



# Land Use Change and Its Impact on Ecosystem Services: Food, Livelihood, and Health Security in Kumaon Himalayas

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## Abstract

This chapter attempts to assess the impacts of land use dynamics on ecosystem services, food, livelihood, and health security in the Himalaya with a case illustration of The Upper Kosi catchment in the Kumaon Himalaya, India. The study used remote sensing and field-based techniques along with qualitative and quantitative empirical methods. The results indicate that population growth and resultant increased demand for natural resources have brought about rapid land use changes, decreasing forests (4.36%), extending cultivation (14.33%), and increasing waste, and degraded land (2.18%). These land use dynamics have adversely affected primary ecosystem services, such as water, biodiversity, and biomass productivity. Nearly 33% of natural springs have dried and 11% have become seasonal, and 736 km stream-length has dried. Consequently, supply of biomass manure to agriculture has declined (41%), irrigation potential has reduced (18%), and food productivity has decreased (25%) increasing deficit levels in food, fodder, and fuelwood by

32%, 20%, and 27%, respectively. The region registered 38%, 24%, 15%, and 28% decline of rural livelihood opportunities, respectively in forest, agriculture, livestock, and traditional handicraft sectors due to loss of forests and biodiversity and decline in agricultural and livestock production. Nearly 47% males and 65% females have been affected by a variety of water-borne diseases in the region.

## Keywords

Groundwater Recharge · Population Growth · Resource Deficit · Subsistence Agriculture · Water-Borne Diseases

## 19.1 Introduction

During recent years, land use changes have emerged as one of the powerful drivers of global change affecting mountain landscapes and ecosystems (Zierl and Bugmann 2005; Löffler et al. 2011). Economic globalization and population growth are likely to have far reaching impacts on the natural ecosystems as well as on human sustainability in mountains (Tasser et al. 2005). The mountain regions of the world, particularly in developing countries have experienced drastic changes in land use patterns during the last some decades (FAO 2008). These changes in ecosystem structure and functions are causing great loss

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of biodiversity and disrupting biogeochemical cycles and hydrological processes in high mountains (Haigh 2002; Borsdorf et al. 2010; Huddleston et al. 2003).

The Himalaya being ecologically fragile, economically underdeveloped, and the most densely populated mountain ecosystem on the planet is highly vulnerable to the impacts of environmental changes (ICIMOD 2010; 2017). The nature of terrain imposes severe limitations on the scale of productive activities as well as on the efficiency of infrastructural facilities in the region (Maithani 1986). As a result, biomass-based subsistence agriculture constitutes the main source of rural livelihood and food security (Tiwari and Joshi 2017). More than 75% population of the region depends on traditional subsistence agriculture even though the availability of arable land is severely limited and crop productivity is considerably low (Tiwari and Joshi 2017). This traditional agriculture is interlinked with forests and pastures and flow of biomass energy from forests to agroecosystem is mediated through livestock (Moench 1989; Singh et al. 1984). During the recent past, a variety of changes have emerged in traditional resource use structure mainly in response to population growth and resultant increased demand for natural resources (Haigh 2002; Ives 1985). Besides, during recent years, the Himalaya has experienced rapid urban growth and emergence of many rural service centers which are intensifying the land use and disrupting hydrological regimes of the Himalayan watersheds (Tiwari and Joshi 2016). A large proportion of arable land is being encroached upon by urban growth and expansion of infrastructure, services, and economic activities in the region (Tiwari and Joshi 2016). Moreover, the improved access to market and growth of tourism has also transformed traditional rural resource utilization patterns, and as a result, 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 a large impact on the traditional resource development process and land use pattern (Singh et al. 1984). Consequently, the critical natural resources, such as land, water, forests, and biodi-

versity have depleted steadily and significantly leading to their conversion into degraded and wastelands in the region (Singh 2007; Tiwari 2000). These land use changes have unprecedented adverse impact on basic ecosystem services, particularly freshwater, biomass, soil nutrients leading to decline in productivity of rural ecosystem and undermining food and livelihood insecurities in the Himalaya (Ives 1989; Valdiya and Bartarya 1991; ICIMOD 2017).

