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Research article

Land-use/land-cover changes and implications in Southern Ethiopia: evidence from remote sensing and informants

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HIGHLIGHTS

- The study employed evidences from remote sensing and informants.
- 52% of cultivation lands were found in the slopes of 15–60% increased soil erosion.
- Soil erosion enhanced barren land increase.
- Reduction in agricultural production is a major implication of LULC changes.

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ABSTRACT

Understanding land use/cover (LULC) changes and their impacts on the catchment are imperative for proper land management. Hence, useful information concerning responses to LULC changes becomes important to minimize negative impacts on future land uses. The aim of the study was to evaluate the LULC changes and consequences of the change at Bilate catchment from 1986 to 2018. The LULC change evaluations were undertaken by using Landsat images of 1986, 2002 and 2018. Supervised image classification was employed to map the land cover classes. Informant interviews and group discussions with field observations were used to identify the consequences of the changes. Over the past periods, built-up areas, water bodies, cultivation, and barren lands have increased by 0.97, 0.13, 9.27, and 1.36%, respectively. However, the forest and grazing lands have decreased by 8.56 and 3.18% respectively. Exhaustive land cultivation without appropriate management and cultivation of sloppy lands have increased soil erosion and sediment yield to water bodies. A decline in crop yields, livestock products and numbers, and fish population in Lake Abaya are the major implications of LULC change in the catchment. Therefore, to ensure sustainable land use, responsible bodies commit and work closely with communities through participatory approaches.

1. Introduction

The fundamental reasons for LULC changes are identified with asset deficiency that prompted an expansion in the power of production, market openings, strategy mediation, disappointment of versatile limit and expanded defenselessness, and change in social association in asset access (Lambin et al., 2003). This further upheld by Yirdaw et al. (2017), population pressure and unfeasible land-use rehearses came about in LULC changes and prompted declining in food uncertainty and arrangement of environment administrations, social and political precariousness and decrease in biological system's strength to common atmosphere fluctuation. The same work reveals population growth articulated change in LULC the most recent two centuries and the progressions will go quicker later on (Roy et al., 2010). This further supported by a study conducted in semi-arid Makueni county, Kenya, population and livestock had made over-cultivation and overgrazing, as a result, increased LULC changes (Mganga et al., 2018).

LULC changes greatly influence catchment hydrologic processes such as surface runoff and stream flows (Gyamfi et al., 2016; Koch et al., 2012; Rientjes et al., 2011). LULC change significantly impacts the productivity of rangelands (Mussa et al., 2016). Besides, it impacts the climate and weather conditions from local to global scales (Kayet et al., 2016; Pielke et al., 2006; Pielk et al., 2002). The LULC changes become aggregate into widespread, and the changes significantly affect the major aspects of

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Earth's systems and processes. Therefore, LULC change studies become imperative to provide sustainable land resources use, rehabilitation measures and evidence-based support to improve management.

The remote sensing method has been broadly engaged for LULC change detection from small to large catchments. The ability of detection of land cover features spatially and temporally, remotely sensed imagery had been engaged for different catchments (Fichera et al., 2012). Studies conducted on land covers change in Ethiopia were executed by using remotely sensed images. For example, a decrease in forest and shrub lands, while an increase in cultivation land in Wallecha watershed, Southern Ethiopia (Babiso et al., 2016). Similarly, in Batena Watershed, Southern Ethiopia, a decrease in forest covers and an increase of cultivation lands were reported in between 1973 and 2008 (Gebiaw et al., 2016). Another study reported that increased farm and built-up areas from 1984 to 2015, while a decline of forest and water bodies from 1984 to 1999, and again the forest and water bodies increased from 1999 to 2015 in Beressa, Northern Ethiopia (Meshesha et al., 2016). In Ethiopia, studies conducted on LULC changes have documented a significant increase in cultivation lands. However, there are studies which have documented different LULC change trends in Ethiopia. For example, a decrease in forest and agricultural lands, while an increase in grassland between 1985 and 2017 in Somodo catchment, South Western Ethiopia was reported (Alemayehu et al., 2019). Agricultural and barren lands have expanded; while woodlands decreased between 1985 and 2010 in North-Western low lands of Ethiopia was reported (Alemu et al., 2015).

Land use/land cover changes were executed by using remote sensing images to verify the ground truth and for monitoring environmental resources. Remote sensing images were employed to map land cover/use changes in a mining area of southwestern of the Witwatersrand Basin, South Africa (Madasa et al., 2021; Orimoloye and Ololade 2020). The investigation of implications of LULC change on temporal variations of land surface temperature was performed using remote sensing (Ogunjobi et al., 2018). Remote sensing images were used to evaluate LULC changes and supplemented with qualitative approaches to verify implications of LULC changes. Remote sensing images in combination with survey data were used to evaluate the LULC changes in different catchments. For example, a study by Roba et al. (2021), reported that the effects of resettlement on the LULC change in Nensebo district of Ethiopia using remote sensing and in situ field surveys over a period of 33 years (1986–2019). Most studies in different catchments reported LULC changes and their implications. Rift Valley Basin, semi-arid, of Ethiopia is distinguished by rivers, lakes and terrestrial ecosystems. In the basin, there is a high competition for irrigation water, decline of natural woodlands, overgrazing, and cultivation of steep slopes experiencing several featured practices. In the basin, the LULC change trends showed a decline in woodlands, soil erosion, crop yield reduction, sediment yield, drying of small lakes and raise in lake levels (Garedew et al., 2009; Godebo et al., 2018; Elias et al., 2019; Degife et al., 2021). Accordingly, the Rift Valley Basin faced with intensive land cover changes in the current years. Extensive conversions of land cover features, expansion of cultivation lands along sloppy terrains have implications for soil erosion, decline in agricultural production, soil and land degradation.

Bilate catchment is a home for remarkable water bodies and terrestrial ecosystems of Rift Valley Basin of Ethiopia. Bilate catchment has diverse land covers such as natural wood, plantation trees, grass covers, water bodies, and crop covers on cultivation lands. The population of the catchment depends on these land covers. In the catchment, there are some districts whose population density exceeding five hundred individuals per kilometer square (Adugna 2014; CSA 2013) and maximum rural population density put pressure on the land covers. The impacts of limited natural resources together with high population growth have posed many environmental challenges. Resettlements, fuel wood and charcoal making, inappropriate agricultural practices, conversion of sloppy terrains to cultivation fields, application of fertilizers, farmland Eucalyptus plantation, conversion of grazing lands to Eucalyptus plantation have produced much of land use/land cover changes. These conditions have significant impacts on catchment hydrology, land fertility decline, pollution of Lake Abaya and sustainability of the environment. Bilate catchment has been exposed to high LULC change and the result of this study would be important to supplement the national, regional and local land use, rehabilitation and management strategy. Therefore, the aim of this study is to assess the trends of LULC changes from 1986-2002 and 2002–2018, to assess the consequences associated with LULC changes.

