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Environmental Changes and their Impact on Rural Water, Food, Livelihood, and Health Security in Kumaon Himalayas

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Abstract Population growth and the resultant land use intensifications have been identified as major drivers of environmental changes in densely populated Middle Himalayan Ranges. Study carried out in Upper Kosi Catchment (107.94 km^2), in Kumaon Himalaya, India indicated that 3.34% forests have been converted into cultivated and degraded land during last 30 years. These land use changes have not only reduced the availability of biomass manure to agriculture, but also caused severe depletion of water resources through reduced groundwater recharge. Nearly 33% natural springs have dried and as many as 61% villages have been facing great scarcity of water for drinking, sanitation as well as for crop production. As a result, food production has decreased by 25%, and livelihood opportunities in traditional forestry and agricultural sectors declined considerably. These situations are increasing the vulnerability of large rural population, particularly poor, landless and socially marginalized communities to food, livelihood and health insecurity.

Key words land use changes, population growth, conversion of forests, food and livelihood insecurity, health risks

Introduction

The Himalayas constitute the sources of various ecosystem services, including water, biodiversity, soils, natural beauty, recreational opportunities, wilderness, and cultural diversity that sustain the livelihood and economy of large population in both the mountains and their vast and densely populated lowlands (Messerli and Ives 1997; Food and Agricultural Organization 2002a). It comprises headwaters of some of the biggest trans-boundary riverbasins on Earth that sustain large population dependent on subsistence agricultural and traditional food systems in South Asia. The indigenous communities inhabiting the Himalayan mountains have evolved diverse cultures that comprise traditional knowledge, resource development, environmental conservation practices, agricultural and food systems, adaptation and coping mechanisms, languages, customs, traditions, costumes, conventions, and rituals. These have immense relevance and practical significance in environmental restoration, climate change adaptation, and ensuring sustained resource productivity in mountain ecosystems (ICIMOD 2010; Food and Agricultural Organization 2005).

At the same time, the Himalayas represent one of the most tectonically unstable, ecologically fragile, economically underdeveloped, and densely populated mountain ecosystems on the planet. The nature of the terrain severely limits the scale of productive activities as well as the efficiency of infrastructural facilities in the region (ICIMOD 2010; Huddleston et al. 2003). As a result, subsistence agriculture constitutes the main source of livelihood and food for more than 75% of the rural population even though the availability of arable land is severely limited and agricultural productivity is considerably poor (Tiwari and Joshi 2012a). This traditional agriculture is interlinked with forests and pastures as they constitute the source of biomass energy required to sustain the Himalayan agricultural system. The flow of biomass energy from forests to an agro-ecosystem is mediated through livestock in the form of compost manure and labor (Food and Agricultural Organization 2008; Singh et al. 1984). During recent years, various changes have emerged in the traditional resource use structure mainly in response to growing population pressure and the resultant increased demand for natural resources, such as arable land, grazing areas, fodder, and fuel wood (ICIMOD 2010). Additionally, the fast expansion of road linkages has facilitated rapid urbanization, the emergence and growth of rural service centers, and increased access to markets. A large proportion of arable land is being encroached upon by growing urbanization and the expansion of infrastructure, services, and economic activities in the region, leading to the exploitation of natural resources, particularly land, water, forests, biodiversity, and pastures (Tiwari and Joshi 2012b). As a result, these critical natural resources have depleted steadily and significantly, leading to their conversion into degraded and waste lands in the region during the last 30 years. These land use changes have an unprecedented adverse impact on the natural environment and basic ecosystem services, particularly declining water productivity of the traditional agricultural system and increasing vulnerabilities of rural communities, particularly the poor and marginalized who constitute nearly 70% the total population, to food and livelihood security (Tiwari 2000; Food and Agricultural Organization 2002b; Beniston, M. 2000; Jandl et al. 2009). Moreover, the changing climatic conditions have already stressed mountain ecosystems through higher mean annual temperatures, melting glaciers and snow, altered precipitation patterns, hydrological disruptions, and more frequent and extreme weather events (Eriksson et al. 2008). In this context, climate change acts as an additional stress that can multiply existing development deficits and may also reverse the process of socio-economic development in the region (UNDP 2010). Furthermore, these changes are likely to undermine the inherent capacity of indigenous mountain communities to respond and adapt to changing environmental conditions including climate change (ICIMOD 2009; Aase et al. 2013). The main objectives of the paper are to interpret the important drivers of environmental changes in the Himalayas and their ecological and socio-economic backdrop and assess their impacts on the ecosystem services, society, and economy with a case illustration of Upper Kosi Catchment, located in the Kumaon Himalayas, Uttarakhand India.

The Study Area

The study was carried out in Upper Kosi Catchment (upstream Someshwar), which encompasses a land surface

Figure 1. Location map

of 107.94 km^2 (10794 ha) and is situated between 1500 and 2650 m altitude in the Kumaon Lesser Himalaya in the Himalayan state of Uttarakhand in India (Figure 1). The catchment is one of the densely populated and agriculturally colonized tracts of Kumaon Himalayas. There are 65 villages in the catchment, and the density of population has been calculated to be 149 persons/km^2 for the watershed as a whole and as high as 469 persons/km^2 for the village area (i.e., excluding state forest) of the region. However, the availability of per capita cultivated land is merely 0.17 ha, and more than 90% of operational land holdings are of less than one hectare. The study area has been divided into four micro-watersheds to study various research parameters in detail.

