

Integrated Approach for Prioritizing Watersheds for Management: A Study of Lidder Catchment of Kashmir Himalayas

Mohammad Imran Malik · M. Sultan Bhat

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Abstract The Himalayan watersheds are susceptible to various forms of degradation due to their sensitive and fragile ecological disposition coupled with increasing anthropogenic disturbances. Owing to the paucity of appropriate technology and financial resources, the prioritization of watersheds has become an inevitable process for effective planning and management of natural resources. Lidder catchment constitutes a segment of the western Himalayas with an area of 1,159.38 km². The study is based on integrated analysis of remote sensing, geographic information system, field study, and socioeconomic data. Multi-criteria evaluation of geophysical, land-use and land-cover (LULC) change, and socioeconomic indicators is carried out to prioritize watersheds for natural resource conservation and management. Knowledge-based weights and ranks are normalized, and weighted linear combination technique is adopted to determine final priority value. The watersheds are classified into four priority zones (very high priority, high priority, medium priority, and low priority) on the basis of quartiles of the priority value, thus indicating their ecological status in terms of degradation caused by anthropogenic disturbances. The correlation between priority ranks of individual indicators and integrated indicators is drawn. The results reveal that socioeconomic indicators are the most important drivers of LULC change and environmental degradation in the catchment. Moreover, the magnitude and intensity of anthropogenic impact is not uniform in different watersheds of Lidder catchment. Therefore, any conservation

and management strategy must be formulated on the basis of watershed prioritization.

Keywords Anthropogenic · Socioeconomic · Watershed prioritization · Land-cover change · GIS · Multi-criteria evaluation

Introduction

The Himalayan region is characterized not only by ecological fragility but also by a deep and historical geopolitical sensitivity (Stone 1992). The pace, magnitude, and spatial reach of human alterations of the Himalayan region are unprecedented (Ives and Messerli 1989). The expansion of agriculture on the mountain slopes, land-cover/land-use (LULC) change, and unplanned development of tourism are major threats to the environment in Kashmir Himalayas. Cumulative watershed effects are the response to multiple land-use activities that are caused by or result in altered watershed functions (Reid 2010). Knowledge of the nature of LULC and its configuration across spatial and temporal scales is indispensable for sustainable environmental management and development (Turner-II et al. 1994).

Different approaches to planning or management of environment-related human activities have been adopted and practiced. Earlier approaches to natural resource management were issue-based and administrative area-based. Linkages between different subsystems have been ignored or not properly understood, and the administrative areas used as planning units are often not spatially integrated. Watershed as an independent geohydrological unit (Maitra 2001) is considered to be the ideal planning unit for analysis and management of natural resources. Watersheds

M. I. Malik (✉) · M. S. Bhat
Department of Geography, University of Kashmir,
Hazratbal, Srinagar 19 0006, India
e-mail: imran.r.malik@gmail.com

M. S. Bhat
e-mail: msbhatgeog@yahoo.com

are ubiquitous units that can be seen as the physical foundation of a nation. They have long been recognized as desirable units for planning and implementing developmental programs (Honore 1999) for sustainable development (DeBarry 2004). The watershed is the smallest unit where the evaluation of human-induced affects on natural resources becomes possible, and it is a physically appropriate spatial unit for research on resource conservation issues (Gregersen et al. 1996). Therefore, the management of natural resources should ideally occur at the watershed level (Davenport 2003).

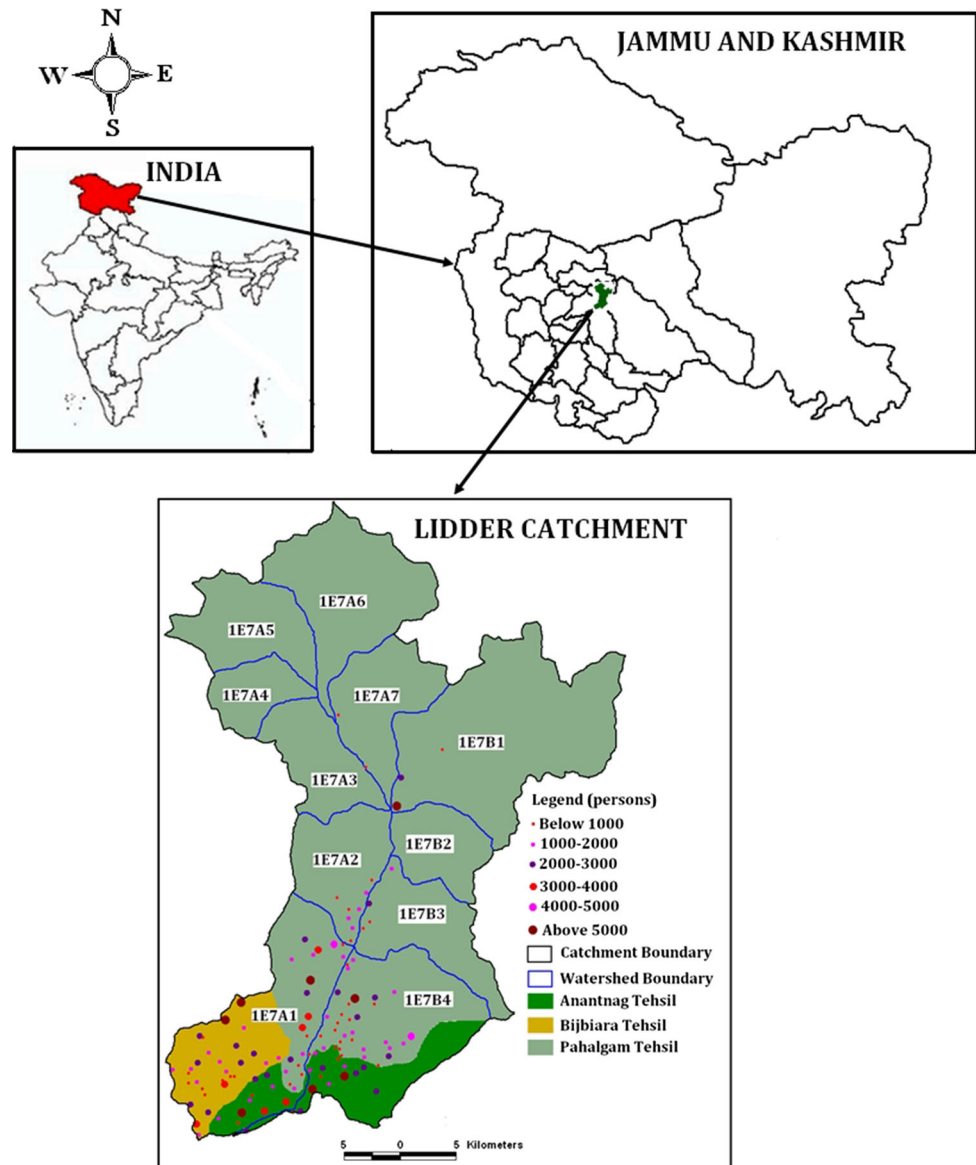
The large financial and manpower commitments involved in treating drainage basins require a selective approach to identify smaller hydrological units for more efficient and better-targeted resource management programs. Division of a catchment into watersheds and their evaluation, based on indicators of environmental degradation, could be an appropriate approach to prioritize watersheds for efficient management. Watershed prioritization is an important aspect of planning for implementation of a watershed-management program (Gosain and Rao 2004). The purpose of the prioritization process is to identify watersheds best suited for priority action in which to conduct management. Watersheds are also considered to be logical spatial constructs for sustainable and integrated management of resources with direct involvement of the local population (Rhoades 2000).

The prioritization of watersheds for management has been carried out on the basis of number of indicators using varied methodologies. The application of remote sensing and geographic information system (GIS) in watershed prioritization has been widely adopted (Shrimali et al. 2001; Ali and Singh 2002; Suresh et al. 2004; Martin and Saha 2007; Shinde et al. 2011; Patil and Mali 2013). The earlier approaches to prioritization were mainly based on physical aspects of watersheds with the focus on water-quality issues (Duda and Johnson 1985; Maas et al. 1985) and morphometric parameters (Reddy et al. 2004; Mishra and Nagarajan 2010; Kanth and Hassan 2012; Panhalkar et al. 2012; Shikalgar 2013). These studies aimed to develop a priority scheme that could help to decrease soil erosion and ensure sustained water availability. The focus was mainly on ranking watersheds on the basis of sediment yield index and soil loss (Chaudhary and Sharma 1998; Srinivas et al. 2002; Suresh et al. 2004; Nooka et al. 2005; Katiyar et al. 2006; Kalin and Hantush 2009; Niraula et al. 2011), whereas anthropogenic drivers of environmental change were ignored. However, the emphasis is now on developing integrated methodologies of watershed prioritization using GIS that encompass both geophysical and socioeconomic indicators (Gosain and Rao 2004; Vittala et al. 2008; Newbold and Siikamaki 2009; Javed et al. 2011; Sarma and Saikia 2012).

