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Original Article

Assessment of land use/land cover dynamics in Zhob river basin, Pakistan

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Abstract

Identification of Land Use/Land Cover (LU/LC) dynamics by using remote sensing data is essential information for numerous decision support systems in the context of conservation of natural resources and sustainable development. Four years (1991, 2001, 2013 and 2021) were selected for this current study. Landsat TM, OLI/TIRS images of 30m resolution and ArcGIS map were utilized to detect the changes. Five land cover classes (water bodies, forest, built up, bare land, and agriculture land) were identified and an accuracy assessment was carried out by using kappa coefficient. According to the results of classification, the overall accuracies were 78.78%, 95.4%, 92%, 100% and the kappa coefficients were 56.87, 94%, 92% and 73% for the years 1991, 2001, 2013 and 2021, respectively. The final classification maps indicate declines by 64% of bare land and by 3% of water bodies, with 21% built-up area increase. LU/LC changes will help the policy makers to ensure sustainable regional planning and development.

Keywords: GIS, image classifications, LU/LC, remote sensing, Zhob river basin

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1. Introduction

Land cover (LC) is the biophysical state of earth's surface and subsurface while Land Use (LU) refers to the human employment of land (Ado, Ejidike, Adetola, & Olaniyi, 2022). LU/LC dynamics are a component in ecological changes from local to global scale due to human interference directly or indirectly (Chatterjee, Dutta, Dutta, & Das, 2022). LU/LC changes affect the climate as well as weather in both local and global level by causing changes in ecological processes, greenhouse gases, water issues and interactions with energy (Sleeter, Wilson, Sharygin, & Sherba, 2017). Climate change has impacted ecosystems and land use by alterations to the use of land, in pattern and in distribution (Belete, Maryo, & Teka, 2021). All hydrological processes (water loss, runoff, infiltration, rainfall pattern, transpiration) are affected by activities such as crop expansion, deforestation and urbanization. According to the Intergovernmental Panel on Climate Change (IPCC) natural land is affected by LU/LC changes from small to large scale, which is an alarming situation. The natural land has been altered in many ways and a number of factors are responsible for its transformations, including migration from rural to urban areas, and expansion of agriculture resources and crop production (Shukla *et al.*, 2019). GIS and remote sensing are essential tools helping collect timely data on the spatial distribution of LU/LC over broad areas (Carlson, & Azofeifa, 1999; Muhammad, Zhonghua, Sissou, Mohamadi, & Ehsan, 2016) and to analyze the patterns of LU/LC dynamics. GIS analyze, display, collect, store, and process digital data, which is essential for the detection of changes in LU/LC (Wu *et al.*, 2006). Many institutions and organizations have carried out studies on the application of LU/LC dynamics by employing synoptic satellite imagery to identify the type of Earth's surface (Ulbricht, & Heckendorff, 1998).

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Balochistan, the largest province of Pakistan, is a drought-prone province and has experienced long-term severe droughts in its history, and between 1998 and 2002 (Aliyar, Zulfiqar, Datta, Kuwornu, & Shrestha, 2022). The Zhob river basin is located in this province. Moreover, factors like rapid population growth, excessive use of groundwater resources, long-term droughts, deforestation, livestock grazing, and inadequate resource management (Dixit *et al.*, 2022) are aggravating this fragility. According to that report, the groundwater levels have declined by up to 75m in the mountainous areas of north-east Balochistan, due to the excessive use of groundwater. It is believed that this extreme decline of the groundwater table is dangerous and a threat to local agriculture, and to the survival of its dependent communities (Dawood, Akhtar, & Ehsan, 2021; Tariq *et al.*, 2022). As a result, many gardens and springs have dried out and crop production has declined by up to 50% during the period 1998-2005.

The aim and objective of this research is to understand and analyze the last three decades for the dynamics of LU/LC changes and the population growth in the Zhob river basin (ZRB) using remote sensing and ArcGIS applications. GIS and remote sensing applications are used for image classification processed to quantify the LU/LC changes, which highlight an increase in urbanization, deforestation, groundwater depletion, and other environmental concerns in the study area. This study provides a guideline to evaluate unplanned LU/LC impacts in the field and develop land management plan, which can be applied to other areas worldwide.

