

Chapter 18

Land-Use Changes and Their Impact on Water Resources in Himalaya

Bhagwati Joshi and Prakash C. Tiwari

Abstract This chapter attempts to assess the impacts of land-use dynamics on the environmental status and availability of water resources in Himalaya with a case illustration of Upper Kosi catchment in Kumaon Himalaya. The study used remote sensing and field-based techniques along with qualitative and quantitative empirical methods. The results indicated that population growth and the resultant increased demand of natural resources have brought about rapid land-use changes decreasing forests (4.36%), extending cultivation (14.33%) and increasing wastelands and degraded lands (2.18%). These land-use changes have disrupted the hydrological regime of the catchment through increased run-off and decreased groundwater recharge and caused severe depletion of water resources. Nearly 33% of natural springs have dried and 11% have become seasonal, and 7.36 km stream length has dried during the last 30 years. Consequently, as many as 61% villages have been facing great scarcity of water for drinking, sanitation as well as for crop production, and this situation turns into a severe water crisis during dry summer months. The catchment has lost 18% of its irrigation potential due to drying of streams and springs resulting in a 25% decline in food production which has resulted in a 32% food deficit during 1981 and 2011. A comprehensive land-use policy based on the integrated management of land, water and forest resources needs to be evolved and implemented for the conservation and sustainable development of water resources in the region.

Keywords Headwaters · Subsistence agriculture · Population growth · Reduced groundwater recharge · Food deficit · Reduced irrigation potential · Comprehensive land-use policy

B. Joshi (✉)
Government Post Graduate College, Rudrapur, Uttarakhand, India
e-mail: bhawanatiwari@yahoo.com

P. C. Tiwari
Department of Geography, Kumaon University, Nainital 263002, Uttarakhand, India
e-mail: pctiwari@yahoo.com

18.1 Introduction

Himalaya is tectonically alive, economically underdeveloped and the most densely populated mountain ecosystems on the planet. Hence, Himalaya is highly vulnerable to the impacts of global environmental changes (ICIMOD 2010). Constituting headwaters of some of the largest trans-boundary river basins of the planet and one of the major global forests and biodiversity hotspots, Himalaya provides a variety of ecosystem services including water, genetic resources, soils and natural beauty (Viviroli and Weingartner 2003). These ecosystem services not only support livelihood of upstream communities but also sustain subsistence agricultural economy in its vast lowland all across Pakistan, India, Nepal, Bhutan, China and Bangladesh. The nature of terrain imposes severe limitations on the scale of productive activities as well as on efficiency of infrastructural facilities in the region. As a result, biomass-based subsistence agriculture constitutes the main source of rural livelihood and food even though the availability of arable land is severely limited and crop production is low (Maithani 1986; Singh et al. 1984). More than 75% of the population of the region depends on traditional subsistence agriculture even though the availability of arable land is severely limited (Tiwari 2007). During recent years, a variety of changes have emerged in traditional resource-use structure in response to population growth and the resultant increased demand of natural resources, economic globalization, growth of tourism, rapid urban development, improved access to market and exploitation of natural resources. Moreover, there is a regional shift from traditional crop farming and animal husbandry system to village-based production of fruits, vegetables, flowers and milk for sale, and this has large impact on the traditional resource development process and land-use pattern (Moench 1989; Singh et al. 1984). These changes are leading to land-use intensification through rapid changes in land cover in Himalayan headwaters. As a result, natural forests, wetlands and rangelands have deteriorated and degraded steadily significantly leading to their conversion into degraded and non-productive lands (Tiwari 2000; Tiwari and Joshi 2005; Bisht and Tiwari 1996). This has an unprecedented adverse impact on basic ecosystem services, particularly water, biomass and soil nutrients leading to a decline in the productivity of the rural ecosystem and undermining food and livelihood insecurities in Himalaya (Ives 1989; Valdiya and Bartarya 1991; Joshi et al. 2003).