The integrated approach to watershed prioritization for management incorporates a number of data sets with different units of measurement and varying significance. Therefore, a compound parameter technique (Hlaing et al. 2008; Paul and Inayathulla 2012) or multicriteria evaluation (MCE) approach for watershed prioritization is generally used (Goicoechea et al. 1992). The use of the MCE approach for water resources planning and management has been adopted by a number of studies (e.g., Raj and Kumar 1998; Chung and Lee 2009; Calizaya et al. 2010; Kumar and Kumar 2011; Yang et al. 2012; AAher et al. 2013). Remote sensing and GIS-based watershed prioritization was carried out by integrating LULC and morphometric parameters by Javed et al. (2011). The study compared the priority maps produced using LULC and morphometric parameters, and the results suggested that only 1 of 13 watersheds attained the same priority for management using both the criteria. Pai et al. (2011) examined the applicability of SWAT model output for the purpose of sub-watershed prioritization in a watershed affected by point and nonpoint sources of pollution. The study aimed to qualitatively validate the prioritization approach using various sub-watershed metrics and known water-quality impairments. Sarma and Saikia (2012) used remote sensing and GIS for prioritization of watersheds based on LULC and slope analysis. Correlation between sub-watershed prioritization based on LULC analysis and integrated analysis of slope and LULC is drawn. It was found that most of the sub-watersheds fell in the same prioritization category on the basis of individual indicators. Chowdary et al. (2013) used a multicriteria decision approach to prioritize watersheds on the basis of potential erosion index and sediment delivery ratio. The study is a demonstration of GIS integration tools found to be of immense utility for watershed prioritization. Badar et al. (2013) used an integrated analysis of geophysical and socioeconomic indicators for prioritization of Dal Lake watersheds. Knowledge-based weighting is assigned to the prioritization indicators. Sarma and Sarma (2014) used vegetation and LU maps for conservation prioritization in a western Himalayan watershed by integration of weighted input computed through analytic hierarchy process. Jaiswal et al. (2014) prioritized watersheds on the basis of soil-conservation measures using analytical hierarchy process developed by Saaty (1988).

Watershed degradation is caused by a number of interacting factors that include both geophysical and socioeconomic characteristics. LULC change, which is recognized as the main driver of environmental change (Foley et al. 2005), is determined by both the geophysical and socioeconomic status of a region. Therefore, the prioritization of watersheds for management should ideally be made by an integrated assessment of all the factors of watershed

Fig. 1 Location map of Lidder catchment showing size class distribution of revenue villages



degradation. Against such a backdrop, the present study is an integrated analysis of geophysical, socioeconomic, and LULC indicators of watershed prioritization. These indicators are assigned knowledge-based weightings as per their relative contribution to watershed degradation. Each indicator was divided into a number of subindicators. Each subindicator was further divided into four categories using quartiles, and knowledge-based ranks were assigned. The watershed-prioritization model presented in this study is flexible and could be applied to similar environmental settings across the globe. The study is particularly applicable to Himalayan watersheds and generally to all rural mountain watersheds of the world. The number of indicators and their weightings could be modified for different regions.

Study Area

Lidder catchment occupies the southeastern part of Kashmir valley (Fig. 1) and is situated between $33^{\circ}45'01''\text{N}$ to $34^{\circ}15'35''\text{N}$ and $75^{\circ}06'00''\text{E}$ to $75^{\circ}32'29''\text{E}$. The Lidder valley forms part of the middle Himalayas and lies between the Pir Panjal range in the south and southeast, the north Kashmir range in the northeast, and Zaskar range in the southwest. It has a catchment area of $1,159.38 \text{ km}^2$, which constitutes approximately 10 % of the total catchment area of river Jhelum (Malik et al. 2011a). There are two sub-catchments in Lidder catchment: These are the East Lidder subcatchment and the West Lidder subcatchment. The West Lidder subcatchment has seven watersheds, whereas the East Lidder subcatchment has four watersheds. These

watersheds are assigned specific systematic codes according to the codification system devised by the All India Soil and Land Use Survey (Fig. 1).

Materials and Methods

A comprehensive methodological framework integrating remote sensing, GIS, field study, and socioeconomic data was adopted for the present study. Because the purpose of the study was to prioritize different watersheds on the basis of various geophysical and socioeconomic indicators, a number of data sets were generated to serve the purpose.

Data Sets Used

Various data layers from different sources having diverse natures and characteristics were collected and generated (Table 1). The Survey of India topographic maps from the year 1961 on a 1:50,000 scale were used to delineate and to demarcate different watersheds of Lidder catchment. Seven toposheets (43 N/4; 43 N/7; 43 N/8; 43 N/12; 43 O/1; 43 O/2; 43 O/5) were georeferenced, and a mosaic was prepared. The mosaic was used for geo-referencing of the satellite data and for generation of various data layers such as a digital elevation model (DEM) and an LULC map of 1961 (using a visual interpretation approach). Satellite data served as an important data source for the present study. Satellite images for three time periods (1992, 2001, and 2010) were used to compare LULC change in Lidder catchment. A primary survey was also conducted to generate socioeconomic data and to validate the LULC map by ground-truthing using differential global positioning system (DGPS).

Table 1 Type and source of data sets used

S. no	Data set	Source	Date of acquisition
1	Topographic maps	Survey of India	1961
2	LANDSAT ETM	USGS	September 1992
3	LANDSAT 7 ETM ⁺	USGS	September 2001
4	IRS P6 LISS III	NRSC, India	September 2010
5	Primary data	Ground-truthing using DGPS/field survey/sample survey	2010, 2011
6	Secondary data	Government departments; published sources; etc.	1961–2011

Generation of the DEM and Its Derivatives

For the generation of the DEM, a contour map was processed in ERDAS Imagine software to create a continuous raster surface by interpolating the elevation values. A 40-m spatial resolution DEM was obtained and was used for topographic analysis of the catchment. DEMs along with their derivatives, such as slope and aspect, provide the basis for LULC classification (Jones et al. 1988; Janssen et al. 1990). Therefore, the DEM was also used as ancillary data in LULC classification to avoid misclassification.

Drainage Density and Stream Frequency Calculation

The drainage map was prepared by onscreen digitization from toposheet mosaic and was updated from IRS P6 LISS III satellite data 2010. The drainage density and stream frequency was calculated using Eqs. 1 and 2 (modified after Horton 1932), respectively.

$$Dd = L\mu/A, \quad (1)$$

where Dd is the drainage density, $L\mu$ is the total stream length of all orders in a watershed, and A is the area of the watershed (km^2).

$$Sf = N\mu/A, \quad (2)$$

where Sf is the stream frequency, $L\mu$ total number of streams of all orders in a watershed, and A area of the watershed (km^2).

LULC Change Detection

Present status and average annual growth (1961–2010) of four LULC categories were taken as LULC indicators: built-up, agriculture, waste lands, and forests. On-screen visual interpretation and digitization was performed at a constant scale of 1:10,000 to prepare the LULC map for 1961 from the mosaic of toposheets. The LULC maps for 1992, 2001, and 2010 were prepared by supervised classification with the maximum likelihood algorithm (Hodgson et al. 2003). The overall objective of the image classification procedure is to automatically categorize all pixels in an image into LC classes or themes (Lillesand et al. 2008). Homogenous sample pixels were identified as training sets on the false color composite image (Foody and Cutler 2006) and were used as representative samples for each LULC category to train the algorithm to discriminate the individual classes. For each LULC class, 5–10 signatures of training samples were prepared at random (Shalaby and Tateishi 2007) to ensure that the spectral properties of each category are represented sufficiently. However, in mountainous areas, the spectral signature is influenced by terrain complexity, elevation, aspect, and slope. The

ground-truthing survey revealed some misclassifications, which were rectified through signature editing as well as reclassification and required onscreen digitization. Thus, a combination of two approaches (digital classification and onscreen digitization) was employed, which provides better results than using just a single approach (Kuemmerle et al. 2006).

The LULC change detection analysis was performed in terms of calculating the area in square kilometers of all the LULC categories. The comparison of the LULC statistics assisted in identifying the percentage change between different time periods. The rate or degree of LULC change was quantified by using Eq. 3 (modified after Wang 2000 and Kasereka et al. 2010).

$$DLC = (L_b - L_a) / L_a \times (1/T) \times 100, \tag{3}$$

where DLC is the degree of LULC change; L_a is the area under a particular LULC in year a , L_b is the area under a particular LULC in year b , and T is the length of time between years a and b .

Solid-Waste Estimation

Direct waste analysis (Hoang 2005), which is one of the most commonly used methods involving direct examination of the waste characteristics (weight and composition), was used for the present analysis. A total of 20 hotels and 20 guest houses were purposefully identified to categorize and measure the solid waste generated from them. The sample hotels and guest houses were provided plastic bags of 50-kg capacity to collect the daily waste generated, which was subsequently weighed and segregated to analyze the composition of the waste. Daily room occupancy was used to determine the waste generated per tourist as well as per room.

Estimation of Firewood Consumption

Fuel-wood consumption was estimated by regular monitoring in the selected households for different months of the year because there is large seasonal variation in its

Table 2 Details of indicators used for watershed prioritization

Prioritization indicator	Subindicator	Priority criteria	Indicator weight	
Socioeconomic	Population (thousands)	Greater the population, more the priority	3 (0.500)	
	Population growth (%)	Greater the population growth, more the priority		
	Population density (persons/km ²)	Greater the population density, more the priority		
	Physiological density (persons/km ² of net sown area)	Greater the physiological density, more the priority		
	Literacy (%)	Greater the literacy, lower the priority		
	Average monthly income (INR)	Greater the income, lower the priority		
	Population below poverty line (%)	Greater the population below poverty line, more the priority		
	Dependency ratio	Greater the dependency ratio, more the priority		
	Firewood consumption (kg/day)	Greater the firewood consumption, more the priority		
	Livestock population	Greater the livestock population, more the priority		
	Tourism impact	Greater the impact, more the priority		
Geophysical	Dominant slope category (°)	Greater the slope, more the priority	1 (0.167)	
	Dominant Altitude zone (masl)	Greater the altitude, more the priority		
	Dd (stream length in kms/km ²)	Greater the drainage density, more the priority		
	Sf (no. of streams/km ²)	Greater the stream frequency, more the priority		
LULC	Existing (%)	Built-up	Greater the built-up area, more the priority	2 (0.333)
		Agriculture	Greater the area under agricultural, more the priority	
		Waste lands	Greater the area under waste lands, more the priority	
		Forests	Greater the area under forests, lower the priority	
	Average annual growth	Built-up	Greater the built-up expansion, more the priority	
		Agriculture	Greater the agricultural expansion, more the priority	
		Waste lands	Greater the waste land expansion, more the priority	
		Forests	Greater the deforestation, more the priority	

