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# GIS-Based Analysis of Land Use and Land Cover Change Dynamics in Boricha Catchment, Central Main Rift Valley Lakes Basin of Ethiopia

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**ABSTRACT**

Land use and land cover (LULC) classification and its change detection is very important to understand the trend and to put strategies for managing land resources globally. Even if there are many techniques for LULC classification and change detection, using remote sensing data and Arc Map is an appropriate classifier and change detector. The major aim of this study is to classify and detect LULC change of Boricha Catchment, Central Main Rift Valley Lakes Basin of Ethiopia. In this research, supervised maximum likelihood classification techniques in GIS with Google earth pro is used. Landsat 7 image of 2003 and Landsat 8 image of 2013 and 2023 is used. Change detection is done by using simple excel formula from output of GIS LULC classification. Confusion matrix is also computed for accuracy assessment of the classification. From the study, six land use classes are identified: agriculture, barren land, forest, pasture, urban and water. The overall accuracy of LULC Classification for 2003, 2013 and 2023 is 91.2%, 91.5% and 92.9% respectively. The study also showed that a significant expansion of Agriculture, settlements, barren land and a significant reduction of forest, pasture and water due to population increase and urbanization. The finding revealed a pattern of unsustainable land conversion that threatens water resources and ecosystem services, necessitating urgent policy intervention to meets the needs of the present, without compromising the ability of future generations to meet their own needs in the study area.

**Keywords:** Arc Map, Boricha catchment, Ethiopia, LULC

## 1. Introduction

The term "land use and land cover" (LULC) is a composite that refers to both land use and land cover types. The distribution of plant, water, soil, and/or man-made structures on the earth's surface are examples of the physical characteristics of land cover (Ioannis & Meliadis, 2011; Moran et al., 2012). The most significant type of global environmental change that takes place at both spatial and temporal dimensions is LULC. Deforestation, agricultural land expansions, human settlements, and other factors resulting from population increase and environmental problems are the causes of this change in land use in both rural and urban areas. LULC change is a basic variable that affects and connects various elements of the physical and human contexts (Foody, 2002).

Because of this, it is essential to monitor and manage LULC changes using accurate and efficient technologies, particularly in developing nations where the population and economy are expanding quickly (Shahfahad et al., 2023). Therefore, accurate classification and change detection is necessary for LULC comprehension and mapping.

Because of their precise geo-referencing techniques, digital format appropriate for computer processing, and repetitive data acquisition, satellite remote sensing and GIS are the most widely used techniques for quantifying, mapping, and detecting patterns of LULC (Chen et al., 2005; Lu et al., 2004; Nuñez et al., 2008; Rahman et al., 2012). Additionally, they allowed for the quicker, less expensive, and more accurate study of LULC alterations (Hassan et al., 2016; Kafy et al., 2021; Rawat & Kumar, 2015; Roy et al., 2015).

There are a number of studies which tried to classify and detect LULC change in Ethiopia as well as in central main rift valley basin of Ethiopia. However, there are no research conducted regarding to LULC classification and which shows trends of LULC changes in Boricha catchment which is found in central main rift valley of Ethiopia, and also it is known that degradation pose a significant agro-ecological challenge in the catchment. Therefore, the main purpose of this study was to classify and detect the change in LULC for the year of 2003, 2013 and 2023 using remote sensing data and Arc Map. It is also anticipated that this study will assist decision makers in developing more effective plans, sustainable land development initiatives, and strategies to lessen the negative effects of high population growth and urbanization.

## 2. Methodology

### 2.1. Description of the study area

The Boricha catchment is situated between latitudes 6°45'30.779''N - 7°1'40.565''N and longitudes 38°4'32.654''E - 38°23'38.045''E in the Central Main Rift valley basin of Ethiopia (Figure 1). It is located in the administrative areas of Sidama region and has an area of 61901 hectares. It consists of 39 Kebeles, three of which are urban and the rest are agricultural with an overall population of 250,260, of whom 125,524 are men and 124,736 women. Only 10,402 or 4.16% of its population are urban dwellers. The main land use of the Woreda is dominated by rain fed agriculture which is owned by smallholder producers. The major crops by coverage are maize, haricot bean, coffee, horticultural crops and teff (CSA, 2007). It stretches from 1320 meters above sea level at the lowest point near the mouth of a branch of the Bilate river to 2080 meters above sea level in the northeast (Bechaye, 2011). Its temperature varies between 21.930C in July and 25.360C in February, and the rainfall pattern varies from 27.82mm mean minimum rainfall in December to the mean maximum rainfall 128.58mm in October.