These changes are disrupting the hydrological system of headwaters through reduced groundwater recharge, drying of natural springs and decreased stream flow and, consequently, increasing vulnerability of large parts of the population dependent on subsistence agriculture to water, food, livelihood and health insecurity, in both upstreams and downstreams (FAO 2005). Moreover, the changing climatic conditions have already stressed the Himalayan ecosystems through higher mean annual temperatures and melting of glaciers and snow, altered precipitation patterns and hydrological disruptions and more frequent and extreme weather events. In this context, the climate change acts as an additional stress which can multiply existing development deficits and may also reverse the process of socio-economic develop-

ment in the region (UNDP 2010). Further, these changes are likely to undermine the inherent capacity of mountain communities to respond and adapt to changing environmental conditions including climate change. This may increase the proportion of health-, food- and livelihood-insecure population in both upstreams and downstreams, which includes some of the poorest people of the world with access to less than 5% of planet's freshwater resources. This will have enormous regional implications for fundamental human endeavours ranging from poverty alleviation to environmental sustainability and climate change adaptation, and even to human security. In view of this, the Himalaya is highly critical from the viewpoint of marginality, environmental sensitivity, climate change, constraints of terrain, geographical inaccessibility and low infrastructural development. The main objective of this chapter is to interpret the trends of land-use dynamics in Himalaya in its ecological and socio-economic backdrop and assess their impacts on the environmental status and availability of water resources with a case illustration of Upper Kosi Catchment in Kumaon Himalaya.

18.2 The Study Area

The Upper Kosi Catchment (upstream Someshwer), which encompasses an area of 107.94 km², lying between 1,405 and 2,720 m altitude above mean sea level in the Kumaon Lesser Himalaya within the newly carved Himalayan state of Uttarakhand has been selected for the present study (Fig. 18.1). The Upper Kosi Catchment is situated in the district of Almora, which, together with 12 other districts, constitutes the Himalayan state of Uttarakhand. Kosi is one of the major rivers of the west Ramganga system of Kumaon Himalaya which ultimately drains into the Ganges system. The catchment is one of the most densely populated and agriculturally colonized tracts of Kumaon Himalaya. There are in total 65 villages in the catchment and the density of the population has been calculated to be 149 persons/km² in 2011. Consequently, the availability of per capita cultivated land is merely 0.17 ha, and more than 90% land holdings are of less than 1 ha. This shows that the pressure on land and other natural resources has been increasing in the region. As in other parts of Kumaon Himalaya, the traditional process of natural resource development has been changing rapidly mainly in response to the growth of the population and the resultant increased exploitation of natural resources for the past few decades. Consequently, the activities of cultivation, grazing and deforestation are extended over large areas of the region with the result that the proportion of degraded lands and wastelands have been increasing. Consequently, the critical natural resources, such as land, forests and water, have degraded and depleted steadily. The study area has been divided into four micro-watersheds for detailed study of various research parameters.

