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Land Use Changes in Himalaya and Their Impacts on Environment, Society and Economy: A Study of the Lake Region in Kumaon Himalaya, India

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ABSTRACT

The traditional resource use structure in Himalaya has transformed considerably during the recent past, mainly owing to the growth of population and the resultant increased demand of natural resources in the region. This transformation in resource use practices is particularly significant in the densely populated tracts of Himalaya. As a result, cultivated land, forests, pastures and rangelands have been deteriorated and depleted steadily and significantly leading to their conversion into degraded and non-productive lands. These rapid land use changes have not only disrupted the fragile ecological equilibrium in the mountains through indiscriminate deforestation, degradation of land resources and disruption of the hydrological cycle, but also have significant and irreversible adverse impacts on the rural economy, society, livelihood and life quality of mountain communities. It has been observed that the agricultural production has declined, water sources are drying up fast due to decreased ground water recharge and a large number of villages are facing enormous deficit of critical resources, such as food, fodder, firewood and water, mainly due to unabated deforestation. As a result, the rural people, particularly the women, have to travel considerably long distances to collect fodder and firewood and to fetching water. It is therefore highly imperative to evolve a comprehensive and integrated land use framework for the conservation of the biophysical environment and sustainable development of natural resources in Himalaya. The land use policy would help local communities in making use of their natural resources scientifically and judiciously, and thus help in the conservation of the biophysical environment and in the increasing of the productivity of natural resources. The study indicates that conservation of forests and other critical natural resources through community participation, generation of alternative means of livelihood, and employment in rural areas can help increase rural income as well as restore ecosystem services.

Key words: subsistence agriculture, population growth, resource use pattern, urbanization, deforestation, hydrological disruptions, resource deficit, integrated land use framework

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1. Introduction

Himalaya represents one of the tectonically unstable, ecologically fragile, economically underdeveloped and the most densely populated mountain ecosystems on the planet. The continuous uplift has led these mountain ranges to be highly vulnerable to large-scale tectonic movements, landslides, and to the processes of surface removal (Valdiya, 1985). The nature of the terrain imposes severe limitations on the scale of productive activities as well as on the efficiency of infrastructural facilities in the region. As a result, survival at the subsistence level is the order and the biomass based subsistence agriculture constitutes the main source of rural livelihood (Maithani, 1996). More than 75 percent of regional population is solely dependent on this traditional agro-ecosystem even though the availability of arable land is severely limited and the productivity is considerably poor (Tiwari and Joshi, 2005). This traditional agricultural system in the region is

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closely interlinked with forests, and animal husbandry is the natural ally of the subsistence agriculture as flow of biomass energy from forests to cropland is mediated through cattle population (Singh et al., 1984; Moench, 1989; Whittaker, 1989).

Thus, the forests of Kumaon, Himalaya have been integral to the development of its economy, culture, traditions and history. The maximum proportion of forests (59%) in the region is under State Forests, which are the property of the State Forest Department and are managed by it. The State Forests are outside the village boundaries and are supposed to be completely free from all kinds of resource use pressures. However, the local communities have enjoyed limited rights and concessions in these forests, and now this facility has been withdrawn in most of the forests, particularly after the creation of large number of protected areas in the region. Out of the total forest land of Kumaon Himalaya, 27% is under Civil Forests. These forests lie within the village boundaries and are therefore generally named as Village Forests. The Village Forests are considered as Common Pool Resources for the village communities. The Common Pool Resources (CPR) are those resources in which all households of the village have equal access for the fulfillment of their various resource needs, such as, fodder, firewood, grazing, timber, collection of other minor forest produces, but no household can claim these resources as its property. Since the Village Forests have been exploited for a long period of time, they are in a highly degraded condition, and the rural communities now encroach upon the resources of State Forests.

During the recent past, a variety of changes have emerged in the traditional resource use structure mainly in response to increasing pressure of population and the resultant increased demand of natural resources (Palni et al., 1998). Besides this, the fast expansion of road linkages has facilitated the rapid urbanization, emergence and growth of rural service centers and increased access to markets. A large proportion of arable land is being encroached upon by the process of rapid urbanization and the expansion of infrastructure, services and economic activities in the region every year (Tiwari and Joshi, 2005). Moreover, there is a regional shift from the traditional crop farming and animal husbandry system to village-based production of fruits, vegetables, flowers and milk for sale in both the nearby and far-off markets. This is occurring in the villages situated in the influence zone of urban centers and market places, and along and near the roads. This has a large impact on the traditional resource development process and land use pattern. As a result, the critical natural resources, such as, forests, pastures, and cultivated land have deteriorated and depleted steadily and significantly leading to their conversion into degraded and non-productive lands during the last 20–30 years. This occurred as vegetable cultivation needs intensive manuring of soils which ultimately increases the number of cattle. Besides this, the quantity of farm residue, which constitutes a major source of fodder for livestock, is also less in vegetable farming compared to the traditional agricultural system and thus, vegetable farming increases the pressure on forests (Singh et al., 1984; Tiwari and Joshi, 2005).