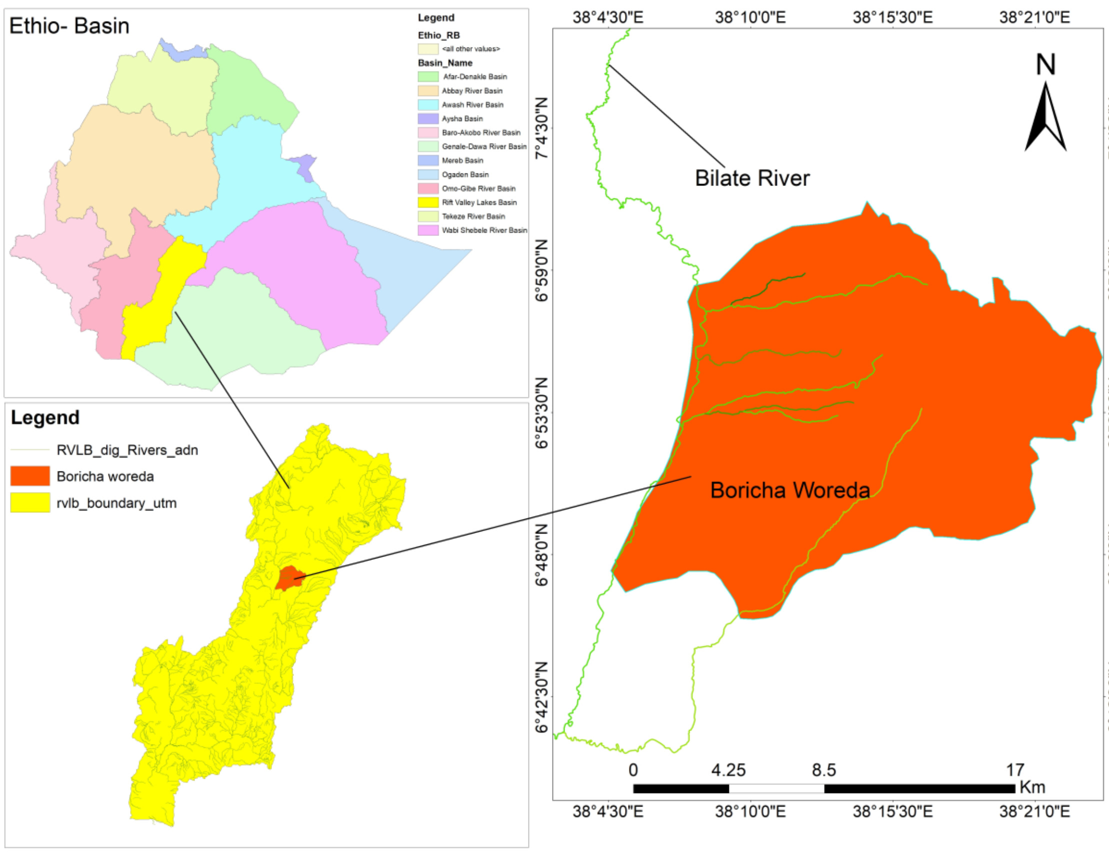


*Figure 1: Location map of Boricha catchment*

## 2.2 Landsat data preparation

Now a day's global use of satellite imagery, such as Landsat data, in research on LULC changes detection is becoming well known. Since cloud-free images are not easy to find, cloud cover less than 10% multi-spectral satellite images for the year 2003, 2013, and 2023 were downloaded from the United States Geological Survey Earth Resources Observation and Science (USGS EROS) center available at http://glovis.usgs.gov/. This study utilizes Landsat 7 imagery for 2003 and Landsat 8 imagery for 2013 and 2023 (Table 1). The years are selected by considering the study year to be 2023 and with gap of 10 years backward for two additional years (i.e. 2023, 2013 and 2003).