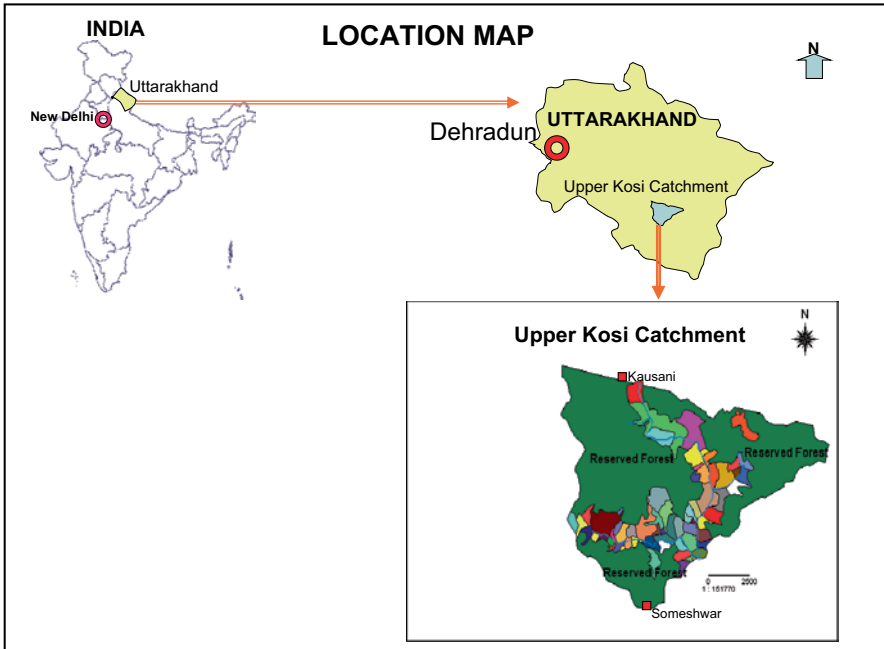


Fig. 18.1 Location map of upper Kosi catchment

18.3 Methodology

Interpretation of land use has been carried out for the years 1981 and 2011. A survey of India Topographical Maps at scale 1:50,000 has been used for land-use mapping for 1981, whereas, high-resolution satellite data were used for interpretation of land use for 2011. Digital interpretation techniques supported by intensive ground validation have been used for this purpose. The first step involved the preparation of the visual interpretation key based on preliminary interpretation of satellite data and extensive ground truth collection. This was followed by the digital classification of land cover/land use through on-screen visual recording and rectification. In order to enhance the interpretability of the remote-sensing data for digital analysis, several image-enhancement techniques, such as principal component analysis (PCA), normalized difference vegetation index (NDVI), etc., were employed. The land-use map of 1981 was digitized and a thematic layer was created, and, finally, the land-use changes that took place in the region between 1981 and 2011 were detected using change detection techniques in geographic information system (GIS; Fig. 18.2). Besides, various qualitative and quantitative empirical methods have been used for the analysis and interpretation of a range of research parameters. Necessary data and information required for the assessment of the impacts on land-use dynamics on the status and availability of water resources have been generated through primary sources employing field observations and monitoring methods, and through con-

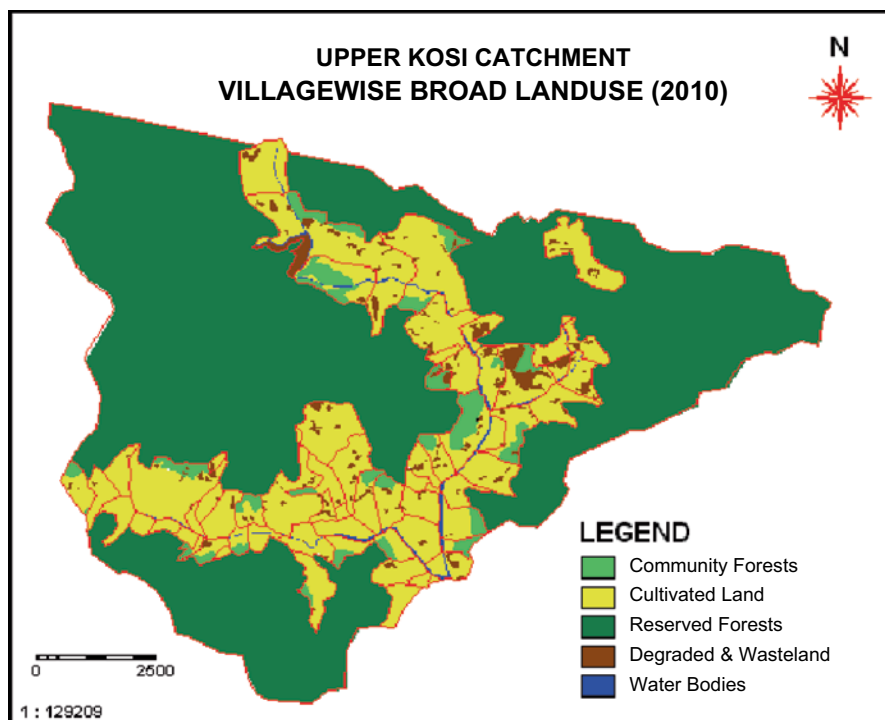


Fig. 18.2 Upper Kosi catchment: village-wise broad land use (2010)

ducting comprehensive socio-economic surveys using exclusively designed schedules and questionnaires.

