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Analysis of land use/land cover change trends over Birr River Watershed, Abbay Basin, Ethiopia☆

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ABSTRACT

Changes in land use/land cover (LULC) are a global environmental concern that has a significant impact on sustainable land and water resource management and development as well as hydrological processes. The primary driving forces of LULC changes in developing countries are population pressure, demand for firewood collection and construction material, shortage of cultivated land, land tenure insecurity, and deforestation. Focusing on the Ethiopian Birr river watershed, the study investigates changes in LULC trends, extents, and magnitudes over the last 32 years using geospatial technologies such as Landsat images of 1986, 2001, and 2018. The supervised land use land cover classification technique was applied to classify the LULC classes using the maximum likelihood algorithm technique. Between 1986 and 2018, agricultural land increased significantly from 56.39% to 70.19%, while settlements increased from 0.73%) to 1.42%. On the other hand, bushlands, forest areas, and grasslands LULC classes in the study area decreased from 26.18% to 19.30%, 4.94%–1.92%, and 11.77%–7.16%, respectively. The findings suggest that integrated watershed management and land use planning should be concerned and implemented in the Birr River watershed.

Author contribution

Demelash Ademe Malede: idea conceptualization, methodology, data curation and analysis, investigation, original draft, writing review, editing, visualizing. **Tena Alamirew:** idea conceptualization, methodology, review, edit, visualization, and supervision. **Job Rotich Kosgie:** idea conceptualization, review, edit, and supervision. **Tesfa Gebrie Andualem:** writing review, editing, and visualization.

1. Introduction

Changes in land use/land cover (LULC) are the conversion of different land-use classes to the earth's terrestrial surface, which are typically the outcome of complicated interactions between the natural environment and anthropogenic processes (Dinka and Chaka, 2019; Pielke et al., 2011). LULC changes are a significant driver of global change, affecting the sustainable environmental management, development of land and water resources, ecosystem services, and hydrological processes (Basommi et al., 2016; Behera et al., 2012; Verburg et al., 2004). Changes in land use have been increasingly influenced by anthropogenic activities on a scale and magnitude that is unidentified in different areas (Wang and Yang, 2020). These changes in land use are primarily driven by population growth, agricultural expansion, urbanization, increasing energy and food demands, and changes in lifestyle and socio-economic conditions. Thus, LULC change analysis is an important source of data for decision support systems for policymakers (Tewabe and Fentahun, 2020).

Agricultural expansion is responsible for almost 90% of global

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deforestation, which has a much greater impact than previously believed (FAO, 2018). One of the world's most serious challenges is forest degradation (Mitchell et al., 2017; Ranagalage et al., 2020). More than half of global forest loss is due to the conversion of forests into agricultural land. To feed the world's rapidly growing population, agriculture is increasingly putting stress on forest natural resources (Deribew and Dalacho, 2019; Negassa et al., 2020). Deforestation in developing countries such as Ethiopia is primarily caused by the expansion of cultivated land and the production of charcoal and timber (Moisa et al., 2022; Regasa et al., 2021). Due to agricultural expansion, overgrazing, settlements, and charcoal production, Ethiopia experienced a rapid decline in forest cover (Kindu et al., 2016; Tesfahunegn, 2016). For instance, forest cover deteriorated from 35% in the early 20th century to 2.4% in 1992 (Sayer et al., 1992). However, the Ethiopian government has been planning and implementing afforestation, and reforestation programs since 2010 (Takele et al., 2022). Though, the effectiveness of the afforestation program, as well as its impact on LULC, and hydrology has received little attention and has not been thoroughly studied.

LULC changes have a variety of negative socio-economic and environmental consequences, including decreased agricultural yield, increased vulnerability to natural hazards (flood, drought, fires), altered ecosystem services, and surface runoff trends (Barlow et al., 2016; Butt et al., 2015; Jin and Fan, 2018; Moisa et al., 2022). Furthermore, LULC affects the earth's terrestrial ecology, hydrological cycle, climate, and geomorphology (Bisri et al., 2017; Dinka, 2012; Negassa et al., 2020). Therefore, analysis and monitoring of LULC changes are important for understanding the extent and magnitude of changes, as well as handling appropriate integrated watershed management (Shimizu et al., 2019). Several studies on LULC change analysis have been conducted in various parts of Ethiopia (Feyissa and Gebremariam, 2018; Geeraert et al., 2019; Minta et al., 2018; Tolessa et al., 2017). However, very little is known about the current state and magnitude of LULC change in the Birr River watershed. Moreover, a recent study discovered a decrease in LULC caused by the natural environment, which was primarily attributed to human activities like population growth, and economic development (Kuma et al., 2022; Näschen et al., 2019). The watershed is located in the northwestern highlands of Ethiopia between the longitude of 37° 10' and 38° 50' E and the latitude of 10° 30' and 11° 10' N. Because of population growth and climate change, anthropogenic activities in the watershed have significantly altered natural landscapes. Thus, understanding the pattern of these LULC changes is important for efficient watershed management.

Deforestation and agricultural land encouragement are the primary causes of land degradation, particularly in Ethiopian highlands and marginal land (Abebe et al., 2022; Bewket, 2002; Shiferaw and Singh, 2015; Teferi et al., 2013). For example, Abebe et al. (2022) reported that cultivated and settlement are the most numerous types of LULC and increased by 9% extent. Furthermore, a consistent trend of increased agricultural fields and settlement coverage, with a significant reduction of forest and shrublands, contributed to an increase in soil erosion, with negative consequences for the basin hillslopes (Asitatikie and Hishe, 2020; Galata, 2020; Regasa and Land, 2022; Tewabe and Fentahun, 2020). The population size of Ethiopia has increased at an alarming rate, with 40 million in 1984 (Central Statistical Agency (CSA), 1991), and 73 million in 2007 (Central Statistical Agency (CSA), 2007), and this is anticipated to be 130 million in 2030. More than 85% of the country's population lives in rural areas and relies heavily on subsistence agriculture for their living, resulting in increased resource demand (Berry et al., 2003).

