Population-environment interface in the Kashmir Himalayan catchment of Lidder River

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Abstract: Population growth, working in conjunction with a number of other constraints such as inappropriate technologies and inadequate development policies, has resulted in pronounced and pervasive over-exploitation of the natural resource stocks that underpin developing mountain economies. Lidder catchment, situated in the south-east of Kashmir valley, with a total area of 1159.38 km2 (10% of Jhelum catchment) has been taken as the study area. Using various demographic and spatial analysis techniques, this paper attempts to analyze the effect of population growth on land use land cover (LULC) and subsequently on the regional environment. The results have shown that the changing demographic scenario has resulted in a general shift in the land use from forest to non forest uses. The study area is one of the leading tourist destinations receiving more than 70 per cent of the total tourists visiting Kashmir valley which is having a significant impact on its ecological set up.

Key words: Anthropogenic impact; population; satellite data, Lidder Catchment, Himalayas, Land use Land cover.

Introduction

The relationships among demographic variables, changes in land use and management, and the states, properties, and functions of environmental systems are not only complex (Alcamo et al. 2003; Turner et al. 2003) but are also the matters of scientific and practical interest (Kates et al. 2001). Intellectual debate about the relationships between human population dynamics and natural resources goes back at least 200 years (Malthus 1803; Lloyd 1833). The most intense focus was on human demands on land because of the simple Malthusian argument that population growth would eventually outstrip the productive capacity of lands. Analysis of population–environment relationships became broader in the second half of the twentieth century, when recognition became widespread that human activity posed major environmental threats not only through land use, which among other effects can degrade the food-producing capacity of lands, but also through pollution resulting from industrial activities that supported economic growth. Among the landmarks in this broadening of focus were the arguments raised in the early 1970s by Ehrlich and colleagues (Ehrlich and Ehrlich 1970; Ehrlich and Holdren 1971) and in the “limits to growth” models of Meadows and colleagues (1972). In this connection major efforts have been devoted to formulating and implementing new policies in the areas of both population and the environment since the 1992 United Nations Conference on Environment and Development and the 1994 International Conference on Population and Development.

Human beings have vastly accelerated the pace of many otherwise natural kinds of change and have introduced numerous kinds of change previously absent from earth. People in their increasing numbers and technological skills have placed their imprints upon the natural landscape and environment, transforming the physical surroundings to conform to their needs. The most significant changes have been those associated with all kinds of agriculture. About 50 percent of the earth’s land surface has been transformed by direct human action, mainly for farming, pasturing, and forestry, and also for industry,

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urban development, and transport (Steffen et al. 2004). The capacity to alter the landscape has increased with technology, and land use change in many areas has accelerated (Buringh and Dudal 1987). Today the human capacity to alter the environment is on a scale equivalent to the forces of nature, a condition that did not prevail in the past (Wolman 1990) and hence in many fields our ecological "footprint" outweighs the impact of all other living species combined.

Humans are perhaps the most successful species in the history of life on Earth. From a few thousand individuals some 2 lakh years ago, we passed 1 billion around 1800 AD and 6 billion in 1999 AD. The twentieth century has been a century of unprecedented population growth, economic development and environmental change. From AD 1900 to 2000, world population grew from 1.6 billion to 6.1 billion persons. While world population increased close to 4 times, world real gross domestic product (GDP) increased 20 to 40 times (DeLong 1998) allowing the world not only to sustain a fourfold population increase, but also to do so at vastly higher standards of living. There remains a concern among many natural scientists that the ecological limits to food production provide little scope for future expansion (Ehrlich and Holdren 1971; Raven 1991). A report of the Secretary-General entitled “Problems of the human environment” cited the “explosive growth of human populations” as first among the portents of a crisis of worldwide scope concerning the relation between man and his environment (United Nations 1969).

Malthus (1803) argued that population, if left unchecked, grows more rapidly than food production, which ultimately leads to death from starvation. Ricardo (1817) added the possibility of people expanding onto new land and then intensifying cultivation by applying additional labour but concluded that returns to labour and capital would eventually diminish owing to the finite quantity of land available. Boserup (1965), on the other hand, introduced the variable of technological change, to argue that food production is able to keep up with population growth. She implicitly included institutional change because for technologies to change, institutions need to be amended. Researchers’ interests have focused increasingly on understanding the driving forces of environmental change, including not only population, affluence and technology (Ehrlich and Ehrlich 1970; McNamara 1991) but also human values, social institutions, public policies (Turner-II and Meyer 1991; Kumar and Turner-II 1994) and more; their effects and interactions; the mechanisms by which they affect environmental outcomes; and feedbacks from environmental conditions to human activity. Ehrlich and others (Ehrlich and Holdren 1971, 1988; Ehrlich and Ehrlich 1990) hold that population growth is the primary force precipitating environmental degradation. It is argued that once population has reached a level in excess of the earth's long-term capacity to sustain it, even stability and zero growth at that level will lead to future environmental degradation (Ehrlich and Ehrlich 1990).