Modified after Javed et al. (2011), Sarma and Saikia (2012), Badar et al. (2013), and Chowdary et al. (2013). Figures in parenthesis indicate normalized weight

Table 3 Assigned ranks and normalized weights of socioeconomic subindicators

Subindicator	Category	Assigned rank	Normalized weight
Population (thousands)	Uninhabited	0	0
	<7	1	0.1
	7–10	2	0.2
	10–60	3	0.3
	>60	4	0.4
Population growth (%)	Uninhabited	0	0
	<4.75	1	0.1
	4.75–4.77	2	0.2
	4.77–5.74	3	0.3
	>5.74	4	0.4
Population density (persons/km ²)	Uninhabited	0	0
	<50	1	0.1
	50–100	2	0.2
	100–400	3	0.3
	>400	4	0.4
Physiological density (persons/km ² of net sown area)	Uninhabited	0	0
	<1,400	1	0.1
	1,400–1,600	2	0.2
	1,600–2,200	3	0.3
	>2,200	4	0.4
Literacy (%)	Uninhabited	0	0
	<45	4	0.4
	45–50	3	0.3
	50–53	2	0.2
	>53	1	0.1
Average monthly income (INR)	Uninhabited	0	0
	<7,050	4	0.4
	7,050–7,250	3	0.3
	7,250–7,450	2	0.2
	>7,450	1	0.1
Population below poverty line (%)	Uninhabited	0	0
	<27	1	0.1
	27–40	2	0.2
	40–53	3	0.3
	>53	4	0.4
Dependency ratio	Uninhabited	0	0
	<0.48	1	0.1
	0.48–0.54	2	0.2
	0.54–0.65	3	0.3
	>0.65	4	0.4
Firewood consumption (kg/day)	Uninhabited	0	0
	<7.5	1	0.1
	7.5–9.5	2	0.2
	9.5–11.5	3	0.3
	>11.5	4	0.4

Table 3 continued

Subindicator	Category	Assigned rank	Normalized weight
Livestock population	Uninhabited	0	0
	<8,800	1	0.1
	8,800–12,500	2	0.2
	12,500–90,000	3	0.3
	>90,000	4	0.4
Tourism impact	No tourism activity	0	0
	Low	1	0.1
	Medium	2	0.2
	High	3	0.3
	Very high	4	0.4

consumption. The average daily consumption was estimated using a weight survey method (Bhatt and Sachan 2004). The wood was weighed using a 50-kg spring balance and then left in the kitchen of each household with instructions to burn wood only from the weighed quantity. On the next day the remaining wood was weighed to calculate the actual consumption per day. The magnitude of energy consumption by tourist accommodation units was also estimated using the same procedure.

Watershed Prioritization

Prioritization was performed by MCE of 23 indicators of human impact on the natural environment (Table 2). These indicators are divided into three broad categories of socioeconomic indicators, geophysical indicators, and LULC indicators. The LULC indicators are assessed on the basis of the existing LULC and average annual growth from 1961 to 2010. A knowledge-based weighting system was assigned to these indicators. Knowledge-based weighting has been successfully used to prioritize watersheds by Badar et al. (2013) and is useful for understudied regions. The weighting factor allows some prioritization indicators to be of more significance than others. The socioeconomic, LULC, and geophysical indicators are assigned the weight of 3, 2, and 1 respectively. These weights are normalized so that the sum of normalized weights is equal to unity.

The prioritization indicators are further divided into different subindicators. Socioeconomic status was analyzed by evaluating 11 subindicators (Table 3). Geophysical subindicators include slope, elevation, drainage density, and stream frequency (Table 4). The LULC subindicators are listed in Table 5. Each subindicator was further divided

Table 4 Assigned ranks and normalized weights of geophysical subindicators

Subindicator	Category	Assigned rank	Normalized weight
Dominant slope category (°)	<10	1	0.1
	10–20	2	0.2
	20–30	3	0.3
	>30	4	0.4
Dominant altitude zone (masl)	<2,000	1	0.1
	2,000–3,000	2	0.2
	3,000–4,000	3	0.3
	>4,000	4	0.4
Dd (stream length in kms/km ²)	<2.13	1	0.1
	2.13–2.84	2	0.2
	2.84–3.2	3	0.3
	>3.2	4	0.4
Sf (no. of streams/km ²)	<2.6	1	0.1
	2.6–3.4	2	0.2
	3.4–4.3	3	0.3
	>4.3	4	0.4

into four categories on the basis of quartiles. Ranks are assigned to each category based of the criteria listed in Table 2. Therefore, the highest rank signifies high priority and vice versa. Because these factors have different units and dimensions, they must be normalized to create dimensionless criteria for MCE (Craig and Karen 1995). These ranks are normalized so that the sum of normalized weights is equal to unity. The uninhabited watersheds, where socioeconomic indicators are absent, are assigned the rank of zero. The assigned ranks and normalized weights of socioeconomic, geophysical, and LULC subindicators are listed in Tables 3, 4 and 5, respectively.

The weighted linear-combination technique (modified from Chowdary et al. 2013) was applied to arrive at final priority. The prioritization indicators were summed to arrive at the priority value of each watershed on the basis of normalized weights of indicators and normalized weights of individual categories of subindicators. The procedure could mathematically be expressed as given in Eq. 4. The watersheds are divided into four categories of very high, high, medium, and low priority on the basis of the quartiles of the prioritization value (PV).

$$PV = SW \sum_{s=1}^{11} sw + \sum_{L=1}^8 Lw + Gw \sum_{G=1}^4 Gw, \quad (4)$$

where SW is the normalized weight of socioeconomic indicator (0.5), sw normalized weight of socioeconomic subindicator for each category, LW is the normalized weight of LULC indicator (0.333), Lw is the normalized weight of LULC subindicator for each category, GW is the normalized weight of geophysical indicator (0.167),

and Gw is the normalized weight of geophysical subindicator for each category.

Results

Management of natural resources on a watershed basis is becoming increasingly important, and attention is shifting to overall socioeconomic welfare along with better water and soil conservation. Environmental degradation is the result of both socioeconomic characteristics and geophysical attributes of a particular watershed, so an integrated approach incorporating both of them was evaluated on watershed basis. The prioritization identifies the watersheds under severe degradation and explores the potential drivers of environmental degradation in these watersheds.

Socioeconomic Indicators

The degradation of the environment in Lidder catchment is caused to a great extent by demographic growth and resultant settlement expansion as it alters the utilization pattern of resource structure available in a region. The absolute number of people in any given region is an important indicator of human impact (Wickham 2000). Population is often assumed to be a primary driver of environmental change in general and LULC change in particular (Mather and Needle 2000). The total population of Lidder catchment is 234,000 persons (Census of India 2011) with 89.1 % of the population constricted in two watersheds of 1E7A1 (54.4 %) and 1E7B4 (34.7 %), whereas five watersheds are uninhabited (Table 6). The population of the remaining four inhabited watersheds is < 11 % of the total population of the catchment.

The population of Lidder catchment has grown by 238 % from 69,300 persons in 1961 to 234,000 persons in 2011. The highest population growth rates in the watersheds of 1E7B1 and 1E7A7 (Table 6) are directly associated with tourism-related activities. Pahalgam, a world-famous tourist destination, is located in the watershed 1E7B1. Apart from being used as a recreation tourist destination, Pahalgam also serves as an important base camp for the Hindu pilgrimage (*Yatra*) to Amarnath Cave. Pahalgam was given the special status of urban center in 1961 only because of its tourism importance (Malik 2012a). Population density of the catchment is 201 persons/km², which is much greater not only than the state average of 124 persons/km² (Census of India 2011) but also that of Indian Himalayan region as a whole (159 persons/km²) (Census of India 2011). The physiological density is also high in Lidder catchment (1,597 persons/km² of net sown area) owing to the high growth rate of population on one hand and constant net sown area available on the other

Table 5 Assigned ranks and normalized weights of LULC subindicators

Description	Subindicator	Category	Assigned rank	Normalized weight
Existing area (%)	Built-up	Uninhabited	0	0
		<1	1	0.1
		1–2	2	0.2
		2–5	3	0.3
		>5	4	0.4
	Agriculture	Uninhabited	0	0
		<2	1	0.1
		2–6	2	0.2
		6–25	3	0.3
		>25	4	0.4
	Waste lands	<20	1	0.1
		20–25	2	0.2
		25–45	3	0.3
		>45	4	0.4
	Forests	<20	4	0.4
		20–45	3	0.3
45–53		2	0.2	
>53		1	0.1	
Average annual growth (%)	Built-up	Uninhabited	0	0
		<5.5	1	0.1
		5.5–7.5	2	0.2
		7.5–9.5	3	0.3
		>9.5	4	0.4
	Agriculture	Uninhabited	0	0
		<3	1	0.1
		3–40	2	0.2
		40–100	3	0.3
		>100	4	0.4
	Waste lands	<1.5	1	0.1
		1.5–2.0	2	0.2
		2.0–3.3	3	0.3
		>3.3	4	0.4
	Forests	<–1.3	4	0.4
		–1.3 to –1.0	3	0.3
–1.0 to –0.95		2	0.2	
>–0.95		1	0.1	

hand. The highest population density is found in the watersheds of 1E7A1 and 1E7B4, whereas the highest physiological density is found in the watersheds of 1E7B1 and 1E7B3 (Fig. 2).

