coupled with changes in composition of livestock holdings is a common trend, but the causes and magnitude of these changes vary (Sharma and Shaw 1993; Mishra 1997). In Pranmati Watershed, a change from the traditional joint families to nuclear families was accompanied by the persistence of traditions of sufficiency at the household level. These included maintaining cattle required for plowing and regarding sheep–goat–mule husbandry primarily as the occupation of lower caste groups. This appears to have contributed to a higher rate of increase in the cattle population. We were able to estimate the area under open and dense forest only for the 1993 period (open and dense forests were merged as 1 class in the 1963 data source). However, local people mentioned conversion from dense to open forest in many locations visited to check the accuracy of land use/cover interpreted from satellite imagery. Conversion of dense to open forests could be attributed to an increase in grazing–lopping pressure (Figure 2) as a result of agricultural expansion to forestland, increase in livestock population, decline in fodder production on farmland, and increase in the amount of litter removed from the forest floor in order to produce larger quantities of manure required for cash crops (Figure 3). The disturbance caused by whole tree cutting for timber, leading to conversion from dense to open forest, was rare in the study area (Saxena et al 1994).

Changes such as complete abandonment or long-term fallowing of agricultural land, use of chemical fertilizers at subsidized prices, and plantation of fodder trees on farmland have been observed as responses to the scarcity of manure and livestock feed (Gilmour and Nurse 1991; Maikhuri et al 1995; Rao and Saxena 1996; Schweik et al 1997; Nautiyal et al 1998). The absence of such changes in Pranmati Watershed suggests that farmers do not yet see manure and fodder as factors limiting farm productivity. However, the trends of agricultural expansion, increase in livestock population, decline in fodder production on farmland, and increase in manure input to sustain cash crops imply forest biodiversity and ecosystem function losses that might be difficult to recover in totality in the fragile Himalayan landscape (Rao et al 1999). As crop and livestock productivity is sustained with inputs derived from forests, continued depletion of forest resources in the long run will result in poor returns from agriculture, the backbone of the rural economy. Research and policy support for improvement in traditional soil fertility management practices and forest resource-based economic development opportunities for local people are needed to reduce threats from agriculture to forest ecosystems.

AUTHORS

K. K. Sen and K. S. Rao
Sustainable Development and Rural Ecosystems Programme, G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora 263643, India.
ksrao1@nde.usnl.net.in

R. L. Semwal, U. Rana, S. Nautiyal, and R. K. Maikhuri
G.B. Pant Institute of Himalayan Environment and Development, Garhwal Unit, PO Box 92, Srinagar (Garhwal) 246174, India.

K. G. Saxena
School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India.
kgsaxena@mail.jnu.ac.in

ACKNOWLEDGMENTS

We are grateful to the Director, G.B. Pant Institute of Himalayan Environment and Development, for facilities, to the TSBF, Nairobi, NORAD, the Delhi office, and ICIMOD, Kathmandu, for financial assistance, and to the editors and referees for comments and suggestions.