Methodology

To analyze the process and magnitude of environmental changes, land use changes were monitored during and interpreted for 1971 and 2011. Survey of India (SOI) Topographical Maps were used for preparing land use map for the year 1971 as satellite data was not available for the year. However, high resolution satellite data was used for the mapping and interpretation of land use for 2011. Digital interpretation techniques supported by intensive ground validation have been used for this purpose. To enhance the interpretability of the remote sensing data for digital analysis, several image enhancement techniques were employed, such as Principal Component Analysis (PCA) and Normalized Deviation Vegetation Index (NDVI). In the Himalayan mountain terrain, the interpretability of the remote sensing data is greatly affected by the complexity of the terrain. Due to the effects of elevation, the slope, and slope aspect, the spectral signatures of the same objects are often different and vice versa. To overcome these constraints and also to interpret land use as accurately as possible, intensive ground truth surveys were carried out in the study region and a visual interpretation key was developed for primary land cover / land use classification. This was followed by the digital classification of land cover / land use through on screen visual recording and rectification. The land use map of 1971 was digitized, a thematic layer was created, and finally the land use changes that took place in the region between 1971 and 2011 were detected using change detection techniques in the Geographic Information System (GIS) (Figure 2). Moreover, necessary quantitative and quantitative information has also been collected and generated from forest and cadastral maps of the areas through field surveys, ground observations, socio-economic surveys, interviews with elderly people, and estimates of production and demand, particularly in the cases of food, fodder, fuel wood, and biomass supply to agriculture.

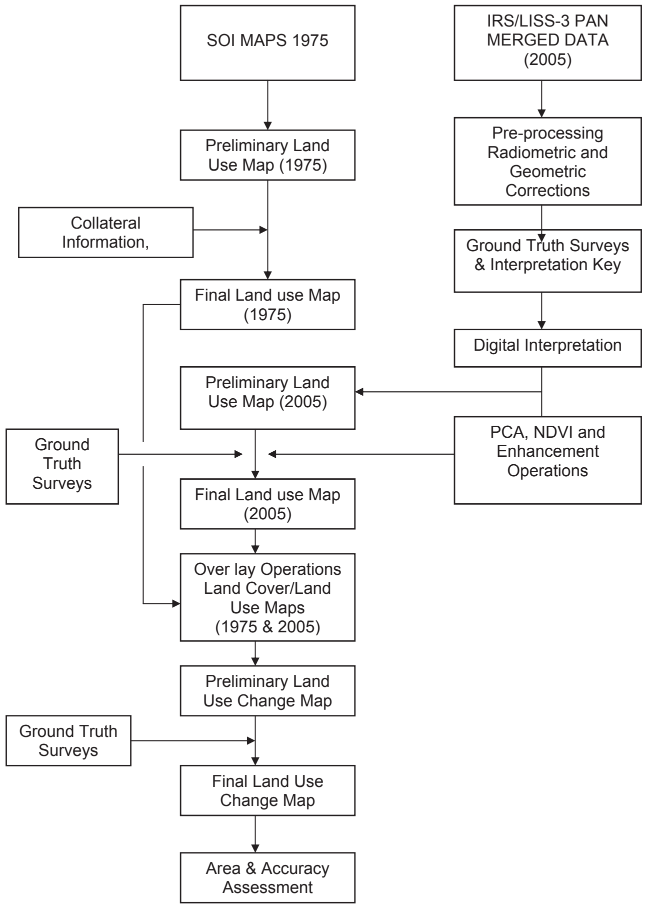

Figure 2. Methodology for Land Use Change Detection

Results and Discussion

The current land use patterns of the catchment have been broadly classified into (i) reserved forests, (ii) community forests, (iii) cultivated land, (iv) degraded and waste lands, and (v) water bodies, which respectively constitute 68.21%, 3.12%, 25.73%, 2.18%, and 0.76% of the total area of the region (Table 1 and Figure 3). The reserved forests are State Property Resources and are always outside village boundaries. The reserved forests are supposed to be completely free from all kinds of resource use pressures. However, the rural communities living interspersed in the reserved forests have traditionally enjoyed limited rights and concessions to collect minor forest-products in return for their work for forest conservation. However, these facilities have now been withdrawn or limited in most of the reserved forests of Uttarakhand. Out of the total geographical area (107.94 km^2) of Upper Kosi Catchment, reserved forests account for 73.63 km^2 or 68.21%. Although the forests and forest

Table 1. Land use changes in Upper Kosi Catchment during 1971 – 2011 (in km²)

Land use classes in 2011	Land use classes in 1971					
	Forests area	Cultivated land	Degraded & wasteland land	Water bodies	Total (2005)	
					in km²	% 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 & degraded Land	1.47	0.06	0.82	—	2.35	2.18
Water bodies	—	—	—	0.82	0.82	0.76
Total (1975) in km²	80.51	24.29	2.32	0.82	107.94	100.00
Total (1975) % of total area	74.58	22.50	2.14	0.76	100.00	