As per the norms of the Planning Commission of India, a minimum of 60% of the geographical area should be under forests in mountain terrain. Against this, on an average, only 29% of the total geographical area of Kumaon, Himalaya, which constitutes the eastern part of the newly carved Himalayan State of Uttarakhand in India, is now under forests and only 4% of the forest has a crown density of more than 60% (Singh et al., 1984). The ratio of forests to cultivated land is a mere 1.26 ha forest for each ha of farming compared to the ecologically recommended standard of 5–12 ha of forest area per ha of cultivated land. Similarly the pressure of grazing has increased far beyond the carrying capacity of available forests and pastures, as the average availability of grazing area in the region is only 0.60 ha/cattle against the minimum requirement of 3.60 ha/cattle (Ashish, 1983; Tiwari, 1995). These rapid and large scale land use changes have not only brought about environmental instability and climatic changes in Himalaya, but have also decreased the productivity of the rural ecosystem and have adversely affected the livelihood securities of rural communities through the considerable shrinkage of forests, degradation of land, and reduced ground water recharge throughout the entire region. The restoration of ecological balance and increasing the adaptive capacity of regional ecosystem and local communities to cope with foreseen environmental changes in Himalaya, particularly in the high population concentration zones of the region, largely therefore depends on the monitoring of land use dynamics in the ecological as well as socio-economic backdrop of the region and effective land use planning. Sustainable development of natural resources under a comprehensive land use policy is also important. A comprehensive land use framework needs to be adopted wherein ecological production potential and socio-economic parameters are taken in account. The land use framework will provide the basic guideline for the sustainable development of natural resources as well as for the conservation of critical environmental components, such as, land, water, forests and biodiversity.

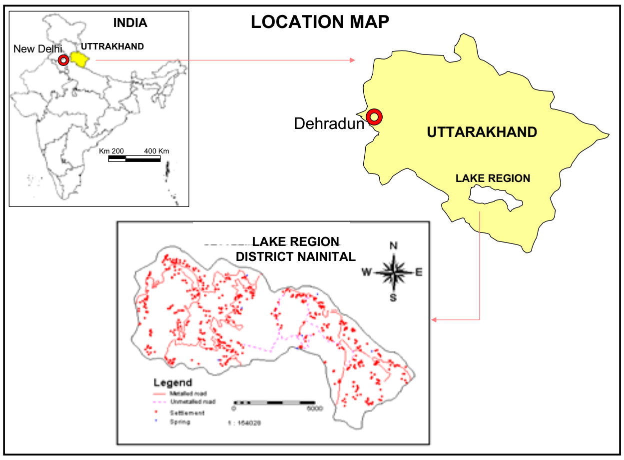

Fig. 1. Location Map (showing location of study area in Uttarakhand State of India).

2. The study area

The Lake Region, consisting of the micro-watersheds of six perennial lakes and part of Balia micro-watershed in the Lesser Himalayan Ranges and Siwalik Hills of the district of Naini Tal, Kumaon, Himalaya, was taken up as the area of study for the present investigation (Fig. 1). The six lake micro-watersheds that constitute the region are—Khurpa Tal, Naini Tal, Nal-Damyanti Tal, Sat Tal, Bhim Tal and Naukuchia Tal with the suffix "Tal", or lake, attached. District Naini Tal, together with 12 other districts, constitutes the newly carved Himalayan state of Uttarakhand in India. The area encompasses a geographical land surface of 94.04 km^2 with an average altitude ranging between 700–2600 m above the mean sea level. The region is situated along the Main Boundary Thrust (MBT)—the major tectonic juncture between the Lesser Himalayan Ranges in the north and the Siwaliks Hills in the south. These complexities are manifest not only in the ecological diversities but also account for the characteristic geomorphic processes operating in the area, and the resultant landscape types. Consequently, the entire area is tectonically alive and ecologically vulnerable. Climatically, the region extends from sub-tropical to cool temperate climatic regimes, and it is a critical zone that lies within the belt of maximum precipitation (298.60 cm). The impacts of physiographic, geomorphic and climatic diversities are clearly visible in a variety of natural vegetation and wildlife in the region. The area has been identified as one of the hot spots of biodiversity in Himalaya (Roy and Tomar, 2000).

The lakes of the region are aesthetically beautiful and geologically interesting. But at present, all the principal lakes of the region are diminishing mainly due to sedimentation and other degradation caused by increased anthropogenic activities in the region. The Balia River originates from Naini Tal and flows across a geologically complex area, in the southwestern direction for about 12 km before joining the river Gaula, at Ranibagh. The region is one of the densely populated mountainous parts of Kumaon. The rural population of the lake region, which lives in 41 revenue villages, was 20840 people as per the 2001 census. This does not include the population of two urban centers—Naini Tal (41058 people) and Bhim Tal (5875 people)—situated in the Lake Region. As a result, there is acute pressure on the land and other natural resources of this ecologically fragile zone. The Lake Region has been divided into 5 micro-watersheds following stream ordering techniques for the analytical study of certain research parameters studied in the present work. From west to east these micro-watersheds are: (1) Nihal Nadi, (2) Balia Nadi, (3) Nalena Nadi, (4) Kuria Gad, and (5) Bhim Tal Gadhera (Fig. 2 and Table 1)

3. Objective

The main objective of the study is to interpret the trends and magnitude of land use dynamics in Himalaya against the ecological and socio-economic backdrop of the region, and assess the impact of land use changes on the natural environment, society and economy of the region. All of this is done with a view to help formulate and implement various resource development programs through the local government departments at the micro-level.

4. Methodology

The information and data required for the study have been generated and collected from various pri-

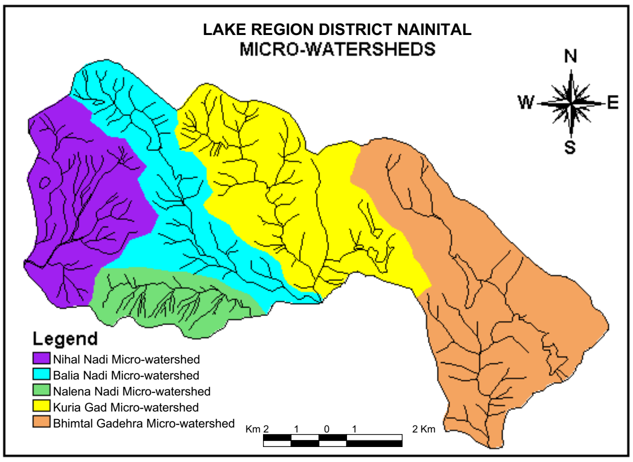

Fig. 2. Micro-watersheds of the Lake Region.