The main objective of this chapter is to interpret the trends of land use dynamics in the Himalaya in its ecological and socioeconomic backdrop and to assess their impacts on ecosystem services, community food, livelihood, and health systems securities with a case illustration of the Upper Kosi catchment in the Himalaya, India.

#### **Box 19.1 Sustainable Development Goals**

In the Upper Kosi catchment of the Kumaon Himalayas, one of the critical challenges is the dramatic and dynamic change in land use resulting in a change of its ecosystem services, food availability, livelihood, and the health of the local population. The authors of this chapter observe that for the sustainable development of the local population, it is important to conserve the ecosystems and alleviate poverty in the low agricultural productivity or ecologically vulnerable areas. This can only happen if stakeholders carefully consider the relationship between land use changes and the economic development in the vulnerable areas of the Kumaon Himalayas. The authors recognize that this region is significant for its enriched biodiversity and immense ecosystem services. However, it emerges from their research that the same is under pressure from rapid population growth, developmental activities, unplanned urbanization, climate change, and the associated changes in land use and land cover. These challenges can be addressed with the help of targets and indicators

enshrined in SDG-15. India's planning organization *Niti Aayog*, mirrors the *SDG* as it moves forward to build capacity to provide integrated sustainable development in Kumaon Himalayas by understanding and articulating the current food system along with climate change as together they will determine food security, livelihood, and health security in the region. This chapter's key findings include the need to preserve Kumaon Himalayas ecosystem, conservation and restoration of degraded habitat, and an understanding of the local and regional drivers of change and its impact on biodiversity and ecosystem loss.

## 19.2 The Study Area

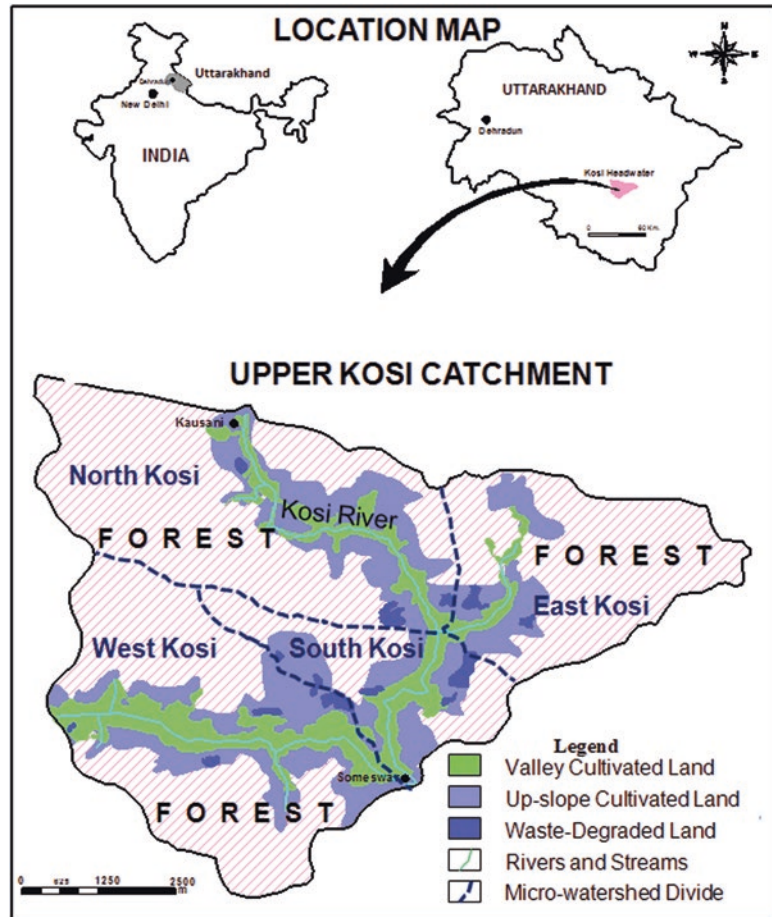
The Upper Kosi Catchment (upstream Someshwar) which encompasses a geographical area of 107.94 km<sup>2</sup> between 1500 and 2650 m above mean sea level in the Kumaon Lesser Himalaya in Uttarakhand was taken as the case study site (Fig. 19.1). The Kosi is one of the major rain-fed rivers of Kumaon which ultimately drains into the Ganges system. The catchment is one of the densely populated and agriculturally colonized tracts of the Kumaon Himalaya. There are total 65 villages in the catchment and the density of population has been calculated to be 149 persons km<sup>2</sup>, whereas the availability of per capita cultivated land is merely 0.17 ha, and more than 90% of land holdings are of less than 1 ha. As in other parts of the Kumaon Himalaya, the traditional process of natural resource development has been changing rapidly mainly in response to the growth of population and resultant increased demand of natural resources for the past few decades. The study area has been divided into four micro-watersheds for a detailed study of various research parameters (Fig. 19.1).