18.4 Current Land Use

The current land-use pattern (2011) of the catchment has been broadly classified into (i) reserved forests, (ii) community forests, (iii) cultivated land, (iv) degraded land and wasteland and (v) water bodies which respectively constitute 68.21, 3.12, 25.73, 2.18 and 0.76% of the total area (107.94 km²) of the region (Table 18.1 and Fig. 18.2). The reserved forests are state property resource and they are situated outside village boundaries and supposed to be completely free from all kinds of resource-use pressures and encroachments. However, traditionally, the rural communities living interspersed in the reserved forests have enjoyed limited rights and concessions, but now these facilities have been withdrawn or limited in most of the reserved forests of Uttarakhand, particularly after the creation of a network of protected areas and the prohibition of green felling above an altitude of 1,000 m in Himalaya. Community forests, which broadly include all those forests and forest

Table 18.1 Land use changes in upper Kosi catchment between 1981 & 2011 (in km²)

Land use classes in 2011	Land use classes in 191				Total (2011)	
	Forests area	Cultivated land	Degraded & wasteland land	Water bodies	in km ²	% of total area
Reserved forests	73.63	–	–	–	73.63	68.21
Community forests	2.07	–	1.30	–	3.37	3.12
Cultivated land	3.34	24.23	0.20	–	27.77	25.73
Waste & de-graded Land	1.47	0.06	0.82	–	2.35	2.18
Water bodies	–	–	–	00.82	0.82	0.76
Total (1981) in km ²	80.51	24.29	2.32	00.82	107.94	100.00
Total (1981) % of total area	74.58	22.50	02.14	0.76	100.00	

land which fall inside the village boundary, except the private forests, are under common pool resources (CPRs). In order to involve the local people in the protection and conservation of these forests, the control of some of the community forests has now been transferred to the respective villages after reviving the system of Forest *Panchayats* (Forest *Panchayat* is a constitutional village-level institution created for participatory management of village forests in India during the British regime). During recent years, some of the village forests have also been brought under the Joint Forest Management (JFM) in the region. This is a recent experiment in the process of participatory forest management in the region which is currently being implemented under project mode with financial support of the World Bank. The JFM projects are being executed by non-governmental organizations (NGOs) through community participation. Interestingly, only 3.37 km² or 3.12 % of the total area of the catchment is under community forests (Table 18.1). But the availability of merely 3.37 km² of community forests for as many as 65 villages is highly inadequate in the region where forest-based subsistence constitutes the main source of rural livelihood. Practically, this is the only forest available to the local population for fulfilment of their all forest-based resource needs. Nevertheless, as many as 36 villages (out of total 65) in the region do not have any community forest. As a result, more than 55 % of the villages of the region are practically dependent on reserved forests for the fulfilment of their various resource needs.

As mentioned in the preceding sections, the Catchment represents one of the densely populated and intensively cultivated regions of Kumaon Himalaya (Joshi et al. 1983). An area of 27.77 km² or 25.73 % is under cultivation of which only 15 % is irrigated. The remaining cultivated land, mainly lying upslope, and ridges are never irrigated because of non-availability of water and its inappropriate management. Although the availability of arable land is severely limited, yet, in the absence of other viable means of livelihood, dependence on agriculture is considerably high. As a result, intensity of cropping is very high (150 %). The higher cropping intensity in low agricultural potential areas symbolizes distress of cultivation of land (Maitani 1986). Out of the total 65 villages, 47 % are intensively cultivated with more than 75 % of their total area under cultivation, 15 have cultivated land ranging from 45 to 75 % and only 3 villages of the watershed have less than 45 % of their area

under cultivation. Out of the total area of the watershed (107.94 km²), 2.35 km² or 2.18% were identified as wastelands and 0.82 km² or 0.76% are under waterbodies that mainly include stream beds and tiny mountain canals.

18.5 Resource-Use Dynamics

The traditional resource utilization pattern in the region has been changing fast mainly in response to population growth (average more than 1.5%/year) and increasing economic and social marginalization. The impacts of changes in the community resource utilization structure are clearly discernible in terms of rapid land-use changes (Tiwari 1995). Agriculture is being extended to forests and marginal and sub-marginal lands, and pastures are turning into wasteland and degraded land due to overexploitation and the resultant decline in productivity. With rapid growth of population, the pressure on cultivated land has increased, and more than 90% of the land holdings are of less than 1 ha. Consequently, the availability of cultivated land is merely 0.14 ha/person against a minimum of 0.2 ha/person as required for practising agriculture on a sustainable basis in the high Himalayan mountain ecosystem (Ashish 1983).