Table 1. Micro-watersheds of the Lake Region.

Micro Watersheds	Area (km^2)	Percent of total area	No. of villages	Total population
Nihal Nadi	15.97	16.98	04	4414
Balia Nadi	16.68	17.74	07	4451
Nalena Nadi	07.45	07.92	01	1175
Kuria Gad	24.17	25.70	04	3140
Bhimtal Gadhera	29.77	31.66	28	7660
Total	94.04	100.00	41	20840

mary and secondary sources. The primary information has been generated through intensive field surveys and mapping, observations, monitoring, and socio-economic surveys. The secondary methods mainly included the interpretation of high resolution satellite data. Besides, the necessary data and information required for the study have also been collected from the Survey of India (SOI) topographical maps of the area at scale 1:50000, forest maps, cadastral maps and other records. LISS-III and The Panchromatic (PAN) data of Indian Remote Sensing Satellite-1C (IRS-1C) of March 2005 were used for the survey and mapping of land use and interpretation of its dynamics. Digital interpretation techniques supported by intensive ground validation have been used for this purpose. In order to enhance the interpretability of the remote sensing data for digital analysis the Normalized Deviation Vegetation Index (NDVI) has been employed (Roy and Tomar, 2000). In the Himalayan mountain terrain the interpretability of the remote sensing data to a large extent is affected by the complexity of the terrain as due to the effect of elevation, slope, and its aspect. The spectral signature of same objects are often different or vice versa. In order to overcome these constraints and also to attain the best possible level of accuracy in the interpretation, traverses along all roads, drainage channels, and hilltops have been made for collecting ground truth and a visual interpretation key was evolved 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 information and data generated and collected from various sources were transformed into spatial and non-spatial database using GIS. The interpretation of satellite data was followed by an intensive reconnaissance survey to get acquainted with the general pattern of land use of the study area. All major land use and vegetation types have been recorded and mapped. The variation and tonal patterns have been observed on existing satellite images. Besides this, a comprehensive survey of all relevant existing literature was made and interaction with land-concerned government agencies including the State Forest Department and local institutions have been made for the collection of existing knowledge base.

The land use map for 1975 was prepared using Survey of India Topographical Sheets as the satellite data for the year was not available. Survey of India Topographical Maps, which are the only authentic maps in country for such purpose, show only four broad land use categories. The methodology of land use classifi-

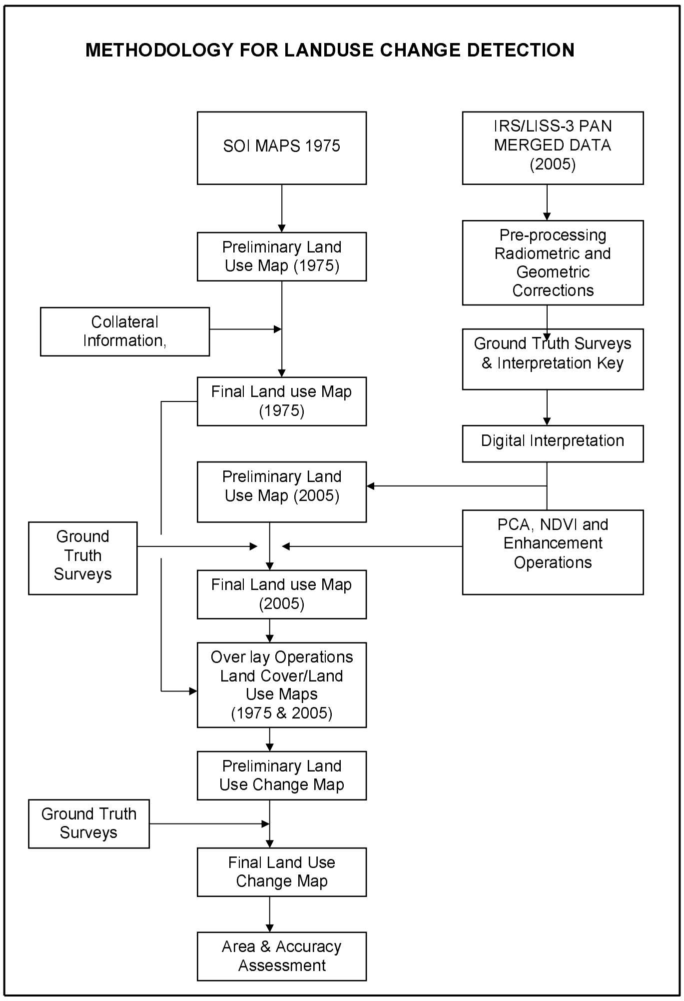

Fig. 3. Methodology used for land use change mapping.

cation has been illustrated in Fig. 3. It was observed that the classification of land use in four broad categories—(1) forests, (2) cultivated land, (3) wasteland, and (4) water bodies, could be done with a maximum level of accuracy keeping in view the aim of the study. LISS III and PAN merged data from the Indian Remote Sensing Satellite has been used for the interpretation of land use for 2005. On the basis of this exercise, 12 land cover/land use classes could be identified in the study area in 2005. Besides the interpretation of the principal mountain land use categories, all the major forest types available in the region could also be identified and mapped during the digital interpretation process. The land cover/land use categories that could be interpreted in the region are: pine forests, oak forests, mixed forests, degraded forests, plantation forests, scrub land, cultivated land, fallow land, settlements, wasteland (including exposed rocky area), river beds and water bodies. The availability of high resolution satellite data (with 5.8 m spatial resolution) enabled us to classify the four broad land use classes of 1975 into 12 sub-classes. The land use maps of 1975 and 2005 have been converted into spatial layers and crossed with each other using GIS which ensures the maximum level of precision possible. A land use change map of the study area was generated out of this exercise with a high level of accuracy (Fig. 6). The resource deficit, sufficiency and surplus situations with respect to food, fodder and firewood productivity and have been determined by developing the estimates of production and demand employing standard techniques (Tiwari, 2003). The environmental status of streams and springs has been determined through intensive field surveys, mapping, and interviewing elderly people in the each of the villages of the study region. The travel distances involved in fetching water, firewood and fodder have been calculated by interviewing people in all the villages of the region and then computing the average distance of each village.

