An Ecological Assessment of Grasslands and their Interfaces in Kumaon Himalaya, India

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Rangelands form one of the major components of the natural landscape in the Himalayas. However, they are changing rapidly due to increasing population pressure, rapid urbanization, the growth of tourism, and economic globalization and the consequent land use intensification. These changes are disrupting the hydrological system of rangelands through reduced groundwater recharge, drying of natural springs, and decreased stream flow, which is increasing the vulnerability to water, food, livelihood, and health insecurity of a large population in the mountains and downstream that depends on subsistence agriculture. It is imperative to monitor land use change, understand the drivers of land use intensification, and evolve an integrated and community-based rangeland management framework. A study was carried out in Dabka Watershed, Kumaon Lesser Himalaya, India, to support this.

The results indicate that nearly 58% of the total geographical area of the watershed is composed of forest, wetlands, and grassland, of which 69% is forest, 20% grassland, and 11% wetlands. Land use changed in approximately 16% of the watershed between 1982 and 2012; the land use intensification decreased the proportion of forests, grassland, and wetlands by 3.0%, 3.3%, and 1.7%, respectively. In total, 37% of the springs and a 7 km length of stream dried up completely, and water discharge from the streams originating from the rangeland headwaters decreased by 15%. As a result, 74% of the villages are facing marked scarcity of drinking water and the watershed has lost 16% of its irrigation potential. Agricultural and food productivity declined by 15% over the 30-year period. A community-oriented, participatory integrated rangeland management framework based on comprehensive rangeland mapping and land use planning was developed in agreement with local communities and government line departments and is expected to affect policy and decision making in the Himalayas in the long term.

Keywords: food security; grassland; ground water recharge; headwaters; land use changes; integrated natural resource management; rural livelihood improvement; wetland

Introduction

Rangelands, comprising grasslands and wetlands, are an important component of the natural landscape in the Himalayas and represent the headwaters of freshwater ecosystems. The temperate and subtropical grasslands in the lower-middle Himalayan ranges have mostly evolved on steeper and more exposed slopes with thin to very thin soil and are somewhat comparable to 'hill-savannah' or 'hay slopes' in western and central Europe. These small grasslands are considered to be secondary anthropogenic grasslands (Knapp 1979), developed and modified by human use associated mostly with forest clearing, grazing by domestic livestock, and in some cases fire (Coupland 1979). They are highly fragmented and interspersed with temperate and sub-tropical forests and are characterized by a high floristic diversity (Pott 1995). The contiguity of these grasslands with alpine meadows, and their proximity with the tropical monsoon grasslands at lower elevation makes them interesting.