Out of the total 65 villages of Upper Kosi Catchment, as many as 36 have no forests within their boundaries, and per capita availability of forests in the remaining 29 villages is below 0.15 ha. In Himalaya, 5–10 ha well-stocked forest is required to support biomass requirement of 1 ha of agricultural land on sustainable basis (Singh et al. 1984), whereas in the Upper Kosi Catchment, the availability of forest to per hectare of cultivated land ranges between 0.10 and 2.07 ha. The grazing pressure is also very acute as only 0.02–1.67 ha/cattle grazing area is available in the catchment against the ecologically recommended norm of a minimum of 3.5 ha/cattle (Singh et al. 1984).

18.6 Land-Use Changes

Results of land-use change detection exercise revealed that out of a total area (107.94 km²) of the region, 8.44 km² or 7.81% have changed from one land use to another during 1981–2011. Table 18.1 makes it clear that in contrast to the general conception, the agricultural land in the region has not increased much during the last 30 years. The total cultivated land has increased from 24.29 km² in 1981 to 27.77 km² in 2011, and, thus, registered an overall increase of 14.33%. This increase in cultivated land has been brought through the extension of cultivation in forests (3.34 km²) and wastelands (0.20 km²). The area under forests in the catchment has declined from 80.51 km² in 1978 to 77.00 km² (73.63 km² reserved forest and 3.37 km² community forests) in 2008 mainly due to diversion of 3.34 km² forest land to agriculture and turning of 1.47 km² community forests into degraded lands

Table 18.2 Changes in status of water resources in upper Kosi catchment (1981–2011)

Micro-watersheds	Total area (km ²)	Springs dried (in %)	Springs become seasonal (in %)	Stream-length dried (in m)
North Kosi	44.23	41	17	311
East Kosi	29.18	36	11	227
West Kosi	23.37	47	21	114
South Kosi	11.16	11	05	84
Total	107.94	33.75	10.80	736

and wastelands, thus registering a total decrease of 4.36%. Wasteland has increased from 2.32 km² or 2.14% in 1978 to 2.35 km² or 2.18% in 2008 as 1.47 km² forests and 0.06 km² cultivated land were converted into wasteland in the catchment. But, at the same time, 0.20 km² and 1.30 km² wasteland have been brought, respectively, under cultivation and community forests in the region during the last 30 years (Table 18.1).

18.7 Impact of Land-Use Changes on Water Resources

These land-use changes are of great significance in the ecologically fragile, tectonically live and economically underdeveloped Himalaya as the ecosystem services that it provides support one of the most densely populated regions of the world dependent on subsistence agriculture. Excavation of fragile slopes for road and house construction, removal of vegetal cover, extension of agriculture to marginal and sub-marginal areas and forests and intensification of land use under the impact of changing resource-use practices are leading to rapid environmental changes in the Himalayan watersheds (Tiwari and Joshi 2007, 2005). The decrease in forests has disrupted the hydrological regime of the Himalayan watershed. Studies indicate that the amount of surface run-off from cultivated (80%) and barren land (85%) is much higher compared to that from forests (25%; Tiwari 1995, 2000). These hydrological disruptions are now clearly discernible in (i) a long-term decreasing trend of stream discharge, (ii) a diminishing discharge and drying of springs and (iii) biotic impact on the surface run-off flow system and channel network capacity (Ives 1985; Rawat 2009; Tiwari and Joshi 2012).