2. Materials and Methods

2.1 Description of the study area

This study is conducted in the ZRB, which is located 1,408 m above the sea-level, having latitude 31.3497N and longitude 69.4665E, in northwest Balochistan, Pakistan (Figure 1). The geographical area of Zhob is 12,400 km^2. ZRB starts near Kan Mehterzai hills, about 70 km northeast of Quetta, runs through the plains of Qila Saifullah, and drains into Gomal river towards northeast that ultimately joins the Indus river. The catchment area of basin is about 16,173 km^2. The total length of Zhob river is 406 km with elevation range between 3,077 m and 704 m, and having an annual 4.9 billion m^3 surface runoff.

The climate of ZRB is arid, sub-tropical and continental, with the average annual rainfall varying from 200 mm (in southwest) to 400 mm (in northeast). Summers are hot and temperatures soar as high as 40°C, and there is snowfall in the winter. The major crops are wheat, rapeseed /mustard, barley, vegetables, fodder, sorghum, maize, mung & mash bean, melons, and chilies, while fruits include apples, grapes, almond and apricots.

2.2 Dataset

The Landsat satellite's cloud-free images were downloaded for the years 1991, 2001, 2013 and 2021 for use in the LU/LC classification and exploration of the land cover changes. These images were taken for the detection of dynamics from short to long-span, beginning from the most recent year. The images were downloaded from the website of United States Geological Survey (https://earthexplorer. usgs.gov/) (Table 1). Ground truth data was used for the identification and accuracy assessment, in addition to Google Earth images.

2.3 Data analysis

The Landsat images used in this study were for 1991, 2001, 2013 and 2021. The images were examined, processed and classified by using ArcGIS 10.3. Supervised classification was used for the dynamics of LU change, which includes accuracy assessment, land use classification, pre-processing of images, and LU change detection from 1991 to 2021. The Landsat-8 was used for the years 2013 and 2021, and Landsat-5 for the years 1991 and 2001. Images acquired were Landsat-5 and Landsat-8 with UTM Zone 42N. Landsat data were processed using WGS1984 geodetic datum.

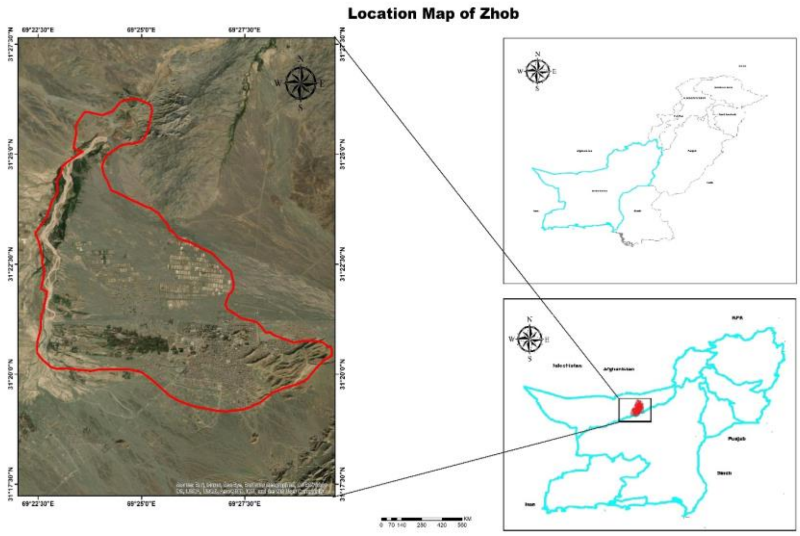

Figure 1. Location map of the Zhob river basin, Pakistan

2.4 Image classification and preprocessing

Preprocessing is a crucial step before the detection of dynamics. Preprocessing of Landsat images was carried out in order to connect the acquired data with biophysical processes. All satellite images were corrected geometrically and radiometrically by using USGS Landsat. This is a crucial step before change detection analysis. In this research, the striping and banding errors and atmospheric effects were compensated by using dark object subtraction and radiometric errors (Jianya, Haigang, Guorui, & Qiming, 2008). Local knowledge of the study area was acquired for analysis of image classification. Images with several bands were mosaiced and classified, and a maximum of seven bands were used in the classification. Band errors were removed by dark-object subtraction. Four land use classes were identified during the study namely water bodies, bare land, vegetation, and urban/built-up area (Table 2). From 500 to 800 training samples were selected around representative classes by drawing polygons. These samples represented the four land-use classes which were identified. Other researchers have used the same process for the image classification (Tolessa, Senbeta, & Kidane, 2017). False color composites were used to enhance the visualization of satellite images. The pixels enclosed by these polygons were used to record the spectral signatures for the respective classes of the satellite imagery. In order to ensure minimum error among the land uses to be mapped, a satisfactory spectral signature was utilized. Pixel-based supervised classification with a maximum likelihood algorithm was used in this study. Five population censuses have been conducted since the independence of Pakistan, in the years 1951, 1961, 1972, 1981 and 1998. The demographic data were collected from the concerned departments such as Pakistan Bureau of Statistics and the local municipal government.