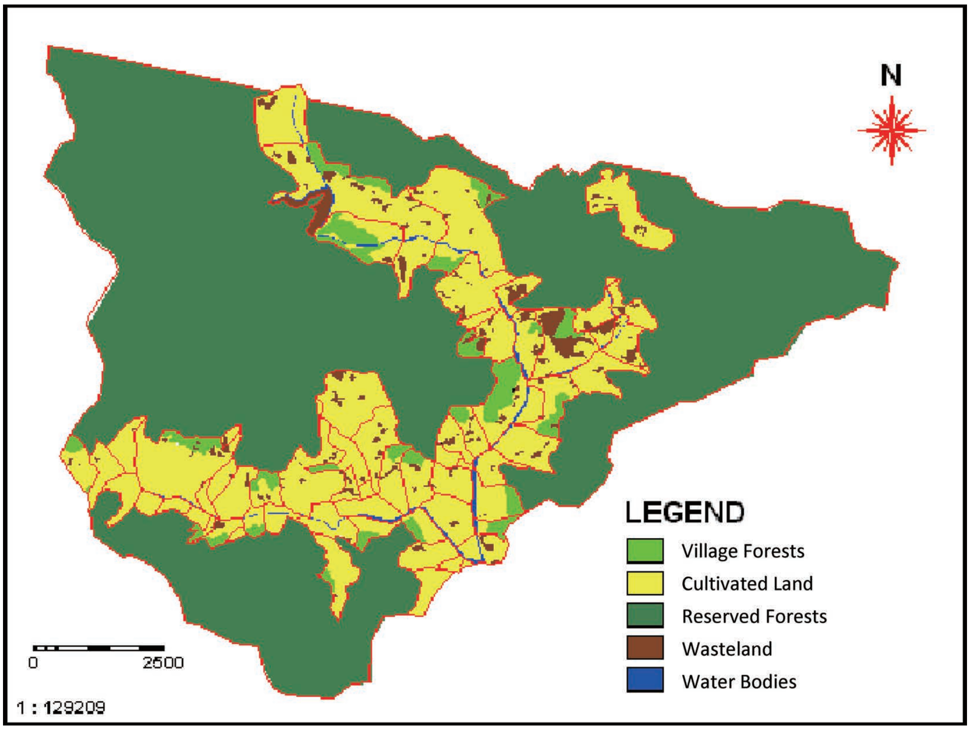

Figure 3. Koshi headwater village-wise broad land use

land that fall inside the village boundary, except the private forests owned by individual households, are in principal the property of state government, these forests are open to local people and are equally accessible to all the households of the respective village for fulfillment of their various resource needs. In view of this, the village-forests are considered Common Pool Resources (CPR) and called Civil Forests or Community Forests. To involve the local people in protecting and conserving forests, the control of some of the community forests in Uttarakhnad State has now been transferred to the respective villages since the establishment of Forest *Panchayats*. (A Forest *Panchayat* is a constitutional and democratic village level institution created for the participatory management of village forests in India.) This is the oldest system of participatory resource management and was introduced by the British colonial administration before India became independent in 1947.

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 participatory forest management in the State of Uttarakhand. The JFM programs are being implemented by local Non-governmental Organizations (NGOs) working in the area through participatory institution building at the village level. Interestingly, community forests make up only 3.37 km², accounting for 3.12% of the total area of the catchment (Table 1). However, considering the village wise distribution of forests in the region, the availability of merely 3.37 km² of community forests for 65 villages is highly inadequate in the Himalayan area, which has traditionally been inhabited by communities that largely depend on forests to fulfill their all basic resource needs. On average, only 5.18 ha of forest area is available for each village of the watershed to fulfill all their forest based resource needs. Nevertheless, as many as 36 villages (out of a total of 65) in the region have no community forest within their boundaries to fulfill their primary resource needs.

As mentioned in the preceding sections of the paper, Upper Kosi Catchment represents one of the most densely populated and intensively cultivated regions of the Kumaon Himalayas (Joshi et al. 1983). An area of 27.77 km^2, accounting for 25.73% of the catchment area, is under cultivation. Out of this total cultivated land, only about 15% is irrigated, and the rest, mainly lying on upslope areas and ridges, is never irrigated because of the non-availability of water and constraints of terrain. The availability of arable land is severely limited, but the dependence on agriculture in considerably high mainly due to the absence of other viable means of livelihood and employment in mountainous environments. As a result, the intensity of cropping in the region was observed to be very high (150%). The high cropping intensity in the low agricultural potential areas symbolizes distress cultivation of land in the absence of alternative means of livelihood (Maithani 1986). Out of the 65 villages of the watershed, 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 three have less than 45% of their total geographical area under cultivation. Out of the total geographical area of the watershed (107.94 km^2), 2.35 km^2 was identified as degraded and waste lands, accounting for 2.18% of the total area of the catchment. About 0.82 km^2, constituting nearly 0.76% of the total land surface of the catchment, is under water bodies that mainly include the beds of the Kosi and its tributary streams and small mountain canals.