## 19.3 Data Collection and Methodology

The information and data required for the study have been generated and collected from various primary and secondary sources. Necessary data and information required for the assessment of the impacts of land use dynamics on ecosystem services, drinking water supply, irrigation, agricultural productivity, food supplies, employment, and health have been generated through primary sources employing field observations and monitoring methods, and through conducting comprehensive socioeconomic surveys using exclusively designed schedules and questionnaires, conducted during 2011–2015. The relevant secondary information was derived from high-resolution satellite images (1985 and 2015), Survey of India (SOI) Topographical Maps, forest maps, cadastral maps, government land records, local Drinking Water, and Irrigation Departments during 2011 and 2015 and used in the present work. The land use dynamics of the study area have been monitored between 1985 and 2015 using high-resolution satellite data. Digital interpretation techniques supported by on-screen visual recording and rectification have been used for this purpose. The first step involved in preparation of visual interpretation is 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 screen visual recording and rectification. To enhance the interpretability of the remote sensing data for digital analysis, several image enhancement techniques, such as Principal Component Analysis (PCA) and Normalized Difference Vegetation Index (NDVI), were employed. The land use changes that took place in the region between 1985 and 2015 were detected using change detection techniques in GIS environment (Fig. 19.2).

Water flow in springs and streams in the region is monitored by the government departments of drinking water supply and irrigation,