2.5 Postprocessing and dynamic analysis

Accuracy assessment of the image classification is one of the steps undertaken in this study to identify the level of agreement of classification labels with respect to a set of reference data (Jianya *et al.*, 2008). This was carried out using 104, 200, 800 and 1000 ground truth regions of interest (ROIs) for the selected years. The validation ROIs used for the 1991 and 2013 images were acquired through visual interpretation based on local knowledge of the study area and by reference to historical Google Earth images, and those for 2013 and 2021 were acquired from ground-truthing undertaken in the same year.

Error matrices were used in statistical comparisons between reference data and the classification calls. Non-parametric Kappa test (which accounts for all elements in the error matrix) was used for the evaluation of classification accuracy (Rosenfield, & Fitzpatrick-Lins, 1986). Lastly, to identify the type and extent of land use changes, pixel to pixel based cross-tabular statistics were assessed.

2.6 Population change detection

The population information, both from population evaluation and projections, was gathered from Zhob river authority for the years (2001, 2013, 2021) while the population data for the year 1991 were taken from a writing audit. The population development rate alluded to the adjustments to population over a particular timeframe. The rate and degree of population changes in the ZRB was determined using Excel in view of the gathered information. The number of inhabitants in ZRB for 1991, 2001, 2013 and 2021 was assessed utilizing the population pattern line from 1985 to 2019. The land use/land-cover elements and population development were quantitatively analyzed utilizing the Pearson correlation coefficient (r) to explore the direct connections in pairs of two factors. The coefficient (r) ranges from -1 to +1 with the extremes indicating a perfect correlation (negative or positive), while 0 means no correlation.

3. Results and Discussion

The classification maps indicate the LU/LC changes over the last 30 years in ZRB (Figure 3). The results showed that more than 94% of the area was barren in 2001 but with the passage of time it has decreased to 65% by 2013 and in 2021 the remaining barren area was 47%. In contrast built-up

Table 1. Description of Landsat images used in land use classification

Year	Data	Resolution	Number of bands	Format	Aquisition date
2021	Land-sat 8 OLI/TIRS C1 L1	30	07	GeoTIFF	27.04.2021
2013	Land-sat 8 OLI/TIRS C1 L1	30	07	GeoTIFF	15.11.2013
2001	Land-sat 4-5 TM C1 L1	30	07	GeoTIFF	30.11.2001
1991	Land-sat 5 TM C1 L1	30	07	GeoTiFF	15.08.1991

Source https://earthexplorer.usgs.gov/

Table 2. Land use/land cover classification in the study area

No	Land class	Description
1.	Bare land	Barren land consists of soil that is so poor that plants cannot grow in it.
2.	Water bodies	Rivers, lakes, dams, reservoirs
3.	Forested area	Mixed and scattered forests, dense green forests
4.	Built up	Rural and urban settlements including buildings, industries and other infrastructure
5.	Agriculture	Cultivated and uncultivated farmlands, crop covered agricultural lands and grassland

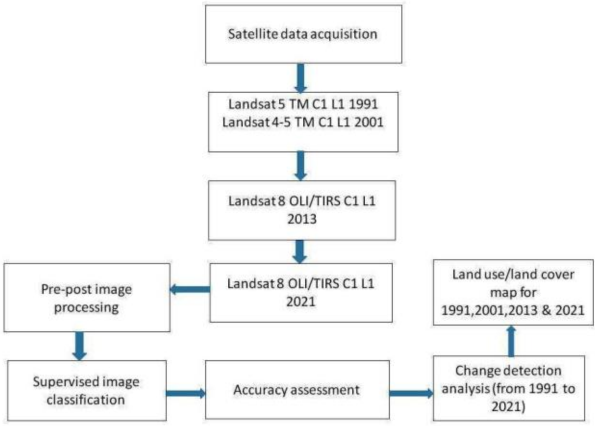

Figure 2. Flow diagram of steps in land use/land cover classification

area increased over the study period from 2001 to 2021.