*Table 1: Characteristics of satellite images*

| Satellite and Sensor | Date acquired | Resolution(m) | Path/row |
|---|---|---|---|
| Landsat 7 (ETM) | 01/12/2003 | 30 | 168/55 |
| Landsat 8 (OLI-TIRS) | 01/12/2013 | 30 | 168/55 |
| Landsat 8 (OLI-TIRS) | 11/12/2023 | 30 | 168/55 |

## 2.3 Classification of Landsat images

Most researchers categorize land use land cover classification methods in to three major categories. These are supervised, unsupervised and hybrid. Since supervised classification method is easy to evaluate and more accurate, it is used in this study. It requires the manual identification of point of interest areas as reference or ground truth within the images, to determine the spectral signature of identified features. Therefore, Maximum likelihood classifier (MLC) of Arc Map 10.7 is used in conjugation with Google earth pro to classify LULC of the study area (Figure 2).

## 2.4 Accuracy assessment for LULC classification

A prerequisite for LULC change detection is the evaluation of categorization accuracy (Wang et al., 2021). This is important to evaluate the correctness and precision of the classified images. In this study, 300 accuracy assessment points are generated from the classified images of each year by using stratified sampling methods in Arc Map 10.7. After importing these points as a KML file to Google Earth Pro and using previous field knowledge of the study area, the validation process is done and the confusion matrix is computed. The overall accuracy and the kappa coefficient, which are obtained from the confusion matrix, were then used to assess the classification accuracy.

According to Wang et al., (2021) kappa values < 0 denote no agreement, 0 – 0.2 slight, 0.0 – 0.41 bad, 0.41– 0.60 moderate, 0.60 – 0.80 significant, and 0.81–1.0 practically perfect agreement. According to Anderson (1976), the LULC classification cannot be accepted unless the overall accuracy is greater than 85%.