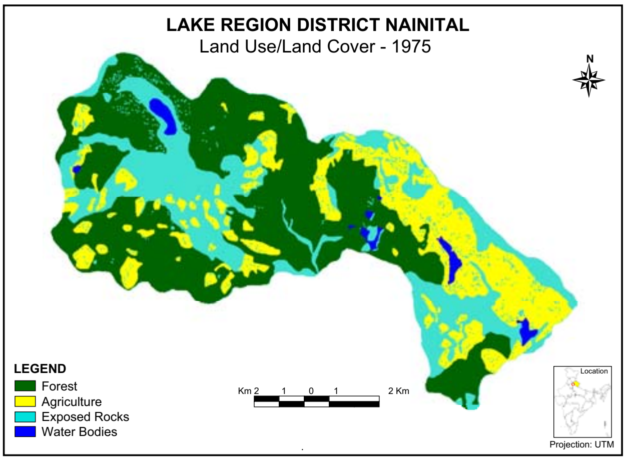

Fig. 4. Land use and land cover in the study region in the year 1975.

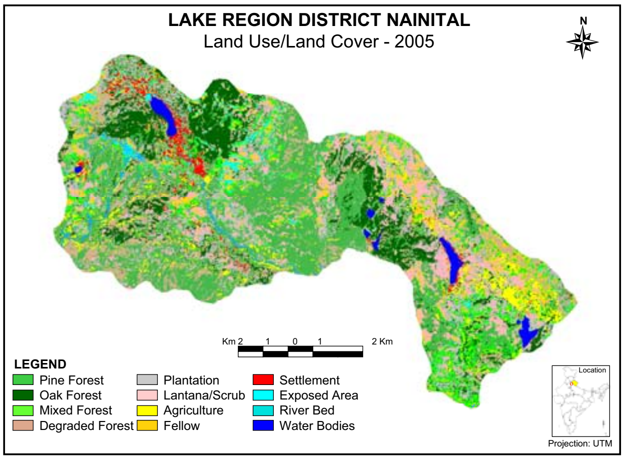

Fig. 5. Land use and land cover in the study region in the year 2005.

5. Results and discussion

5.1 *Land Cover/Land Use-1975*

The land use interpretation for the year 1975 is based on the SOI topographical maps at scale 1:50000 as satellite data for the year was not available. Only four land use classes can be identified on the Survey of India topographical maps. In 1975, out of the total geographical area (94.04 km^2) of the Lake Region, 43.90 km^2 or 46.68% of the total area was under forests; 21.99 km^2 or 23.38% was under cultivation; 26.61 km^2 or 28.30% was identified as degraded and wasteland; and 1.54 km^2 or 1.64% of the total region was under water bodies (Fig. 4 and Table 2).

5.2 *Land cover/land use patterns-2005*

Satellite data was used for the interpretation of land use for the year 2005. On the basis of the interpretation of high resolution satellite data 12 land cover/land use classes could be identified in the study area, in 2005 (Fig. 5 and Table 3). Besides the interpretation of the principal mountain land use categori-

Table 2. Land cover/land use pattern in the Lake Region (1975).

Land cover/land use class	Area (km^2)	Percent of total area
Forests	43.90	46.68
Cultivated land	21.99	23.38
Wasteland (includes exposed areas also)	26.61	28.30
Water bodies	1.54	1.64
Total	94.04	100.00

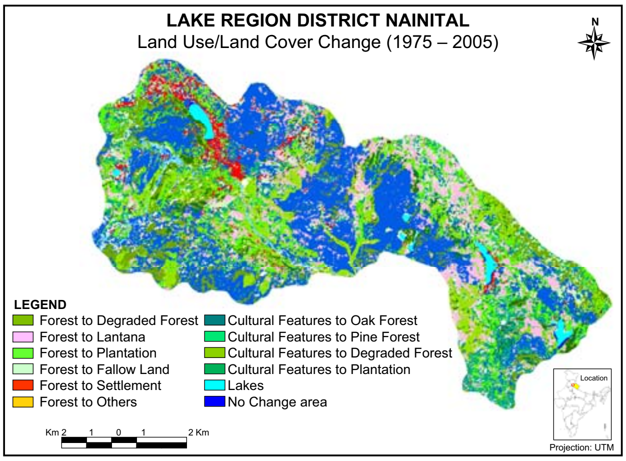

Fig. 6. Land Use and Land Cover Changes in the study region during 1975–2005.

Table 3. Land cover/land use pattern in Lake Region (2005).