The dynamics of LULC change extent, magnitude, and trends are changing and are strongly linked to natural resource overexploitation; this process is governed by climate, soil characteristics, vegetation density, topography, and natural hazards (Anteneh, 2022). Human pressure has increased significantly over the last decades, and therefore the process has been accelerated. Birr River watershed stretches from the southern side of Mount Adama to Temcha River junctions, which finally join the Abbay Rivers (BDU, 2017). Shrubland, grazing, forest, and steep slopes in the watershed are being converted into agricultural land for crop production, which leads to severe land degradation. This has an impact on the drainage of shallow water tables, increasing surface runoff, and reducing croplands availability. The novelty of our study is that it updates LULC information, maps, and monitors LULC changes in extent, trend, and magnitudes that all of which are of critical and valuable importance for sustainable development and for monitoring environmental change. Therefore, this study aimed to analyze the trends and changes in land use and land cover dynamics over the Birr River watershed using Satellite image data with the help of the geographical information system (GIS) and earth resource data analysis system (ERDAS) imagine 2015 software. The findings of this study could provide reference point information about the trend, extent, and magnitude change of LULC in the Birr River watershed to monitor and evaluate the watershed's physical dynamics. Furthermore, the study reveals valuable information on the regional and national governments, decision-makers, stakeholders, and local community awareness of sustainable natural resource management.

2. Materials and methods

2.1. Study area

The Birr River watershed is situated in the northwestern highlands of Ethiopia. Geographically, the Birr watershed is located between the longitude of 37° 10' and 38° 50' E and the latitude of 10° 30' and 11° 10' N. The watershed's elevation ranges between 1691 and 4084 m above the mean sea level (Fig. 1). The total drainage area of the watershed is 1500 km^2 and based on the rainfall patterns, the area has 3 separate periods: the main rainy season from June to September, the small rainy season from February to May, and the dry season from October to February (Bekele et al., 2019; Gebere et al., 2015). Based on 32 years of recorded data (1986–2018) obtained from nearby representative meteorological stations, the estimated mean annual rainfall for the Birr River watershed is 1389 mm (Malede et al., 2022). The maximum temperature ranges between 23 and 30 °C, while the minimum temperature varied between 8 and 12 °C, with an average temperature of 18 °C (Bekele et al., 2019).

There are six major soil types found in the Birr River watershed, which include Haplic Alisols, Eutric Fluvisols, Haplic Luvisols, Eutrc Leptosols, Haplic Nitisols, and Eutric Vertisols (Fig. 3). Amongst all soil types, Haplic Alisols is the greatest dominated soil types, accounting for approximately 816 km^2 (59.78%) followed by Eutric Fluvisols 236 km^2 (17.29%), Eutrc Leptosols 125 km^2 (9.16%), Haplic Luvisols 96 km^2 (7.03%), Haplic Nitisols 65 km^2 (4.76%), and Eutric Vertisols 5 km^2 (0.37%). The soil map was found by the Ethiopian Ministry of Water, Irrigation, and Energy (MoWIE). Agricultural land, bushland, forest area, grassland, and settlements are the main LULC types in the Birr River watershed. Rainfed agriculture is the predominant crop cultivation method, with maize, teff, sorghum, barley, wheat, bean, and peas being the most well-known crops and the main stable crop is maize (Bekele et al., 2019). The Birr River watershed is important to both local and national communities, due to its high irrigation potential, the high value of cash crops, livestock production, and tourism, as well as the presence of an impressive landscape, and unique source of biological diversity (Bekele et al., 2019; Minwyelet, 2014).

2.2. Data acquisition and processing

Satellite imagery from 1986, 2001, and 2018 was used to identify the changing pattern of LULC in the Birr River watershed (Fig. 2). These Landsat images of the study area were freely downloaded from https://earthexplorer.usgs.gov/. The Landsat images were selected based on: the availability and quality of the satellite images available in the