**Fig. 19.1** Location Map of the Study Area



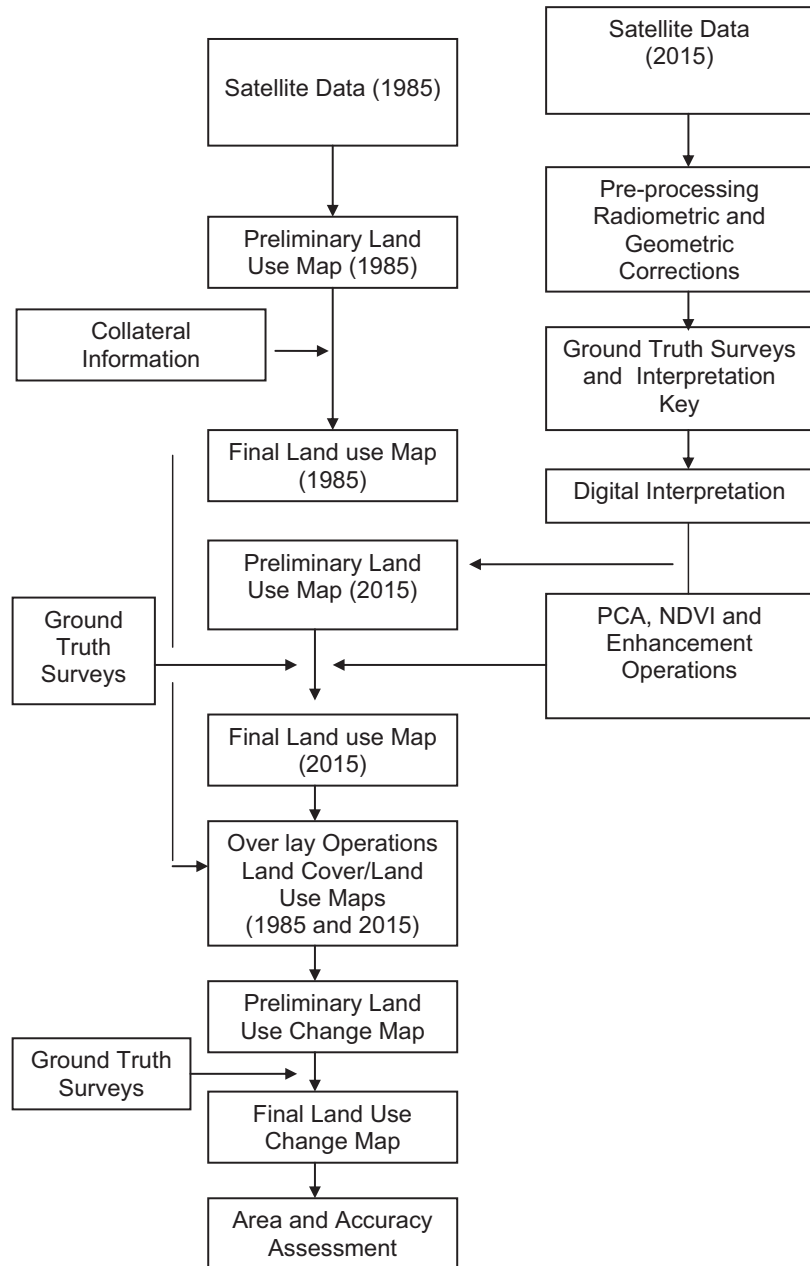
**Figure 1**

and the relevant information on these hydrological parameters have been obtained from these agencies for the period during 1985 and 2015 and used in the present study. Besides, the information with respect to environmental status of water resources (e.g., streams and springs) has been generated through intensive field surveys, mapping, and interviewing elderly people in each of the villages of the study region using exclusively framed schedules and questionnaires. In order to make the outcomes of the study more applicable and community-oriented, detailed appraisal and mapping of the land, water, and forest resources in all 65 villages of the Kosi headwater have been carried out with the involvement of local people.

#### 19.4 Current Land Use

The current land use pattern of the catchment has been broadly classified into: (1) reserved forests, (2) community forests, (3) cultivated land, (4) degraded and wasteland, and (5) water bodies which respectively constitute 68.21%, 3.12%, 25.73%, 2.18%, and 0.76% of the total area (107.94 km<sup>2</sup>) of the region (Table 19.1 and Fig. 19.3). The reserved forests are State Property Resource which 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 the reserved forests have enjoyed limited rights and concessions, but now these facilities have been withdrawn or

**Fig. 19.2** Methodology of land use change detection



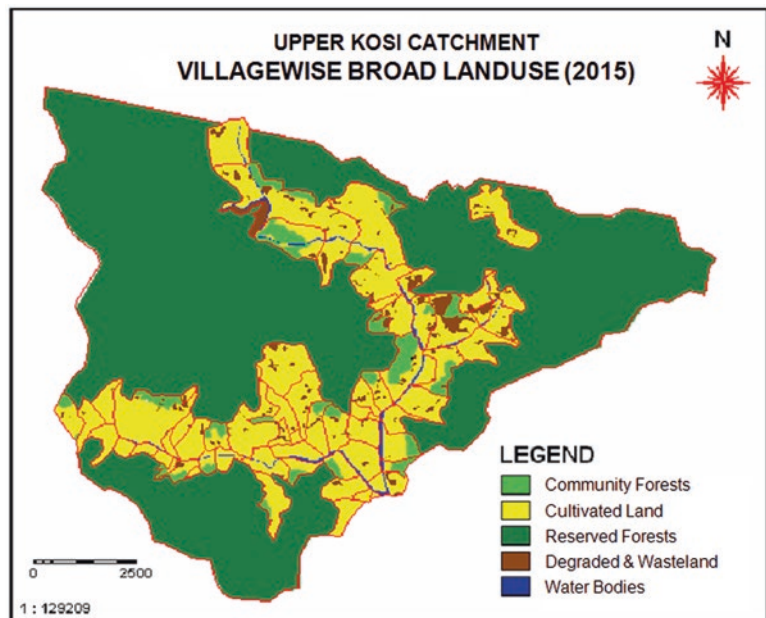
limited in most of the reserved forests of Uttarakhand, particularly after the creation of network of protected areas and prohibition of green felling above an altitude of 1000 m in the Himalaya. Community forests which broadly include all those forests and forest land which fall inside the village boundary, except the private forests, are under Common Pool Resources (CPR).