Community resource utilization structure

More than 75% of the population of the region is dependent on traditional biomass based (forest based) subsistence agriculture. Nevertheless, crop farming is not economically viable in most areas of the region due to several geo-environmental constraints and resultant poor agricultural productivity. However, little arable land is available, land holdings are very small, and consequently the intensity of cropping is as high as 150%. To preserve the soil fertility level and productivity of land under sustained cropping in such an agro-ecosystem, there must be a net transfer of energy from the forests to arable land. This flow of energy from forest to cultivated land in the Himalayan agro-ecosystem is mediated through livestock, which is usually in the form of fodder of stall-fed cattle whose manure and labor are applied to the cultivated land (Figure 4). Forest, livestock, and arable land are the three basic components of the Himalayan agro-ecosystem, in which forests are pivotal to the maintenance of crop production levels. On average, one unit of agronomic production in the region involves nine units of energy from the surrounding forest ecosystem (Singh et al. 1984).

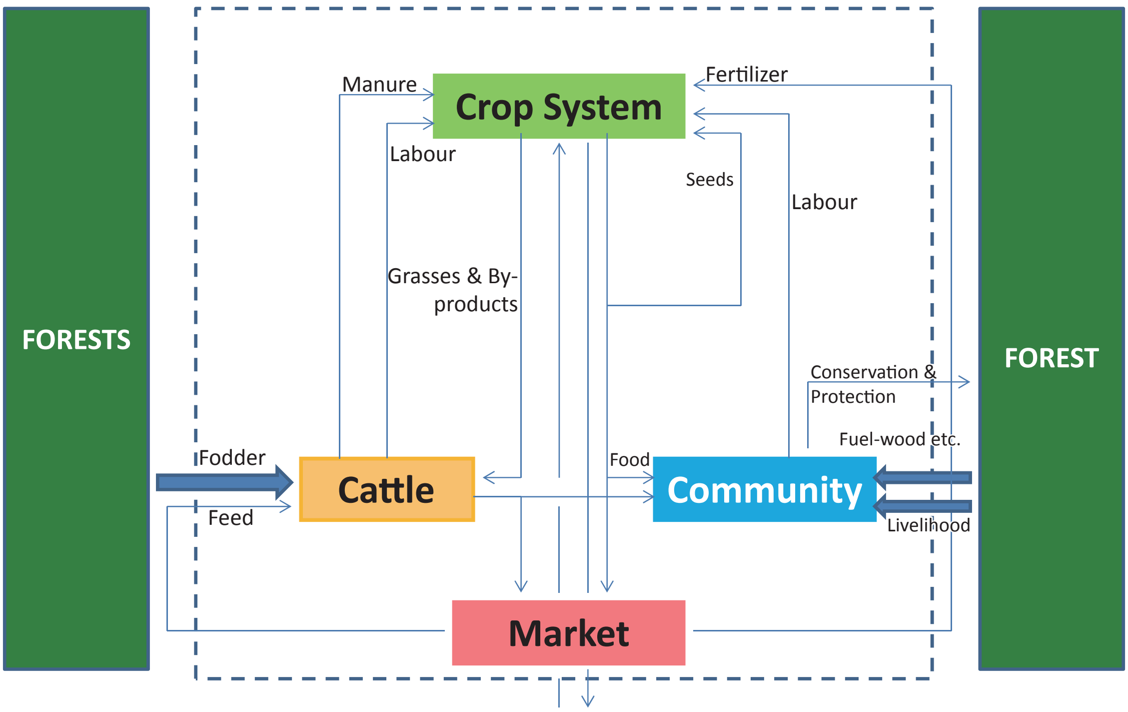

Figure 4. Traditional Himalayan agro-ecosystem

As mentioned in the preceding sections, the traditional resource utilization pattern in the region has been changing fast mainly in response to population growth (more than 1.5 percent/year on average) (Tiwari and Joshi, 2012b). The impacts of the changes in community resource utilization structure are clearly discernible in terms of rapid land use changes (Ives 1989). Forests are being brought under plough. Community forests, marginal and sub-marginal cultivated land, and pastures are turning into degraded and waste lands due to overexploitation and the resultant decline in productivity. As the population has rapidly grown, the pressure on cultivated land has also increased in the region. Consequently, the availability of cultivated land has declined considerably during the last 30 years. A minimum of 0.2 ha per capita land is required for practicing agriculture sustainably in the Himalayan mountain ecosystem (Ashish 1983). Considering this as a standard, not even a single village in the entire catchment has this minimum per capita cultivated land. The average availability of per capita cultivated land in Upper Kosi Catchment has been estimated to be less than 0.14 ha. The study of operational land holdings revealed that more than 90% of land holdings in the area are less than 1 ha, and not a single land holding is above 5 ha in any of the villages of the catchment.