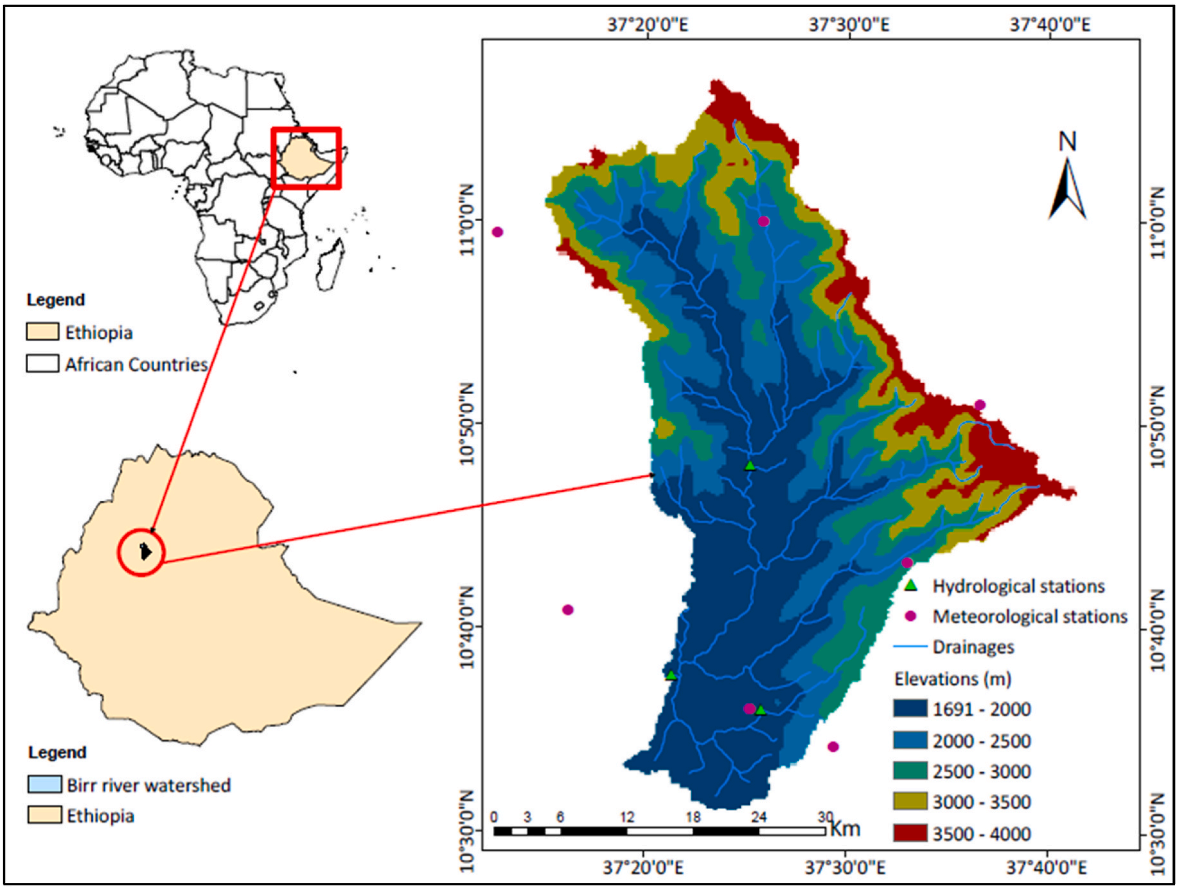

Fig. 1. Location map of the study area, meteorological and hydrological gauging stations.

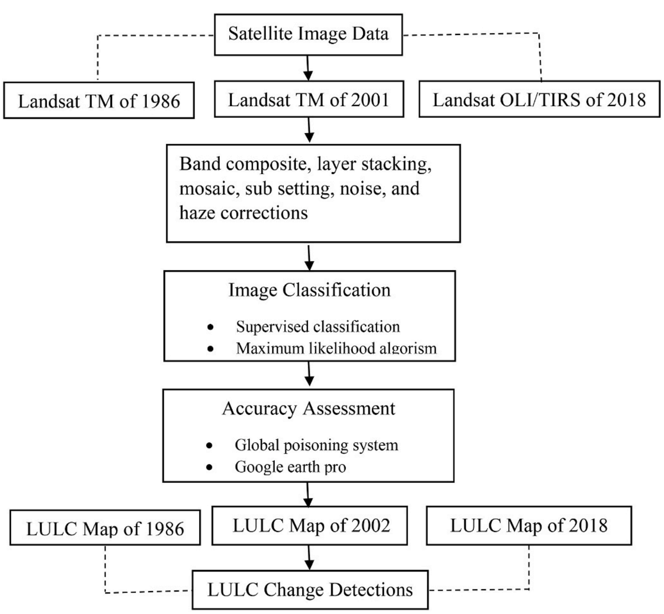

Fig. 2. A flowchart for detecting changes in land use and land cover.

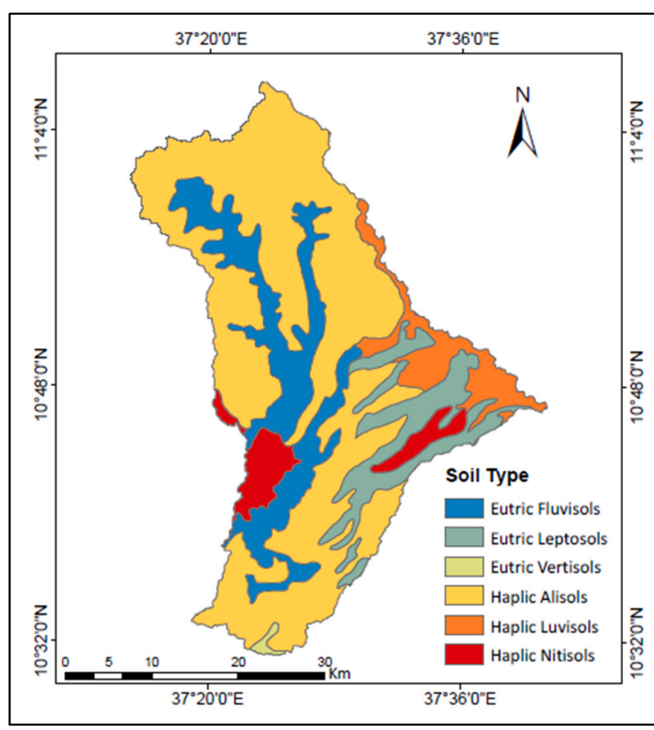

Fig. 3. Major soil types in the Birr River watershed (source: MoWIE).

study area for each decade in the USGS database, significant LULC changes period in the study area by field observation and interviews with local communities, the biophysical environment and socioeconomic activities based on the discussion of local communities, key informants, and administrative agricultural office experts. Landsat images from the dry season and without clouds were used because they are easier to analyze. To avoid the impact of seasonal variation, cloud cover in the atmosphere on the image quality all Landsat image was acquired during the dry (winter) season, and to obtain cloud-free images and real land cover features (Mengistie Kindu et al., 2013). The Landsat image has a spatial resolution of 30*30 m (see Table 1).