The study revealed that out of a total of 107 springs of the Kosi headwater, nearly 33% have completely dried up and more than 11% have become seasonal during the last 30 years (Table 18.2), mainly due to large-scale deforestation and the resultant loss of water-generating capacity of the soil (Tiwari 2000; Rawat 2009). It was observed that more than 75% of the dried springs are located in areas where the forests have been either brought under agriculture or converted into degraded land. The application of change detection techniques using remote-sensing data also revealed that a stream length of 7.36 km has completely dried up out of the total of 26 km of stream length in the Kosi headwater due to rapid land-use changes as a dried stream length of more than 2.5 km lies in wastelands and degraded lands. The

Table 18.3 Changes in water availability, biomass supply and irrigation potential in upper Kosi catchment (1981–2011)

Micro-watersheds	% Villages facing water scarcity	% Decrease in biomass supply to agriculture	% Irrigation potential reduced	% Agricultural productivity declined
North Kosi	67	35	14	25
East Kosi	51	29	17	33
West Kosi	69	41	21	19
South Kosi	57	58	19	24
Total	61	41	18	25

degradation of land and forests is not only reducing groundwater recharge resulting in the decline of water-generating capacity of land, but also rendering the degraded and fragile mountain slopes highly vulnerable to landslides and other such natural hazards in the headwater. As many as 17 active landslides have been identified on the deforested and degraded slopes in the region.

Moreover, the rapid degradation of forests and the resultant decline in the availability of water resources have increased the vulnerability of the region to resource deficiency resulting in food and livelihood insecurity. Currently, the region faces a huge deficit of food (42%), fodder (46%) and fuelwood (44%). Table 18.3 shows that as many as 61% of villages have been facing a great scarcity of water for all purposes where the situation turns into severe water crisis during dry months. As a result, people of the headwater have to walk up to 5, 7 and 2 km for the collection of fodder, fuelwood and water, respectively. A study revealed that the depletion of forests and the resultant hydrological disruptions have caused a 29% (East Kosi) to 58% (South Kosi) decline in supply of biomass to agro-ecosystems and a loss of 14% (East Kosi) to 21% (South Kosi) of irrigation potential (in terms of irrigated area) in different micro-watersheds of the Upper Kosi Catchment during the last 30 years (Table 18.3). The loss of primary ecosystem services, particularly water and biomass, has a direct adverse impact on the productivity of the subsistence agricultural system. The different micro-watersheds of the Upper Kosi Catchment have lost their agricultural productivity ranging from 19% in West Kosi to 25% in North Kosi with an overall decline of 25% (Table 18.3).

The study made clear that the entire Kosi headwater is now facing severe water deficiency, which is evinced by inadequate or even non-availability of water for various domestic needs and decline of irrigated land in the region. The main reason investigated for increasing the scarcity of water for both domestic and irrigation was the rapid depletion of water resources in the watershed. However, it was also observed that improper management, conservation and utilization of available water resources are also contributing towards increased water stress in the region to some extent. For instance, no measures have so far been taken for converting huge amounts of run-off during the monsoon season into water resource, wider rain water harvesting and inter-catchment transfer of water (particularly transfer of water from snow-fed rivers to rain-fed water scarcity basins) for meeting the growing demand of drinking and irrigation water, and even effective strategies for replenishing, regeneration and conservation of dwindling water resources are ex-

tremely lacking in the entire region. Furthermore, it was observed during the field surveys that in a number of villages, the water supply is irregular and mainly due to inappropriate maintenance and inefficient governance of the water supply system causing great hardship to local people and resulting in the underdevelopment of the entire region.

18.8 Conclusions

During the last three decades, there has been significant conversion of forests into cultivated and degraded land in the Himalaya. As a result, the proportion of both agricultural lands and wastelands have increased, while the area under forests has declined in the region. The main driving forces of these land-use dynamics are the population growth and the resultant changes in community resource-use structure. These land-use changes have shown an unprecedented adverse impact on the water-generating capacity of land to springs and streams, biomass supplies to agro-ecosystems and productivity of natural resources in the region. As a result, a considerably large proportion of natural springs and heads of a number of perennial streams have dried affecting rural water supplies, leading to a loss of irrigation potential and rendering rural areas highly deficit in food, fodder and fuelwood. These ecological impacts of ongoing land-use changes have not only undermined community health, threatened the livelihood and food securities of rural poor but also increased the trends of outmigration of entreprenuring rural male youths and, thus, have contributed to further worsening the quality of rural life in the region. The conservation of water resources is, therefore, closely interlinked with rationalizing rural resource utilization patterns and management of land and forest resources in the region. In view of this, it is highly imperative to evolve integrated land-use policies, which are conservation oriented, and also attune to community resource needs and developmental priorities.