Out of the 65 villages of Upper Kosi Catchment, as many as 36 have no forests within their boundaries (community forest), and the per capita availability of forests in the remaining 29 villages is below 0.15 ha. The pressure on arable land is mounting as the availability of cultivated land in as many as 53 villages of the catchment is less than 0.10 ha per person. In the Himalayan agro-ecosystem, it is thought that 5–10 ha of well-stocked forest area is necessary to meet the biomass requirement of 1 ha of arable land (Singh et al. 1984). In Upper Kosi Catchment, the ratio of forest to cultivated land ranges between 0.10 – 2.07 ha/ha in different villages, and more than 50% of these forests are highly degraded. This clearly shows that the biotic stress on the forests in the region is very high. The grazing pressure on pastures is very acute as only 0.02 to 1.67 ha/cattle grazing area is available in the catchment. The entire catchment faces a massive deficit of fodder and fuel wood that exceeds 80%, and a considerably large number of villages in the region is facing great scarcity of water for all purposes.

Land use dynamics

To monitor the dynamics of land use in the region, a land use change detection exercise was carried out comparing the land use map of 1971 prepared with the help of Survey of India Topographical Maps and the land use map of 2011 prepared using the remote sensing and field mapping techniques. Finally, the land use changes that took place in the region during the last 30 years were detected by employing change detection techniques in the Geographic Information System (GIS). The results of this exercise are presented in Table 1. Out of the total geographical area (107.94 km^2) of the region, 8.44 Km^2 or 7.81% changed from one land use to another between 1971 and 2011.

Table 1 makes it clear that, in contrast to the general conception, the agricultural land in the region did not increase much from 1971 to 2011. The total cultivated land increased from 24.29 km^2 in 1971 to 27.77 km^2 in 2011 and thus registered an overall increase of 3.48 km^2 or 14.33% over 30 years. This increase in the cultivated land was brought about through the extension of cultivation in forests (3.34 km^2) and wastelands (0.20 km^2). Moreover, 0.06 km^2 cultivated land in the region has been abandoned owing to several reasons and has been classified as abandoned cultivated wasteland. The area under forests in the catchment declined from 80.51 km^2 in 1975 to 77.00 km^2 (73.63 km^2 reserved forest and 3.37 km^2 community forests) in 2011, thus making a total decrease of 3.51 km^2 or 4.36% during the period. This decrease in forests was mainly because of the diversion of 3.34 km^2 forest land to agriculture and turning of 1.47 km^2 community forests into degraded and waste lands between 1971 and 2011. The degraded and waste lands in the catchment increased from 2.32 km^2 or 2.14% in 1971 to 2.35 km^2 or 2.18% of total watershed area in 2011. This increase in wasteland is due to the conversion of some forest (1.47 km^2) into degraded lands. Additionally, some cultivated land (0.06 km^2) that was abandoned during the recent past is now affected by scrub growth and thus has been included in the category of wasteland. However, at the same time, some of wasteland in the region has also been brought under cultivation (0.20 km^2) and community forests (1.30 km^2) (Table 1, Picture 1, 2).

The creation of a number of Forest *Panchayats*, implementation of Joint Forest Management (JFM) programs and rehabilitation of degraded and waste land through afforestation in several villages by the forests department and non-governmental organizations in collaboration with the local communities have played significant role in initiating the process of environmental regeneration and ecological restoration in the region. Nevertheless, the wasteland in the watershed recorded an overall increase of only 1.29% during 1971–2011 (Table 1). The table shows that the area under water-bodies (0.82 km^2) remained

Picture 1. Conversion of forest into agricultural land

Picture 2. Conversion of forest into degraded and waste lands

unchanged during the 30 period. However, it is important to explain here that the water bodies in the catchment have slightly shrunk due reduced water flow in rivers and streams and downward shifting of stream heads. However, a large network of tiny mountain canals created for irrigation in the low lying valley areas during the period has perhaps compensated for the decrease in area under water bodies in the region during the last 30 years. The interpretation of the trends of land use dynamics reveals that forests areas are declining and the proportion of cultivated and waste land is increasing in the catchment. Most reserved forests, particularly those lying along the boundaries of villages, are highly degraded due to over-exploitation of forest resources and indiscriminate and unregulated grazing by cattle.

Environmental impacts

These land use changes are of great significance in an ecologically fragile and tectonically live mountain ecosystem where the steepness of slope and the instability of landscape increase the susceptibility of the region to various environmental changes (Tiwari and Joshi 2013). Excavating fragile slope to construct roads and houses, removing vegetal cover, extending agriculture to marginal and sub-marginal areas and forests, and carrying out other such anthropogenic processes along with changing resource use practices are leading to various kinds of environmental problems including the loss of forests and biodiversity, disruption of the hydrological system, and climatic change (Tiwari 2000; Tiwari 2008). Similar types of impacts of land use changes have also been identified in other mountain regions of the world (Theobald et al. 1996; Tasser et al. 2005; Tiwari and Joshi 2003)

The rapidly changing land use pattern and the resultant decrease in forest area have disrupted the hydrological regime of the entire catchment, and this has an unprecedented adverse impact on the water resources of the region (Tiwari and Joshi 2010a; 2011a; 2011b; 2012a). The water resources of the catchment are diminishing and depleting fast owing to the rapid land use changes and resultant reduced ground water recharge (Tiwari 2000). The studies carried out in the region revealed that the amount of surface runoff from cultivated and barren lands is much higher than the amount of runoff from other categories of land, particularly, forests and areas under horticulture (Tiwari and Joshi 2012a). These hydrological imbalances are clearly discernible in (i) the long-term trend of decreasing stream discharge, (ii) diminishing discharge and drying of springs, and (iii) biotic impact on surface run-off flow system and channel network capacity (Tiwari and Joshi 2012b). Since, a large proportion of the rainfall is lost through surface run-off without the groundwater reserves being replenished, a large number of springs that support various life sustaining activities have gone dry or become seasonal and stream heads have dried to several meters in length in the region during the last 30 years.