Each Landsat image is processed using the earth resource data analysis system (ERDAS) imagine 2015 software. The ERDAS imagine 2015 software is important by increasing the productivity of simplifying for classifications, orthorectification, mosaicking, reprojection, map production, and change detection (Twisa and Buchroithner, 2019). Before LULC classification, image preprocessing such as band composite, layer stacking, mosaic, sub-setting, noise, and haze correction was performed. A LULC classification method was developed based on previous information on the Birr watershed, with the help of google earth pro, GPS surveying in the watershed, information from Kuarit, Dembecha, and Jabitenan Administrative agricultural office, and interviews with local communities and stakeholders (Table 2). Using the supervised classification method, various spectral signatures associated with each land use class were used based on a chosen representative sample of a known LULC type in each training site.

2.3. The LULC classes

Because of the prevalent land covers, the spectral responses of features on Landsat images, extensive field observation, and a literature review, the Birr River watershed was divided into five major LULC classes or types that were generated namely; agricultural, bushland, forest, grassland, and settlement (Table 2). Then, using a maximum likelihood algorithm, a supervised classification method was used. The LULC classes and their description were stated by (Jaleta et al., 2016).

2.4. Accuracy assessment of LULC classification

The accuracy assessment of a classified image is important for analyzing LULC changes and determining the classification process's acceptability. A total of 250 reference data points were used to ensure that all five LULC classes were adequately represented based on their proportional area. The reference ground truth data was chosen in such a way that it appears in both the Landsat images for the respective period of 1986, 20021, and 2018 and the google earth map. Additionally, the validation of land use types with local datasets, and visual inspections were used and adapted to retrieve the reference data. The producer's accuracy (PA), user's accuracy (UA), overall accuracy (OA), and kappa coefficient (K) was used to evaluate the LULC classification accuracy, which is comprised of a 'confusion matrix' or 'error matrix' (Liu et al., 2006). The total number of correctly classified pixels is divided by the total number of referenced pixels in the matrix yielding the overall accuracy (Eq. (1)) (Tilahun and Teferie, 2015). When all elements of the error matrix are considered, the Kappa coefficient measures the degree of agreement between two maps (eq. (2)) (Jensen and Cowen, 1999).

$$\text{Overall Accuracy} = \frac{\text{Total Number of Correctly Classified Pixels (Diagonal)}}{\text{Total Number of Reference pixels}} \times 100 \tag{1}$$

$$\text{Koppa Coefficient (T)} = \frac{(\text{Total sample} \times \text{Total corrected sample}) - \sum(\text{Column Total} \times \text{Row Total})}{\text{Total sample}^2 - \sum(\text{Column Total} - \text{Row Total})} \times 100 \tag{2}$$

Kappa coefficient statistics criteria agreements are as follows: poor when Kappa <0.4, good when $0.4 <$ kappa <0.7, and excellent when k > 0.75 (Ismail and Jusoff, 2008).

A post-classification was performed using each classified Landsat image. Then, each classified LULC map from 1986 to 2001, 2001–2018, and 1986–2018 was compared. Arc GIS 10.4, EDAS imagine 2015 software, and Google earth pro was successfully used to analyze and detect the classified Landsat image.

Table 1
Satellite data acquisition in the study area.

Source	Sensors	Path/row	Spatial resolution	Acquisition date
Earth explorer. usgs.gov	Landsat TM	169/053	30 m × 30 m	1986-01-12
	Landsat TM	169/053	30 m × 30 m	2001-02-22
	Landsat OLI/TIRS	169/053	30 m × 30 m	2018-02-05

Table 2
Description of LULC classes in the Birr River watershed.

LULC classes	Description of LULC classes
Agricultural land	Enclosed with permanent crops, following land, and irrigated cultivation
Bushlands	Covered with small to medium-sized perennial woody or natural vegetation
Forest land	Trees taller than 5 m and covering more than 0.5 ha of land
Grasslands	Terrestrial vegetation dominated by grass, suitable for grazing by livestock
Settlements	Built-up areas and roads, the establishment of a person in a new region

2.5. Trends of LULC change analysis

The significance of LULC change trend analysis is that determines which land use class or type is transitioning to other land uses (Tewabe and Fentahun, 2020). Land cover classification comparisons, from 1986 to 2001, 2001–2018, and 1986–2018 were used to analyze and detect the trend of changes in LULC in the Birr River watershed. The watershed area covered by each LULC class in various periods was compared. Then, for each LULC class, the direction of change was determined. The trend of LULC analysis provides information about the magnitude, extent, and trend of conversions in terms of temporally. The magnitude of the changes between two periods was used to compute the percent and rate of changes (Eq. (3))

$$\textit{Rate of change}\left(\frac{km^2}{Year}\right) = \frac{A2 - A1}{Z} \tag{3}$$

where A2 is the area of LULC (km^2) in period 2, A1 is the area of LULC (km^2) in period 1, and Z is the period interval in years between A2 and A1.

3. Results

3.1. Analysis of LULC classification

In the Birr River watershed, five major LULC types (agricultural land, bushland, forest, grassland, and settlements) were used during the