The mountainous areas are generally characterized by low levels of literacy. The literacy rate in Lidder catchment is 53.3 %. The highest literacy is found in watershed 1E7B4 (55.2 %), whereas the lowest literacy is found in

watershed 1E7A7 (43.3 %). Rural poverty is an important issue in watersheds that is directly affecting the quality of the environment. It is found that the economically weaker sections of population have high dependence on forest-based fuel wood as their main source of energy compared with the more wealthy section; hence, they exert significant pressure on the forest resources of the area. The watershed-wise distribution of literacy and household income is given in Fig. 3. The average household income was estimated at Rs. 7,250/month. However, approximately 27.4 % of the total population is living below poverty line, which indicates a marked inequality in income distribution. The results have also shown that poverty increases as we move from Lidder flood plain in the south to the outer limits of the catchment toward the north. Lack of employment opportunities and less per-capita agricultural land induces heavy dependence on forest resources to meet the basic requirements resulting in forest degradation in upper reaches of the catchment.

The animal husbandry sector serves as one of the important sources of productive asset generation and makes a useful contribution toward the augmentation of income for rural households. The total livestock population of the catchment is 305,000 units with 8.5 livestock units/household. The highest average found in watershed 1E7B1 (9.6 units/household) could be attributed to the abundance of grassy slopes and meadows where fodder is easily available. Pahalgam, popularly known as the “village of shepherds,” falls into this watershed, which has a long tradition of animal rearing. This huge livestock population is mostly fed on the meadow and grazing lands of the catchment, which may lead to their degradation in the absence of proper regulation and management strategy. It has been observed (Polunin and Stainton 1984) that some uncultivated lands in the rural areas have suffered from intensive grazing.

Magnitude of Firewood Consumption

The magnitude and pattern of energy consumption for both households and hoteliers reflects a high degree of dependence and use of fuel wood as a source of energy especially for cooking and heating. The average consumption of fuel wood was worked out to be approximately 43 metric tons/day comprising 28 metric tons/day by households and 15 metric tons/day by hoteliers and guest houses. The average consumption of fuel wood for households is approximately 10 kg/household/day. It is highest in watersheds 1E7A7 (13 kg/day) and 1E7B1 (12 kg/day), both of which are located in forest areas where forest wood is easily available and winters are relatively severe. Easy access to firewood, lower levels of household income, commercialization of fuel wood, and limited availability and lack of accessibility

Table 6 Socioeconomic profile of watersheds in Lidder catchment

Watershed	Population (in thousands)	Average annual population growth (1961–2011) (%)	Population density (persons/km ²)	Physiological density (persons/km ² of net sown area)	Literacy (%)	Average monthly income (INR)	Percentage of population below poverty line	Dependency ratio	Firewood consumption (kg/household/day)	Livestock population
1E7A1	127.15	4.76	734	1,463	50	8,000	25	0.44	6	157,288
1E7A2	8.03	4.78	110	1,388	48.3	7,200	52	0.68	9	12,842
1E7A3 ^a	0	0	0	0	0	0	0	0	0	0
1E7A4 ^a	0	0	0	0	0	0	0	0	0	0
1E7A5 ^a	0	0	0	0	0	0	0	0	0	0
1E7A6 ^a	0	0	0	0	0	0	0	0	0	0
1E7A7	0.93	6.06	12	1,225	43.3	6,500	58	0.57	13	1,427
1E7B1	10.38	7.47	45	3,474	54.9	7,300	28	0.52	12	12,099
1E7B2 ^a	0	0	0	0	0	0	0	0	0	0
1E7B3	6.00	4.33	77	2,392	44.5	7,000	52	0.79	10	7,714
1E7B4	81.14	4.63	499	1,713	55.2	7,500	26	0.47	7	114,269

Source Census of India 1961–2011 and primary survey 2011 and 2012

^a Uninhabited watershed

to procure alternative noncommercial sources of energy are among the leading causes responsible for heavy dependence on fuel wood.

Impact of Tourism

Tourism is one of the important factors causing environmental degradation in the study area (Bhat et al. 2007). The unplanned expansion of tourist-related infrastructure has been on account of the heavy tourist rush to Pahalgam especially in the summer season (Fig. 4). The 3 months of May, June, and July constitute 83 % of the total tourist flow to Pahalgam. It is also pertinent to mention here that the *Yatra* to Amarnath Cave is performed in these 3 months. More than 16,000 tourists visit Pahalgam on a daily basis during the month of July, which is beyond the carrying capacity of the destination, which is estimated at approximately 4,300 tourists/day (Malik 2012b). The impact of tourism is most pronounced in the watersheds of 1E7A7 and 1E7B1, which constitute the beautiful meadow of Aru and Pahalgam town, respectively, where the tourist infrastructure is developing very fast and >50 % of the working population is engaged with tourism. The impact of tourism was assessed on the basis of recreational area available, development of tourist infrastructure, and use of natural resources for tourism development. There has been continuous expansion of tourist accommodations, especially the construction of new hotels, mostly in ecologically sensitive LU areas such as forests and meadows, river fronts and unstable hill slopes in the watersheds of 1E7A7 and 1E7B1.

The road transport facility has been extended to various ecologically sensitive areas, which has resulted in the fragmentation of different ecohabitats, especially forests, meadows, and grazing lands. Moreover, the use of ponies as a mode of transport to various tourist sites has resulted in multiple “braided” patterns of unmarked pathways, which has led to the degradation of soil and forests, resulted in trampling of meadowlands, and enhanced the vulnerability of unstable slopes. The braided pattern of unmarked pathways through ecologically sensitive areas used by ponies to carry the tourists to various tourist destinations has resulted in the degradation of forest, soil, and water resources in the catchment.

The generation of solid waste is one of the major threats to the environment of Lidder catchment and to the tourism business itself. Huge quantities of liquid and solid waste are being generated by tourism, which ultimately finds its way into Lidder River because there is no waste-treatment plant or any other waste-management policy to avoid environmental degradation. Moreover, the *Yatra* base camps of Nunwan, Zagipal, Chandanwari, and Sheshnag, which are located on the banks of different tributaries of

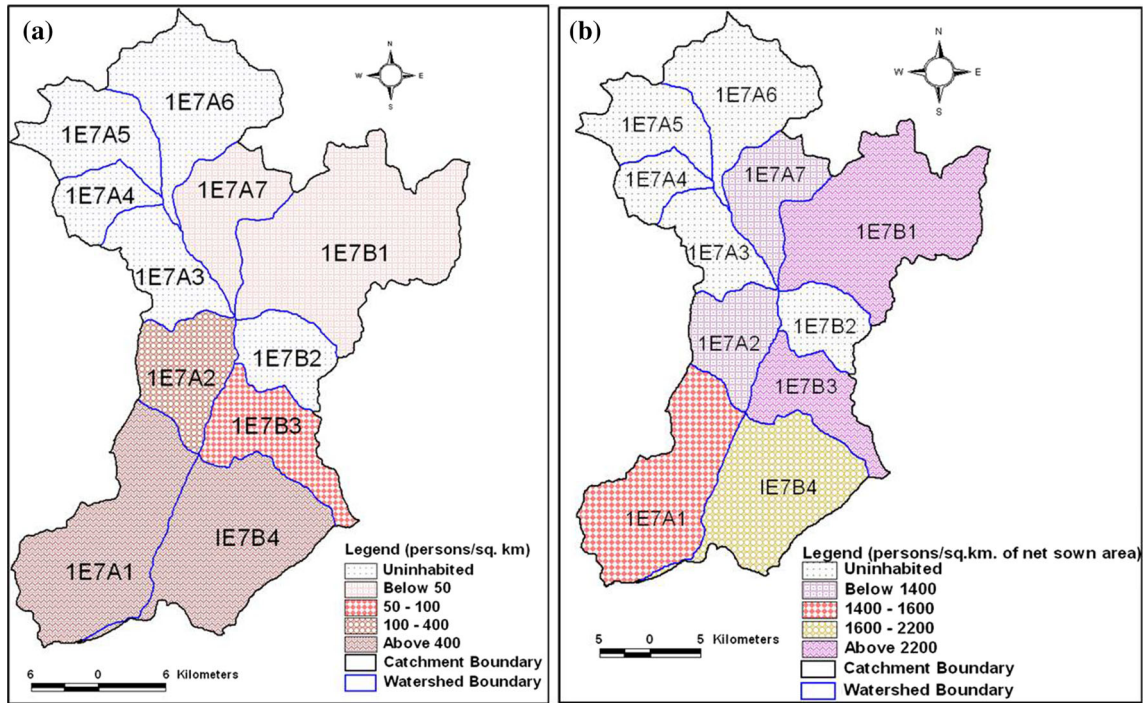


Fig. 2 Watershed wise distribution of **a** arithmetic and **b** physiological density in Lيدر catchment