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

**Table 19.1** Land use changes in upper Kosi catchment between 1985 and 2015 (in km<sup>2</sup>)

Land use classes in 2015	Land use classes in 1985				Total (2015)	
	Forests area	Cultivated land	Degraded and wasteland	Water bodies	in km <sup>2</sup>	% 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 and degraded Land	1.47	0.06	0.82	–	2.35	2.18
Water bodies	–	–	–	00.82	0.82	0.76
Total (1985) in km <sup>2</sup>	80.51	24.29	2.32	00.82	107.94	100.00
Total (2015) % of total area	74.58	22.50	02.14	0.76	100.00	

**Fig. 19.3** Broad Land Use Pattern of the Study Area



**Fig. 3**

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 Nongovernmental Organizations (NGOs) through community participation. Interestingly, only 3.37 km<sup>2</sup> or 3.12% of the total area of the catchment is under community forests (Table 19.1). But the availability of merely

3.37 km<sup>2</sup> of community forests for as many as 65 villages is highly inadequate in the region, where forest-based subsistence farming constitutes the main source of rural food and livelihood. Practically, this is the only forest available to the local population for the fulfillment 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 villages of the region are practically dependent on reserved forests for the fulfillment of their various resource needs.



As mentioned in the preceding sections, the Catchment represents one of the densely populated and intensively cultivated regions of the Kumaon Himalaya. An area of 27.77 km<sup>2</sup> 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 the nonavailability 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, the intensity of cropping is very high (150%). The higher cropping intensity in low agricultural potential areas symbolizes distress cultivation of land (Maithani 1986). Out of 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 km<sup>2</sup>) 2.35 km<sup>2</sup> or 2.18% was identified as wastelands, and 0.82 km<sup>2</sup> or 0.76% is under waterbodies that mainly include streambeds and tiny mountain canals.

## 19.5 Resource Use Dynamics

Traditional resource utilization pattern in the region has been changing fast mainly in response to population growth and increasing economic and social marginalization (Maithani 1986). The impacts of changes in community resource utilization structure are clearly discernible in terms of rapid land use changes (Tiwari 2000). Agriculture is being extended to forests, and marginal and submarginal lands, and pastures are turning into waste and degraded land due to overexploitation and resultant decline in productivity. With the rapid growth of population, the pressure on cultivated land has increased, and more than 90% of land holdings are of less than 1 ha. Consequently, availability of cultivated land is merely 0.14 ha/person against a minimum of 0.2 ha/person as required for practicing agriculture on a sustainable basis in high Himalayan Mountain ecosystem (Ashish 1983; Singh et al. 1984).

Out of total 65 villages of the 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 the Himalaya, 5–10 ha well-stocked forest is required to support biomass requirement of 1 ha of agricultural land on a sustainable basis (Singh et al. 1984). Whereas, in the Upper Kosi Catchment, the availability of forest per ha of cultivated land ranges between 0.10–2.07 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 minimum 3.5 ha/cattle (Singh et al. 1984).