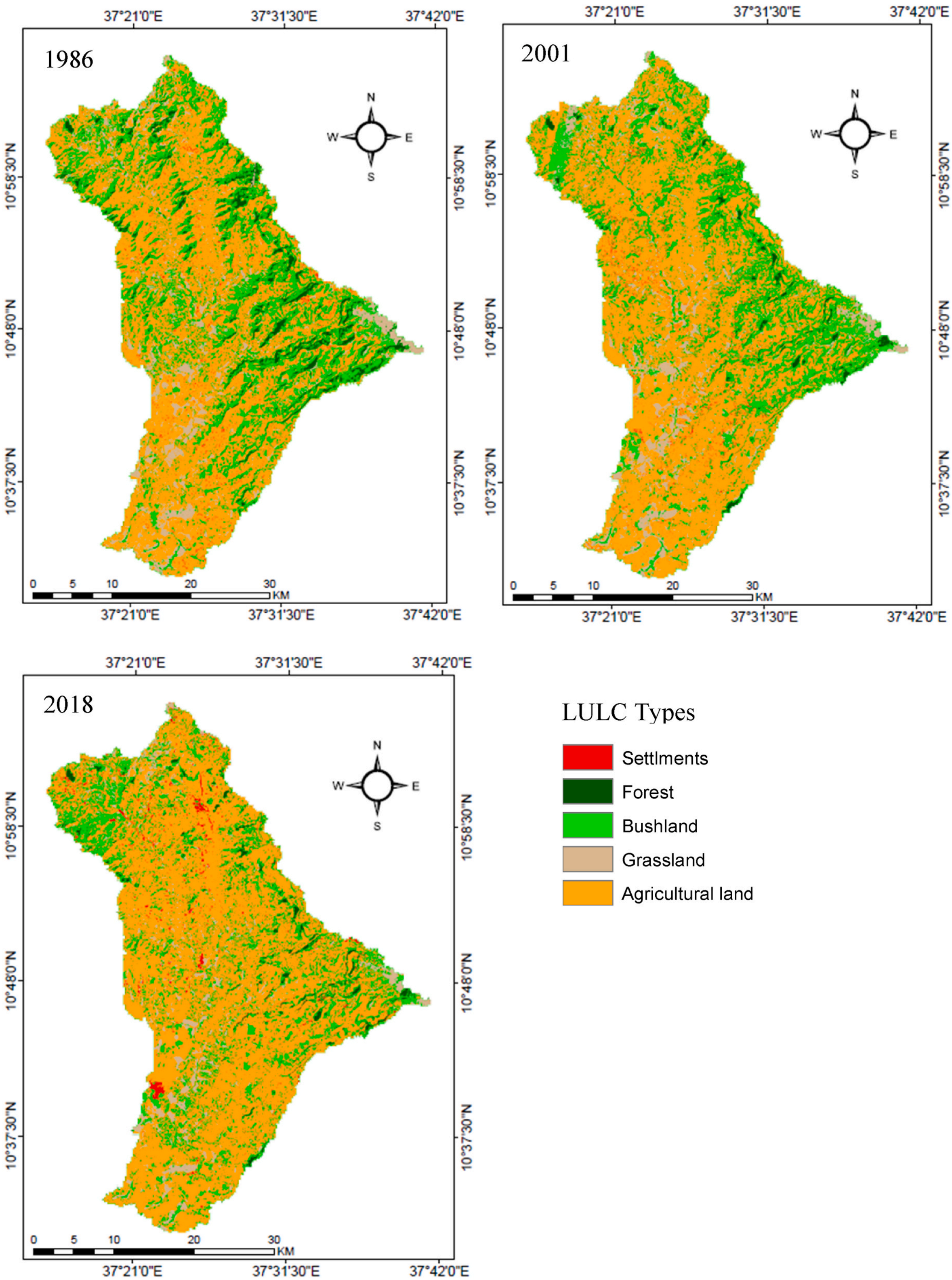

Fig. 4. Classified land use land cover map of Birr watershed 1986, 2001, and 2018, respectively.

classification of Landsat images (1986, 2001, and 2018) (Fig. 4). Table 3 summarizes the area coverage in kilometer squares (km^2) and percentage (%) of each LULC classes over the Birr River watershed for the three time periods (1986, 2001, and 2018). In 1986, agriculture and bushland constituted the majority of the study area, covering an area of 773.04 km^2 (56.39%) and 358.91 km^2 (26.18%), respectively, whereas forest, grassland, and settlements occupied an area of 67.69 km^2 (4.94%), 161.38 km^2 (11.27%), and 9.96 km^2 (0.73%), respectively according to the LULC classification schemes in the study area.

Similarly, in 2001 the majority of LULC classes were agriculture and Bushland, which covered an area of 849.90 km^2 (61.99%) and 326.35 km^2 (23.80%), respectively. Forest, grassland, and settlements occupied

Table 3
The area coverage in kilometer squares (km^2) and percentage (%) of LULC classes in the Birr River watershed.

LULC classes	LULC area in kilometer squares (km^2) and percentage (%)					
	1986		2001		2018	
	km^2	%	km^2	%	km^2	%
Agricultural land	773.04	56.39	849.90	61.99	962.34	70.19
Bushland	358.91	26.18	326.35	23.80	264.64	19.30
Forest	67.69	4.94	24.23	1.77	26.39	1.92
Grassland	161.38	11.77	154.26	11.25	98.22	7.16
Settlements	9.96	0.73	16.25	1.19	19.40	1.42

Table 4
Rate of LULC changes between 1986 and 2001.

LULC classes	1986	2001	Change in 1986 and 2001		Rate of changes	
	km^2	km^2	km^2	%	km^2/year	%
Agricultural land	773.04	849.90	76.86	9.94	2.40	0.31
Bushland	358.91	326.35	−32.56	−9.01	−1.02	−0.28
Forest	67.69	24.23	−43.46	−0.64	−1.36	−2.01
Grassland	161.38	154.26	−7.12	−4.41	−0.22	−0.14
Settlements	9.96	16.25	6.29	43.15	0.20	1.97

an area of 24.23 km^2 (1.77%), 154.26 km^2 (11.25%), and 16.25 km^2 (1.19%), respectively, during the same period. Furthermore, 2018 LULC classification types also indicate that agriculture and bushland comprise the greatest share of all other LULC classes, which occupied 962.34 km^2 (70.19%) and 154.26 km^2 (19.30%), respectively, while forest, grassland, and settlements LULC classes occupied an area of 26.39 km^2 (1.92%), 98.22 km^2 (7.16%), and 19.40 km^2 (1.42%), respectively (Table 4).