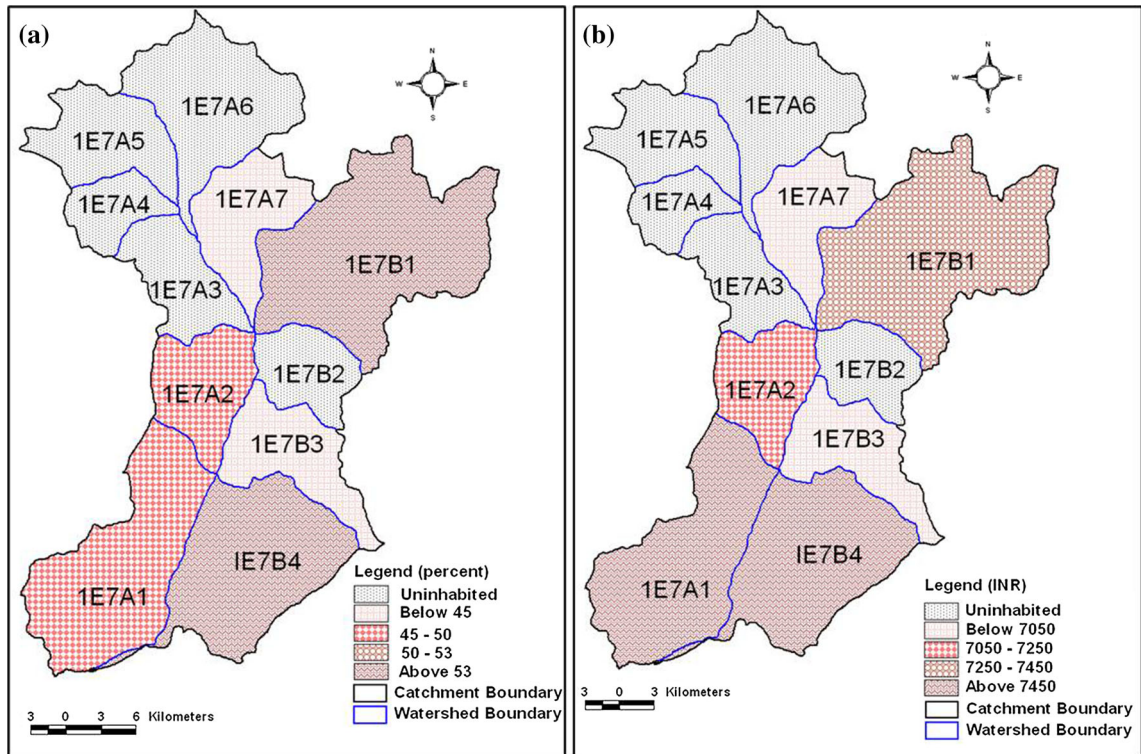


Fig. 3 Watershed wise distribution of **a** literacy rate and **b** average monthly household income in Lيدر catchment

river Lidder and along ecologically sensitive areas, are not adequately equipped to deal sufficiently with the collection of solid waste during the *Yatra* period. These camping sites pose a serious threat to the environmental quality of Lidder catchment. The tourist accommodation sector generates approximately 2,682 metric tons of solid waste annually comprising 975 metric tons from hotels and 1,707 metric tons from *Yatra* base camps. Solid waste generation is highest in the summer season (Fig. 4). The 3 months of June, July, and August constitute approximately 83 % (2,231 metric tons) of total annual generation with an average generation of approximately 24.77 metric tons/day.

Geophysical Indicators

The geophysical setup plays an important role in determining the environmental quality of a region. The physical setting of Lidder catchment is governed by its mountain topography. Being predominantly a mountainous one, the region is dominated by steep slopes, rugged terrain, and immature soils, and hence has limited availability of productive arable land, which is confined to the Lidder flood plain. The geophysical indicators of slope, altitude, drainage density, and stream frequency (Table 7) determine the fragility of a place and its susceptibility of the soil to erosion. The catchment was divided into different slope categories on the basis of the change in LU characteristics, which exhibit a pattern with change in slope. The highest percentage area of Lidder catchment (26.2 %) falls in the slope category of 20° to 30° and is under mixed-crop farming of paddy cultivation and horticulture crops. The slope category of <10° constitutes 22.4 % of the total catchment area, whereas 5.2 % lies in the slope category of <5°. This occupies the flood plain of Lidder River in the southern and southwestern parts of the catchment, which is devoted to paddy cultivation. A significant percentage (22.9 %) falls in the slope category of 30° to 40°, which is under natural LC. However, the expansion of dry-land farming is posing a serious threat of soil erosion in this area. The slope category of >40° covers 11.4 % of the total catchment area and is not suitable for cultivation. The higher elevations are noted toward the outer limits of the basin in the north, east, and west from which the heights decrease toward the trunk stream and the outlet of the basin in the southwest. The high-altitude watersheds are more susceptible to erosion compared with low-altitude watersheds. The watershed-wise distribution of slope and altitude is given in Fig. 5. Drainage density has a direct impact on runoff potential, soil erosion, and landscape dissection, whereas stream frequency is related to the permeability, infiltration capacity, and relief of a watershed. Greater values of drainage density and stream frequency (Fig. 6) in

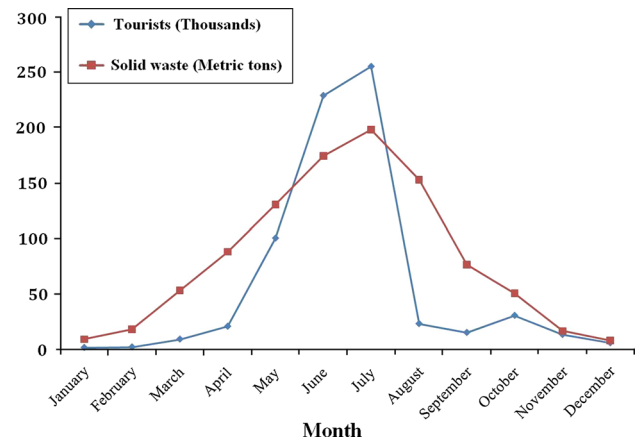


Fig. 4 Monthly variations in tourist flow and solid waste generation at Pahalgam 2012

the watersheds of 1E7B3 (3.52 and 5.26, respectively) and 1E7A2 (3.40 and 5.10, respectively) can be attributed to impermeable subsurface material, sparse vegetation, high relief, and low infiltration capacity.

LULC Change

Changes in LULC can be related to natural dynamics or to human activities (Bonetemps et al. 2008). LULC change and land management has principally resulted in deforestation, biodiversity loss, global warming, and increased natural disasters (DeFries et al. 2010; Warwick et al. 2013; Owrangi et al. 2014) contributing to global environmental change (Vitousek 1992; Foley et al. 2005; Trail et al. 2013). Inventory, assessment, and monitoring of LULC change provide vital input to environmental decision-making (Prenzel 2004; Munsu et al. 2009) and are crucial for further understanding and modeling of change mechanisms at different scales (William et al. 1994). Unplanned land cover changes cause environmental degradation (Bonetemps et al. 2008; Johnson and Zuleta 2013; Zorrilla-Mirasa et al. 2014) and are regarded as one of the more pervasive environmental threats (Wickham 2000; Lambin et al. 2001; Akber and Shrestha 2013). Information about LULC change is essential in natural resource management (Boles et al. 2004) and figures among important indicators of watershed prioritization (Badar et al. 2013).

This analysis has revealed that the LULC pattern has been changing since the 1960s as a result of mounting pressure on natural resources. Lidder catchment has exhibited undesirable change in its LULC during the last half century mostly on account of growth in the agriculture sector and tourism development. The present scenario of LULC change dynamics is haphazard and unsustainable

(Table 8). The area under dense forests has decreased by 191.53 km² from 1961 to 2010 with an average annual loss of 3.91 km² (1.13 %)/year. The primary reason for forest destruction has always been the expansion of agriculture to grow food. It was observed that there has been a marked expansion of agriculture and horticulture land in some watersheds such as 1E7A7 and 1E7B1. The expansion of waste lands is an important indicator of land degradation caused by human interventions. Waste lands have increased from 154.69 km² in 1961 to 307.2 km² in 2010 registering a growth of 98.59 % with an average annual growth of 2.01 %. Lidder valley is experiencing a substantial increase in the built-up area mainly because of the development of tourism-related infrastructure and the growth of native population. Built-up area has increased from 0.5 km² in 1961 to 2.22 km² in 2010 registering a growth of 347.05 % with an average annual growth of 7.08 %.

Priority Regions

The watersheds of Lidder catchment were classified into four priority zones (very high priority, high priority, medium priority, and low priority) on the basis of the quartiles of the priority values (Table 9). The final priority rank of a watershed indicates its ecological status in terms of degradation caused by anthropogenic interventions. The watersheds were also prioritized on the basis of individual indicators (Fig. 7), and correlation between the priority ranks was drawn (Fig. 8). These correlation scenarios facilitate analysis of the relative importance of the different indicator of watershed prioritization for management. Negative correlation between priority ranks based on geophysical indicators and priority ranks based on LULC indicators was observed (Fig. 8a). A low degree of positive correlation was found between priority ranks of socioeconomic and geophysical indicators (Fig. 8b). However, a high degree of positive correlation ($r = 0.66$) between priority ranks based on socioeconomic and LULC indicators was found. It emphasizes that socioeconomic indicators are the main drivers of LULC change in the catchment. Therefore, socioeconomic indicators need relatively more attention than geophysical indicators. The correlation between priority ranks of individual indicators and integrated priority ranks was also drawn. It was found that there is a low degree of positive correlation between priority ranks of geophysical indicators and integrated priority ranks (Fig. 8d). High positive correlation between priority ranks of LULC indicators and integrated priority ranks (Fig. 8e) as well as very strong correlation between socioeconomic priority ranks and integrated priority ranks was found (Fig. 8f). This indicates that socioeconomic characteristics are the leading indicators of environmental

Table 7 Geophysical attributes of different watersheds in Lidder catchment

Watershed	Dominant slope category (°)	Dominant altitude zone (masl)	Drainage density	Stream frequency
1E7A1	<5	<2,000	1.52	1.84
1E7A2	30–40	2,000–2,500	3.4	5.1
1E7A3	20–30	3,500–4,000	2.84	3.58
1E7A4	20–30	3,500–4,000	2.86	3.39
1E7A5	20–30	3,500–4,000	2.7	3.24
1E7A6	20–30	3,500–4,000	1.96	2.36
1E7A7	20–30	3,000–3,500	2.04	2.28
1E7B1	20–30	4,000–4,500	3.05	4.19
1E7B2	30–40	3,500–4,000	3.35	4.39
1E7B3	20–30	3,500–4,000	3.52	5.26
1E7B4	<5	<2,000	2.23	2.83

Source Computed from DEM and drainage map

degradation in the catchment. These priority scenarios facilitate the identification of watersheds that need to be managed on a priority basis and explore the causes of environmental degradation in a particular watershed. Different management strategies could be formulated, keeping in view the drivers of environmental change in a particular watershed, to increase the standard of living of the local population while maintaining environmental quality at the same time. The integrated priority ranks (Fig. 9a) are assigned such that the low rank value indicates high priority and vice versa.