2. Materials and methods

2.1. Study area

The Bilate catchment covers 5625 km^2 of land area and is located in southern Ethiopia (Wodaje et al., 2021) (Figure 1). The catchment area spans different climate zones ranging from the highlands to the lowlands of the Rift Valley. The catchment area has a tropical climate with pronounced aridity in the southern part and a warm-temperate rainy climate in the central and northern highlands. It receives about 854–1039 mm rainfall annually. The mean annual maximum and minimum temperatures are between 22.8 to 30.4 °C and 10.7 to 16.8 °C. Depending on the landscape and topography, there are different types of indigenous and non-indigenous vegetation existing in the catchment. The lowlands have semi-arid biomass such as acacia, scrubs, and grass that are common in the area. The highlands are common to non-indigenous vegetation such as eucalyptus and others. Farmyard eucalyptus plantations are mostly practiced to overcome the shortage of construction material, firewood and to generate additional income. Natural woodlands are found along the ridges, the Bilate River and its tributaries in the catchment. Grass and woodlands are steadily declining. Common grazing lands are changed into cultivated lands and plantations. The highlands and middle areas of the Bilate catchment are known for their intensive cultivation due to the high population density. The land-use system was dominated by rain-fed agriculture and subsistence agriculture. The highlands and middle areas are known for growing different crops such as wheat, clover, barley, and Teff (EragrostisTef). Farmers have intensive home gardens close to their homes, where they cultivate Enset (staple to the catchment) and coffee. Enset plantation is a staple food for the high and middle lands in the catchment.

2.2. Data sources and image classification

Landsat images, Digital Elevation Model, field data and Google Earth were utilized in this study. A 30 m DEM was utilized to delineate the study area periphery. Ground control points were gathered during direct field observations with Global Positioning System. Thematic Mapper, Enhanced Thematic Mapper Plus, and Operational Land Imager-Thermal Infrared Sensor images were used for 1986, 2002 and 2018 respectively. Landsat images and DEM were downloaded from USGS available at https://earthexplorer.usgs.gov and used for the evaluation of LULC change (Table 1). The images were downloaded by using the Landsat grid describing with the WRS-2 path and row (168/55, 169/54, 169/55) search. To reduce the effects of seasonal differences in vegetation pattern and distribution, the selection of dates was made in the same dry annual season of the years. Image processing was executed by using ArcGIS10.3 (Esri 2014) and ERDAS Imagine 2015 (Hexagon Geospatial 2014). Google earth images and field verifications were used for image classification.

The remote sensing images of 1986, 2002, and 2018 were passed over radiometric and geometric corrections (Lefsky and Cohen 2003; Jensen 2005). Band combinations was performed to create features and their association on the ground surfaces (Horning 2004; GIF 2008). Both composite and mosaics were performed, and finally, the images of 1986, 2002, and 2018 were extracted with the shape file of the Bilate catchment.

Supervised image classification through the maximum likelihood algorism was performed. In maximum likelihood, it selects the set of values of the model parameters that maximize the likelihood functions