Agriculture and bushland covered the largest area in the watershed than the other LULC types in all three years (1986, 2001, and 2018), whereas forest and settlements covered less area. Similarly, Badasa et al. (2022) indicated that the coverage of agricultural land is higher than other LULC classes in the Geba watershed, western Ethiopia from 1990 to 2020. LULC of forests is being converted into cultivated land settlements, due to the high population increase in the Geba watershed (Mekuriaw, 2019). Human activities have reduced forest cover in most parts of Ethiopia (Abera et al., 2020).

The LULC map from 1986, 2001, and 2018 were used to assess the classified accuracy. Based on the accuracy of 1986, 2001, and 2018 LULC maps, the overall accuracies were 90.69, 91.01, and 92.22% respectively, while kappa coefficients were 0.87, 0.88, and 0.89 respectively. Therefore, these results indicate that the classified map and ground truth LULC classes were agreed upon. The classified map also established the minimum accuracy required for the subsequent post-classification operations (Munthali et al., 2019).

Table 5
Rate of LULC changes between 2001 and 2018.

LULC classes	2001	2018	Change in 2001 and 2018		Rate of changes	
	km^2	km^2	km^2	%	km^2/year	%
Agricultural land	849.90	962.34	112.44	13.23	3.51	0.41
Bushland	326.35	264.64	−61.71	−18.91	−1.93	−0.59
Forest	24.23	26.39	2.16	8.91	0.07	0.28
Grassland	154.26	98.22	−56.04	−36.33	−1.75	−1.13
Settlements	16.25	19.40	3.15	19.38	0.10	0.60

Table 6
Rate of LULC changes between 1986 and 2018.

LULC classes	1986	2018	Change in 1986 and 2018		Rate of changes	
	km^2	km^2	km^2	%	km^2/year	%
Agricultural land	773.04	962.34	189.3	24.49	5.92	0.77
Bushland	358.91	264.64	−94.27	−26.27	−2.95	−0.82
Forest	67.69	26.39	−41.30	−61.01	−1.29	−1.91
Grassland	161.38	98.22	−63.16	−39.14	−1.97	−1.22
Settlements	9.96	19.40	9.44	54.78	0.31	2.96

3.2. Extent and rate of LULC change

For three time periods, the extent and rates of changes for each LULC were summarized below: 1986, 2001, and 2018 (Tables 4–6). Agricultural land and settlements increased by 9.94% and 43.15%, respectively between 1986 and 2001. In contrast, bushland, Forest, and grassland all showed a decreased trend of −9.01%, −0.64%, and −4.4% respectively in the same period (Table 4). Agriculture and settlements had an increasing LULC change pattern, while bushland, forest, and grasslands had a decreasing trend in the study area. From 1986 to 2001, agricultural land and settlements have grown at a rate of 2.40 km^2/year (0.31%) and 0.20 km^2/year (1.97%), respectively. In contrast, bushland, Forest, and grassland all dropped at a rate of −1.02 km^2/year (−0.28%), −1.36 km^2/year (−2.01%), and −0.22 km^2/year (−0.14%), respectively. The findings show that forest cover, bushland, and grassland in the Birr River watershed have been decreasing, which is consistent with previous research (Belay and D.M, 2019; Negassa et al., 2020; Nigatu Gebreyes et al., 2010). The reduction of forest, bushland, and grassland are due to agricultural and settlement expansions, which worsens soil erosion and land degradation problems in developing countries (Moisa et al., 2022).

In addition, the extent and rate of change in LULC between 201 and 2018 were presented in (Table 5). During this period (2001 and 2018) agricultural land, forest and settlements have increased by 13.23%, 8.91%, and 19.38%, respectively. On the other hand, bushland and grassland had decreased by −18.91% and −36.33% respectively (Table 5). Agricultural land, Forest, and settlement growth rates have also increased by 0.41%, and 0.60% respectively. Bushland and grassland, on the other hand, fell at rates of −0.59%, and −1.13%, respectively. The agricultural land expansion increased to produce more crops at the expense of grassland and bushlands, which leads to land and soil degradation (Abebe et al., 2022). Forest cover, on the other hand, showed an increasing trend from 2001 to 2018 in the study area. These findings were consistent with an earlier study by Takele et al. (2022) who reported that coverage of forests has been increasing since 2010, mainly as a result of the recently Ethiopian government-planned afforestation and reforestation package programs.

The extent and rate of LULC change patterns from 1986 to 2018 are also presented in (Table 6). Agricultural land and settlements increased by 24.49%, and 54.78%, respectively during this period, following the same trend from 1986 to 2001, whereas bushland, forest, and grasslands had a decreasing trend in the study area. The rate of change in agricultural land and settlements was also raised by 0.77% and 2.96%, respectively. Bushland, forest, and grasslands had also dropped by −0.82%), −1.91%, and −1.22% respectively (Table 6). Similarly, Ewunetu et al. (2021) showed the highest gain in agricultural land was obtained from grassland and bushland in the North Gojjam sub-basin from 1986 to 2017.

3.3. Trend of LULC changes

The agricultural land and settlements revealed an increasing trend increasing from 79.86 km^2 to 189.30 km^2 and 6.29 km^2–9.44 km^2 for

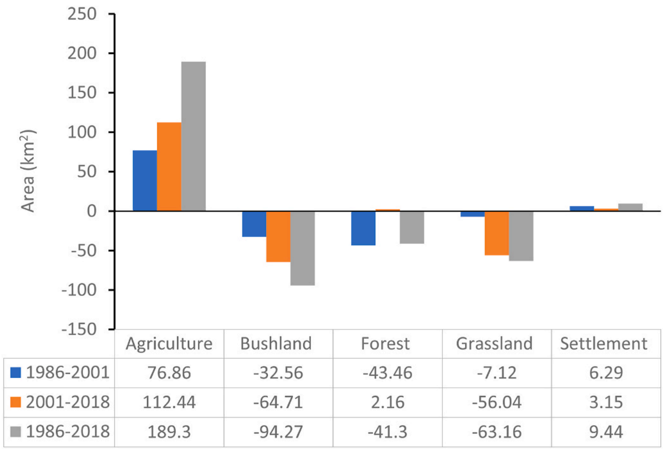

Fig. 5. Trends of LULC changes in the Birr River watershed.