Very High-Priority Zone

This zone consists of three watersheds: 1E7B1, 1E7A7, and 1E7B3 (Fig. 9b). A significant human impact is observed in this zone because watershed 1E7B1 is used extensively for tourism. The watershed comprises most of the tourist infrastructure in terms of various accommodation units and remains very crowded in tourist season. The *Yatra* base camps of Chandanwari, Zagipal, and Sheshnag are located in this watershed. These are extensively used in the *Yatra* season for accommodation purposes and are the major sources of water pollution (Rashid and Romshoo 2012). Apart from the noticeable tourism impact, the watershed has experienced a significant average annual population growth (7.47 %) with greater physiological density (3,474 persons/km² of net sown area). Watershed 1E7B3 is in the mid-altitude zone of Lidder catchment. The inhabitants have a low standard of living with low per-capita income and poor literacy. They have a heavy reliance on the forests in terms of firewood extraction, charcoal formation, and smuggling of timber and other forest products, which has severely degraded the environmental quality of the region.

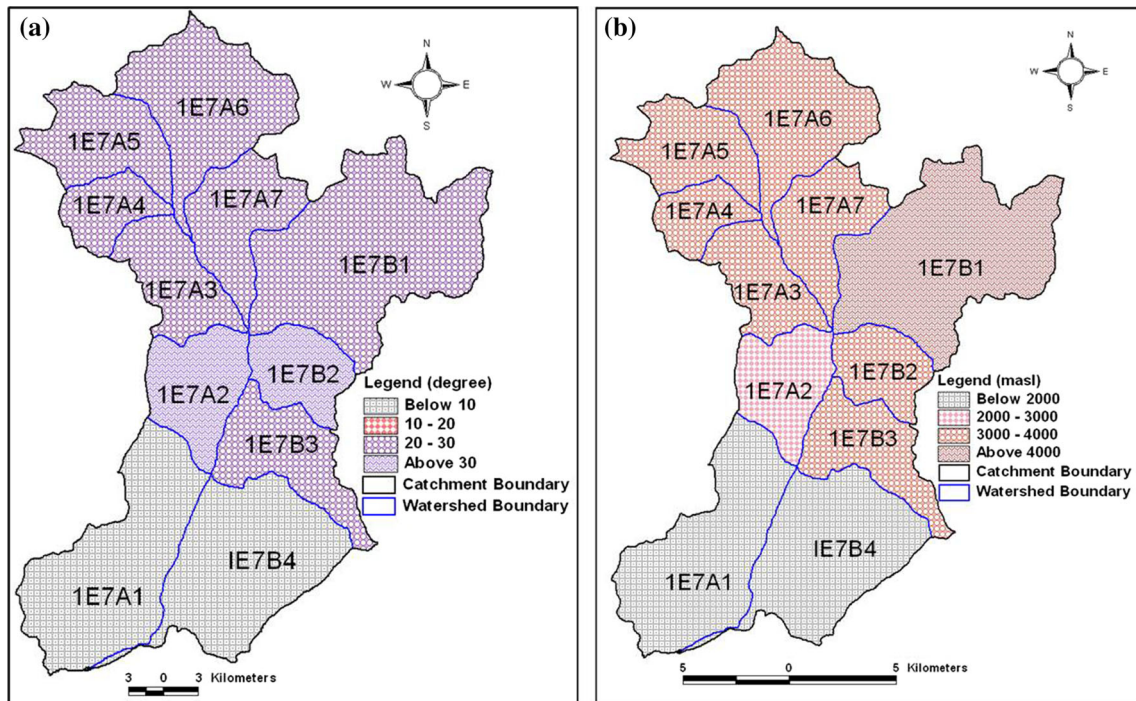


Fig. 5 Watershed wise distribution of **a** slope and **b** altitude in Lidder catchment

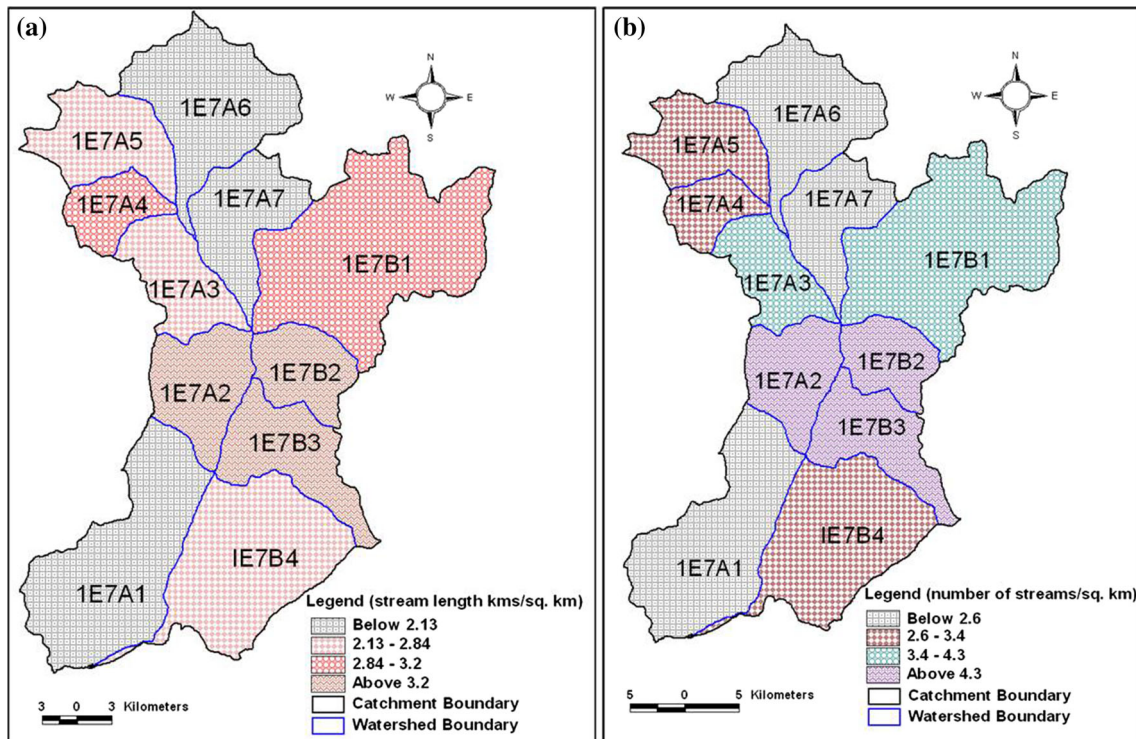


Fig. 6 Watershed wise distribution of **a** drainage density and **b** stream frequency in Lidder catchment

The problem is further accentuated by steep slope, rugged terrain, greater drainage density, and high stream frequency in the region. Watershed 1E7A7 has poor socioeconomic

conditions and suffers from the negative impacts of tourism. The watershed ranks first in fuel-wood consumption and the expansion of agriculture. The management strategy

Table 8 Existing LULC and its change in different watersheds of Lidder catchment

Watershed	LULC							
	Existing (%)				Average annual growth (1961–2010)			
	Built-up	Agriculture	Waste lands	Forests	Built-up	Agriculture	Wastelands	Dense forests
1E7A1	6.56	66.92	3.66	18.66	8.4	8.97	−0.4	−1.20
1E7A2	2.64	12.25	9.99	65.78	2.2	−12.16	3.1	−1.23
1E7A3 ^a	0	0	26.32	52.29	0	0	1.9	−0.99
1E7A4 ^a	0	0	48.59	20.32	0	0	1.1	−1.13
1E7A5 ^a	0	0	44.72	19.39	0	0	2	−1.72
1E7A6 ^a	0	0	46.34	19.15	0	0	3.9	−1.44
1E7A7	0.84	2	23.41	47.95	9	492.31	3.5	−0.98
1E7B1	0.85	1.72	43	34.31	5.7	187.59	1.7	−1.42
1E7B2 ^a	0	2.09	34.19	52.57	0	41.77	3.5	−0.89
1E7B3	1.01	6.29	24.43	54.48	1.8	38.1	2.6	−0.83
1E7B4	5.51	39.02	5	47.5	9.7	−2.92	0.2	−0.93

Source Computed from Survey of India toposheets, 1961, LANDSAT ETM, 2001, 1992 and IRS P6 LISS III, 2010

^a Uninhabited watershed

for this region should include a sound tourism policy, especially for watersheds of 1E7A7 and 1E7B1, with a focus on developing winter tourism. This will help to decrease the seasonality of tourism by ensuring year-round employment of the tourism-dependent population and will decrease its environmental impact during the summer season. The quality of life could be improved by providing skilled education so that the inhabited population could be employed in tourism industry in various capacities. This will also help to decrease the anthropogenic impact on forests, especially in watershed 1E7A7, once an alternative source of income generation (tourism-related employment) is provided. It is pertinent to mention here that the major share of income generated from the tourism industry is shared by the people from the nearest urban centers (Anantnag and Srinagar), whereas the regional economic base is excluded from the benefits of tourism industry. The heavy reliance on forest-based firewood could be decreased by providing alternative source of energy (liquefied petroleum gas) at cheaper rates to mountain-dwelling people.

High-Priority Zone

This zone comprises of two watersheds: 1E7A1 and 1E7A2 (Fig. 9b). Watershed 1E7A1 has the maximum built-up area accommodating the largest concentration of population and thus has the paramount anthropogenic impact. The watershed has lowest area under forests. However, the gentle slope, lowest drainage density, and stream frequency and negligible area under wastelands indicate that the geophysical arrangement is ecologically favorable. The important driving forces of LU change in the watershed are

population growth and maximisation of economic returns from arable land (Malik and Bhat 2014). There has been large-scale conversion of agriculture to horticulture land use (especially apple orchards) in these watersheds. Watershed 1E7A2 is in the mid-altitude zone of the catchment. It received second-priority rank for geophysical indicators and fourth-priority rank for both socioeconomic and LULC indicators. The watershed is dominated by steep slopes with high drainage density and stream frequency; therefore, engineering measures are suggested to decrease soil erosion.