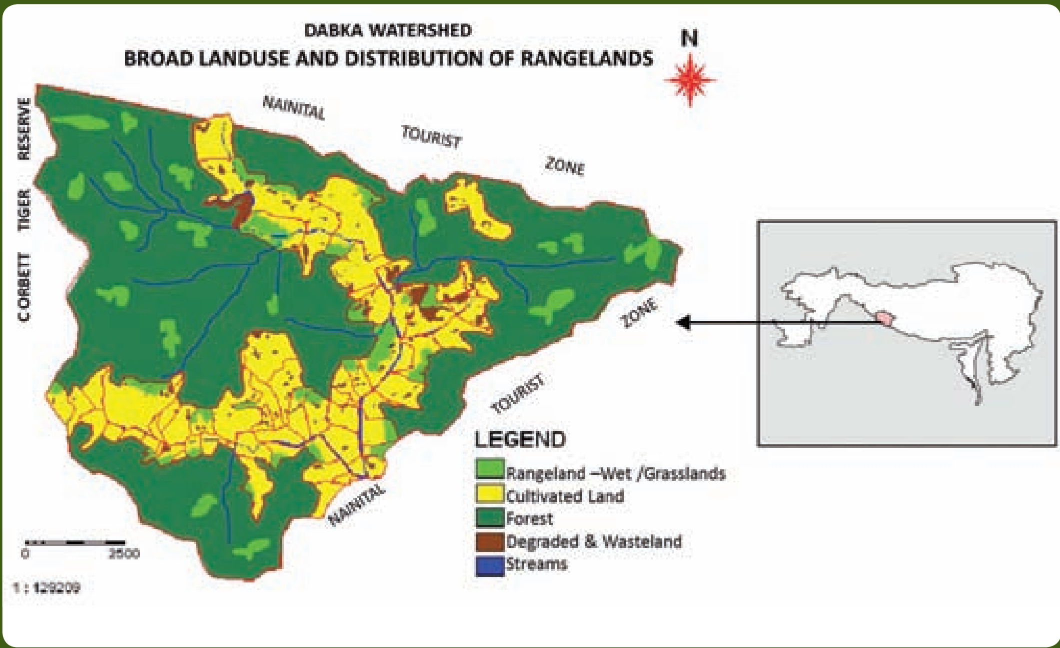
Gentler slopes in outer Himalayan ranges in India are used for livestock grazing by the local rural communities. Water flowing down from the upper catchments in the form of springs and streams not only contributes to the discharge of the rivers which form a lifeline for the local communities, it also supports the food and agricultural systems downstream (Tiwari and Joshi 2012a). However, there has been a rapid change in land use practices throughout the Himalayan range primarily due to increasing population pressure, rapid urbanization, and infrastructure development for economic gains (Wasson et al. 2008; Tiwari 2000). These changes have lead to the disruption of the hydrological system, reduced groundwater recharge, drying of natural springs, and decreased stream flow (Rawat 2009; Tiwari and Joshi 2012a). As a result, the regime of the rangeland water resources is likely to change with respect to discharge, volume, and availability, thereby increasing the vulnerability to water, food, livelihood, and health insecurity of the large population dependent on subsistence agriculture, both in the mountains and in the densely populated adjoining lowlands (Tiwari and Joshi 2013). Furthermore, climate change has already stressed the Himalayan rangelands through changes in temperature and precipitation and an increase in extreme weather events (ICIMOD 2009). It is therefore imperative to monitor land use change, understand the socioeconomic drivers of the change, assess the impact on rangeland ecosystems, and evolve an integrated and community-based rangeland management framework.

This paper deals with the status of anthropogenic grasslands and their interfaces in the Dabka watershed in the outer Himalayan range of Uttarakhand (India). The study aimed to monitor land use dynamics and the socioeconomic drivers. The key findings of the study are presented together with the implications for conservation and management of the forest-grassland interface.

Study Area

Dabka watershed lies in the catchment of the Koshi River, which originates in the Lesser Himalayan ranges, in Almora District in the Indian state of Uttarakhand. The Dabka drainage basin extends from the low lying narrow foothill zone comprising the Bhabar and Siwalik Hills to the Lesser Himalayan ranges to the north of Nainital District in Uttarakhand. The watershed lies in close proximity to the world famous Corbett National Park. It encompasses a geographical area of approximately 69 km^2 at an elevation of 700 to 2,623 masl (Figure 6).

Figure 6: **Detailed map of Dabko watershed study area**



Average annual rainfall is about 190 cm. The catchment is intersected by the Main Boundary Fault; the area is tectonically active and prone to landslips, landslides, and soil erosion, and, therefore, considered to be ecologically sensitive. The principal geomorphic features of the region are dissected hills, active landslides, colluvial fans, old talus, cones, fluvial terraces, hogbacks, and saddles. The altitudinal and topographic variation result in a rapid transition of ecoclimatic zones. Approximately 40 km^2 (57.6%) of the watershed consists of natural vegetation including different types of forest, interspersed with grasslands.

The watershed has a total population of 5,250 persons living in 43 villages, with a population density ranging from approximately six to 322 persons per square kilometres. The foothill belt along the southern fringe of the catchment is formed by alluvial soils deposited by streams and rivers flowing down from the Lesser Himalayan ranges and Siwaliks Hills, and constitutes one of the most productive and densely populated tracts of the Kumaon Himalaya. The high population pressure in the foothill zone is affecting resource use practices such as grazing and collection of fodder and fuelwood and moving them to higher elevations, which is leading to degradation and depletion of the grasslands as well as forests.