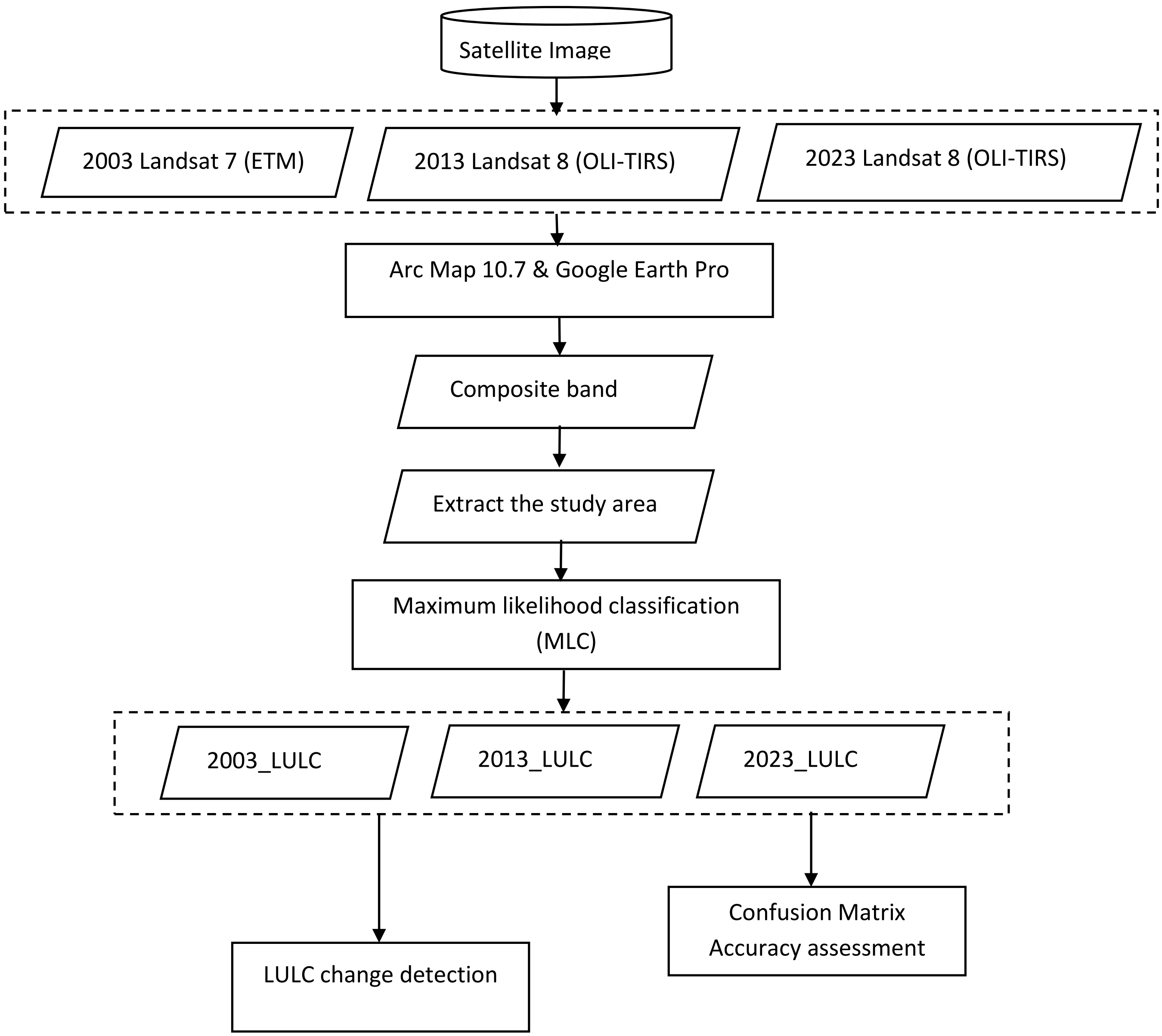


*Figure 2: Methodological framework*

### 2.5 Change detection of LULC

Finding changes of LULC in two or more images of the study area taken at different times is the main goal of the LULC change detection technique (Mariye et al., 2022). For the purpose of determining changes that have taken place in a certain area, change detection is utilized (Singh, 1989). Microsoft Excel 2016 is used to calculate both graphical and statistical LULC change detection for the respective year. Equations **Error! Reference source not found.** and **Error! Reference source not found.** is used to calculate the area and percent of change for each LULC (Leta et al., 2021).

$$\% \text{ of change} = \left(\frac{\text{Current year} - \text{Previous year}}{\text{Previous year}}\right) * 100 \qquad (1)$$

$$\text{Area change} = (\text{Current year} - \text{Previous year}) \qquad (2)$$

## 3. Result and Discussions

The study area was classified in to six land use types. It includes Agriculture, Barren land, Forest, Pasture, Urban and Water (Table 2 and Figure 3).

*Table 2: Principal LULC types with descriptions (Hassan et al., 2016b; Leta et al., 2021)*

| Class value | LULC type | Description |
|---|---|---|
| 1 | Agriculture | Includes areas used for perennial and annual crop production, irrigated areas, commercial farms |
| 2 | Barren land | Includes land areas of exposed soil, bare soil and barren area |
| 3 | Forest | Areas covered with dense trees (deciduous forests, evergreen forests, mixed forests) |
| 4 | Pasture | Areas covered by grasses, small trees, bushes, and shrubs |
| 5 | Urban | Includes commercial areas, urban, residential, and rural settlements, industrial areas |
| 6 | Water | Areas covered by rivers, streams, canals and reservoir |

For LULC 2003, barren land covers the highest (33.2%) and urban area cover the lowest (0.8%). Water bodies make up the lowest percentage (0.8%) and Barren lands the highest (36.4%) of the LULC 2013. Image classification of 2023 LULC shows that Agricultural lands covers most of the study area (35%) and water bodies cover the least areas (0.5%). The LULC classes percentage coverage is shown in **Error! Reference source not found.**.