The critics of this thought argue that technological and socioeconomic factors are primary (Commoner 1972; Schnaiberg 1980). Another criticism comes from those who argue that population, though it may be a driving force of change, is not necessarily a driving force of degradation (Boserup 1981; Simon and Kahn 1984). But it is beyond doubt that driving forces of environmental change generally act in combination with each other. Just as demographic driving forces may lead to environmental outcomes in various ways, environmental conditions and changes may also influence population size, structure, and change.

LULC studies are of interest to a wide range of social and environmental scientists because land is a key factor in social relationships and resource use. Land use studies provide a powerful rationale for maintaining land. Changing LULC are fundamental drivers of global change (Fischer and O’Neill 2005) and direct reflections of human activity and impacts (Jolly and Torrey 1993). Understanding past and present impacts of land use changes is very important to the study of human-driven environmental change (Liu and Chen 2006). Intensification and diversification of land use, together with advances in technology have led to rapid changes in the global cycles of carbon, nitrogen, and other critical elements (Melillo, Field and Moldan 2002) which is responsible for a significant proportion of the phenomenon of global climatic change. Although overall population numbers are sometimes strongly related to land cover changes, such as deforestation (Brown and Pearce 1994; Mather and Needle 2000) recent research shows that this overall relationship depends on many other factors as well including land settlement policies and market forces (Geist and Lambin 2002). It is essential to consider both numbers of people and their behaviour.

By the early 1990’s, human influences on the natural environment were understood to occur through two main processes: change in LULC and “industrial metabolism,” that is, the transformation of materials and energy for industrial production and economic consumption. In the conceptual framework developed for the Millennium Ecosystem Assessment, changes in LULC figure among the “direct drivers” affecting ecosystem services, demographic factors among the “indirect drivers” (Alcamo, Bennett and the Millennium Ecosystem Assessment Project 2003). Many studies on human population and environment have been conducted at the aggregate level (Ehrlich and Holdren 1971; McKee et al. 2004) taking population growth and/or population density as an indicator of environmental change. But the change in population structure like age and arrangement of people into different households are also important to the understanding of land use and environmental changes (Perz, 2001; Fox et al. 2003) as age structure and sex structure affect patterns of land use and environmental conditions (McCracken et al. 1999). The present study focuses on research in which LULC change is a key mediator of human-environment interactions, in which demographic variables figure prominently among the driving forces investigated, and in which efforts are made to investigate the causal mechanisms by which human population changes affect land use and environmental outcomes.

Study Area

The Lidder catchment occupies the south eastern part of the Kashmir valley (Fig. 1) and is situated between 33º 45′ 01″ N - 34º 15′ 35″ N and 75º 06′ 00″ E – 75º 32′ 29″ E. The Lidder valley forms part of the middle Himalayas and lies between the PirPanjal range in the south and south-east, the north Kashmir range in the north-east and Zanskar range in the south-west. It has a catchment area of 1159.38 km^2, which constitute about 10 percent of the total catchment area of river Jhelum (Malik et al. 2011a). The study area reveals a variegated topography due to the combined action of glaciers and rivers. The valley possesses distinctive climatic characteristics because of its high altitude location and its geophysical setting, being enclosed on all sides by high mountain ranges. The valley is characterized by sub-Mediterranean type of climate with nearly 70 per cent of its annual precipitation concentrated in winter and spring months (Meher 1971).There are two sub-catchments in Lidder catchment; these are the East Lidder sub-catchment and the West Lidder sub-catchment. The West Lidder sub-catchment has seven watersheds while the East Lidder sub-catchment has four watersheds (Malik et al 2016). The total population of the catchment is 2.34 lac persons (Census of India, 2011)distributed in six watersheds while five watersheds are uninhabited.

Methodology

The methodological framework of the present study includes the delineation of Lidder catchment (AOI) from SOItoposheets 1961 (1:50,000 scale) on the basis of drainage. The same AOI was used to subset IRS P6LISS III satellite image 2010 and were geo-