As in other parts of the Kumaon Himalaya, animal husbandry is an integral part of the subsistence agricultural economy in the catchment. Primary data collected from all 43 villages in the catchment indicate that livestock and crop production constitute the main source of food and livelihoods for about 51% of households, while 35% depend primarily on animal husbandry. The environmental impacts of the resource development processes associated with traditional biomass-based subsistence agriculture and animal husbandry are of special significance in this region. The practices of cultivation, grazing, and construction now extend over large areas, and land use on the fragile slopes is intensifying, leading to degradation and depletion of critical natural resources including the rangeland ecosystem. The region, therefore, deserves special attention and priority measures to ensure conservation and sustainable development of the rangeland resources.

Methodology and Data Source

The methodological approach included (i) geospatial analysis of land use and land cover using high resolution satellite data supported by intensive ground validation; (ii) hydrological monitoring of springs and streams and assessment of the impacts of hydrological disruptions on water resources and agricultural productivity; (iii) appraisal and analysis of natural resources using participatory resource appraisal (PRA) methods and a comprehensive socioeconomic survey; (iv) comprehensive discussion and consultation with local government agencies and rangeland user communities for developing a rangeland conservation framework; and (v) integration of various parameters to develop a watershed management action plan using GIS. Analysis of land use and rangelands was carried out for the years 1982 and 2012. Survey of India Topographical Maps at a scale of 1:50,000 were used for the land use survey and mapping for 1982. Linear Imaging Self Scanning Scanner-III (LISS-III) and Panchromatic (PAN) merged data from the Indian Remote Sensing Satellite-1C (IRS-1C) were used for the survey and interpretation of land use for the year 2012.

Digital interpretation techniques supported by intensive ground validation were used for the analysis. Image enhancement techniques such as principal component analysis (PCA) and normalized deviation vegetation index (NDVI) were used to enhance the interpretability of the remote sensing data for digital analysis. In the Himalayan region, the interpretability of the remote sensing data is affected to a large extent by the complexity of the terrain and the effects of elevation and slope and aspect, which can lead to the same object having a different spectral signature and vice versa. In order to overcome these constraints and attain the best possible level of accuracy, 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 digital classification of land cover land use through on screen visual recording and rectification (Joshi et al. 2003).

The land use map of 1982 was digitized and a thematic layer created. The land use map generated for the year 2012 was used as the base map for further characterization of different types of rangeland through intensive field surveys and mapping in the watershed. The land use maps of 1982 and 2012 were used for detecting land use changes during the period using a geographic information system (GIS). Information related to important drivers of land use change, water availability and utilization patterns, and food production was generated through intensive socioeconomic surveys using specifically designed questionnaires and schedules. The status of water resources was monitored through long-term hydrological monitoring of streams and springs. In addition, quantitative and qualitative information was collected and generated from forest and cadastral maps of the areas, through field surveys, ground observations, socioeconomic surveys, and interviews with local people.

Results and Discussion

Land use/land cover dynamics

Land use in the watershed in 1982 and 2012 was classified in terms of the seven categories of forest, grassland, wetlands, cultivated land, settlements (mainly houses, hotels, resorts and roads), degraded and wasteland, and other (Figure 6) using the land use maps prepared using information from multiple sources as outlined in the methods section. The results are shown in Table 4.

Overall, approximately 11 km^2, or 16% of the total watershed area, showed a change in land use between 1982 and 2012. The area of all the components of rangeland decreased: the proportion of forest area in the watershed decreased from 43 to 40%; grassland from 15 to 12%; and wetland from 8 to 6%. The total rangeland area decreased by 12%, and that of grasslands and wetlands by 20%. At the same time, the area under cultivation increased from 15 to 17%, settlements from 1 to 2%, and degraded and wasteland from 17 to 21%.