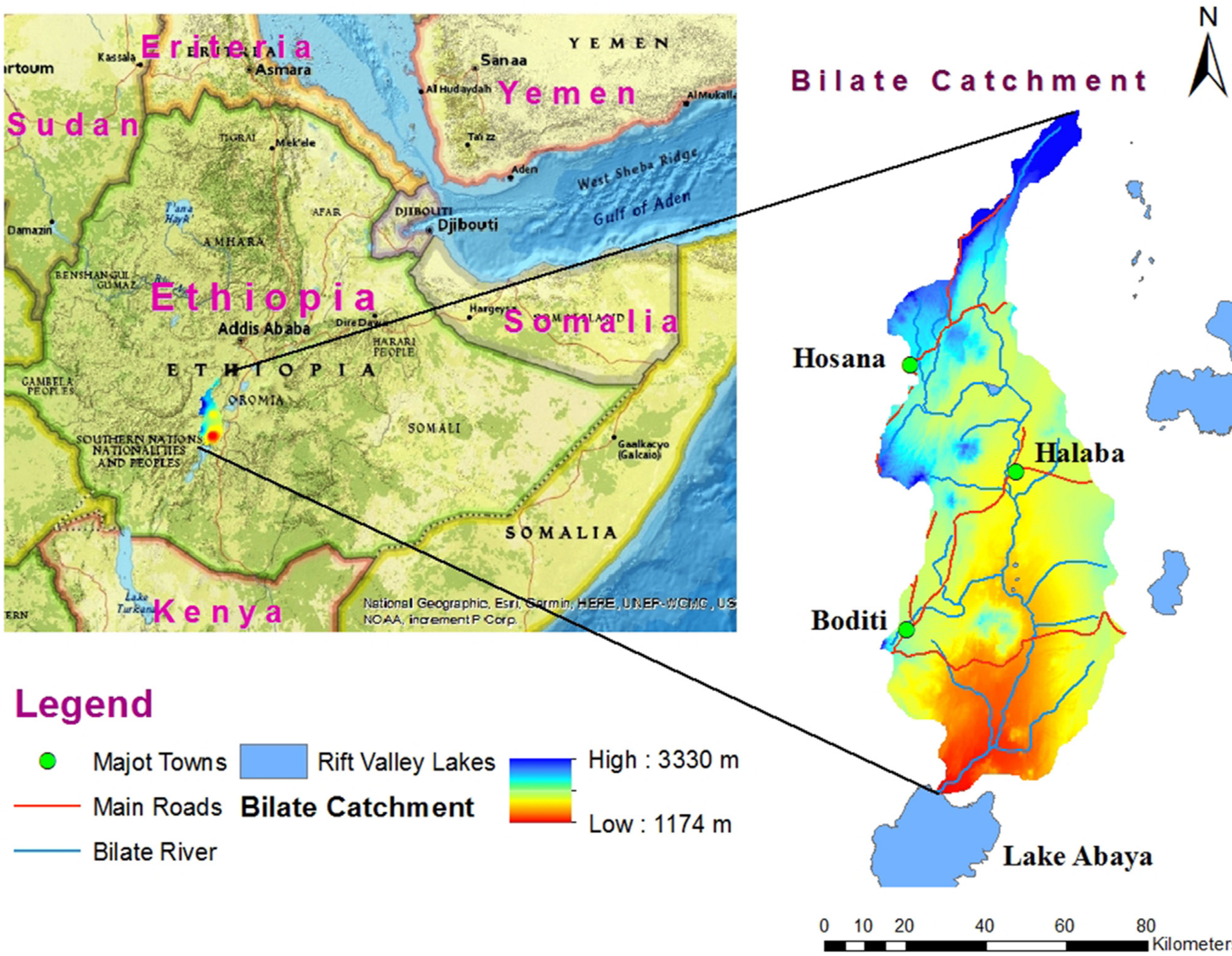

Figure 1. Location of the Bilate catchment.

Table 1. Characteristics of environmental parameters of the satellite and sensors.

Satellites and their Sensors	Spatial resolution(m)	Acquisition period	Bands used	Source
L5 (TM)	30	December 1986	1-5,7	USGS
L7 (ETM+)	30	December 2002	1-5,7	USGS
L8 (OLI-TIRS)	30, 15	January 2019	1-5,7,8*	USGS

Note: Path/Row used = 168/55, 169/54 and 169/55. *8 panchromatic band has 15 m resolution.

(Sisodia et al., 2014). Image classification was carried out based on multispectral data, spectral patterns together with cluster segmentation of the sensor images. The Google Earth images of 1986 and 2002 had downloaded from the internet web, connected to ERDAS Imagine 2015 software, and image classification was performed. This allowed to cross-check uncertain locations in the study areas and to assure which land cover class type this location belongs to. After the image classification, thematic maps for 1986, 2002 and 2018 were developed.

2.3. Accuracy assessment, LULC classification, change detection and inter-class conversion

The LULC maps produced from Landsat imageries have image categorization errors. Accuracy measurement provides information on where the errors were created. Landsat-classified.tiff maps, reference data, Microsoft excel, and Arc Map was used in accuracy measurement. In this study, overall accuracy assessment was executed by using the error matrix (Mathur and Foody 2008). The overall accuracy is calculated by summing the number of correctly classified values and dividing by the total number of values.

$$\text{Overall accuracy} = \left(\frac{\text{The number correctly classified values}}{\text{The total number of values}}\right)*100 \tag{1}$$

User's accuracy is the probability that a value predicted to be in a certain class actually is that class.

$$\text{Users}'\text{saccuracy} = \left(\frac{\text{A diagonal number}}{\text{The row total}}\right)*100 \tag{2}$$

Producer's accuracy is the probability that a value in a given class was classified correctly.

$$\text{Producer}'\text{s accuracy} = \left(\frac{\text{A diagonal number}}{\text{The column total}}\right)*100 \tag{3}$$

Observed accuracy determined by diagonal and chance agreement incorporates off-diagonal in the error matrix.

Effective LULC change detection recommends the minimum threshold value for overall accuracy needs to be Kappa coefficient of 85% (Anderson et al., 1983). Kappa coefficient depicts the decline in the percentage of the error, whose values from 0.81 to 0.99, 0.61to 0.80, 0.41 to 0.60, and 0.21 to 0.40 to be used as strong, considerable, sensible, and fair agreements respectively (Viera and Garrett 2005).

kappa coefficient reveals the difference between actual agreement and the agreement expected by chance was calculated by Eq. (4) (Adam et al., 2013; Anand 2017)

$$K = \left(\frac{\text{Observed accuracy} - \text{Chance agreement}}{1 - \text{Chance agreement}}\right) * 100 \quad (4)$$

Probability sampling technique was employed to collect sufficient numbers of reference points. Probability sampling takes in the use of a sufficient number of training samples, in which the minimum sample size be 20 to 100 per class (Chen and Stow 2002; Stehman and Czaplewski 1998). Reference points were used to execute accuracy assessments via an error matrix. 320 reference points were collected by GPS for the year 2018, and 360 random points were created for 1986 and 2002.

Based on the current ground truth in Bilate catchment and Food and Agricultural Organization assessment that land covers classification, evaluation, and monitoring their changes become crucial to have a sustainable environment (Grogorio et al., 2016; Kohat 2016). The LULC history of Bilate catchment was obtained during interviews and group discussions. Field observation method was employed using field notes, checklists, rating scales and photographs to supplement the study (Gray et al., 2012). With the aid of field observation and information from the informants, and photographs of particular sites, six classes of LULC types were identified. Based on field observation, expert opinions and information from previous studies in Bilate catchment, six LULC classes were identified (Table 2).

The extent of change in LULC type within and between these periods was compared. The share of each LULC class in hectares has been calculated for the periods 1986, 2002, and 2018. The share of LULC type within the given period was calculated by the formula:

$$\textit{Percentage area of LULC} = \frac{\text{Area of each land use}}{\text{Area of the catchment}} \quad (5)$$

The LULC change rates in between different periods were calculated by the formula,

$$\textit{Percentage change of LUL} = \frac{(\text{Land area of final year}) - (\text{Land area of initial year})}{\text{Area of the catchment}} \quad (6)$$

The evaluation of LULC inter-class conversion matrix was performed by using Arc GIS through geo-processing and intersection tools. The conversion matrix was developed for 1986 to 2002 and 2002 to 2018. In the conversion matrix, the land class gained, lost, substituted and net persisted between the land use land covers were evaluated. In the transition, the net persistence was computed by the relation:

$$\textit{Net persistent} = \frac{\text{Net change(Gain} - \text{Loss)}}{\text{Diagonal of each class}} \quad (7)$$

Overlay analysis between the classified LULC map and terrain slope was executed to show the increasing demand of cultivation land. Besides, the result was helpful to indicate the relationship between the LULC changes and slope gradient.