## 19.6 Land Use Changes

Results of land use change detection exercise revealed that out of the total area (107.94 km<sup>2</sup>) of the region 8.44 km<sup>2</sup> or 7.81% has changed from one land use to other during 1985 and 2015. Table 19.1 shows 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 24.29 km<sup>2</sup> in 1985 to 27.77 km<sup>2</sup> in 2015, 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 km<sup>2</sup>) and wastelands (0.20 km<sup>2</sup>). The area under forests in the catchment has declined from 80.51 km<sup>2</sup> in 1985 to 77.00 km<sup>2</sup> (73.63 km<sup>2</sup> reserved forest and 3.37 km<sup>2</sup> community forests) in 2015 mainly due to diversion of 3.34 km<sup>2</sup> forestland to agriculture and turning of 1.47 km<sup>2</sup> community forests into degraded and wastelands thus registered a total decrease of 4.36%. Wasteland has increased from 2.32 km<sup>2</sup> or 2.14% in 1978 to 2.35 km<sup>2</sup> or 2.18% in 2008 as 1.47 km<sup>2</sup> forests and 0.06 km<sup>2</sup> cultivated land was converted into wasteland in the catchment. But, at the same time 0.20 km<sup>2</sup> and 1.30 km<sup>2</sup> wasteland have been brought, respectively, under cultivation and community forests in the region during the last 30 years (Table 19.1).

### 19.6.1 Impact of Land Use Changes on Ecosystem Services

These land use changes are of great significance in ecologically fragile, tectonically live, and economically underdeveloped The 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 submarginal areas and forests, and intensification of land use under the impact of changing resource use practices are leading to rapid environmental and climate changes and resultant loss of ecosystem services in the Himalaya (ICIMOD 2017; Joshi et al. 2003).

The decrease in forests has disrupted the hydrological regime of the Himalayan watershed. Studies indicate that amount of surface run-off from cultivated (80%) and barren land (85%) is much higher compared to that from forests (25%) (Tiwari 2000). These hydrological disruptions are now clearly discernible in: (1) long-term decreasing trend of stream discharge, (2) diminishing discharge and drying of springs, and (3) biotic impact on surface run-off flow system and channel network capacity (Ives 1985; Tiwari and Joshi 2017). Table 19.2 shows that more than 33% of natural springs have completely dried, nearly 11% of springs have become seasonal, and a stream-length of 736 km has dried during the last 30 years mainly due to deforestation and resultant decreased recharge of groundwater in

the region. Table 19.3 shows that as many as 61% of villages have been facing great scarcity of water for all purposes, where the situation turns into a severe water crisis during dry months (Tiwari and Joshi 2017).

The study revealed that depletion of forests and the resultant hydrological disruptions have caused 29% (East Kosi) to 58% (South Kosi) decline in supply of biomass to agroecosystem and loss of 14% (East Kosi) to 21% (South Kosi) irrigation potential (in terms of irrigated area) in different micro-watersheds of the Upper Kosi Catchment during the last 30 years (Table 19.3). The loss of primary ecosystem services, particularly water and biomass, have 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 19.3).

The studies carried out in different parts of the middle Himalayan mountains investigated that the changes in land use pattern are one of the important factors responsible for hydrological disruptions and depletion of water resources in the Himalaya. Pathak et al. (1983) while studying the partitioning of rainfall by certain forest stands in the Kumaon Himalaya observed that well stock oak forest infiltrates nearly 70% of the total rainfall, and, thus, significantly increase the groundwater recharge. Rai and Sharma (1995) and Sharma et al. (2007) explored that degradation of forests and their conservation into degraded land contributed to reducing groundwater recharge and resultant decreased water generating capacity of soil in several parts of the Sikkim Himalaya. The works of Haigh and Rawat (1990), Tiwari (2008, 2010), and Verma and Kothyari (2005) proved that the amount of overland flow is considerably high in agricultural, barren, and degraded land compared to the areas under forests in the catchments of Kosi and other rivers in the Uttarakhand Himalaya. Investigations conducted in several other mountain ecosystems of the world also substantiated these findings (FAO 2005; Wasson et al. 2008).