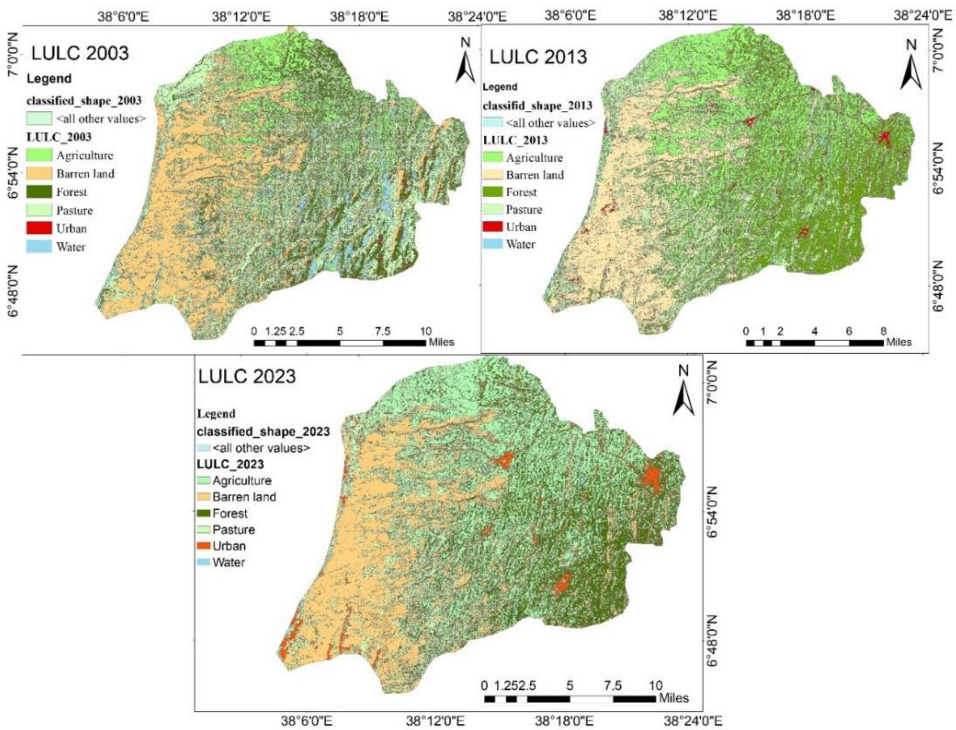


*Figure 3: Different LULC types*

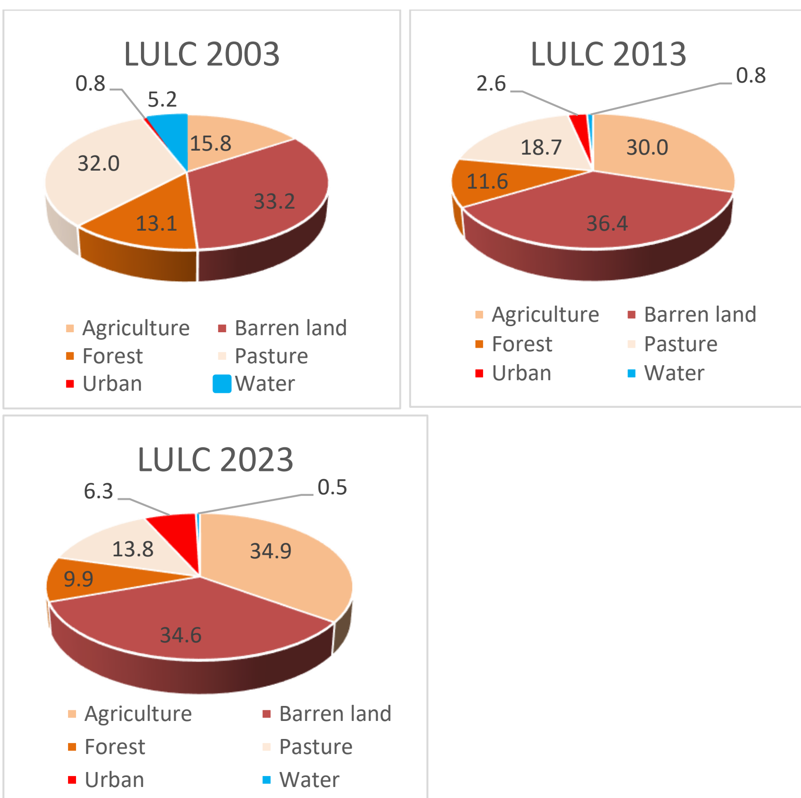


*Figure 4: Percentage Coverage of LULC classified*

The findings of the post-classification accuracy assessment indicated that the year 2003 had the lowest overall accuracy evaluation (90.2%), while the year 2023 had the greatest overall accuracy evaluation (92.9%) (Table 3).