Medium-Priority Zone

This zone consists of the three watersheds: 1E7B4, 1E7B2, and 1E7A6. The greater population density, significant concentration of livestock population, and greater percentage area under built-up and agriculture show that the socioeconomic variables are the major drivers of environmental change in watershed 1E7B4. Watersheds 1E7B2 and 1E7A6 are uninhabited. However, agriculture is being practiced in watershed 1E7B2 by the inhabitants of nearby watersheds. Tourism-related activities also contribute to environmental degradation in this watershed. The increasing rate of deforestation with consequent waste land expansion is the major cause of concern in watershed 1E7A6. The overall vegetation density has decreased considerably in this zone during the last 50 years.

Low-Priority Zone

This zone consists of three uninhabited watershed: 1E7A3, 1E7A4, and 1E7A5. The absence of socioeconomic

Table 9 Priority results of watersheds

Watershed	Sum total of normalized values			Sum multiplied by respective normalized weight			PV	Priority zone
	Socioeconomic	Geophysical	LULC	Socioeconomic	Geophysical	LULC		
1E7A1	2.2 (5)	0.4 (9)	2.2 (1)	1.1	0.0668	0.7326	1.8994 (5)	High
1E7A2	2.7 (4)	1.4 (2)	1.6 (4)	1.35	0.2338	0.5328	2.1166 (4)	High
1E7A3 ^a	0.1 (8)	1.2 (4)	0.9 (8)	0.05	0.2004	0.2997	0.5501 (10)	Low
1E7A4 ^a	0 (9)	1.1 (5)	1.1 (7)	0	0.1837	0.3663	0.55 (11)	Low
1E7A5 ^a	0 (9)	1 (6)	1.4 (6)	0	0.167	0.4662	0.6332 (9)	Low
1E7A6 ^a	0 (9)	0.8 (7)	1.6 (4)	0	0.1336	0.5328	0.6664 (8)	Medium
1E7A7	3 (1)	0.8 (7)	2 (2)	1.5	0.1336	0.666	2.2996 (2)	Very high
1E7B1	2.9 (2)	1.3 (3)	2 (2)	1.45	0.2171	0.666	2.3331 (1)	Very high
1E7B2 ^a	0.2 (7)	1.5 (1)	1.5 (5)	0.1	0.2505	0.4995	0.85 (7)	Medium
1E7B3	2.8 (3)	1.4 (2)	1.5 (5)	1.4	0.2338	0.4995	2.1333 (3)	Very high
1E7B4	2.1 (6)	0.6 (8)	1.8 (3)	1.05	0.1002	0.5994	1.7496 (6)	Medium

Numbers in parentheses indicate priority rank

^a Uninhabited watershed

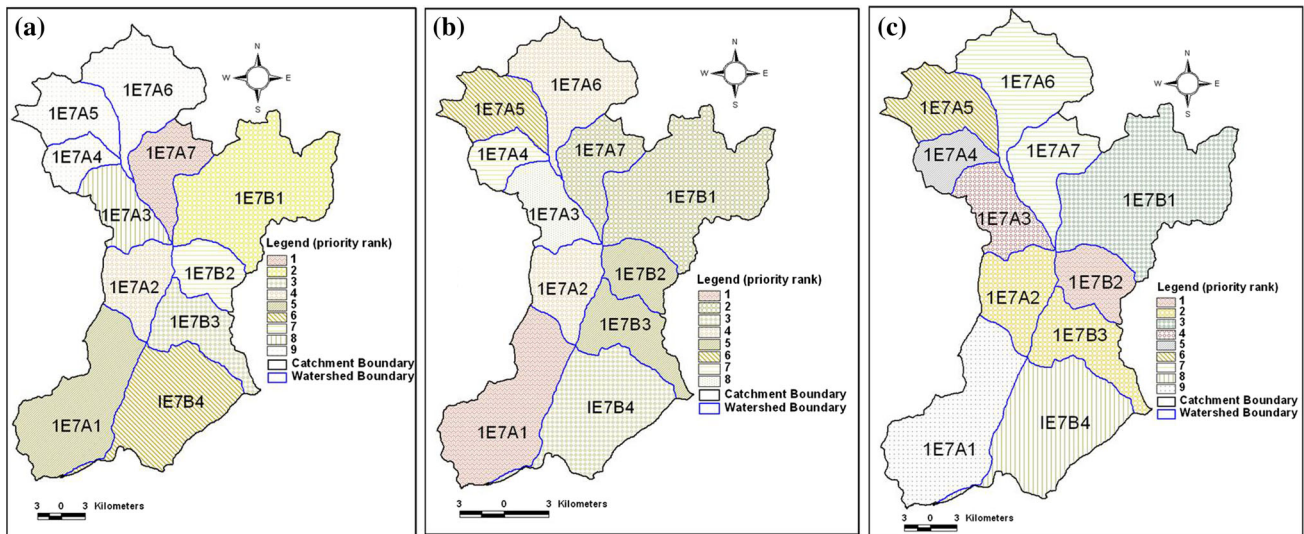


Fig. 7 Priority ratings of watersheds on the basis of **a** socioeconomic, **b** LULC, and **c** geophysical indicators

attributes has resulted in low priority of these watersheds. The deforestation rate is high in watershed 1E7A5, which has affected the forest cover of the watershed. It is also pertinent to mention here that the illegal felling of trees, which is usually not monitored by the concerned authorities, is carried out in remote areas of the catchment.

Discussion

The Himalayas have been the cradle of everything precious and beautiful in India’s heritage (Madan and Rawat 2000). However, the fragility of mountain ecosystems (Stone 1992), overdependence of Himalayan inhabitants on forests

(Xu 2008), and subsistence-based economy (Singh 2006) have led to natural resource depletion and environmental degradation. The pace, magnitude, and spatial reach of human alterations of the Himalayan region are unprecedented (Ives and Messerli 1989). Degradation of watersheds has posed serious problems to environment and people dwelling both upstream and downstream (Mountain 2002). The vulnerability of Himalayan watersheds to anthropogenic LU and climate change has increased (Ma et al. 2010). Therefore, developmental efforts for the Himalayan region should be made according to demographic traits and needs while keeping in mind the resource availability and ecological fragility of the Himalayan environment (Pant 2003). The present study elaborates a

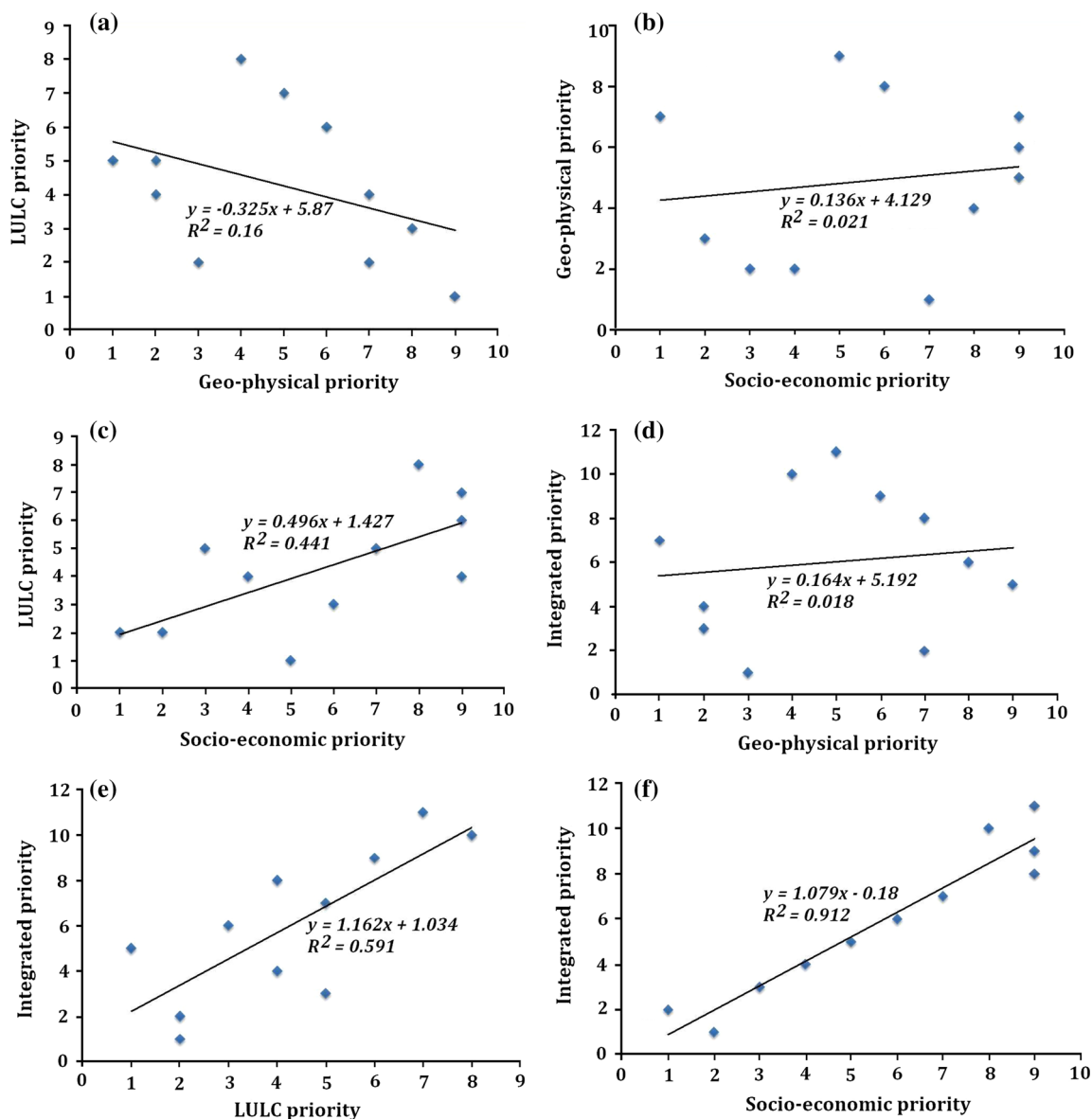


Fig. 8 Correlation between priority ratings on the basis of **a** geo-physical and LULC indicators, **b** socioeconomic and geophysical indicators, **c** socioeconomic and LULC indicators, **d** geophysical and

integrated indicators, **e** LULC and integrated indicators, and **f** socioeconomic and integrated indicators

management strategy by prioritizing watersheds that are under severe environmental stress so that the natural resources could be managed on watershed basis by improving the socioeconomic status of the inhabited population. Because watershed degradation is attributed to geophysical parameters, LULC dynamics, and socioeconomic change, integrated evaluation using knowledge-based MCE is carried out to recommend a priority rating of the watersheds.