2.4. Informants data and LULC change

The study was based on survey of native informants and remote sensing data integration to get the implications of LULC changes in the catchment. The combined use to assess LULC change implications were recommended to use the main and underlying drivers (Kleemann et al., 2017). This approach was recommended because of the high relationships between the community and surrounding systems. Informant interview, focus group discussion and field techniques were employed in the study. Based on the agro-ecological locations and population density five representative districts were selected. The identified districts are Damot Gale, Damot Pulassa, Damot Woyde, Badawacho, and Halaba. 75 informants and 25 agricultural experts who have been living over 40 years were identified from the districts. Ten focus group discussions and twenty interviews were conducted to get implications of LULC changes. Focus group discussion performed to discuss a given issue in-depth (Stewart et al., 2007). Semi-structured interview method was employed (Wilson 2014). Focus group discussion and interview comments were analyzed using narrative method to draw the conclusions (Allen 2017). Similarly, narrative method was employed for Fincha catchment, Northwestern Ethiopia (Dibaba et al., 2020). Implications of LULC changes were further elaborated during the group discussions and interviews. Field observation by taking pictures was supplemented to indicate the implications of LULC changes in the catchment.

Table 2. Land cover classes and description.

LULC class	Description
Forest (mixed wood) Land	Areas that covered with scattered natural mixed woods, plantations of indigenous and non-indigenous species of trees, Eucalyptus, agroforestry home gardens, shrubs and farm plantations were included.
Built-up Areas	Urban residential and commercial services, public institutions, infrastructures like roads made of asphalt, pavements and have drains.
Grazing Lands	Community grazing fields, grazing lots at each farmyard and other grasslands were classified in this category.
Cultivated Lands	Areas used for crop cultivation, mechanized farmlands, sparsely located rural settlements were included in this category.
Water Body	Streams, rivers, reservoirs, and lakes.
Barren Lands	Lands that have no grass cover, degraded soils lands, and exposed rocks were included in this class.

3. Results and discussion

3.1. The trends and distributions of LULC change

Bilate catchment has undergone various land covers changes over periods 1986, 2002, and 2018. Cultivation land, the dominant land use type, covered 60.18% in 1986, 72.4% in 2002 and 69.45% in 2018 of the study area (Table 3). Similarly, barren land, built-up areas and water bodies increased from 1986 to 2018. The proportion of barren land in 1986, 2002 and 2018 was 2.91%, 3.81% and 4.27% of the total area of the catchment, respectively. The proportion of built-up areas in 1986, 2002 and 2018 was 1.53%, 1.82% and 2.50% of the total area, respectively. Besides, the water body in 1986, 2002 and 2018 was 0.160%, 0.163% and 0.29% of the total area of the catchment, respectively. The forest and grazing lands covered 31.52% and 3.7% in 1986, 20.50% and 1.30% in 2002, and 22.96% and 0.51% in 2018 area of the catchment, respectively.

In 1986, next to cultivation land, the forest and grazing lands were the major LULC contributing 31.52% and 3.7% of the catchment, respectively. Similarly, cultivation and forest lands were the major LULC in 2002 and 2018. For the periods 1986 to 2002 and 2002 to 2018, grazing land showed the decline, while water bodies, settlement areas and barren lands showed increment. From 1986 to 2002, cultivation land showed

Table 3. LULC classes and their changes in 1986, 2002 and 2018.

	Area of LULC (ha) and percentage share						LULC change (%)		
	1986		2002		2018		1986–2002	2002–2018	1986–2018
Land class	ha	%	ha	%	ha	%	%	%	%
BL	16,370.3	2.91	21,455.2	3.813	24,044.30	4.274	0.90	0.48	1.36
BA	8,589.78	1.53	10,245.3	1.821	14,069.40	2.501	0.29	0.68	0.97
CL	338,565	60.18	407, 270	72.4	390,714	69.453	12.21	-2.94	9.27
FL	177,335	31.52	115,349	20.504	129,181	22.963	-11.02	2.46	-8.56
GL	20,796.3	3.7	7,319.3	1.30	2,886.39	0.513	-2.40	-0.79	-3.18
WB	903.78	0.16	922.32	0.163	1,665.36	0.296	0.003	0.127	0.13
Total	562,560		562,560		562,560				

Note: BL = barren land; BA = built-up areas; CL = cultivated land; FL = forest land; GL = grazing land; and WB = water body.

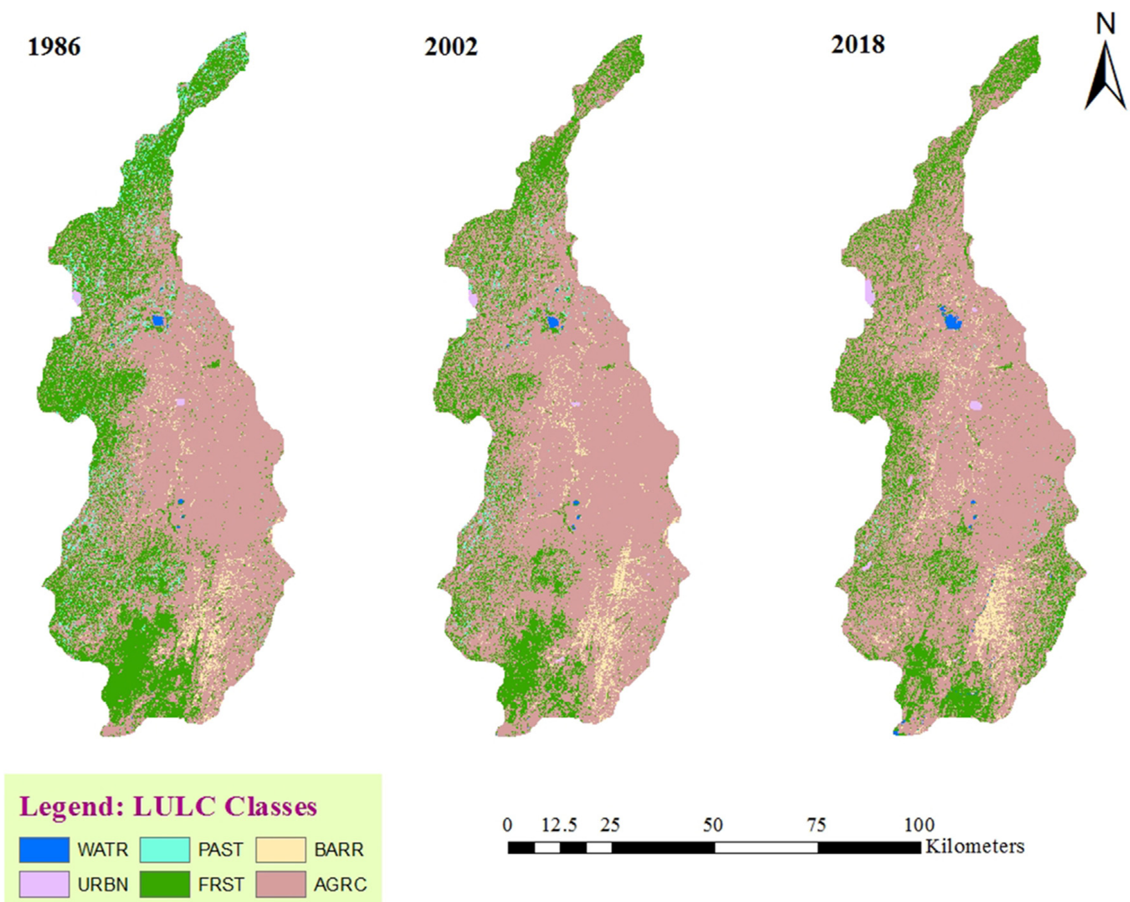

Figure 2. LULC map of 1096, 2002 and 2018.