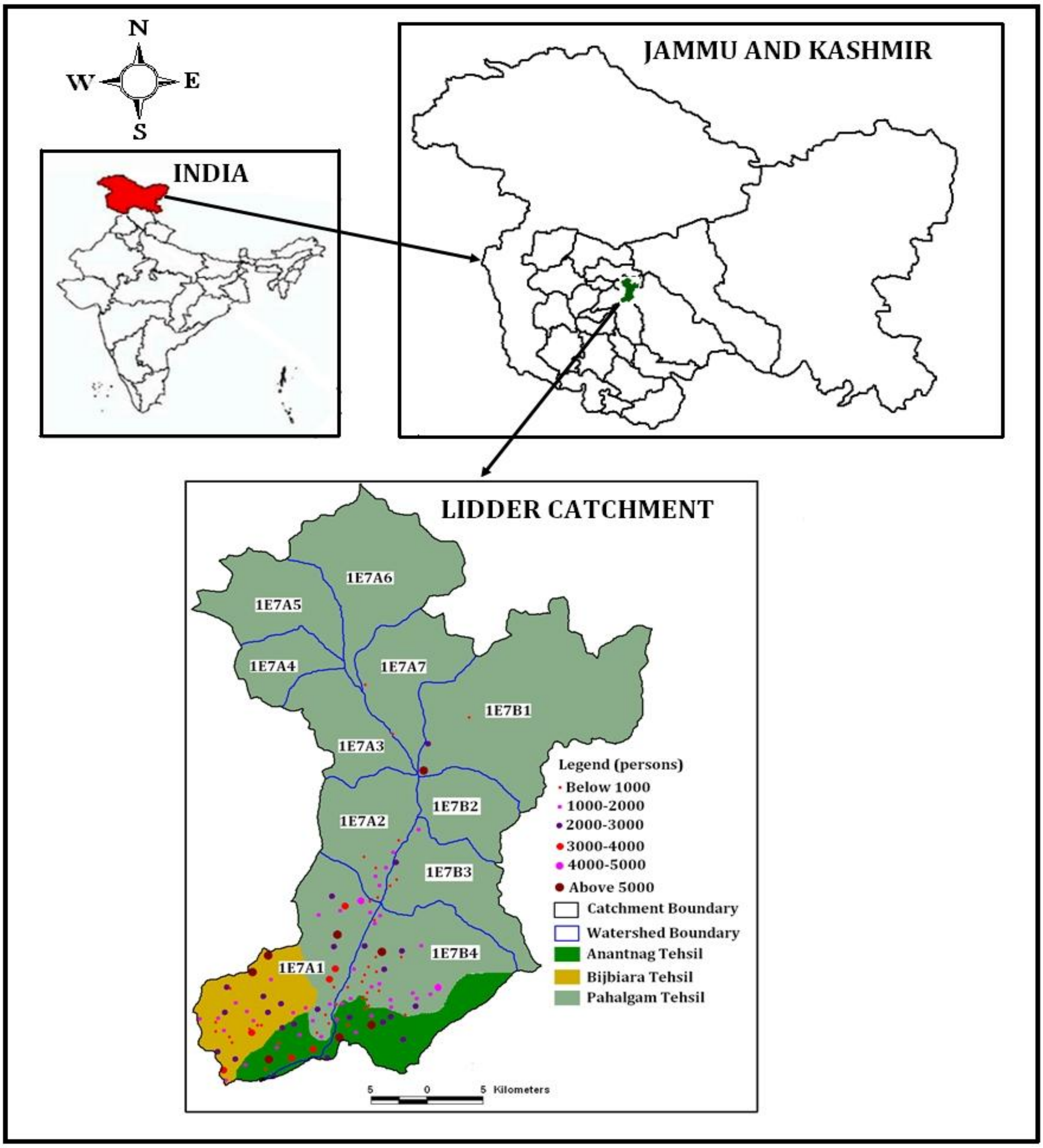


Figure 1: Location map of Lidder catchment

referenced to a common projection. The LULC map of 1961 was prepared by onscreen digitization method in Arc view GIS software while that of **2010** was generated by supervised classification in ERDAS Imagine - image processing software (fig. 2). The LULC change detection analysis was done in terms of the calculation of the area in square kilometers of all the LULC categories. The data pertaining to various socio-demographic variables was obtained from census of India (1961-2011). Finally the impact of these socio-demographic variables on LULC was assessed.

Results and discussion

Socio-demographic change

Population interacts with other factors in society through cultural, political and economic institutions to affect land use and the environment. But in turn these factors (environment and changing land use patterns)