According to the results of the classification, the overall accuracies were 78.78%, 95.4%, 92%, 100% and kappa coefficients were 56.87%, 94%, 92% and 73% for the years 1991, 2001, 2013 and 2021, respectively (Table 3). The final classification maps indicate declines by 64% of bare land and 3% of water bodies, with 21% built-up area increase. The accuracy of the classification was greater than 80% except for built-up area in the images of 1991 (70.6%) and 2001 (71.9%).

The evaluation highlights that population development is one of the significant main impetuses for an expansion of the developed region, and for lessening in the area of woods. The precision evaluation (Table 3) demonstrated the general correctness of the labeling for all chosen years, surpassing 85% accuracy. The precision of classifier calls for developed regions was lower than for other land use classes in the chosen years. An illustration of an impossible change, which might have brought about the low accuracies, was seen in the period 1991 to 2001, where just 31% of the developed region was preserved as built up, and the rest was assigned to different classes. Nonetheless, this instance could be a result of blended pixels, which is typically an issue in metropolitan regions with heterogeneous coverage, like uncovered land, framework, and vegetation. The land cover map for Zhob river basin demonstrated that most of the land was bare, trailed by vegetation. The greater part of the area was described as shrubland with a wide fruitless region and little bushes. The land-cover changes in Zhob incorporate backwoods decay/deforestation, cropland and developed area extension, and woodland region decrease. Besides, the development of metropolitan region has caused a decrease in backwoods in 2013. The extension of cropland and built-up area results in reduction of shrub-land and bare land. 30% of the forested area was converted into cropland during 1991 to 2021. This is because of the growing population increased the demand for crop production as an essential source of livelihoods for the people living in the basin.

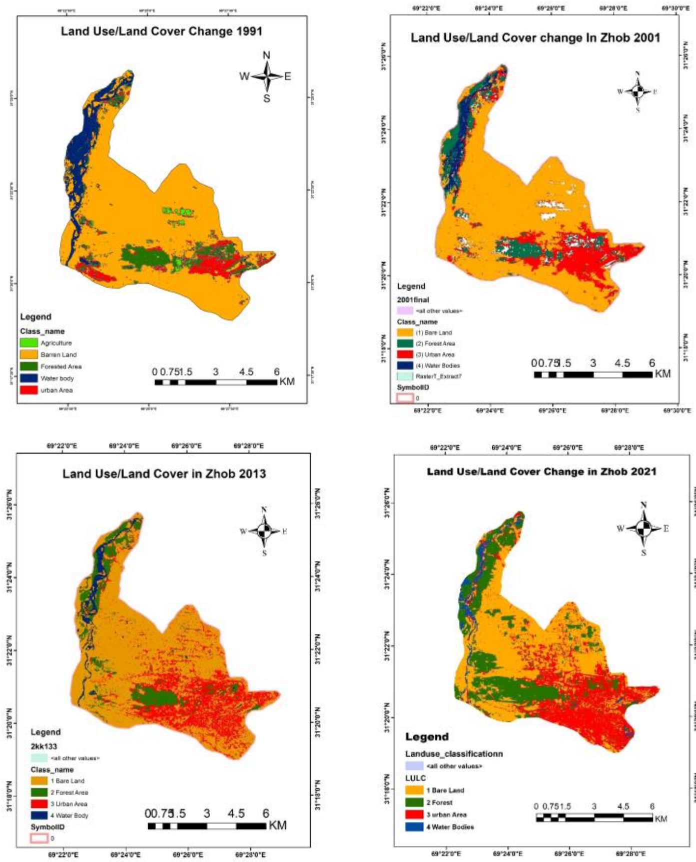

Figure 3. Land use/land cover mapping for the years 1991, 2001, 2013, and 2021

Table 3. Accuracy assessment of classification by confusion matrix for each land use class