**Table 19.2** Changes in status of water resources in upper Kosi catchment (1985–2015)

Micro-watersheds	Total area (km <sup>2</sup> )	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



**Table 19.3** Changes in water availability, biomass supply, and irrigation potential in upper Kosi catchment (1985–2015)

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

**Table 19.4** Changes in food, Fodder, and fuelwood deficit Situations in upper Kosi catchment (1985–2015)

Micro-watersheds	% Food deficit	% Fodder deficit	% Fuelwood deficit
North Kosi	38	19	37
East Kosi	27	13	15
West Kosi	39	25	31
South Kosi	23	24	26
Total	32	20	27

### 19.6.2 Impact on Food and Livelihood Security

The region has been facing deficit situations in food, fodder, and fuelwood for long period mainly due to constraints of subsistence economy and population growth. However, the loss of ecosystem services has further enhanced the resource deficit levels. The region recorded, respectively, 23–39%, 13–25%, and 15–37% deficit of food, fodder, and fuelwood in different micro-watersheds of the region between 1985 and 2015 (Table 19.4). A huge proportion of the rural population, particularly, landless, marginalized, and poor, largely depend on agricultural labor, village-based processing of agricultural and livestock products, making agricultural tools and traditional handicraft items and collection of herbs, fruits, and medicinal plants from forests for livelihood. But, due to the depletion of forests and biodiversity, livelihood in forest-based and medicinal plant collection activities has, respectively, increased from 37% to 40% and from 20% to 29% in different micro-watersheds. Similarly, livelihood opportunities in agriculture, livestock, and handicraft sectors have also increased, respectively, between 19% and 29%, 9% and 22%, and 22% and 40% in different micro-

watersheds of the Upper Kosi Catchment during the last 30 years owing to reduced agricultural and livestock productivity (Table 19.5).

### 19.6.3 Impact on Community Health

Owing to reduced availability of water for various uses people are not able to take proper care of their sanitation and personal hygiene affecting the health conditions of population in rural areas. The study revealed that a large proportion of population of all age groups, particularly the rural women are affected by several kinds of water-borne diseases (Tiwari and Joshi 2013). It was observed that 47% male and 65% female population in all age-categories are under severe threat of a variety of health risks generated mainly due to unhygienic conditions and lack of sanitation in homes and environs (Tiwari and Joshi 2007). Children below the age of 15 years and aged people above 55 years are most affected by water-generated health risks. Further, decline in food and livestock productivity has reduced nutrient supplies to the rural population, particularly the children which are already malnourished and deficient in nutrients, and, thus, affecting the overall health of the rural population in the region.

## 19.7 Conclusion

During the last three decades, there has been a significant conversion of forests into cultivated and degraded land in the Himalaya. As a result, the proportion of both agricultural and wastelands has increased, while the area under forests

**Table 19.5** Impact of land use dynamics on rural livelihood in upper Kosi catchment (1985–2015)

Micro-watersheds	% Decline in forest-based activities	% Decline in agro-based activities	% Decline in medicinal plant collection activities	% Decline in livestock production activities	% Decline in traditional handicraft and agricultural tool making activities
North Kosi	40	24	29	14	26
East Kosi	34	29	22	15	24
West Kosi	39	19	23	22	22
South Kosi	37	24	20	09	40
Total	38	24	24	15	28

has declined in the region. The main driving forces of these land use dynamics are population growth and the resultant changes in community resource use structure. These land use changes have shown unprecedented adverse impact on water generating capacity of the land to springs and streams, biomass supplies to agroecosystem, and productivity of natural resources in the region. As a result, considerably large proportion of natural springs and heads of several perennial streams have dried affecting rural water supplies, leading to 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 have also increased the trends of outmigration of entrepreunering rural male youths, and, thus, have contributed to further worsening the quality of rural life in the region. A comprehensive land use policy considering both natural and socioeconomic parameters is therefore imperative for the restoration of ecological services and attaining community sustainability in the entire Himalayan region.

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