the highest increment and again declined from 2002 to 2018. The forest land declined from 1986 to 2002 and again increased from 2002 to 2018.

The time series distribution and conversion of LULC of Bilate catchment is presented in (Figure 2). The major LULC change observed comprises of expansion of cultivated land, barren land, settlement areas, and water body, while a decline in grazing and forest lands. The LULC change was executed to quantify the changing trends from 1986-2002, 2002–2018, and 1986–2018. The conversions of forest and grazing lands to cultivated land were observed in all parts of the catchment. The individual farmers, commercial state farms and investors were concerned in the land class conversions. The cultivated land comprised of the largest proportion of Bilate catchment in the three periods and it continuously increased from 1986-2002 and declined to 2018. Irrigation projects were introduced to sustain the livelihoods of the growing population in the catchment. Irrigated agriculture has increased the water bodies in the middle areas in the catchment from 1986-2018. Bilate and Abaya irrigation districts are state farms to the lower parts, while Halaba, Sankura, Buge, Shone, Sankura and Shashego irrigation districts are community ownership in the middle parts of the basin. Lake Boyo to the upper part, crater Lakes such as Budamada, Tido and Bode Ameda to the middle are the water bodies in the catchment. Grazing land has continuously decreased from 1986 - 2018. Resettlement at downstream Bilate areas and redistribution of community grazing lands to military veterans and landless youth in Damot Pulasa district significantly declined grazing lands. In the catchment, community and farmyard grazing lands were converted into cultivation fields. A considerable decline of grazing land was observed in all parts of the Bilate catchment. Other studies conducted in catchments of Ethiopia have documented similar observations.

For example, rangeland degradation (Mussa et al., 2016), in the range lands of Ethiopia. Forest land has decreased from 1986 - 2002 and again increased from 2002-2018. The increment of forest land and a decrease in cultivated land was attributed to plantations of Eucalyptus Saligna and Cupressus Lusitanica Gravellia trees. Most districts of Bilate catchment such as Damot Glale, Damot Pulassa, Sodo Zuria, Damot Woyde, Badawacho, and Kedida Gamela farmers plant eucalyptus tree in their farms to generate extra income to supplement their livelihoods. Built-up areas are continuously increasing from 1986-2018 in the catchment. The increment of built-up areas is due to the expansion of small towns and institutions in many parts in the catchment. Migration suffering from scarcity of cultivation lands, low agricultural production, job opportunities in the cities and absence of infrastructures were the major responses of informants and agricultural experts in the catchment. For example, the population of Boditi town in 2007 was 24,133 and 40,167 in 2018 (CSA 2013). The association among population density and LULC change is significantly pronounced in rural Ethiopia (WoldeYohannes et al., 2018). In rural areas, farmlands are owned by aged persons and the youth have no farmlands. As a result, the youth moved to towns and built-up areas were increased. A similar trend was observed in the Blue Nile Basin, the Geleda catchment, Ethiopia (Hassen and Assen 2017).

3.2. Accuracy assessment

Accuracy assessment was executed to validate image classification by using the error matrix. The overall image classification accuracies were 88.0, 89.33 and 91.67% for 1986, 2002 and 2018, respectively. Kappa coefficients were 0.84, 0.86 and 0.89 for 1986, 2002 and 2018 respectively. Kappa coefficients indicate strong agreements for the years 1986, 2002, and 2018. Kappa coefficients, overall classification accuracy, producer's and user's accuracies are indicated (Table 4).

3.3. LULC inter-class conversion and change path

The LULC change evaluation of Bilate catchment showed that the catchment featured land covers conversions. The conversion matrix was developed from 1986 - 2002 and 2002–2018. In the conversion matrix, the LULC class gained, lost, substituted and net persisted were presented (Table 5). From 1986 to 2002 LULC change conversion, the highest loss occurred in forest land, followed by cultivated land and grazing land. The lowest loss showed by barren land, settlement areas and water bodies. Between 2002 and 2018 LULC conversion, the highest loss occurred in cultivated land, followed by forest land and barren land, whereas the lowest loss showed by grazing land, settlement areas and water body. The highest gain from 1986 - 2002 was shown by cultivated land and followed by forest and built-up areas, while the lowest gain was shown by barren land and followed by grazing and water bodies. Between 2002 and 2018 the highest gain was shown by forest land and followed by cultivation and barren lands, while the lowest gain was shown by built-up area and followed by grazing and water bodies. Between 1986 and 2002, 41.12% of forest land and 29.87% of grazing land were converted into cultivation land. In the same period, 33.48% of grazing land was converted into forest land. Between 2002 and 2018, 17.2% of forest land and 38.5% of grazing lands respectively, were converted into cultivation land. In the same period, 23.85% of grazing land and 7.63% of cultivated lands were converted into forest land. Concerning unchanged land class, built-up area showed the highest persistence than the other land classes from 1986 - 2002 and 2002–2018. Grazing land, forest land and water bodies showed less persistence from 1986 - 2002 and grazing land, forest and cultivated lands showed less persistence from 2002 - 2018 in Bilate catchment.

Table 4. Accuracies of classified images.