Acknowledgement The authors are grateful to the Department of Science and Technology, Government of India for providing generous financial support for carrying out this study.

References

- Ashish M (1983) Agricultural economy of Kumaon Hills: a threat to ecological disaster. In: Singh OP (ed) *The Himalaya: nature, man and culture*. Rajesh, New Delhi, pp 233–245
- Bisht BS, Tiwari PC (1996) Land use planning for sustainable resource development in Kumaon Lesser Himalaya: a study of Gomti Watershed. *Int J Sustain Dev Ecol* 3:23–34
- ICIMOD (2010) Mountains of the world—ecosystem services in a time of global and climate change: seizing Opportunities—meeting challenges, Framework paper prepared for the Mountain Initiative of the Government of Nepal by ICIMOD and the Government of Nepal. Ministry of Environment
- FAO (2005) *Forest and water*. FAO, Rome, Forestry Paper No 155

- Ives JD (1985) Himalayan environmental regeneration: an overview what are the problems and how can they be tackled. In: Singh JS (ed) Environmental regeneration in Himalaya. Gyanodaya Prakashan, Nainital, pp 1–11
- Ives JD (1989) Deforestation in the Himalaya: the cause of increased flooding in Bangladesh and Northern India. *Land Use Policy* 6:187–193
- Joshi SC, Joshi DR, Dani DD (1983) Kumaun Himalaya: a geographical perspective on resource development. Gyanodaya Prakashan, Nainital, pp 108–139
- Maithani BP (1986) Towards sustainable hill area development. *Himalaya: man, nature and culture*, 16:4–7
- Moench M (1989) Forest degradation and the structure of biomass utilization in a Himalayan foothill village. *Environ Conserv* 16(2):137–146
- Rawat JS (2009) Saving Himalayan rivers: developing spring sanctuaries in headwater regions. In: Shah BL (ed) Natural resource conservation in Uttarakhand. Ankit Prakashan, Haldwani, pp 41–69
- Singh JS, Pandey U, Tiwari AK (1984) Man and forests: a Central Himalayan case study. *Ambio* 13:80–87
- Tiwari PC (1995) Natural resources and sustainable development in Himalaya. Shree Almora Book Depot, Almora
- Tiwari PC (2000) Land use changes in Himalaya and their impact on the plains ecosystem: need for sustainable land use. *Land Use Policy* 17:101–111
- Tiwari PC (2007) Urbanization and environmental changes in Himalaya: a study of the lake region of district Nainital in Kumaon Himalaya, India, International Working Paper Series ISSN 1935-9160. Urbanization & Global Environmental Change (UGEC), International Human Dimension Programme (IHDP). Working Paper 07-05, pp 1–19
- Tiwari PC, Joshi B (2005) Environmental changes and status of water resources in Kumaon Himalaya. In: Libor J, Haigh M, Prasad H (eds) Sustainable management of headwater resources: research from Africa and Asia. United Nations University, Tokyo, pp 109–123
- Tiwari PC, Joshi B (2007) Rehabilitation and management of wasteland in the Himalayan headwaters: an experimental study of Kosi Headwater in Kumaon Lesser Himalayas in India. *Int J World Assoc Soil Water Conserv* J2:39–62
- Tiwari PC, Joshi B (2012) Environmental changes and sustainable development of water resources in the Himalayan headwaters of India. *Int J Water Resour Manage*, 26(4):26:883–907. doi:10.1007/s11269-011-9825-y
- UNDP (2010) Summary of implications from the East Asia and South Asia consultations: asia pacific human development report on climate change, Colombo, UNDP Asia Pacific Regional Centre, Human Development Report Unit
- Valdiya KS, Bartarya SK (1991) Hydrological studies of springs in the catchment of Gaula River, Kumaon Lesser Himalaya, India. *Mt Res Dev* 11:17–25
- Viroli D, Weingartner R (2003) Mountains: sources of the world's freshwater. Newsletter (32), ICIMOD, Kathmandu