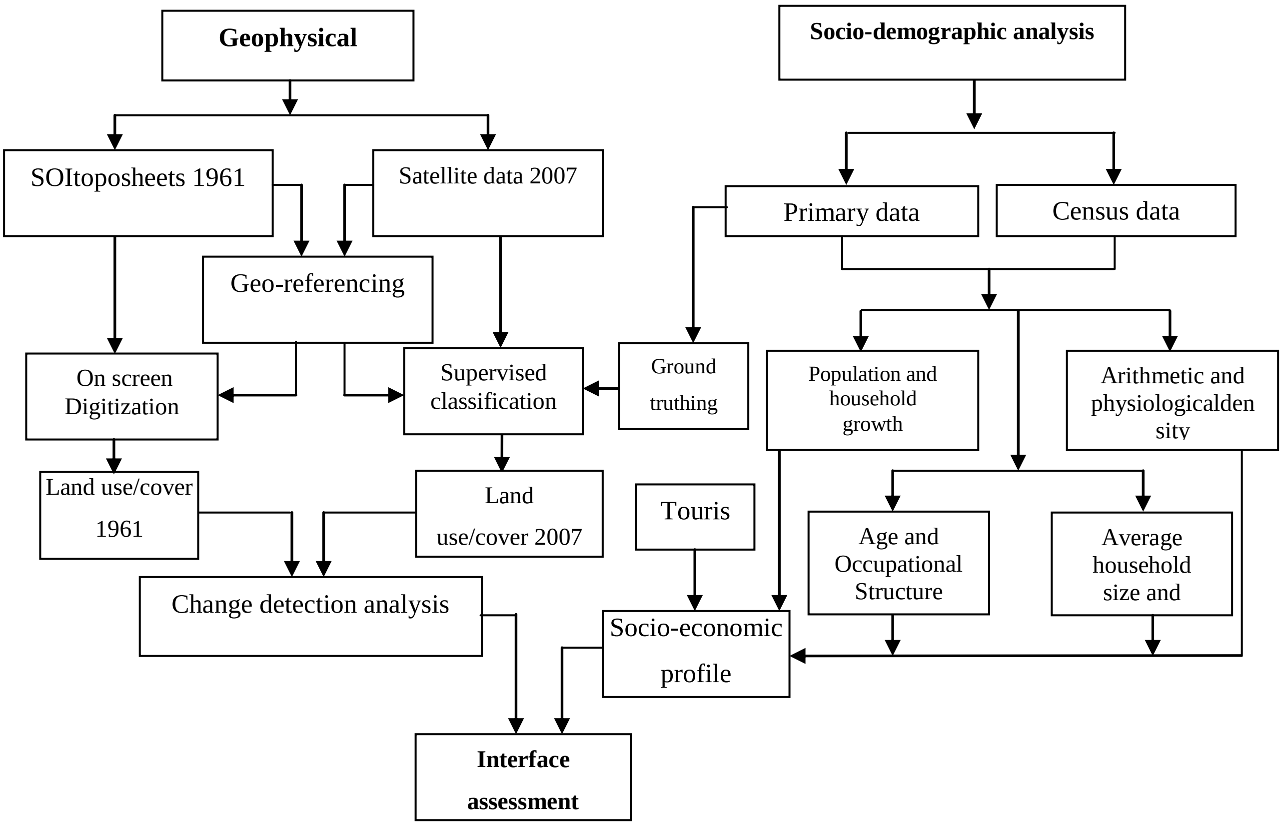


Figure 2: Flow chart showing methodological framework of the study

cause changes in the size, growth rate and distribution of population itself. The rapid growth in human numbers imposes unsustainable burdens on the environmental-resource base that underpins much economic activity (Myers 1992) contributing to environmental degradation and poverty in Himalayan region (Martins and Nautiyal 1988; Ives &Messerli 1989), reducing the carrying capacity and consequent destruction of natural habitat and agricultural land (Ehrlich and Ehrlich 1988).

By the middle of the present century, population growth alone may cause an approximate doubling of the demand for the products of agriculture. But even moderate growth in income in the developing world will add at least as much to increases in demand as population alone—thus increasing demand to at least 3 times the present level. Increasing population has been associated with shortening of the fallow period and limitation of the regenerative time provided for forest growth and restoration of the soil reducing the productive capacity of the land (Grigg 1987) and contributing to a widening gap between the quantity of resources, especially food, needed by the human population and the amount that can be extracted from the planet.

The Lidder catchment is inhabited by 124 rural settlements and one urban centre (Pahalgam) belonging to three tehsils of Anantnag, Pahalgam and Bijbiara of Anantnag district (Jammu and Kashmir). The total population of the catchment is 2.33 lac persons. The population of Lidder catchment has increased more than 3.3 fold from 69299 persons in 1961 to 233664 persons in 2011 with the compound growth rate of 4.74 per cent per annum **(table 1)**. The analysis has revealed that the growth rate of population has increased at an increasing rate since 1961 with the highest annual growth rate (3.17) recorded during the period 2001-2011.