Land cover/land use class	Percent of total area
Pine forests	27.98
Oak forests	13.46
Scrub land	12.15
Plantation forests	10.89
Mixed forest	07.84
Degraded forest	08.75
Settlement	02.36
Wasteland	02.39
Cultivated land	05.04
Fellow land	06.04
Water bodies	01.71
River beds	01.39
Total	100.00

es, all the major forest types available in the region could also be identified and mapped through the digital interpretation techniques. The land cover/land use categories that could be interpreted in the region are pine forests, oak forests, mixed forests, degraded forests, plantation forests, scrub land, cultivated land, fallow land, settlements, exposed areas, river beds and water bodies (Fig. 5 and Table 3). These 12 identified land use categories are actually the subsets of four land use classes identified for the year 1975 using Survey of India topographical maps. The five types of forests—pine forests, oak forests, mixed forests, degraded forests and scrub land—identified in this classification are the sub-classes of forest available in the region. Out of the total geographical area pine forests has the largest coverage of 26.31 km^2, which accounts

Table 4. Land use changes in Lake Region (1975 and 2005).

Land cover/land use classes (2001)	Land Cover/Land Use Classes (1975) Agriculture	Rocks	Water Bodies	Forest	Total (2005)
Pine	4.69	4.01	0.00	17.61	26.31
Oak	1.62	2.40	0.05	8.59	12.66
Scrub	1.68	2.71	0.06	6.98	11.43
Plantation	3.66	4.21	0.00	2.37	10.24
Mixed forest	2.21	1.41	0.00	3.75	7.37
Degraded forest	3.17	3.02	0.03	2.01	8.23
Settlements	1.97	0.08	0.00	0.11	2.16
Exposed areas	0.05	2.10	0.03	0.07	2.25
Agriculture	2.32	1.32	0.13	0.97	4.74
Fellow land	0.30	4.73	0.00	0.7	5.73
Water bodies	0.26	0.61	0.00	0.74	1.61
River beds	0.06	0.01	1.24	0.00	1.31
Total (1975)	21.99	26.61	1.54	43.9	94.04

for 27.98% of the total area of the lake region. This is followed by oak forests (13.46%), scrub land (12.15%), plantation forests (10.89%), degraded forests (8.75%) and mixed forests (7.84%). Comparatively, agriculture is now confined to a very small area of only 4.74 km^2 or 5.04% of the total area of the region. Fallow land extends over 6.04% of the total geographical land surface of the study area (Table 3 and Fig. 5). The settlements, wasteland, riverbeds and water bodies occupy respectively 2.36%, 2.39%, 1.39% and 1.71% of the total area of the region.

5.3 *Land use dynamics*

The results of land use change detection exercises have been presented in Table 4. Out of the total geographical area (94.04 km^2) of the Lake Region 57.53 km^2 or 61.18% has changed from one land use to other during the last 30 years. Table 4 and Fig. 6 reveal that in contrast to the general conception, the agricultural land in the region has drastically reduced from as much as 23.38% in 1975 to as little as 5.04% of the total geographical area of the region in 2005. A considerably large proportion (14.82 km^2) of the cultivated land was diverted to forests which includes pine (4.69 km^2), oak (1.62 km^2), plantation (3.17 km^2) and mixed forests (3.66 km^2) during this process of land transformation. Also, a large part of cultivated land that was abandoned during the recent past has now been degraded and converted into scrub land (2.21 km^2) and miscellaneous forests (1.68 km^2), but now they are in degraded states. The other remarkable change that took place concerning the agricultural land use in the region during the last 30 years has been the diversion of cultivated land into settlements, and 2.32 km^2 of the region has been encroached upon by such transformation process (Table 4).

The interpretation of the steering factors of land transformation revealed that the high growth of population and the process of rapid urbanization in the Lake Region and also in its surrounding belt have been mainly responsible for large-scale land use changes in the region. Despite an increasing trend of rural out-migration observed in the region, the region has experienced a very high rate of population growth, particularly during 1991–2001 (Table 5). The region registered an overall population growth of 22.46% during the last decade. The total population of the region has been enumerated to be 20840 people, not including the urban population of Naini Tal (41058) and Bhimtal (5875) which are respectively located in the Balia and Bhimtal micro-watersheds of the Lake Region. The highest concentration of population (7660) was found in the Bhimtal micro-watershed and the lowest (4414) in the Nalena micro-watershed of the region (Table 5). The Bhimtal micro-watershed registered a phenomenal growth of population (43.56%) during this period. In other micro-watersheds the growth of population varies from 4.44 in the very sparsely populated Nalena micro-watershed to 24.60% in the densely populated Balia micro-watershed during 1991–2001.

In general, the main factors of high population growth in the region have been the growth of settlements in the periphery and commuter zones of urban complexes, roads and the established nuclei, development of road connectivity, and increased tourist activity in existing tourist resorts and its extension in several new locations within the region. The reasons for the very high growth of population in the Bhimtal micro-watershed are that (1) the micro-watershed forms the hinterland of the fast growing urban and industrial centre of Bhimtal and developing tourist resort of Naukuchia Tal and Sat Tal, (2) the branches of the national highway connecting the gateway town of Haldwani-Kathgodam with all interior locations of Kumaon pass through the heart of the region, and (3) in a move to reduce anthropogenic stress in the Naini Tal lake ecosystem and in that way to decentralize the secondary and tertiary activities in its surrounding areas, a large number of district and sub-district level offices are now being shifted from Naini Tal town—that houses the district administration Naini Tal district—to Bhimtal town, particularly after the creation of the new State of Uttarakhand. As a result, a considerably large proportion of conservation oriented land has been diverted to other resource development processes.

Besides the population growth, rapid urbanization

Table 5. Spatial pattern and growth of population in the Lake Region (2001).