LULC Class	Accuracy (%)					
	1986		2002		2018	
	Producer's	User's	Producer's	User's	Producer's	User's
Barren land	88.24	93.75	84.21	100	80.77	95.45
Cultivated land	90.20	85.19	94.12	86.49	95.65	91.67
Forest land	95	92.68	96.97	84.21	95.35	93.18
Grazing land	90.91	76.92	87.88	85.29	81.25	81.25
Built-up area	46.15	100	60	100	97.14	89.47
Water body	100	100	100	100	85.71	100
Overall Accuracy	88.00		89.33		91.67	
Kappa Coefficient	0.8424		0.8679		0.8960	

3.4. LULC change with slope gradients

The intensifying demand of land for cultivation has brought about changes in LULC. Cultivated land cover expanded considerably to the higher slopes. The distribution of LULC along terrain slope in 2018 showed (Table 6). The highest land share 26.83% and 25.52% of the cultivated land was found in the slopes ranging from 15 to 30% and 30 to 60%, respectively. The cultivated land found on the slopes 15 to 30% and 30 to 60% covered about 18.63% and 17.72% of the total catchment area. As well, 2.25% of the cultivated land was found on slopes higher than 60%. The remaining 2.51%, 10.22%, 14.35% and 18.67% of the cultivated land covered by slopes 0 to 2%, 2 to 5%, 5 to 8% and 8 to 15%, respectively. The cultivation land increase along the higher slopes was mainly due to human impact with population growth and subsequent cultivation land expansion in Bilate catchment. The highest land coverage 20.48%, 27.05% and 28.06% of the barren land, was found in the slope ranging from 8-15%, 15–30% and 30–60%, respectively. The highest proportion of barren land along the highest slopes was attributed to human induced practices.

3.5. Implications of LULC change

LULC changes in Bilate catchment were run by proximate (direct) and underlying (root) drivers. The direct LULC change causes are prompted by underlying (root) drivers. The LULC change drivers and their effects were explained by informants and agricultural experts in the catchment from 1986-2018. Resettlements to the middle and downstream areas and expansion of cultivation lands put a significant role in the decline of forest and grazing lands. Expansion of cultivation land, Eucalyptus plantation on community and private grazing lands significantly declined the grazing lands. As a result, the decline of grazing lands forced the community to reduce their livestock. Besides, the livestock becomes weak and distressed. Therefore, the decline and mismanagement of grazing lands have put into land use/land cover change in Bilate catchment.

Cultivated sloppy lands along Bilate River and its tributaries increased soil erosion. As a result, fertile top soil removed and crop yield become reduced. The decline in crop yield reputed by the informants agrees with other studies. For example, the erosion-induced reduction in crop yields is attributed to loss of fertile top soil, degradation of soil structure, reduction in organic matter, decrease in plant-available water reserves and nutrient imbalance (Bhandari et al., 2021; Lal and Moldenhauer 2008). The highlands of Ethiopia addressing as home to about 80% of the population making a strong base of rural community, and as a result the areas are threatened with erosion and loss of agricultural productivity (Worku and Tripathi 2015).

The beginning and expansion of infrastructure (roads and institutions) initiated the community to start and expand built-up areas in Bilate catchment. Cultivation fields were changed into built-up areas due to the emergence of roads and small towns. Fertilizer use enhanced soil salinity and as a result the soil becomes hard and degraded. Sloppy lands along Bilate River and its tributaries highly eroded and the lands become degraded. The increment of barren lands is due to the emergence of new

Table 5. LULC change conversion matrix.

		BL	C L	FL	GL	BA	WB	Total	Loss
		Land Class 2002							
Land Class 1986	BL	**13,365.8**	2,007.1	50.7	0	946.7	0	16,370.3	3,004.5
	C L	4,260.2	**323,106.9**	4,141.1	545.2	6,483.4	28.3	338,565.0	15,458.1
	FL	103.8	72,928.4	**103,822.8**	208.9	261.7	9.4	177,335.0	73,512.2
	GL	64.4	6,211.5	6,962.4	**7,558.0**	0	0	20,796.3	13,238.3
	BA	1,413.9	1,006.9	0.1	0	**6,168.7**	0.1	8,589.7	2,421.0
	WB	0	11.3	6.1	8.3	0	**878.0**	903.7	25.7
	Total	19,208.1	405,272.1	114,983.2	8320.4	13,860.5	915.8	562,560.1	
	Gain	5,842.3	82,165.2	11,160.4	762.4	7,691.8	37.8		
	Net change	2837.8	66,707.1	-62,351.8	-12,475.9	5,270.8	12.1		
	Net persisted	0.21	0.21	-0.60	-1.60	0.85	0.01		
		Land Class 2018							
Land Class 2002	BL	***9,423.0***	*11,346.1*	609.9	10.2	65.5	0.5	21,455.2	12,032.2
	C L	11,796.9	**352,192.9**	31,081.8	1,925.8	9,946	326.6	407,270.0	55,077.1
	FL	217.3	19,941.9	**94,297.2**	524.5	235.0	133.1	115,349.0	21,051.8
	GL	23.8	2,817.6	1,745.8	**2,621.5**	104.2	6.4	7,319.1	4,697.8
	BA	1,383.8	759.9	217.2	3.9	**7,879.0**	1.7	10,245.1	2,366.1
	WB	2.0	64.5	23.2	25.5	5.4	**801.7**	922.2	120.6
	Total	22846.8	387122.9	127975.1	4639.4	18165.1	1270	562,560.1	
	Gain	13,423.8	34,930	33,677.9	2,017.9	10,296.1	468.3		
	Net change	1391.6	-20147.1	12626.1	-2679.9	7929.8	347.7		
	Net persisted	0.15	-0.06	0.13	-1.02	1.01	0.43		

Note: The diagonals indicate the areas of land unchanged.

Table 6. Terrain slopes and LULC distribution in 2018.

LULC class	Slope classes and LULC coverage area (hectares)							
	0–2%	2–5%	5–8%	8–15%	15–30%	30–60%	>60%	Total
BL	120.2	928.1	3750.5	4924.3	6504	6746.8	1060.4	24044.3
C L	9807.1	39931	56067.5	71578.8	104828.6	99710.2	8791.8	390714
FL	2609.5	14507	17839.9	21534.5	29970	35563.5	7156.6	129181
GL	560.8	1117.9	409.3	275.1	245.3	184.7	93.2	2886.3
BA	599.4	2915.2	2857.5	3812.8	2138.5	1632	114	14069.36
WB	1340.3	197.7	63.5	46.5	17.5	0	0	1665.36

settlements along the major roads, expansion of towns and built-up areas, erosion, and fertilizer use in the catchment.