Table 1: Dynamics of socio-demographic change in Lidder Catchment, 1961-2011

Year	Population (persons)	Population growth rate (Annual)	Population density (persons/km²)	Physiological density (persons/km² of net sown area)	Number of households	Household growth rate (Annual)	Average Household size	Number of Tourists
1961	69299	-	59.77	514.71	12028	-	5.76	28002
1971	85024	2.27	73.33	627.43	13688	1.38	6.21	50149
1981	106339	2.50	91.72	726.90	16320	1.92	6.51	172620
1991*	136215	2.80	117.49	886.08	19744	2.09	6.90	5230
2001	177361	3.02	152.97	1212.06	25315	2.82	7.00	198636
2011	**233664**	3.17	**201**	**1597**	**35759**	4.12	**6.5**	**1340361**

Source: Computed from SOItoposheets 1961, census of India 1961-2011; * projected figures

The crudest measure of the relationship between population and land is simple population density. The extent of ecosystem loss and alteration is closely related to population density, which is very uneven across the planet. Today, one half of the human population lives on less than 10 per cent of the Earth's land, and three quarters on only 20 percent. From 1950 to 2000 the world's population density increased more than two fold, from 20 persons to 46 persons per square kilometer. India's population density increased over 175 per cent during the last half-century, rising from 124 persons per square kilometer in 1950 to 324 persons per square kilometer in 2001 (Census of India 2001). The population density of Lidder catchment has increased by 155.93 per cent from 59.77 persons per square kilometer in 1961 to 152.97 persons per square kilometer in 2001 with the population density of 201 persons per square kilometer in the year 2011which is much higher not only than the state average of 99 persons per square kilometer but also than that of Indian Himalayan Region as a whole (74 persons per square kilometer).

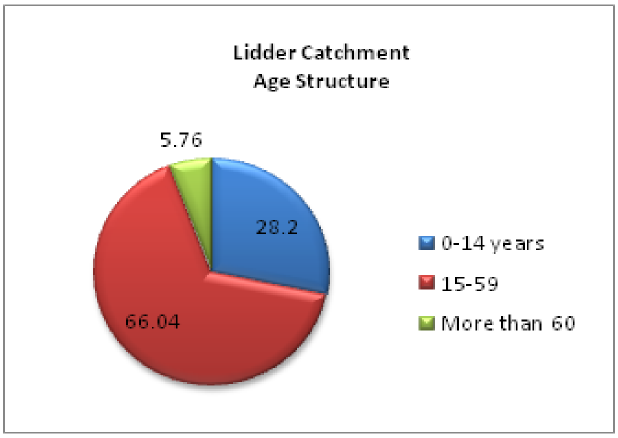
The increase in population density has aggravated the physiological density, which is the more meaningful population measure where the inhabitants are dependent mainly on agriculture. The higher physiological density of a region indicates higher pressure on cultivated area to feed more people. The physiological density has increased more than 3 fold from 514.71 persons per km^{2}of net sown area in 1961 to 1597 persons per km^2 of net sown area in 2011 (table 1). This phenomenal growth in physiological density could be attributed to high population growth on the one hand and the constant net sown area available on the other because more than 60 per cent of the catchment area falls in the slope category of steep to very steep which is not suitable for agricultural practices.

The number of households and their composition significantly influences land use and environmental change (Walsh et al. 1993). Household numbers have been increasing much faster than population size has worldwide, and this trend is most likely to continue (Liu et al. 2003). Even in areas with declining population size, household numbers are nevertheless increasing substantially. Growth in the number of households is at least as important as growth in the number of persons (Liu et al. 2003). Land use decisions are affected by the transition from fewer to more households. The total number of households in the study area has increased about 3 fold from 12028 in 1961 to 35759 in 2011 registering a growth of 197 per cent in fifty years. The increase in the number of households means more land is used for house construction as well as for farming, and more timber is needed for house construction and furniture resulting into increasing built-up and decreasing forest cover in the catchment.

Average household size is also an important factor contributing to environmental change. Households may adjust to increasing family size and subsistence needs in a variety of ways (Bilsborrow 1987; Davis 1963) including enlarging the area under cultivation (Umezaki et al. 2000), putting pressure on lands held in common (Shivakoti et al. 1999) or intensifying land use. The average household size of the catchment has increased from 5.76 persons per household in 1961 to 6.5 persons per household in 2011 registering an average increase of 0.74 persons per household. Apart from population growth**,** the average household size and age structure determine fuel wood consumption (An et al. 2001) which is 13.12 kgs per day per household in Lidder catchment amounting to 1.2 lac metric tons per year. The analysis has further revealed that 28.20 per cent of the population belongs to the age group of less than 14 years where as 5.76 per cent is in the age group of 60 years and more. The economically productive population in the age group of 15 to 59 years age constitutes 66.04 per cent of the total population (fig. 3). While the rise in the proportion of adults increases the labor force involved in fuel wood collection and farming, the rise in the number of old age people increases fuel wood consumption.

The analysis of occupational structure serves a vital clue about the structural position of an economy. The results have shown that 49.98 per cent of the working population is engaged in service sector which comprises of government employees, business men and the people engaged with tourist activity. It has also been inferred that 42.71 per cent of the working population is engaged in agriculture and allied sectors while the secondary sector is quite insignificant in the region as only 7.13 percent(fig. 3) of the working population is engaged in small scale household industrial sector. Moreover, the literacy rate of Lidder catchment is 53.3 percent with the male literacy rate of 64.2 percent and female literacy rate of 41.8 percent against the literacy rate of 68.74 percent for the Jammu and Kashmir state with the male literacy rate of 78.26 percent and female literacy rate of 58.01 percent (Census of India, 2011).