*Table 3. Overall accuracy and Kappa coefficient*

| Accuracy indicators | LULC classification year | | |
|---|---|---|---|
| | 2003 | 2013 | 2023 |
| Overall accuracy | 91.2% | 91.5% | 92.9% |
| Kappa coefficient | 88.8% | 89.4% | 90.9% |

According to Table 3, the overall accuracy for each of the three years exceeded the 85% accuracy limit for a reliable LULC categorization(Anderson, 1976) . Additionally, it shows that the Kappa coefficient for the entire LULC classification year falls between 81% and 100%, which suggests that the referred images and the categorized image are very compatible(Anderson, 1976).

Over the past 20 years (2003–2023), the only land use types that have increased in area coverage are urban, agriculture land and barren land in ascending order (Table 4). Urban areas, agriculture land and barren land are increased by 729.7%, 121.9% and 4.5%. This demonstrates how the last 20 years have seen a major increase in urbanization, placing pressure on and absorbing rural territory. Furthermore, the majority of the study region is covered by barren land, even though these LULC type have only slightly increased over the previous 20 years relative to other LULC. Generally, since the areas to the lower altitude are severely degraded (barren land) and there was significant land use conversion in to urban areas and agriculture, it needs high attention of land use planning and management practices.

*Table 4. LULC change detection*

| LULC type | LULC Area ($km^2$) | | | Area change($km^2$) | | | % of change | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2013 | 2023 | 2003-2013 | 2013-2023 | 2003-2023 | 2003-2013 | 2013-2023 | 2003-2023 |
| Agriculture | 95.5 | 181.8 | 212.0 | 86.3 | 30.2 | 116.5 | 90.3 | 16.6 | 121.9 |
| Barren land | 200.9 | 220.3 | 210.0 | 19.4 | -10.3 | 9.1 | 9.6 | -4.7 | 4.5 |
| Forest | 79.4 | 70.0 | 60.0 | -9.4 | -10.0 | -19.4 | -11.8 | -14.3 | -24.4 |
| Pasture | 193.9 | 113.3 | 84.0 | -80.6 | -29.3 | -109.9 | -41.6 | -25.8 | -56.7 |
| Urban | 4.6 | 15.5 | 38.0 | 10.9 | 22.5 | 33.4 | 237.5 | 145.9 | 729.7 |
| Water | 31.4 | 4.9 | 3.0 | -26.5 | -1.9 | -28.4 | -84.5 | -38.4 | -90.4 |

## 4. Conclusion

The classification of the different land types and the detection of LULC changes in the Boricha catchment were carried out using Arc Map 10.7, Google Earth Pro, and prior research area knowledge for the years 2003, 2013, and 2023. The accuracy of the classification was also assessed by computing a confusion matrix. This led to the study area's classification into six different land use categories: agriculture, pasture, forest, urban, and water. The classification is reliable because

The overall accuracy for the three respective years is greater than the minimum accuracy value (85%). And also, there is strong agreement with the classified image and referenced images since Kappa coefficient for the whole the respective LULC classification year is between 81% and 100%. During the previous twenty years, there has been a rise of 729.7%, 121.9%, and 4.5% in urban areas, agricultural land, and barren land. This illustrates how urbanization has significantly increased during the past 20 years, putting pressure on and absorbing rural land.

Furthermore, although barren land has only minimally increased over the preceding 20 years relative to other LULC, the majority of the research region is covered by barren land. In general, land use planning and management techniques require close attention because the lower altitude regions are badly degraded (barren land) and there is substantial land use conversion to urban areas and agricultural in the cost of forest, pasture, and water bodies.

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**Conflict of interest**

The authors declare no conflicts of interest in relation to this study.

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