Characteristics of the forest-grassland wetland interface

The forest-grassland-wetland interface in the Dabka watershed comprises sub-tropical forest, Himalayan temperate forest, grasslands, and wetlands. The main characteristics are summarized below.

Table 4: **Land use change in Dabka Watershed, Uttarakhand between 1982 and 2012**

Land use category	1982		2012		% change
	Area (km^2)	% of total area	Area (km^2)	% of total area	
Forest	29.4	42.5	27.3	39.5	(-) 3.0
Grassland	10.4	15.1	8.1	11.7	(-) 3.3
Wetlands	5.5	8.0	4.4	6.3	(-) 1.7
Cultivated land	10.5	15.1	11.8	17.2	(+) 2.0
Settlements	0.7	1.1	1.5	2.2	(+) 1.2
Degraded and wasteland	11.8	17.1	14.6	21.2	(+) 4.0
Other	0.7	1.1	1.3	1.9	(+) 0.9
Total	**69.1**	**100.00**	**69.1**	**100.00**	**16.1**

Sub-tropical forests consist of (a) sub-tropical deciduous forests found up to an elevation of 1,000 masl along the foothills zone and (b) chir pine forests upto 1,600 masl.
Himalayan temperate forest includes (a) forests banj oak (*Quercus leucotrichophora*); (b) temperate moist deciduous forest at 1,800–2,623 masl, which includes many broad-leaved species, principally tilonj oak (*Quercus dilatata*), between 2,000 and 2,100 masl, replaced by other species of oak at higher elevations.

Grasslands are interspersed with natural forest. The individual grasslands are very small, ranging in size from 0.05 to 0.88 km^2, with an average of 0.32 km^2. A total of 25 grassland patches were mapped in the watershed.

Wetlands are also interspersed with natural forest. The wetland areas are also small, ranging in size from 0.01 km^2 to 0.53 km^2 with an average of 0.27 km^2. A total of 16 wetland areas were mapped in the watershed.

Distribution of grasslands and wetlands

The extent and distribution of grasslands and wetlands were assessed in terms of altitudinal range, slope, and aspect. The results are shown in Tables 5–7. The grassland area increased with altitude up to 2,500 masl; whereas the greatest area of wetland (43%) lay between 1,500 and 2,000 masl (Table 5). Approximately 78% of grassland and 71% of wetlands were found between 1,500 and 2,500 masl. Grasslands were most common on the steeper slopes (>35°) and wetlands on slopes of 10–25°, with 81% on slopes between 10 and 35° (Table 6). Close to 50% of the grasslands are located on slopes with a south, southeast, or southwest aspect; whereas the single most common aspect for wetlands was west (Table 7).

Status of forests and grasslands

Dabka watershed has only around 2.8 ha forest for each hectare of cultivated land, and more than 60% of this forest is in a highly degraded condition, mainly due to increased encroachment and resultant degradation and depletion of forest resources. The area under cultivation increased from 15.1% in 1982 to 17.2% in 2012, an increase of 14% (Table 4),

Table 5: **Distribution of grassland and wetlands with altitude in Dabka watershed**

Altitude (masl)	Grassland		Wetlands	
	Area (km^2)	% of total grassland	Area (km^2)	% of total wetland
<1,000	0.25	3.15	0.55	12.66
1,000–1,500	0.72	8.91	0.46	10.54
1,500–2,000	2.35	29.05	1.89	43.25
2,000–2,500	3.99	49.34	1.20	27.43
>2,500	0.78	9.55	0.27	6.12
Total	**8.09**	**100.00**	**4.37**	**100.00**

Table 6: **Distribution of grassland and wetlands with slope in Dabka watershed**

Slope	Grassland		Wetlands	
	Area (in km²)	% of total grassland	Area (km²)	% of total wetland
<10°	0.03	0.34	0.24	5.51
10–25°	0.52	6.45	2.16	49.45
15–35°	2.23	27.55	1.39	31.75
>35°	5.31	65.66	0.58	13.29
Total	**8.09**	**100.00**	**4.37**	**100.00**