In looking at the effects of human population increase on resources and environment we should not forget the parallel increase in the number of animals and plants we have somewhat arbitrarily chosen for our nourishment, support and enjoyment (Tickel1993). This is particularly important in case of Kashmir valley where livestock far outnumber people (Raina 1981). This is also true for Lidder catchment where average units of livestock per household is 9 against the average house hold size of 7 persons per household. The total number of livestock is estimated to be 228341units comprising of 52250 cattle, 48908 herds of sheep and goat, 10936 horses and 116247 units of poultry population.



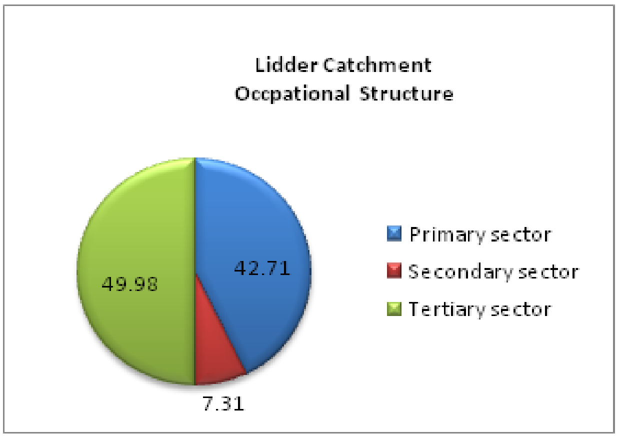


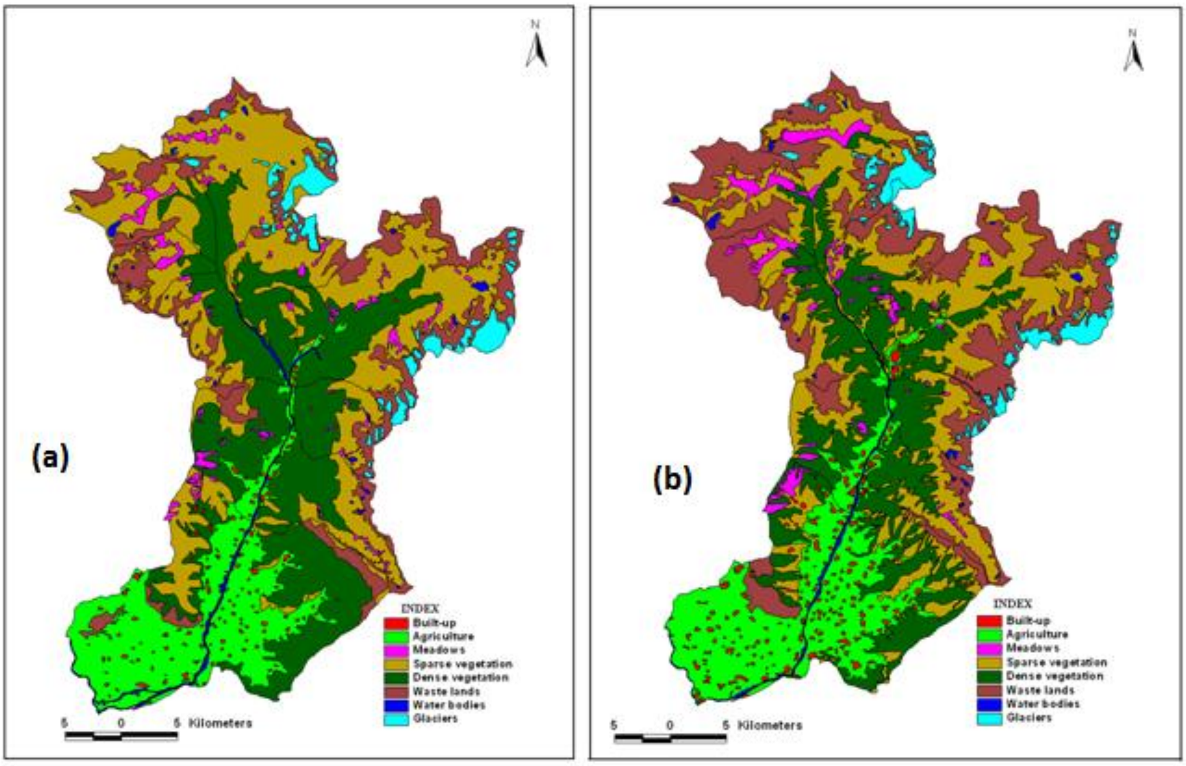
Figure 3: Age and occupational structure, Lidder catchment, 2011