Managing watersheds for sustainable rural development in developing countries is a relatively new concept. The watershed development approach in India was first adopted

in 1974 when the Government of India enforced the scheme for “soil conservation in the watershed of river valley projects.” In 1982, the Government of India launched another ambitious program for the development of dry-land agriculture on a watershed basis, under which 47 model watersheds were identified under different agroclimatic zones all over the country. Initially in the watershed-management programs, a structure-driven approach for soil conservation and rainwater harvesting was adopted (Ozyuvaci et al. 1997; Raju et al. 2008). This approach does not consider local participation or demands and the

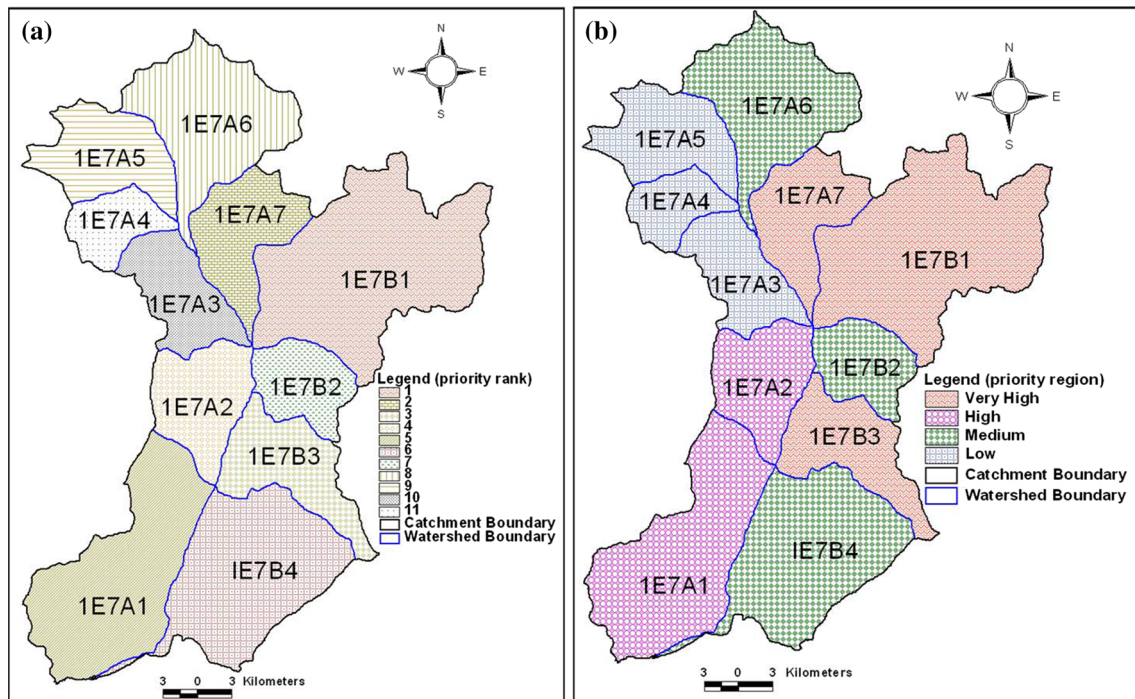


Fig. 9 **a** integrated priority ratings and **b** priority regions in Lidder catchment

aspirations of the inhabitants and was thus unsuccessful in bringing sustainable regional development. The need of a holistic approach was felt, which is critical for sustainable development (Wani et al. 2003). To attain sustainable regional development and natural-resources management through local participation, participatory watershed development projects were implemented (Sen et al. 1997). Although engineering solutions were not excluded where appropriate, the emphasis was placed more on farming systems and on participatory and demand-driven approaches implemented at the decentralized level (Mountain 2002).

Watershed-management planning requires the integration of sound scientific and social processes to be successful (O'Neill 2005). When adopted within the boundary of a watershed, proper LU, in conjunction with mechanical soil conservation measures, can enhance sustainability of the production system (Singh et al. 2006). Geophysical and socioeconomic factors have a dominating role in LULC change in mountain landscapes (Mottet et al. 2006). Because they are an integral part of the environment, the natural resources and the socioeconomic status of a watershed should be paid equal attention (Erickson 1995). The socioeconomic factors used for prioritization (Table 3) are identified as the main drivers of LULC change and consequent environmental degradation in the catchment. Changing LULC is a fundamental driver of global change (Fischer and O'Neill 2005) and direct reflections of human

activity and impacts (Malik and Bhat 2014). Understanding past and present impacts of LULC change is important to the study of human-driven environmental change (Liu and Yaning 2006). Expansion of agriculture on marginal lands and decreasing crop yields are considered to be the major unsustainable trends in the Himalaya (Ives and Messerli 1989; Jodha 1990). Unsustainable tourism development has resulted into unplanned LU change (Bhat et al. 2007; Malik et al. 2013), solid-waste generation, deforestation (Malik et al. 2011b), water-quality degradation (Rashid and Romshoo 2012), and other environmental problems in Lidder catchment. The geophysical indicators of slope, elevation, drainage density, and stream frequency play a dominating role in watershed dynamics especially in determining erosion and sediment yield (Patil and Mali 2013). Therefore, these factors are also given due consideration in this study.

The earlier approaches to watershed prioritization were mainly based on the physical aspects of the watersheds, which include evaluation of morphometric parameters to prioritize watersheds on the basis of sediment yield index and soil loss (Kalin and Hantush 2009; Londhe et al. 2010; Niraula et al. 2011; Panhalkar et al. 2012; Shikalgar 2013). Socioeconomic factors, which play an important role in LULC change dynamics by accelerating soil erosion and environmental degradation, have largely been ignored. Although the emphasis is now on integrated watershed prioritization studies by combining geophysical

characteristics and LULC dynamics, either using a compound parameter technique (Hlaing et al. 2008; Paul and Inayathulla 2012) or MCE analysis (Kumar and Kumar 2011; AAher et al. 2013), socioeconomic variables are yet to be given due consideration. However, some socioeconomic variables have been used for watershed prioritization (Badar et al. 2013). The present study identifies three major contributors of environmental degradation (socioeconomic variables, geophysical setup, and LULC change) in Lidder catchment, which are used to prioritize watersheds for management. The MCE approach was adopted by assigning knowledge-based weights to prioritization indicators. The study identifies watersheds that require immediate attention and explores the main drivers of environmental change. To combat environmental degradation and to raise the quality of living of the local community, the management strategies could be formulated per the prioritization scheme presented in this study. This would certainly help move sustainable regional development forward while maintaining environmental quality at the same time. However, the major limitation of the study was the unavailability of relevant spatial data, which hampered the use of other indicators for prioritization. The prioritization model presented in this study is simple and flexible and could be applied to other parts of the world with similar geophysical and socioeconomic characteristics. However, the number and the relative importance (weighting) of the variables must be adjusted per the environmental settings of the region concerned.

Conclusion

Lidder catchment, being one of the leading tourist destinations of Kashmir valley, faces severe environmental stress, which is aggravated by its poor socioeconomic development. Socioeconomic indicators are identified as being major drivers of environmental degradation in the catchment. Apart from tourism development, the unplanned demographic growth, coupled with increasing arithmetic and physiological densities, has resulted in unsustainable LULC change in different watersheds. Low levels of literacy, poor economic conditions, and greater dependency ratios compel people to rely on forest-based resources for their survival. MCE showed that the magnitude and intensity of human impact is not the same throughout Lidder catchment. Integration of remote-sensing and socioeconomic data with field observations using GIS has facilitated the identification of watersheds under severe anthropogenic impact as well as the drivers of environmental degradation in a particular watershed. The results of this study argue that mere engineering measures are not sufficient to evade environmental deterioration. The

need for developing an integrated approach is that could address all the factors of watershed degradation is sorely felt. Therefore, socioeconomic indicators of watershed prioritization are given due consideration in this study.

The results show that socioeconomic indicators are the main drivers of LULC change in the catchment. The watersheds under very high priority are dominated by tourism-related activities, and tourism-driven LULC change is posing a serious threat to the natural environment. There is a need to adopt a sound tourism policy that will focus on engaging local inhabitants in tourism business while maintaining environmental quality at the same time. The development of winter tourism is a relevant option that will help to regulate tourist flow throughout the year. This will ensure year-round employment of the tourism-dependant population. Forest-conservation measures deserve special attention because the rate of deforestation is very high in some watersheds. The LULC pattern and its dynamics could be regulated by developing an LU policy with a focus on monitoring built-up expansion and extension of agriculture in forest areas. The continuous monitoring of remote-sensing-based geophysical and environmental indicators, as well as changing demographic trends, could be used in the future to assess the priority status of the watersheds. The methodological framework presented in this study could be applied to other mountain watersheds. However, the number of prioritization indicators and their relative contribution to environmental degradation must be weighed according to the regional socioeconomic and geophysical characteristics.

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