Fish population decline was related with sediment and nutrient loads to water bodies perceived by the informants during interview and group discussion in Bilate catchment. Besides the informants' information, studies conducted at Lake Abaya reported that the fish resources face extinction due to the use of fertilizers and sediment eroded from the upstream areas in the catchments. For example, Kamaylo et al. (2021), reported that the past total catch of Tilapia from 126,306 kg/year was reduced to 42,205 kg/year in 2021 in Lake Abaya, Ethiopia. Similarly, Vijverberg et al. (2012), reported that the fish species richness was higher in the past than their study, because of high sediment load, overfishing and degradation of habitats in Ethiopia Lakes.

According to group discussions and interviews, they perceived major implications of LULC change in Bilate catchment. They concluded that soil and land degradation, the decline of crop yield, soil erosion, sediment and nutrient loads to water bodies, livestock and fish population reduction and dryness to downstream. The decline of crop yield was caused by fertility loss and soil erosion. Improper land-use and management practices are policy-related drivers of LULC change.

3.6. Discussions

Bilate catchment experienced considerable LULC change between 1986-2018 (Table 3 and Table 5). Cultivation land expansion in between 1986 and 2002 was mainly related to population growth in the catchment. Resettlement which is limited to the downstream areas was another contributing factor for the expansion of cultivation lands in the basin. Studies conducted at different catchments reported similar conclusions. Population growth is attributed to the dependency of many people on agricultural activities. Agricultural growth is a direct and population pressure is the root causes of LULC change (Hailemariam et al., 2016). To attain food self-sufficiency all steep-sloped lands were changed into cultivation fields. Population increase was taken as a major driver of the land covers change in developing countries (Desalegn et al., 2014). This was further verified by the Southern Regional Government report (Adugna 2014). According to the report, the population densities were 648, 546, 543, 515, and 435 individuals per km^2 in Damot Gale, Soddo Zuriya, Angacha, Kedida Gamela, and Badawacho, respectively. Based on the arguments of respondents and the regional government report, population growth is the major underlying driver of land covers change in Bilate catchment. Population growth and resettlements together with lack of appropriate technology to improve land management were the main contributing factors to the LULC change and they resulted in surface runoff and soil erosion in Bilate catchment. Studies conducted at different catchments reported similar conclusions. Population growth and LULC changes are highly linked in Ethiopia and soil erosion and sediment yield in Southern Ethiopia (Schutt et al., 2002).

Forest lands started increasing between 2002 and 2018 in Bilate catchment. The increment of forest land was at the outlay of grazing and cultivation lands. This is due to the environmental restoration program practiced in the catchment by the community and individual farmers. Studies conducted in Ethiopia have reported similar conclusions. For example, Promising vegetation growth between 1985 and 2015 in South Gondar, Ethiopia was reported (Min 2016). Similarly, the forest cover of Gerado catchment, have increased between 1980 and 2006 (Asmamaw et al., 2012). Eucalyptus, exotic trees have been planted in Ethiopia for over a century. In Ethiopia, Eucalyptus tree has been planted and community are reliant on it as a source of fuel and construction wood. It dominated many landscapes because of fast-growing, coppices after harvest, resists stress, and grows in poor environments. Similarly, the same observation was reported Eucalyptus: exotic tree crop in Ethiopia (Dessie et al., 2019). In Bilate catchment, individual farmers planted Eucalyptus tree in their farms to earn extra money to sustain their livelihood. According to the informants, the sale of Eucalyptus has the potential to raise farm income. The reports further indicated its adverse effects such as drains water resources, enhance soil erosion, suppress undergrowth, deplete the soil nutrients, and cannot provide food for live stocks and wildlife. Studies performed in Ethiopia have documented similar observations. For example, Eucalyptus has the adaptability to high land climate and soil conditions, coppicing and non-palatability for livestock (Pohjohen and Pukkala 1990). Eucalyptus has the potential to improve rural livelihood, planting on farmyards has negative environmental concerns and desire to reverse farmlands for crop production (Jagger and Pender 2001). In the Bilate catchment, Eucalyptus plantation on the cultivation and grazing lands was the fourth major driving factor which has decreased cultivation and grazing lands in between 2002 and 2018. Besides, the Eucalyptus tree results in negative environmental consequences in Bilate catchment. This study suggests additional studies on Eucalyptus related to soil nutrient and structure. Eucalyptus planting should be supported by land use management decision.

Barren lands are continuously increasing from 1986-2018, with the highest rate in Bilate catchment. These are exposed rocks and over cultivation of steep-sloped lands along the shorelines of Bilate River and its tributaries. The over-cultivated and steep-sloped lands in Damot Woyde (Motala, Chifisa, Girara, Bedessa), Soddo Zuriya (BugeWanche), Duguna Fango, Halaba, Adilo, Loko Abaya and Boricha became eroded and degraded lands in the catchment. Studies conducted in Ethiopia and China has documented similar observations. There are enormous degraded landscapes and returning them to the productive system have substantial importance to the development of country (Lemenih and Teketay 2004). Over-cultivation on steep slopes has increased the susceptibility of land to soil erosion. Soil erosion takes away the nutrients and sediment to water bodies. As the process continues from year to year, the land becomes degraded. Several studies reported that soil erosion is the major driver of land degradation (Esa et al., 2018; Adugna et al., 2015). The magnitude of LULC change differs with the slope gradient and elevation range. The higher soil loss and sediment export were estimated from the highest slope gradients, from slopes with 5–30% gradients (Degife et al., 2021). They reported the 1.6 ton per hectare per year of sediment exported to Hawassa watershed and water bodies. From their report, the water bodies receive a total of 226,690.3 ton of sediment annually. Sediment transport from Abaya Chamo Basin to water bodies and Lakes affected the water levels and fish population (WoldeYohannes et al., 2018; Schutt and Thiemann 2006). The problem of nutrient and sediment loads is pronounced by soil erosion in Bilate catchment. Consequently, soil erosion put nutrient and sediment loads to water bodies and then to Lake Abaya. Besides, nutrient and sediment deposition reduce storage capacity, water quality and fish productivity.