the period 1986 to 2018, respectively. On the other hand, forest, bushland, and grasslands showed a decreasing trend from 1986 to 2018 (Fig. 5). Agricultural and settlement classes are growing in the encroachments of bushland, forest, and grasslands LULC types. This indicates that there is a reduction of bushland and grassland and an increasing trend of agriculture and settlements in the study period. The population has recently grown and environmental consequences have been detrimental. From the evidence of the study area, the primary cause of natural resource depletion is population growth, cultivation of marginal and steep slope areas, mostly sharing grazing and bushland areas with landless youth, timber production, charcoal production, fuel wood, and construction material collections. This finding is in line with previous research (Betru et al., 2019; Bufebo and Elias, 2021; Gebru, 2016; Ogato et al., 2021). For example, Bufebo and Elias (2021) reported that understanding the scope of land use change, its driving force, and its consequences are critical for proper land resource management over the Shenkolla watershed, in south-central Ethiopia.

3.4. LULC change matrix

The LULC change matrix depicts the distribution of main transitions in the five LULC classes used in the study area over the study period (1986–2018) (Table 7). This study found that significant difference between the five LULC classes. The settlement area had the highest conversion matrix between 1986 and 2018, accounting for 95.09% (7.75 km^2) of its total area in 1986. During the same period, 120.63 km^2 (15.45%), 235.64 km^2 (65.98%), 47.70 km^2 (71.13%), and 95.92 km^2 (60.81%) of agricultural land, bushland, forest, and grassland were converted to different classes respectively. Agricultural land experienced the least transition during the study period, taking into account 15.45% (120.63 km^2) of its total agricultural land. During these times, the majority of agricultural land was converted to bushland and grassland areas with 82.96 km^2 and 25.74 km^2, respectively. These findings were consistent with previous research scholars (Abebe et al., 2022; Juliev et al., 2019; Munthali et al., 2019). For example, Munthali et al. (2019) reported that agricultural land experienced the fewest transaction out of its total agricultural land in the period 1991 to 2015. Similar results done by Badasa et al. (2022) reported that between 1990 and 2020, 647 km^2 of dense forest and 750.4 km^2 of open forest were transformed into cultivated land. The decline of natural resources due to the expansion of agricultural land and settlements speeds up land degradation, resulting in food insecurity in developing countries (Moisa et al., 2022).

4. Discussion

This study showed five major LULC classes (i.e., agricultural land, bushland, forest land, grassland, and settlements) in the Birr River watershed (Fig. 4). The watershed was divided into five major LULC classes or types was generated based on the prevalent land covers, the spectral responses of features on Landsat images, extensive field observation, and a literature review. The supervised classification method was then used with a maximum likelihood algorithm. Agricultural land and Bushland were the most prevalent land cover types, while forests and settlements were the least constituted from 1986 to 2018. From the total area, agriculture and settlements covered an area of about 56.39% and 26.18% in 1986 and 70.19% and 19.30% in 2018, respectively. On the other hand, forests, and settlements covered 4.94% and 0.73% in 1986 and 1.92% and 1.42% in 2018. Previous research in various parts of Ethiopia found similar results (Abebe et al., 2022; Dibaba et al., 2020; Galata, 2020; Gashaw et al., 2017; Shiferaw and Singh, 2015). For instance, recent studies by Abebe et al. (2022) concluded that agricultural and bushland constitute the most type of LULC in the Gubalafto district from 1986 to 2016. The most recent LULC map classification accuracy assessment, conducted in 1986,2001, and 2018, produced an excellent result. The overall accuracies of 1986, 2001, and 2018 LULC maps were 90.69, 91.01, and 92.22%, respectively, with kappa coefficients of 0.87, 0.88, and 0.89. Therefore, these results indicate that the classified map and ground truth LULC classes were agreed upon and these classified maps also satisfy the minimum accuracy required for the subsequent post-classification operations (Munthali et al., 2019). The overall accuracy is consistent, which was reported (Tadese et al., 2020). Furthermore, the kappa coefficient revealed a high level of agreement for the most recent Landsat image classification (M Kindu et al., 2013).

The findings of the study revealed that LULC has changed over the last 32 years (1986–2018) in the BirrRiver watershed. Agricultural and settlements have grown significant expansion in the study watershed, increasing by 24.49% and 54.78%, respectively during this period (1986–2018). In contrast, for this period, bushland, forest, and grassland have decreased by 26.27%, 61.01%, and 39.14%, respectively (Table 6). Similarly, previous studies produced consistent results. As an example, Shiferaw (2011)reported that cultivated land has grown due to the loss of forest and grassland from 1972 to 2003. Dibaba et al. (2020) concluded that agricultural land, built-up areas, and water bodies have increased, while forestland, rangeland, and grazings areas have decreased over the last three decades from 1987 to 2017. More than half of the watershed area that was agricultural land in 1986 was still

Table 7
LULC conversion matrix between 1986 and 2018.