Mountain ecosystems have meager tolerance for human artifacts especially for such activities that are resource exhaustive (Price 1973). Tourism has assumed an overwhelming importance as a component of mountain economies around the world. Though the lowlands remained the major regions of industrial and urban concentration in the past, the mountain regions are now attracting major economic investments for hydro-power and communication routes and above all a number of mountain regions have experienced "tourist revolution" causing substantial economic, social and environmental changes (Malik and Bhat 2015). Over the last half century mountaineering, trekking and mass tourism have developed dramatically in the Himalayan region (Ivas 2004). The mass tourist influx in the catchment is one of the leading contributory factors involved in the process of deforestation (Bhat et al 2007). Pahalgam was given the status of an urban centre only because of tourism development (Malik 2012). Fuel wood consumption in hotels is imposing major stress on environment in the catchment especially at Pahalgam. The average fuel wood consumption was calculated about 62 kgs/day/hotel which amounts to the total fuel wood consumption of 1964.16 metric tons/year (Malik and Bhat 2014a). The amount and disposal of waste products is another environmental problem emerging at Pahalgam. The average solid waste generated at Pahalgam has been estimated about 25 kgs/day/hotel. The liquid waste was estimated to be 198 lts/day/hotel which amounts to the total liquid waste of 9.53 million lts/year.

LULC change

LULC changes take two forms: conversion from one category of land cover to another and modification of condition within a category (Turner-II and Myer 1991). The LULC classification of the study area (fig. 4) for the year 1961 and 2010 has been analyzed as per the classification scheme devised byGautam and Krishna (2005) which revealed eight LULC classes (table 2). The Liddercatchment has exhibited the undesirable changes in its LULC pattern since 1961 (Malik et al 2013; Malik and Bhat 2014b).The analysis (Fig. 4) has revealed that the area under dense forests has recorded a decrease of 28.24 per cent (98.39 km^2) with the average annual decrease of 0.58 per cent while the area under sparse forests has registered a decrease of 18.28 per cent (68.55 km^2) which accounts for the average annual loss of 0.37 per cent (Table 2). Thus the forest cover in the catchment has been reduced from 62.39 per cent in 1961 to 47.99 per cent in 2010 which is less than the total forest cover of Indian Himalayan region (52 per cent) as well as than the total forest cover of 60.10 per cent for western Himalaya as a whole (Pandit et al. 2006). The per capita forest area in the catchment is 0.31 hectares with no forests remaining below 2000 meters. The high rates of deforestation in the catchment are attributed not only to high population growth (Malik et al 2011b) who, apart from timber, depend on forest fuel wood for cooking and heating (13.12 kg/day/household) but also to overgrazing (9.02 livestock units/household) and fuel wood consumption by the hotels (62 kgs/day/hotel).

The area under built-up category has registered an increase of 11.83 km^2 (130.43 per cent) from 1961 to 2010 which is the highest percentage increase of all the LULC categories. Such an increase in built-up area is directly attributed to high growth rate in the number of households (3.94 per cent per annum) associated with the high growth rate of population (4.74 per cent per annum) on the one hand and the tremendous increase in the tourist infrastructure on the other. The area under agriculture has increased by 18.94 km^2 (10.06 per cent) with the net average annual increase of 0.21 per cent to meet the food requirements of growing population as well as fodder requirements of livestock. The area under waste lands has shown highest increase of 139.08 km^2 (92 per cent) with the average annual increase of 1.88 per cent. The area under meadows have also registered an



Source: Generated from SOItoposheets (1961) and IRS P6LISS III, September 2010

Fig. 4: Map showing different LULC classes in Lidder catchment for (a) 1961 & (b) 2010

increase of 6.99 km^2 (22.94 per cent) with the average annual increase of 0.47 per cent.

The area under water bodies has decreased by 3.44 km^2 (20.52 per cent) with the net average annual decrease of 0.42 per cent in the Lidder catchment as decreasing water bodies have been observed in the entire Indian Himalayas (Afroz 1989). The area under glaciers has also decreased by 6.44 km^2 (16 per cent) with the average annual decrease of 0.33 per cent. Thus, in the Lidder catchment area under waste lands, agriculture, meadows and built up has increased (fig. 5) at the cost of the area under forests, water bodies and glaciers.