Year: 1991

Class name	Ground truth (Pixels)				User accuracy
	Bare land	Vegetation	Built-up	water bodies	
Bare land	53	5	1	1	90.14
Vegetation	4	2	0	1	80.50
Built-up	2	25	10	1	44.44
Water bodies	2	0	0	20	90.80
Total					
Producer accuracy	72.60	96.15			

Note: Overall accuracy=78.78%; Kappa coefficient= 0.80

Year: 2001

Class name	Ground truth (Pixels)				User accuracy
	Bare land	Vegetation	Built-up	water bodies	
Bare land	29	0	1	0	96
Vegetation	2	19	0	0	90
Built-up	1	0	24	0	96
Water bodies	0	0	0	11	100
Total					
Producer accuracy	90	100	96	100	

Note: Overall accuracy=95.4%; Kappa coefficient= 0.90

Year: 2013

Class name	Ground truth (Pixels)				User accuracy
	Bare land	Vegetation	Built-up	water bodies	
Bare land	20	0	0	0	100
Vegetation	1	10	0	0	90
Built-up	2	1	25	0	89
Water bodies	2	0	0	20	90
Total					
Producer accuracy	80	90	100	100	

Note: Overall accuracy=92%; Kappa coefficient= 0.88

Year: 2021

Class name	Ground truth (Pixels)				User accuracy
	Bare land	Vegetation	Built-up	water bodies	
Bare land	12	4	1	2	63.6
Vegetation	0	12	0	1	92.3
Built-up	0	0	6	0	100
Water bodies	0	0	0	5	100
Total					
Producer accuracy	100	75	85.7	100	

Note: Overall accuracy=81.4%; Kappa coefficient= 73%

Prior discoveries additionally showed upstream land debasement because of development of land and deforestation in various parts of Balochistan (Hurni *et al.*, 2010). Besides, the growth of cropland and environmental changes (Tadese, Kumar, Koech, & Kogo, 2020) pose a significant danger to water assets, biological systems, and financial viability in ZRB. The discoveries of this study showed that water-bodies and wetlands expanded from 1991 to 2021. In the same period, forest cover decreased slightly, expanded due to a combined effect of rainfall variability, groundwater inflows, and surface runoff, sedimentation, and land use changes (Dinka, & Klik, 2019). Alongside the base decrease in timberland cover, extension of these lakes may be the reason for increased wetland and water-bodies during this period. Going against the norm, there was a decrease of wetlands and water-bodies somewhere in the range from 2013 to 2021. From 2001 to 2021, the growth of cropland and developed region went on, while backwoods cover diminished essentially. Timberland cover is one of the critical elements that impact climatic factors like precipitation, evapotranspiration, and temperature. More significant levels of deforestation joined with populace development, urbanization, and cropland extension affect the accessible water assets, spillover, and wetland-inclusion nearby (Loucks, & Van Beek, 2017). Moreover, wetland was reduced in the entire sub-basins from 2001 to 2013. The dynamics of land use change and rapid population growth in ZRB have a direct influence on the climate and characteristics of the ecosystem in the basin. The LU/LC changes coupled with population growth have forced the communities to cultivate hilly areas for expansion of agricultural land with continuous farming. This has resulted in soil degradation and huge sedimentation in hydraulic structures. Improper land use practices and lack of sustainable conservation management coupled with intensive rainfall, rugged topography, and reduced vegetation cover can cause severe land degradation and natural resource depletion in the ZRB. Images show the increased built-up area, while reduction in vegetation, water bodies (by 3%) and bare land occurred from 2001 to 2021 in ZRB (Figure 3). Increased urban population exerts a pressure on existing limited resources due to which forested areas are converted into cropland for livelihood. The degradation affects environmental and human health (Akhtar, Tang, & Mohamadi, 2014; Ilyas, Khattak, Nasir, Qurashi, & Durrani, 2010). The increased population has caused many environmental issues as well as traffic congestion, water depletion, and land subsidence (Akhtar *et al.*, 2021; Iliyas *et al.*, 2010). The porosity of lithology of the basin shows potential of an aquifer (Lohawijarn, 2005).

3.1 Accuracy assessment

The accuracy assessment evaluated the calls in relation to areal local knowledge, for various classifiers. The review utilizes reference maps to arbitrarily choose testing samples for every category characterized by the reference maps. Similar test information has been utilized to evaluate various classifiers. The overall accuracies were 81.4%, 92.5%, 95.4% for 2021, 2013 and 2001 images. The Kappa coefficients were 82% for year 2001, 89% for year 2013, and 77% for year 2021 (Table 3).