REFERENCES

Bjonness I. 1983. External economic dependency and changing human adjustment to marginal environment in the high Himalaya, Nepal. *Mountain Research and Development* 3:263–272.
Fox J. 1993. Forest resources in Nepali village in 1980 and 1990: the positive influence of population growth. *Mountain Research and Development* 13:89–98.
Gilmour DA, Nurse MC. 1991. Farmer initiatives in increasing tree cover in Central Nepal. *Mountain Research and Development* 11:329–337.
Ives JD, He Y. 1996. Environmental and cultural change in the Yulong Xue Shan, Lijiang District, NW Yunnan, China. *In:* Rerkasem B, editor. *Montane Mainland South East Asia in Transition.* Chiang Mai, Thailand: Chiang Mai University, pp 1–16.
Ives JD, Messerli B. 1989. *The Himalayan Dilemma: Reconciling Development and Conservation.* London: Routledge.
Maikhuri RK, Nautiyal S, Rao KS, Chandrasekhar K, Gavali R, Saxena KG. 2000. Analysis and resolution of protected area–people conflicts in Nanda Devi Biosphere Reserve, India. *Environmental Conservation* 27:43–53.
Maikhuri RK, Rao KS, Saxena KG. 1995. Experiences in developing a village agroforestry project in Garhwal Himalaya. *International Tree Crops Journal* 8:213–221.
Maikhuri RK, Rao KS, Saxena KG. 1996. Traditional crop diversity for sustainable development of Central Himalayan agroecosystems. *International Journal of Sustainable Development and World Ecology* 3:8–31.
Mishra C. 1997. Livestock depradation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation prospects. *Environmental Conservation* 24:338–343.
Nautiyal S, Maikhuri RK, Semwal RL, Rao KS, Saxena KG. 1998. Agroforestry systems in the rural landscape: a case study in Garhwal Himalaya, India. *Agroforestry Systems* 41:151–165.
Nusser M, Clemens J. 1996. Impacts of mixed mountain agriculture in the Rupal Valley, Nanga Parbat, Northern Pakistan. *Mountain Research and Development* 16:117–133.
Preston D. 1998. Post-peasant capitalist graziers: the 21st century in southern Bolivia. *Mountain Research and Development* 18:151–158.
Rai SC, Sharma E, Sundriyal RC. 1994. Conservation in the Sikkim Himalaya: traditional knowledge and land use of the Mamlay watershed. *Environmental Conservation* 21:30–34.
Ramakrishnan PS, Purohit AN, Saxena KG, Rao KS. 1994. *Himalayan Environment and Sustainable Development.* New Delhi: Indian National Science Academy Diamond Jubilee Publication.
Rao KS, Maikhuri RK, Saxena KG. 1999. Rehabilitation of degraded community land: a case study in a high altitude Himalayan village. *International Tree Crops Journal* 10:1–17.
Rao KS, Saxena KG. 1996. Minor forest products' management problems and prospects in remote high altitude villages of Central Himalaya. *International Journal of Sustainable Development and World Ecology* 3:60–70.
Renaud F, Bechstedt HD, Udomachai N. 1998. Farming system and soil conservation practices in a study area of northern Thailand. *Mountain Research and Development* 18:345–356.
Saxena KG, Rao KS, Pande A, Rana U, Sen KK, Nehal, Majila BS. 1994. *Sustainable Rural Development Opportunity and Constraints: A Micro-level Analysis of Pranmati Watershed in Uttar Pradesh Himalaya.* Almora: Himavikas Publication.
Schweik CM, Adhikari K, Pandit KN. 1997. Land-cover change and forest institutions: a comparison of two sub-basins in the Southern Siwalik Hills of Nepal. *Mountain Research and Development* 17:99–116.
Semwal RL, Maikhuri RK. 1996. Structure and functioning of traditional hill agroecosystems of Garhwal Himalaya. *Biological Agriculture and Horticulture* 13:267–289.
Sharma UR, Shaw WW. 1993. Role of Nepal's Royal Chitwan National Park in meeting the grazing and fodder needs of local people. *Environmental Conservation* 20:139–142.
Singh JS, Pandey U, Tiwari AK. 1984. Man and forests: a Central Himalayan case study. *Ambio* 13:80–87.
Singh GS, Rao KS, Saxena KG. 1997. Energy and economic efficiency of the mountain farming system: a case study in the north-western Himalaya. *Journal of Sustainable Agriculture* 9:25–49.
Thapa GB, Weber KE. 1995. Status and management of watersheds in the Upper Pokhara valley, Nepal. *Environmental Management* 19:497–513.
Virgo KJ, Subba KJ. 1994. Land use change between 1978 and 1990 in Dhankuta District, Koshi Hills, Eastern Nepal. *Mountain Research and Development* 14:159–170.