Table 2 shows that more than 33% of natural springs have completely dried, nearly 11% springs have become seasonal, and a stream-length of 736 km has dried during the last 30 years mainly due to deforestation and the resultant decreased recharge of groundwater in the region. The West Kosi micro-watershed, which constitutes the source of one of the major tributary streams of the Kosi, has the largest and the South Kosi micro-watershed has the lowest proportion of dried springs in the catchment. The percentage of seasonal springs as well the length of the stream dried is highest in the North Kosi micro-watershed (Tiwari and Joshi 2010a; 2010b; 2011; 2012). The length of dried streams varies from 84 to 227 m in the other three micro-watersheds of the catchment (Table 2). As a

Table 2. Changes in the Status of Water Resources in Upper Kosi Catchment (1971-2011)

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	5	84
Total	107.94	33.75	10.80	736

Table 3. Status of water availability, biomass supply and irrigation potential in Upper Kosi Catchment

Micro-watersheds	% Villages facing water scarcity	% Decrease in biomass manure 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

result, the percentage of villages facing water scarcity for all purposes ranges from 51% in East Kosi to as much as 61% in the North Kosi micro-watershed (Table 3). In these villages, this water scarcity situation turns into a severe water crisis during the summer and dry winter months (Tiwari and Joshi 2005).

The process of rapid land use changes has reduced the forest area in the catchment more than 3 km^2 during the last 30 years. In view of this, the biotic stress on forest resources is mounting up. This is discernible in huge resource deficits, particularly fuel wood and fodder, in most of the villages, and in the felling of trees and excessive lopping, which effects the natural regeneration of trees, particularly in high altitude areas of the region where, due to low temperature, the regeneration process of plants is comparatively slow. As discussed in the preceding sections, many villages have no more forest available within their boundaries to fulfill basic rural resource needs. Due to massive degradation of community forests within villages, the resource use pressure is now diverting to reserved forests. As a result, the reserved forests in the surrounding areas of villages are frequently encroached upon by rural populations to fulfill their various resource needs. It has been observed that nearly 65% of the rural resource needs in the catchment are now met from the reserved forests, leading to overexploitation and the resultant degradation and degeneration of natural vegetation and erosion of biodiversity in the reserved forests. The massive depletion of forest resources has resulted in a 40% decline in the supply of biomass to the agro-ecosystem in the region during the last 30 years. The decrease in the supply of biomass to agriculture varies from 29% in East Kosi to 58% in the South Kosi micro-watershed. The land use changes and the resultant hydrological disruptions have had a direct adverse impact on irrigation potential, which has reduced considerably during the last three decades mainly owing to reduced groundwater recharge and drying of springs and streams. The irrigation potential has been analyzed in terms of the decline of the irrigated area owing to non-availability of adequate water in the irrigation system. The catchment has lost 25% of its irrigated area due to non-availability of water during the last 30 years. The decrease in irrigated area ranges between 14% in North Kosi and 21% in the West Kosi micro-watershed (Table 3). The loss of basic ecosystem services, particularly water and biomass, has an unprecedented adverse impact on the productivity of the traditional agricultural system. The different micro-watersheds of the Upper Kosi Catchment have all lost agricultural productivity, ranging from 19% in West Kosi to 25% in North Kosi, with an overall decline of 25% in the region as a whole mainly owing to severe loss of ecosystem services (Table 3). Besides, the urban expansion in agricultural land is also contributing to decline in agricultural productivity in Himalaya (Picture 3, 4, 5 and 6).

Impact on Food and Livelihood Security

The land use changes and the resultant ecological imbalances have undermined food and livelihood security, economy, and quality of life of the rural population in the region. As mentioned in the preceding sections, forest based subsistence agriculture constitutes the main source of rural livelihood as there are no other viable means of employment available in the region mainly due to severe geo-environmental constraints. Due to constraints of the forest based subsistence economy and increase in population, the region has been facing deficits in food, fodder, and fuel-wood for a long period. However, the level of deficit has further increased owing to ongoing impacts of land use changes on primary ecosystem services. The food deficit has further increased between 23% and 38% in different micro-watersheds, and the fodder deficit has shown an overall increase of 20% (Table 4). Similarly, the fuel-wood supplies have declined between 15% and 37% in different micro-watersheds of the region during the last 30 years (Table 4). The observed decrease in fodder supplies have a great adverse impact on livestock health

Picture 3. Urban encroachment into agricultural land

Picture 4. Women spreading biomass manure in the agricultural field

Picture 5. Heaps of biomass manure in agricultural field

Picture 6. Women carrying home-yard biomass manure to agricultural terraces

Table 4. Food, fodder and fuel-wood deficit situations in Upper Kosi Catchment (2011)

Micro-watersheds	% Food deficit	% Fodder deficit	% Fuel-wood 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

and productivity, which is further worsening the situation of nutrient supplies to the rural population, particularly children who are already mal-nourished and deficient in nutrients, and thus affecting the overall health of the rural population in the region.