Micro-watersheds	Area (km^2)	Total population	Density of population	Percent growth of population (1991–2001)
Nihal	15.97	4414	276.39	22.16
Balia	16.68	4451	266.85	24.60
Nalena	07.45	1175	157.72	04.44
Kuria	24.17	3140	129.91	24.02
Bhimtal	29.77	7660	257.31	43.56
Total	94.04	20840	221.61	22.46

has also facilitated the process of land transformation, particularly from agricultural land to settlements in this densely populated region. Two important urban centers of the district, Naini Tal and Bhimtal, are situated in the region, and one other fast growing town, Bhowali, also has its location along its northern boundary. In addition, due to geographic advantages of their location, several other sites have had vast human agglomerations that now tend to develop as the largest centers of tourist, educational and industrial activities, in Kumaon. Naini Tal, besides being one of the famous hill resorts of the country, also houses the headquarters of district and divisional administrations. Also, the High Court of the new State of Uttarakhand was established in the town immediately after the creation of the State in 1999 demanding more and more suitable land and infrastructure for its proper functioning. Bhowali is growing as a nodal center of transport, trade and tourism in the region. Bhimtal is developing quickly as an industrial, tourist and educational urban complex. Consequently, the process of urban growth is very fast in the entire region, which is responsible for the change in agricultural land use pattern.

Moreover, the main national highway and its branches that connect the big market town of Haldwani and the rail head of Kathgodam is situated just to the south of the region in the foothills, with the entire Kumaon region passing through the region. Consequently, a large volume of traffic passes through the region each day from foothill towns to all interior locations in Kumaon. This has played a very crucial role in changing the traditional agricultural practices to secondary and tertiary sectors of resource development activities. Thirdly, the availability of good quality arable land is severely limited, net sown area is very low, and the agricultural productivity is very poor. As a result, in the hinterland of urban centers, people are abandoning the non-productive un-irrigated cultivated land. In most of the areas, agriculture is now practiced only in the irrigated land and that too is for producing a variety of vegetables mainly for sale in the markets within, as well as outside, the region.

However, it is heartening to observe that the area under forests has increased from 46.68% to 61.54% of the total geographical area of the region during the last 30 years (Table 4). As explained in the preceding section, this increase in the forest area is owing to gradual shift from traditional primary resource development practices to secondary and tertiary sectors of economic activities in the region. This change in the resource utilization pattern has facilitated the conversion of 14.82 km^2 of non-productive cultivated land and 13.64 km^2 of degraded land and wasteland into different types of forests. Besides this, some of the dead lake basins in the region have now developed as small pockets of forests of oak and other species. Although only a very small proportion of this entire forest area in under dense forests, this increase in forestland has facilitated the regeneration process of natural vegetation in the region.

The creation of a number of Van Panchayat (a village level participatory institution for the management of village forests), effective implementation of community based Joint Forest Management (JFM) programs, and rehabilitation of degraded and wasteland through forestation in some villages by the Forests Department and non-governmental organizations in collaboration with the local communities have played significant roles in the regeneration and development of forests in the region. But, Table 4 clearly brings out the fact that 3.75 km^2 and 6.98 km^2 of forest land, which lies with the disturbance regime of densely populated settlements of the region, has been degraded and converted into wasteland, and depleted by lopping and indiscriminate and excessive grazing by an increasing number of cattle, respectively. Besides this, as much as 2.59 km^2 of forest area in the lake region has been partially encroached upon by settlements and agriculture and also partially turned in wasteland and degraded land during the last thirty years.

5.4 *Environmental impacts*

Himalaya, being economically underdeveloped and being the most densely populated mountain ecosystem, is highly vulnerable to environmental changes. Owing to limitations of the terrain, biomass based subsistence agriculture constitutes the main source of rural livelihood. This traditional agro-ecosystem is interlinked with forests, and the flow of biomass energy from forests to agriculture is mediated through livestock. During the recent years, as in other parts of Kumaon, Himalaya, a variety of transformations in traditional resource utilization patterns have emerged mainly in response to increasing population pressures and the resultant increased demand of arable land, fodder, firewood, market forces, economic growth, land tenure policies, negative trends in agro-ecosystem, such as, decreasing agricultural productivity, declining carrying capacity of rangelands (Palni et al., 1998), expansion of cultivation on marginal lands, and environmental degradation and social disintegration, in the region (Ramakrishnan, 1972). As a result, the traditional land use pattern has changed leading to environmental degradation, ecological disruptions and livelihood insecurities in the entire region.

These changes in the traditional resource use patterns are of great significance in this ecologically fragile and tectonically active mountainous region where the steepness of the slope and the instability of the landscape increase the susceptibility of the region to a variety of hazards. Excavation of fragile slopes for road and house construction, removal of vegetation cover, extension of agricultural and horticultural activities to virgin forests, and such other anthropogenic processes initiated by the alternative resource utilization practices are leading to various kinds of environmental problems including the loss of forests and biodiversity, the disruption of the hydrological system and micro-climatic changes (Roy and Tomar, 2000; Joshi et al., 2003).

The biotic stress on forest resources is mounting up. It is discernible in the huge deficit of firewood and fodder in most of the villages, and in the felling of and excessive lopping of trees which effects the natural regeneration particularly in high altitude areas of the region. Due to low temperatures the regeneration process of plants is comparatively slow in these areas. Due to massive degradation of community forests within villages, the resource use stress on the state forests has been increasing. At present, most of the rural resource needs are met out of the state forests in the area leading to the overexploitation and resultant degradation and degeneration of natural vegetation and the erosion of biodiversity in the entire area.

The rapidly changing land use pattern and the resultant decrease in forest area have decreased the ground water recharge in the region (Ives, 1985, 1989). The studies carried out in the region revealed that the amount of surface runoff from cultivated and barren lands is much higher compared to the amount of runoff from other categories of land, particularly forests and horticulture (Tiwari, 1995, 2000). The large-scale depletion of forest resources is causing great damage to the underground water resources by reducing the water generating capacity of the land to springs and streams in the region. Since a large proportion of the rainfall is lost through surface run-off without replenishing the groundwater reserves, a large number of springs that support a variety of life sustaining activities are drying up fast in the region. The water resources of the region are diminishing and depleting quickly owing to the rapid land use changes and resultant reduced water-generating capacity of the land (Valdiya, 1985; Tiwari, 1995, 2000; Bisht and Tiwari, 1996; Tiwari and Joshi, 2005; Pal, 2002). These hydrological imbalances can be substantiated by (1) a 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, and (4) dwindling capacity of lakes (Rawat, 1988, 1999; Tiwari and Joshi, 2005).