Table 7: **Distribution of grassland and wetlands with slope aspect in Dabka watershed**

Slope aspect	Grassland		Wetland	
	Area (km²)	% of total grassland	Area (km²)	% of total wetland
South	3.00	37.13	0.22	5.11
Southeast	0.90	11.07	0.69	15.75
Southwest	0.10	1.21	0.52	11.97
North	1.70	21.07	0.42	9.55
Northeast	0.77	9.47	0.32	7.28
Northwest	0.12	1.49	0.15	3.35
East	0.59	7.31	0.48	11.02
West	0.91	11.25	1.57	35.97
Total	**8.09**	**100.00**	**4.37**	**100.00**

with a similar increase in the livestock population. The availability of grazing land is 0.21 ha per head of cattle, compared with an ecologically recommended standard minimum of 3.5 ha per head of cattle (Ashish 1983). The grazing pressure is very high, and the pastures are coming under increased biotic stress. As a result, the forest and rangelands around rural settlements are in a highly degraded condition to a distance of 7 km on average.

Daily subsistence and resource use patterns in the Himalayan region centre around agriculture and animal husbandry, which is strongly influenced by the agriculture-forest interface and other landscape elements (Aase et al. 2013; Moench 1989; Maithani, 1996). Singh et al. (1984) estimated that 5–10 ha of well-stocked forest is required to meet the energy requirement of one hectare of agricultural land in the Himalayas in terms of manure and draught power. One of the important reasons for the rapid land use change in Dabka watershed is the town of Nainital, which is located on the southeastern boundary of the watershed and is one of the most popular and heavily visited tourist centres in the Himalayas. Furthermore, the densely populated foothill belt of Bhabar is situated to the south, and the geographic advantages of the region have led to several other locations developing into large centres of tourism. The processes of urban development and tourism growth are very fast across the entire region, and are to a great extent responsible for the intensification of land use in the area. Moreover, the main national highway of Kumaon and its several branches pass through the western, eastern, and southern margins of Dabka watershed and have opened access to remote areas, thus facilitating the exploitation and depletion of forest and other natural resources in the entire region.

Status of watersheds

The rapidly changing land use pattern and the resultant decrease in forest area and degradation of grasslands have severely affected catchment capability in the watershed. In the mid-Himalayas, the amount of surface runoff from cultivated and barren land is much higher than the amount of runoff from other categories of land, particularly forests and rangelands (Tiwari 2000). The continued depletion of wetlands during the last 30 years has also affected groundwater recharge and availability of water in the watershed. Of the 195 natural springs identified in 1982, 73 (37%) had dried up by 2012 and 28 (14%) had become seasonal (Table 8). The number of dry and seasonal springs was higher at low elevation (below 1,000 masl) and mid elevation areas (1,500–2,500 m) than at high altitudes (above 2,500 m). Satellite data indicated that 7.4 km of a total stream length of 105.8 km had also dried, and that this particularly affected the first order perennial streams which have their source in headwater areas situated in wetlands, grassland, and forests. Observations during the hydrological monitoring indicated that 75% of the dried and seasonal springs and dried up streambeds were located in aquifers situated in the recharge zone composed of forest, grassland, and wetlands.

The changing climatic conditions are likely to intensify these impacts across the Himalayas as well as downstream since the contribution of rainfed discharge is much higher than the contribution of snowmelt to the Himalayan river basins (ICIMOD 2009). The rangeland and forest ecosystems have been important components of rural resource utilization in the Himalayas for several thousand years, and have been integral to the development of the economy, culture, traditions, and history. Thus these resources need to be looked at as part of