	LULC of 2018 (km^2)						
	LULC classes	Agriculture	Bushland	Forest	Grassland	Settlements	Total
LULC of 1986 (km^2)	Agriculture	**659.98**	82.96	0.91	25.74	11.02	780.61
	Bushland	218.54	**121.50**	4.59	9.25	3.26	357.15
	Forest	17.91	28.32	**19.18**	0.13	1.34	66.87
	Grassland	65.23	27.64	0.91	**61.83**	2.14	157.75
	Settlements	7.28	0.37	0.01	0.09	**0.39**	8.15
	Total	968.94	260.80	25.59	97.04	18.15	**1370.52**

Note: the bold numbers represent the constant LULC proportion from 1986 to 2018.

agricultural land in 2018. Forest cover, on the other hand, showed a decreasing trend from 1986 to 2001, but an increasing trend from 2001 to 2018 due to the Ethiopian government's recently planned afforestation and reforestation package programs since 2010. Overall, the findings show that agricultural land and settlement expansion increased to produce more crops by increasing farm size, but at the expense of natural resource degradation and severe soil erosion.

The population of the Birr River watershed has grown recently with detrimental consequences for the environment. As discussed with the agricultural office experts, key informants, local respondents, and community leaders, the main cause of natural resource degradation and soil erosion is population growth in the Birr River watershed. Land sharing by parents for their youth and marginal land fragmentation are increasing in the study area to meet crop production needs. This has resulted in natural resource scarcity and has increased the degradation of natural resources, and expansion of cultivated land at the expense of natural vegetation and grassland coverages in the Birr River watershed. Moreover, The adverse impacts of LULCC were associated with the underlying factors related to human activities. The scarcity and the need to farm more, joined with resettlement have resulted in fewer grazing lands. The decrease in the grazing land forced the community to reduce their livestock, which harmed household income and their consumption of livestock products. Similarly, population growth and agricultural expansion were linked to biophysical degradations such as soil, water, and the environment This finding is consistent with other area study findings (Bewket, 2002; Gebru, 2016; Gessesse and Bewket, 2014). According to the local respondents, land tenure insecurity was also the major factor driving the LULC change in the study area. During the Durg regime (1974–1991), the majority of the study watershed was heavily forested. However, in the early 1990s, natural forests were improperly removed for a variety of reasons, including settlements, cultivation, fuel wood, and charcoal production. This type of common property has also resulted in widespread forest decline across the country (Dinka and Chaka, 2019; Kindu et al., 2016; Tadese et al., 2020; Tewabe and Fentahun, 2020). Many poor people rely on the sale of firewood collections, charcoal production, and house-building materials to make a living. Overall, population pressure agricultural and settlement expansions to marginal and steeply sloping areas, rising demand for fuelwood and building materials, livestock grazing, regime changes, and charcoal production are the main causes of lulc changes.

Changes in LULC and their dynamics are directly related to biodiversity and land productivity and have huge environmental and societal effects (Geist and Lambin, 2002; Kafy et al., 2020; Meer and Mishra, 2020). LULC has an impact on local and global systems because it alters the interactions of energy and water between land and the atmosphere (Sleeter et al., 2017). In addition, rapid LULC change has had a significant impact on surface runoff, resulting in larger and more frequent flooding incidents in many areas (Sun et al., 2011). Understanding LULC change is important because it allows enables the earth's surface and immediate subsurface changes. At the local level, changes in the use of land and its cover affect watershed runoff, the climate resource process of land degradation and land ape level diversity, soil erosion, and sediment load. All of these have a direct impact on the livelihoods of local communities (Tasgara and Kumar, 2022; Kafy et al., 2020; Mekuriaw, 2019; Näschen et al., 2019; Tolessa et al., 2017).

Thus, from the grassroots to government levels, sustainable integrated watershed planning, management, and development should be applied and implemented, with close supervision of area afforestation, reforestation, and conservation of the existing watersheds forest, bushland, and grasslands. Furthermore, soil and water conservation on the degraded land, controlling the further expansion of cultivated land, and fuelwood and charcoal production demands.

5. Conclusion

This study investigated how LULC changed and its dynamics in the Birr River watershed in the last 3 decades (1986–2018) using geospatial technologies. The changing pattern of LULC was used to identify using satellite imagery from 1986, 2001, and 2018. Landsat images from the dry season and without clouds were used due to easier to analyze. To avoid the impact of seasonal variation, and cloud cover in the atmosphere on the image quality all Landsat image was acquired during the dry (winter) season, and to obtain cloud-free images and real land cover features. The image classification, field survey, and observations of the study area have shown significant LULC changes over the last 32 years. The observed agricultural land and settlements showed an increasing trend, while bushland and grassland revealed a decreasing trend over the study period. Forest cover, on the other hand, showed a decreasing trend from 1986 to 2001, however, this tendency showed an increasing trend from 2001 to 2018 due to the recently planned afforestation and reforestation package programs by the Ethiopian government since 2010. This study demonstrated that the present observed LULC changes are primarily related to population growth and the resulting demand for natural resources through deforestation for various purposes in the Birr River watershed. Agricultural expansions, firewood collection, charcoal production, timber production, settlements area expansion, and collection of construction materials are the major driving forces for LULC changes. Changes in LULC had an impact on land degradation, soil erosion, biodiversity loss, ecosystem service damage, and hydrological cycle alteration. Since it has been observed in the study area that bushland, grassland, forest, and steep slopes are being converted to agricultural land for crop production which leads to severe land degradation and soil erosion. There is also the cultivation of marginal and steep slope lands with a lack of suitable land management practices, resulting in severe land degradation. Many impoverished people rely on the sale of firewood, charcoal, and building materials to make a living. Therefore, implementing sustainable integrated watershed management practices is important. The findings suggest that in the study area there is a need for sustainable LULC practices, such as integrated watershed management, to protect and wise use of natural ecosystem services. Moreover, the local community, stakeholders, policymakers, and governmental and non-governmental awareness are required.

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Availability of data and materials

The data that supports the funding of this study is available from the corresponding author upon reasonable request.

Ethical approval

Is not applicable.

Consent to participate

Is not applicable.

Declaration of competing interest

This manuscript has not been published or presented elsewhere in part or entirety and is not under consideration by another journal. There is no conflict of interest to declare.

Data availability

Data will be made available on request.

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