These geo-hydrological transformations in the region have not only disrupted the fragile mountain ecosystem but have also affected the sustainability of rural communities in the region as well as in downstream areas in the south (Tiwari, 2000). Table 6 makes it clear that 159 natural springs have completely dried and 50 have become seasonal during the last 30 years mainly due to large-scale deforestation, reduced percolation and resultant decreased water generating capacity of the land in the area. As a result, a large number of villages of the region are facing acute shortage of drinking water. Also, the headstreams of many of the rivers in the study area have dried, reducing 89.21 m of the total stream-length in region during the last 30 years (Table 7). This fact was revealed by the change detection techniques employed in the present study. As a result, as many as 28 villages have been facing great scarcity of water for all purposes. This acute scarcity of water turns into severe water crisis during the summers and dry winter months in these villages. The rural women of the region have to travel long distances to fetch water. This is mainly due to the drying up of natural springs within and in the surrounding areas of the rural settlements in the region. The average travel distance involved in fetching 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 firewood and fodder respectively range between 2.5 and 3.5 km and 1.5 and 4 km in the region (Table 8). The region as a whole is currently facing food-grain, fodder and wood deficit of respectively, 75.22%, 52.90% and

Table 6. Status of natural springs in the Lake Region.

Micro-watersheds	Springs perennial	Springs seasonal	Spring density (No. km^{-2})	Perennial springs dried	Perennial springs became seasonal
Nihal	27	06	01.69	14	03
Balia	56	17	03.36	23	07
Nalena	24	15	03.22	07	05
Kuria	97	21	04.01	51	14
Bhimtal	111	29	03.73	64	21
Total	315	88	03.20	159	50

Table 7. Hydrological parameters of streams in the Lake Region.

Micro-Watersheds	Stream Density (km km^{-2})	Stream Flow (L d^{-1})	Stream Length Dried (m)
Nihal	02.90	77540	21.05
Balia	02.90	143750	11.17
Nalena	04.10	81200	07.10
Kuria	02.20	95700	23.15
Bhimtal	01.70	67370	26.74
Total	02.32	465560	89.21

41.52% due to land use changes and the resultant depletion of natural resources (Table 9).

These geo-hydrological changes have large impacts not on the geo-ecology and community sustainability, but also on the quality of social life of the rural communities in the region. The investigation carried out in the region revealed that the area has lost about 6 percent of its irrigation potential due to reduced water flow in streams and springs, and consequently, the productivity of the agro-ecosystem has declined by about 9% despite continued extension of cultivation during the last 30 years. The lake ecosystem of the region is also under increased biotic stress. Most of the lakes in Kumaon are situated along tectonically active and ecologically fragile but densely populated zones. Also, all the principal lakes are situated within or in the surroundings of the fast growing urban areas. More recently, comparatively less accessible areas of the lakes region of Kumaon are also coming under the process of fast urbanization mainly from to the extension of the road network, development of horticulture, gradual shift from primary resource development practices to secondary and tertiary sectors, and the growth of domestic and foreign tourism through the publicity and marketing of new tourist sites. The natural risks of this unplanned urban growth and infrastructure development are clearly discernible in terms of silting and pollution of lakes. Bathymetric investigations of Bhimtal and Naini Tal Lake revealed that the capacity of these important lakes has respectively decreased by 5494 m^3 and 14150 m^3 during the last 100–110 years due to rapid siltation of the lakebeds. The annual average rate of siltation in Naini Tal Lake was 65.32 m^3 (Khanka and Jalal, 1984; Rawat, 1987). Most of the lakes of the region are heavily infested by weeds and invading marshy conditions (Rawat, 1988). Thus, the natural ecosystem of the Lake Region has come under great biotic stress resulting in unsustainable development of natural resources, loss of biodiversity and acute ecological imbalances in the entire region.

However, the study indicated that the forests and other natural resources can be conserved and protected through community participation and involvement. The development of the appropriate infrastructural facilities can also play a very significant role in generating alternative means of livelihood and employment in rural areas and thus help in reducing dependency on traditional forest based subsistence agriculture and can increase the income level of the rural population. These developmental goals can be attained by evolving a comprehensive land use policy that allows local communities to make use of their natural resources scientifically and judiciously and diversify the rural economy.

6. Conclusions

The study reveals that the process of land transformation has been very significant and rapid land use changes have recently taken place in the region. The main reasons for these increasing trends of land use dynamics have been population growth and the resultant speedy transformation of biophysical components into natural resources and partly due to fast urbanization in the area. These land use dynamics have not only disrupted the fragile ecological system through the devastation of forests and biodiversity, destruction of wildlife habitats, degradation of land, disruption of hydrological system and micro-climatic changes, but have also adversely affected the productivity of the rural ecosystem and livelihood securities of rural communities, particularly, marginalized groups and the poor in the region. This clearly indicates that the process of land use changes and their impacts are particularly critical in the densely populated areas throughout Himalaya, like the Lake Region of district Naini Tal. However, the environmental conditions in close proximity to urban centers is improving mainly with the availability of alternative means of livelihood and employment in secondary and tertiary sectors and the resultant decreased dependency on traditional forest based agriculture and increase in the area under forests. It is, therefore, imperative to evolve a comprehensive framework of land use and development of rural infrastructure and services in the region which will help to restore the ecosystem services

Table 8. Resource collection distances in the Lake Region.