Table 8: **Changes in water resources in Dabka Watershed**

Altitude (masl)	Changes in water resources between 1982 and 2012							
	No. of springs in 1982	Springs that dried between 1982 and 2012	% springs dried	Springs that became seasonal between 1982 and 2012	% springs seasonal	Stream length 1982 (km)	Stream length dried between 1982 and 2012 (km)	% length dried
<1,000	71	29	41	12	17	15.00	0.84	5.60
1,500–2,000	58	21	36	6	11	25.17	1.14	4.53
2,000–2,500	45	21	47	9	21	26.00	2.27	8.73
>2,500	21	2	10	1	5	39.58	3.11	7.85
Total	**195**	**73**	**37**	**28**	**14**	**105.75**	**7.36**	**6.96**

the economic and sociocultural system as well as the local natural system. It is not possible to manage forests, protected areas, or rangeland ecosystems sustainably without considering the needs and problems of the rural communities that live within them, particularly when traditional activities have been limited or prohibited in many parts of the region following the creation of national parks, sanctuaries, and biosphere reserves, and the rangeland resources cannot be conserved and protected in isolation following a sectoral approach. It is imperative to analyse both the natural and the socioeconomic issues related to the conservation and protection of the rangeland resources in a holistic and integrated manner, and to consider rangeland management as one essential component in the overall land use policy and a part of any sustainable development strategy. This approach is a necessary basis for developing a realistic and integrated framework for the conservation of the rangeland ecosystems while ensuring the wellbeing of the rural communities that traditionally depend on the rangeland resources.

The hydrological disruptions can be attributed to large scale deforestation and degradation of wetland and grassland ecosystems and the resultant loss of water generating capacity of the land in the area (Rawat 2009). On average, the water discharge in the streams originating from wetlands, grassland, and forests has decreased by about 15% over the last 30 years, and these changes are affecting the availability of water for both domestic and agricultural use. The number of villages facing water scarcity, loss of irrigated land, and decline in agricultural productivity in the Dabka watershed between 1982 and 2012 is shown in Table 9. In total, 32 of 43 villages were identified as water scarce in terms of water availability for domestic use based on the water requirement norms set by the Government of India (GoI 2005). The irrigated area fell by 78 ha or 16% between 1982 and 2012, and agricultural production fell by 15%. This increases the vulnerability of the rural communities to food and health insecurity, particularly the poor and marginalized households that constitute nearly 75% of the total population of the region (Tiwari and Joshi 2012b). The problem of water availability is likely to have long-term implications for water, food, livelihoods, and health security in the watershed if the expected changes in precipitation and temperature resulting from climate change take effect (Tiwari and Joshi 2013).

Table 9: **Water availability, irrigated land, and agricultural productivity in Dabka watershed (1982–2012)**

Altitude (masl)	Number of villages	Villages currently facing water scarcity	Irrigated agricultural land (ha)		Loss of irrigated agricultural land (1982–2012)		Decline in agricultural productivity (1982–2012)
			1982	2012	ha	%	%
<1,500	19	13	285	245	40	14	11
1,500–1,800	15	14	107	89	18	17	15
1,800–2,200	5	3	81	64	17	21	15
>2,200	4	2	15	12	3	20	17
Total	**43**	**32**	**488**	**410**	**78**	**16**	**15**

Conclusion

The grassland–forest interfaces of Kumaon region in the lower and mid-Himalayan ranges are changing rapidly, mainly due to increasing population pressure, rapid urbanization, growth of tourism, and resultant land use changes. More than 15% of the total area of Dabka watershed changed its land use between 1982 and 2012, mainly as a result of increased human encroachment on forests, and there was a reduction in the proportion of forests, grassland, and wetlands in the watershed. These changes have disrupted the hydrological regime of the watershed through reduced groundwater recharge, drying of natural springs, and decreased stream flow. Villages in both the mountains and the adjoining foothill zone are facing scarcity of water for domestic and irrigation purposes, and agricultural productivity has declined. Degradation of natural forest and grassland ecosystems and resultant loss of ecosystem services, particularly freshwater, is likely to increase the vulnerability of rural communities both upstream and downstream. It is imperative to monitor the land use dynamics, understand the social and economic drivers of land use change, and develop a comprehensive land use policy for the lower to mid-Himalayan ranges. Rangeland conservation should constitute an integral component of an overall land use and sustainable resource development action plan for the region.

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