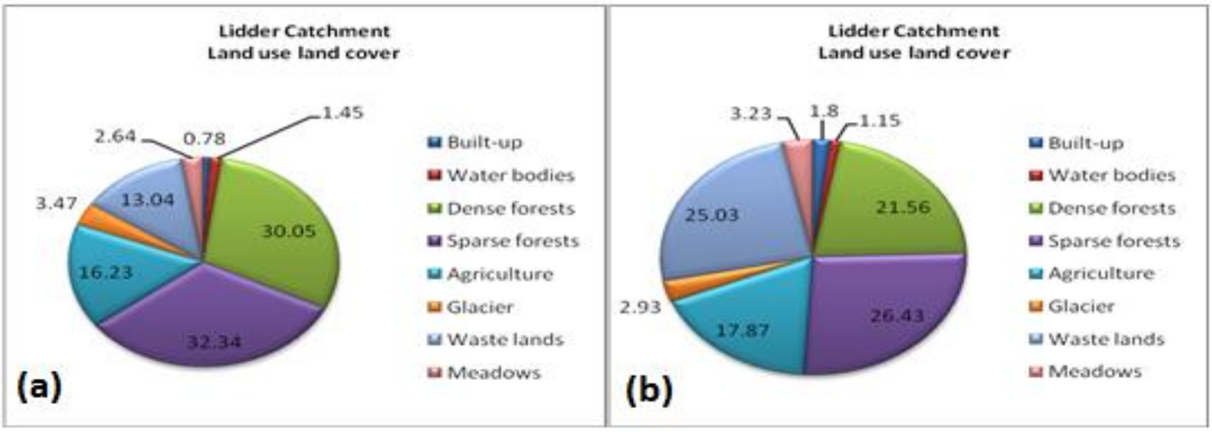
Conclusions and suggestions

Ecological dilemma is a human made phenomenon resulting from basic advances in health and agricultural sciences coupled with the development technologies needed to support contemporary industrial life styles. Human activity is the principal agent of landscape change in most of the world's mountain ecosystems and that population size serves as an effective measure of human activity. Although the objective of the alterations produced by human beings was to improve the living condition, in some cases they have created major long term problems and in still others they have been catastrophic both for the natural environment and for themselves. For centuries highlanders have lived in partnership and equilibrium with nature, creating some of the planet's most harmonious landscapes. Today, however, the pressure of population growth and movement coupled with new demands of development, are placing this equilibrium in jeopardy. Himalayas being tectonically active, economically underdeveloped and the most densely populated mountain ecosystem is highly vulnerable to human intervention and impact. Here the natural factors cause more harm to environment but the human interface aggravates the situation. Environment degradation poses a serious threat to the long term sustainability of ecologically fragile

Table 2: Land use/ Land cover change in Lidder Catchment, 1961-2010

Land use/ land cover category	Area (km²)		Net change (Area km²)	Rate of change (Annual)
	1961	2010		
Built-up	9.07 (0.78)	20.90 (1.80)	+11.83 (+130.43)	+0.24 (+2.66)
Water bodies	16.76 (1.45)	13.32 (1.15)	-3.44 (-20.52)	-0.07 (-0.42)
Dense forests	348.43 (30.05)	250.04 (21.56)	-98.39 (-28.24)	-2.01 (-0.58)
Sparse forests	375.00 (32.34)	306.45 (26.43)	-68.55 (-18.28)	-1.40 (-0.37)
Agriculture	188.21 (16.23)	207.15 (17.87)	+18.94 (+10.06)	+0.39 (+0.21)
Glacier	40.23 (3.47)	33.79 (2.93)	-6.44 (-16.00)	-0.13 (-0.33)
Waste lands	151.19 (13.04)	290.27 (25.03)	+139.08 (+92.00)	+2.84 (+1.88)
Meadows	30.47 (2.64)	37.46 (3.23)	+6.99 (+22.94)	+0.14 (+0.47)

Source: Computed from SOItoposheets (1961) and LANDSAT ETM, September **2010**.
Note: Figures in parenthesis indicate percentage.



Source: Computed from SOItoposheets (1961) and LANDSAT ETM, September 2010.
Fig. 5: LULC change in Lidder catchment from (a) 1961 to (b) 2010

mountainous Himalayan watersheds characterized by subsistence farming. Socio-economic and environmental change have impacted heavily on land use in the region, mainly manifested by the extension of cultivation into marginal lands and forested areas, degradation of cultivated lands, deterioration of grazing lands, soil erosion, landslides and the development of tourism.

The socio-economic development and technological advancement has direct bearing on the dynamics of the geo-physical system of any region. The ever increasing demographic pressure coupled with the growing energy demands for domestic and tourism sector have brought about significant changes in the LULC of Lidder catchment which has influenced the ecology of the area. The growth and expansion in agriculture, tourist activities and settlements at the expense of forest cover in the Lidder flood plain has extended to the mountainous areas affecting the carrying capacity of the region and also exhibiting environmental transformation in the form of deteriorating environment, depletion of natural resources and conditions of poverty. The prime factor responsible for the deforestation in the catchment is the increasing expansion of agricultural land. As economic development and population growth continue to threaten environmental stability in the Himalaya, the problem of presenting further environmental deterioration becomes urgent. If the current rate of population growth, the influx of tourism and deforestation continues, the Lidder catchment will become very fragile and might face an ecological disaster. Participatory approaches of environmental conservation that leads to socio-economic development of local communities need to be implemented.

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