Micro watersheds	Villages	Distances involved in resource collection (km average)		
		Fodder	Fuel-wood	Water
Nihal	Kurpatal	1.5	3.0	0.0
	Ghalna	3.0	3.5	0.0
	Devidhura	1.5	2.0	0.0
	Belwakhan	1.5	2.0	0.0
	Nihal Total	1.9	2.6	0.0
Balia	Belwakhan	2.5	3.0	1.5
	Chopra	2.5	3.0	0.0
	Baluti	3.0	3.0	0.0
	Jeolikote	3.0	3.5	2.0
	Dogal Sandal	–	–	–
	Vergopant	3.0	3.0	2.0
	Gethia	2.5	3.5	2.5
	Balia Total	2.8	3.2	1.3
Nalena	Belwakhan	1.5	2.0	0.0
	Nalena Total	1.5	2.0	0.0
Kuria	Sariatal	3.5	3.5	2.0
	Gethia	3.0	3.0	2.0
	Kuriagaon	3.0	3.5	1.0
	Nagori	1.0	1.0	0.0
	Kuria Total	2.6	2.8	1.3
Bhimtal	Lewsal	2.0	3.5	0.0
	Mehragaon	3.0	3.5	1.5
	Bhagturia	3.5	3.5	2.0
	June State	3.5	3.5	2.5
	Aru	3.5	3.5	2.5
	Bharatpur	4.0	4.0	3.0
	Gairmaokia	–	–	–
	Sangurigaon	4.0	4.5	3.0
	Saungaon	1.5	2.5	3.0
	Mehragaon (C)	4.0	4.0	3.0
	Karki (C)	2.5	3.0	1.5
	Pandey Gaon	3.0	3.5	2.5
	Dhungsil (R)	3.5	3.5	2.5
	Dhungsil (S)	3.0	3.0	2.5
	Dhungsil (M)	3.0	4.0	2.5
	Dhungsil (T)	2.0	2.5	1.5
	Salari	2.5	3.0	0.0
	Kherol Pant	3.0	3.0	1.5
	Kherol Pandey	–	–	–
	Kharki	–	–	–
	Siloti Pant	3.0	3.0	2.0
	Siloti Pandey	2.0	2.5	2.0
	Chanoli	3.0	3.5	2.0
	Mehragaon (T)	2.5	3.0	2.0
	Shakhola	3.0	3.5	1.5
	Bijroli	4.0	4.0	3.0
	Naol	3.5	3.0	0.0
	Bohragaon	2.5	2.5	1.5
	Bhimtal Total	3.0	3.3	2.0
Lake Region	**Total**	2.4	2.8	0.9

Table 9. Resource efficiency status in the Lake Region.

Micro Watersheds	Villages	Percent Food Surplus/Deficit	Percent Fodder Surplus/Deficit	Percent Fuel-wood Surplus/Deficit	Water Availability
Nihal	Kurpatal	−71	−60	−41	Sf
	Ghalna	−72	+07	+15	Sf
	Devidhura	−36	−29	−31	Sf
	Belwakhan	−21	+14	+09	Sf
	Nihal Total	−50	−17	−12	Sf
Balia	Belwakhan	−66	−29	−31	Sc
	Chopra	−69	−41	−45	Sf
	Baluti	−91	−57	−61	Sf
	Jeolikote	−92	−61	−11	Sc
	Dogal Sandal	–	–	–	–
	Vergopant	−92	−72	−31	Sc
	Gethia	−81	−72	−57	Sc
	Balia Total	−81.83	−55.35	−39.33	Sc
Nalena	Belwakhan	−43	+21	+05	Sf
	Nalena Total	−43	+21	+05	Sf
Kuria	Sariatal	−72	−62	−67	Sc
	Gethia	−77	−37	−57	Sc
	Kuriagaon	−87	−41	−40	Sf
	Nagori	−99	−55	−47	Sf
	Kuria Total	−55.83	−32.05	−35.17	Sc
Bhimtal Lewsal	Lewsal	−72	−72	−57	Sf
	Mehragaon	−90	−67	−39	Sc
	Bhagturia	−67	−61	−60	Sc
	June State	−62	−35	−42	Sc
	Aru	−61	−67	−65	Sc
	Bharatpur	−90	−81	−32	Sc
	Gairmaokia	–	–	–	–
	Sangurigaon	−81	−42	−57	Sc
	Saungaon	−83	−74	−21	Sc
	Mehragaon (C)	−98	−95	−11	Sc
	Karki (C)	−92	−81	−31	Sc
	Pandey Gaon	−51	−42	−51	Sc
	Dhungsil (R)	−87	−77	−31	Sc
	Dhungsil (S)	−97	−81	−22	Sc
	Dhungsil (M)	−91	−71	−27	Sc
	Dhungsil (T)	−41	−39	−77	Sc
	Salari	−79	−21	−39	Sc
	Kherol Pant	−87	−61	−60	Sc
	Kherol Pandey	–	–	–	–
	Kharki	–	–	–	–
	Siloti Pant	−70	−64	−57	Sc
	Siloti Pandey	−72	−61	−59	Sc
	Chanoli	−90	−47	−50	Sc
	Mehragaon (T)	−73	−62	−60	Sc
	Shakhola	−82	−74	−61	Sc
	Bijroli	−81	−57	−67	Sc
	Naol	−62	−77	−71	Sf
	Bohragaon	−81	−33	−41	Sc
	Bhimtal Total	−77.60	−61.68	−47.52	Sc
Lake Region Total		−75.22	−52.90	−41.95	Sc

Note: “Sf” and “Sc” respectively stand for sufficiency and scarcity of water.

and improve the life quality of local rural communities.

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