3.2 Population dynamics

According to 1998 census the population of Zhob was 193,458 persons. In 2017 the total population of Zhob was 310,544 persons including urban population 46,248 (14.89 %) and rural 264,296 (85.11 %), with population growth rate was 2.52 % (average annual 1998-2017) (BRDCP 2017-2022). The Average Annual Growth Rate over the span 1981 - 98 was 1.51 % and from 1998 to 2017 it was 2.52% per year including both urban and rural populations. The investigation showed that the farming and developed regions expanded, to the detriment of backwoods and water bodies. For example, in the period from 2013 to 2021, 43.2% of forestland was changed over into cropland. A large portion of the networks in Balochistan live in good country regions, with 85% of the population relying upon farming for an occupation (Ashraf, & Routray, 2013). The population in Zhob showed a growth pattern during the chosen period, and the general populace development rate from 1991 to 2021 was 3.1%. Additionally, both the country and the metropolitan populaces showed a growth pattern, and around 62% of the complete populace of Zhob is under provincial regions. Therefore, the expansion of the agribusiness was connected with populace development and water system extension in the basin. Furthermore, the expansion in populace caused extension of developed region and urbanization from 1991 to 2021. Essentially, past examinations have demonstrated that the increases of cropland and settlement in Balochistan stem from quick population growth (Miheretu and Yimer, 2018). LU/LC changes occurred in a non-linear manner spatially and temporally, due to a number of factors ranging from natural processes to human interventions. Human interventions are dominating over the natural causes (Tolessa *et al.*, 2016). For example, an increase in population burdens the land, with increased production pursued by expansion of cropland.

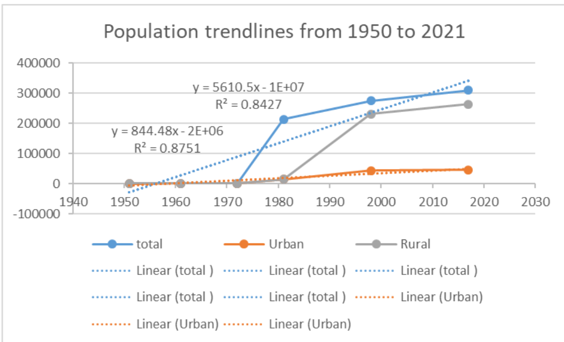

Figure 4. Population growth from 1950-2021 in the district of Zhob, Pakistan

4. Conclusions

LU/LC is the outcome of cooperation of various groups of factors, including both natural and human causes, in three decades in ZRB. In order to demonstrate visual interpretation, images were classified and processed by using ArcGIS and the expertise of remote sensing, to study the spatial distribution of LU/LC dynamics. The years 1991,

Table 4. Cultivated and uncultivated areas in the district of Zhob, Pakistan

Reported area	Cultivated area			Cropped area		Uncultivated area			
	Total	Current fallow	Net sown	Total	Area sown more than once	Total	Cultivable waste	Forest area	Area not available for cultivation
227,341	58,355	42,588	15,767	15,778	11	168,986	73,991	7,383	87,612

Source: GoB, 2014-15

2001, 2013 and 2021 were selected and classified in order to observe the LU/LC changes due to human intervention. The area was highly covered with vegetation, forest, and shrub-land, in the classification maps. This classification map showed that shrubland and forest areas have been reduced due to land required for agricultural practices to satisfy the demand for food. The unplanned urbanization has promoted deforestation and conversion of land. Rapid demographic increase was observed in the area, which affected the expansion of cropland and irrigation use. LU/LC dynamics explore the impacts of such factors as variability of precipitation pattern, agriculture activities, geographic changes, and food shortages.

The effects of LU changes on water resources and water irrigation are vital to the management policies and strategies. The main effects are conversion of land, water scarcity, deforestation, and mismanagement of LU. Therefore, ecologists and policy makers need to take action, preserve the land and reclaim it by studying multi-dimensional fields such as socioeconomics. Land management is mandatory for proper use of resources, infrastructure, and community development. The findings of this paper can help in developing effective environmental policies and management of LU/LC at national/international level for sustainable regional progress.

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