A huge proportion of the rural population, particularly the landless, marginalized, and poor, largely depends on agricultural labor, village based processing of agricultural and livestock products, making of agricultural tools and traditional handicrafts, collection of medicinal plants, etc. All these activities are completely based on the availability of local resources, mainly agriculture, livestock, forests, and biodiversity, and traditionally provide livelihoods and employment to a large section of rural society in the region. However, due to the depletion of forests and decline in agricultural and livestock productivity, the availability of livelihoods in these traditional rural sectors has declined considerably during the last three decades. The rural employment in forest based activities had decreased 17% in South Kosi and as much as 40% in the North Kosi micro-watershed, with an average decline of 38% in the entire catchment. Similarly, the opportunities of livelihood in agriculture and livestock based processing in the region have reduced respectively by 24% and 15%, with observed declines of varying proportions in different micro-watersheds (Table 5).

Collection of medicinal plants from village forests and pastures constitutes one of the major sources of rural livelihood for rural poor in the region. However, due to massive depletion of forests resources and the consequent loss of biodiversity, the employment opportunities in this traditional sector have decreased by 9% in South Kosi and

Table 5. Impact of Environmental Changes on rural livelihood in Upper Kosi Catchment (1971–2011)

Micro-watersheds	% Decline in forest based activities	% Decline in agro-based activities	% Decline in herbs collection activities	% Decline in livestock production activities	% Decline in traditional handicraft & 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	9	40
Total	38	24	24	15	28

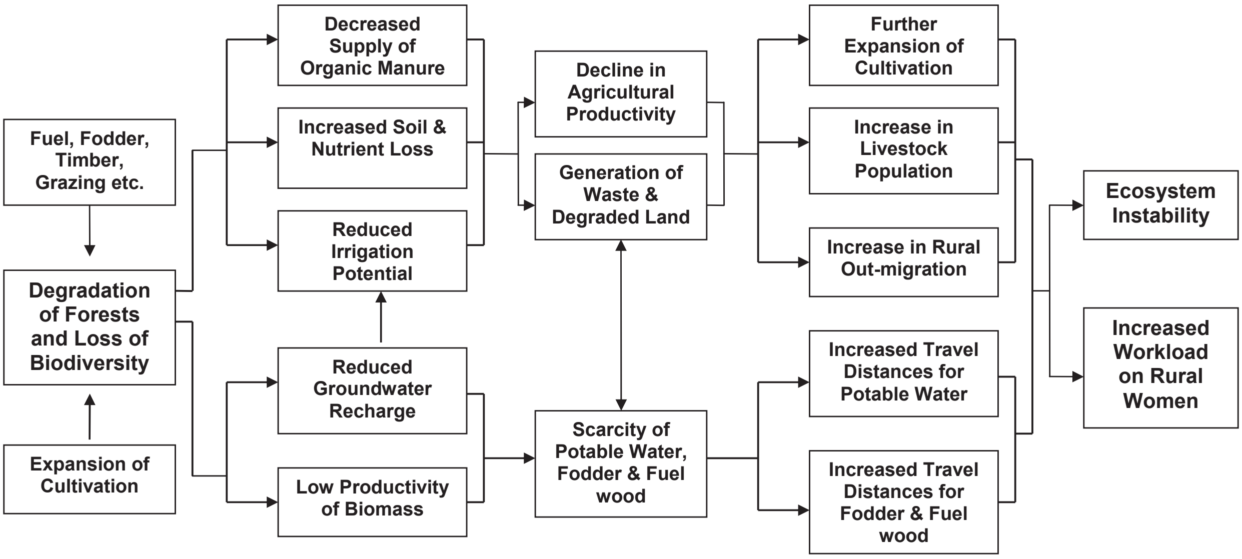

Figure 5. Environmental and Socio-Economic Impact of Forest Degradation

22% in the West Kosi micro-watershed. In addition, making of traditional rural handicrafts and agricultural implements used to be one of the principal sources of rural livelihood and employment, particularly for rural artisans and landless households. This sector has also registered considerable loss mainly due to exploitation of forest resources and erosion of biodiversity. The catchment has shown an overall decrease of 28% in rural handicraft and agricultural tool making sectors during the past 30 years. The loss of employment in these important sectors varies from a minimum 22% in West Kosi to a maximum 40% in the South Kosi micro-watershed (Table 5). Moreover, these environmental changes and resultant constraints of the subsistence agricultural economy have increased the trends of out-migration of rural male youths. This is not only increasing the work-load on rural women but also eroding the rich traditional knowledge that rural communities have developed through their long experimentation with natural conditions and management and conservation of natural resources and responding to environmental changes (Figure 5). As a result, rural women of the region have to travel increasingly longer distances to fetch water and collect fodder and fuel-wood. The average travel distance involved in fetching of potable water ranges between 1 and 3 km in the different villages of the region. Similarly, the average travel distances involved in the collection of fuel wood and fodder respectively range between 2.5 and 3.5 km and 1.5 and 4 km in the region.

Implication for community health

Owing to reduced availability of water for various uses, people are not able to take proper care of sanitation in their surroundings or personal hygiene, affecting the health conditions of the population in rural areas. A study on the impact of environmental changes on community health revealed that a large proportion of the population of all age groups, particularly the rural women, are affected by several kinds of water borne diseases, and the children have been found to be worst affected by the unhygienic conditions and lack of sanitation (Tiwari and Joshi 2010b). Children under 15 and adults over 55 are most affected by water generated health risks. Girls below the age of 15 have been found to suffer the most from water borne health hazards because less attention is paid to their health due to prevailing gender discrimination. It has been observed that large proportions of both male and

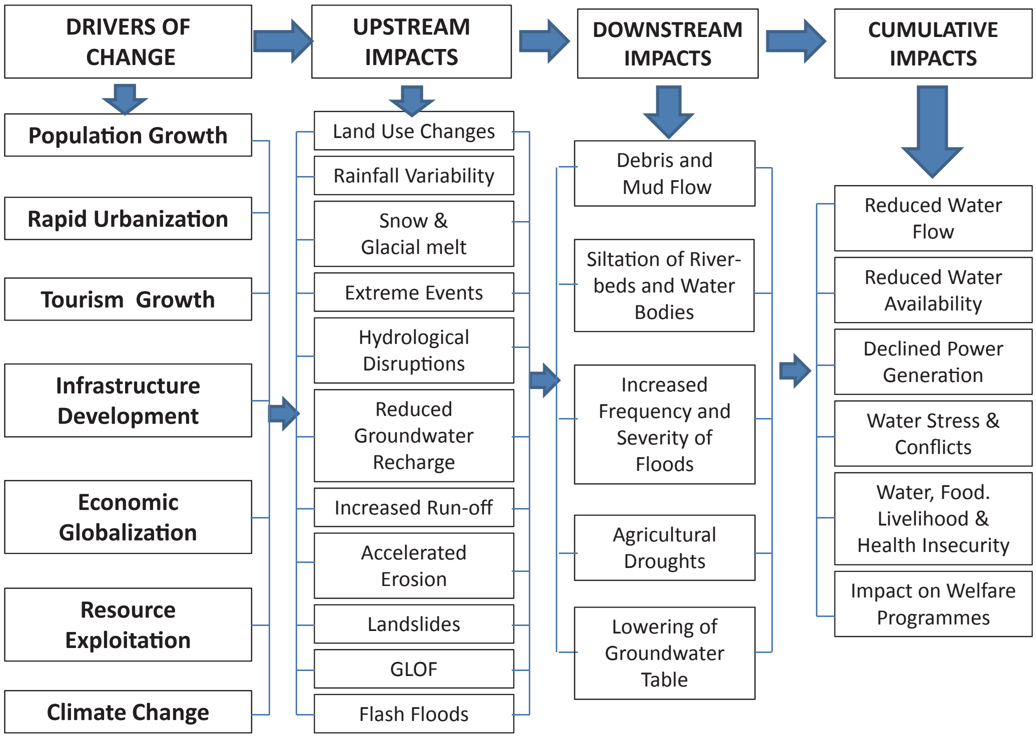

Figure 6. Environmental changes in Himalaya: Upstream and downstream impacts

female rural populations in all age-categories are under severe threat of several health risks generated mainly due to unhygienic conditions and lack of sanitation in homes and surroundings (Tiwari and Joshi 2010b). Similar observations have also been made in other parts of the Himalayas (Jianchu et al. 2008). The impacts of environmental changes in the Himalayas are not confined to the mountains, but these changes are increasing the vulnerability of downstream areas to increasingly frequent and severe natural disasters through the siltation of riverbeds and reduced availability of water for drinking and food production (Tiwari 2000) (Figure 6).

Conclusions

During the last three decades, significant amounts of forests have been converted into cultivated and degraded lands in the Upper Kosi Catchment. As a result, the proportions of both agricultural and waste lands have increased, while the forest area continues to decline in the region. The main driving forces of these land use dynamics are population growth and the resultant changes in the community resource use structure. These land use changes have had unprecedented adverse impacts on water generation from land to springs and streams, biomass supplies to the agro-ecosystem, and the productivity of natural resources in the region. As a result, considerably large proportions of natural springs and heads of a number of perennial streams have dried, affecting rural water supplies, leading to loss of irrigation potential, and rendering rural areas highly deficient of water, food, fodder, and fuel-wood. These ecological impacts of ongoing land use changes have not only undermined community health and threatened the livelihood and food securities of rural poor but also increased the trends of out migration of enterprising rural male youths and thus contributed to further worsening the quality of rural life in the region. A comprehensive land use policy taking into account both natural and socio-economic parameters is therefore imperative for restoring ecological services and attaining community sustainability in the entire Himalayan region.

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