Over-cultivation and use of fertilizers resulted in soil structural deterioration which makes the soil degraded and agricultural production becomes slowed. Studies conducted at different places confirm soil degradation due to use of fertilizers. For example, the use of fertilizers build up heavy metals and thus results in soil salinity induced land degradation in Ethiopia (Negasa 2020; Mesene 2017). Soil salinity is a problem in attaining food safety and land degradation in Ethiopia (Qureshi et al., 2018). Fertilizers have resulted in a significant area of degraded land and the land becoming infertile because of salinity in low lands of Ethiopia (Asmamaw et al., 2018). Fertilizers have been responsible for strongly influencing the microbial properties of the soil (Prashar and Shah 2016). Worms provide increased nutrient, better drainage and a more stable soil structure, all of which improve crop productivity. Soil microbes and worms play important functions in the basic soil processes. They endorse suitable soil structure, increase soil

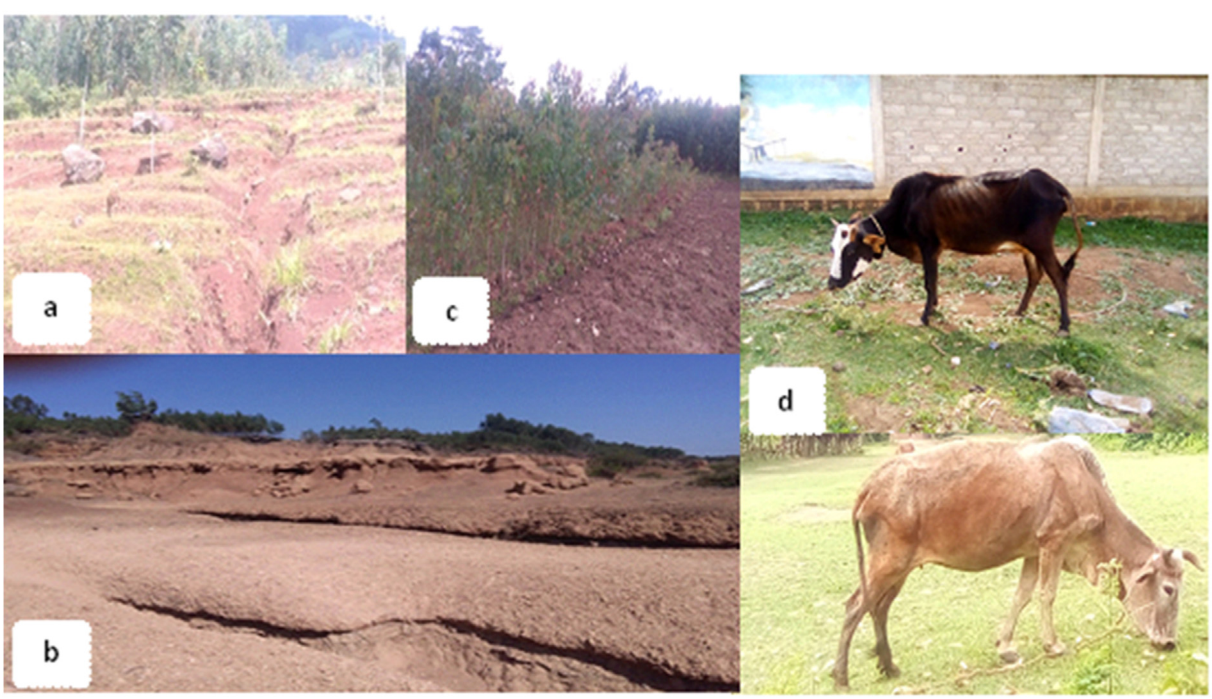

Figure 3. Soil erosion, Woshi Gale (a); Land degradation, Gacheno (b); Farm land Eucalyptus plantation, Fate (c); distressed cows, Boditi Qorke and Sakke (d) of Bilate catchment (May 16, 23, 25 and 29, 2020).

fertility and crop productivity. However, their numbers and functions were hindered due to the use of fertilizers. Respondents clarified that a vast number of worms destroyed and currently absent in the soil. Besides, they elucidated that the soil is hard during plough and crop production has been declined in Bilate catchment. Studies conducted have documented similar observations. For example, Prolonged use of fertilizers makes the soil degraded by breaking down the soil structure (Massah and Azaadegan 2016; Abad 2018; Savci 2012). Next to soil erosion, fertilizer has been verified to be the origin of soil degradation (Tetteh 2015). In Ethiopia, fertilizer has extensively used since 1993 to enhance crop productivity. For example, the amount of fertilizer used for five major kinds of cereals (Teff, Barely, wheat, maize and sorghum) averaged was 190.8 kg/ha over 1995–2004 (Endale 2011). The salinity problem caused land degradation due to compaction and soil structural breakdown. Land degradation which has increased barren land is a common environmental problem in Biate catchment. Therefore, salt induced degraded lands have to be treated to make them productive. Frequent cultivation of steep-sloped lands and use of fertilizes for the prolonged period together with mismanagement have put in land covers change and increased the barren land in Bilate catchment.

Evidences from the remote sensing and informants' information confirmed that there was relatedness in the Bilate catchment. For example, decline of grazing land from 1986 to 2018 was observed from both remote sensing and informants. As a result, reduction in livestock number and product was confirmed during interview, group discussion and field observation. The expansion of barren lands from 1986 to 2018 due to erosion and settlements, expansion of wood/forest lands from 2002 to 2018 due to Eucalyptus plantations at the expense of cultivation and grazing lands were resulted in crop and livestock products. These were confirmed during interview and group discussion. Studies executed at different catchments agree with these outcomes. For example, local people's perceptions about LULC changes in Namibia (Haindongo et al., 2020); landscape dynamics and its implications on Isimangaliso Wetland Park (Orimoloye et al., 2019); LULC change drivers and implications in contrasting agro-ecological environments of Ethiopia (Berihun et al., 2019); LULC changes and encroachment issues in Kapkatet wetland, Kenya (Kebet et al., 2021). Crop yield reduction, livestock product and number reduction, and reduction in fish population in Lake Abaya are the most notable effects of the LULC changes in the catchment. Besides, Eucalyptus plantation displaces nearby crops, reduces cultivation and grazing lands. Field observations confirmed the existence of soil erosion, land degradation, distressed cows and Eucalyptus plantation in Bilate catchment (Figure 3).

4. Conclusions

The study was set out to look at the long term trends in LULC changes, drivers, and implications of the change at Bilate catchment. Population growth and their demand to maintain their livelihood put stress on land resources. The analysis of 1986, 2002 and 2018 Landsat images showed significant changes of LULC in Bilate catchment. The continuous-time series expansion of cultivated land, barren land, built-up areas, and water bodies from 1986-2018 has been accompanied by the decline of forest/wood from 1986-2002 and grazing lands from 1986-2018.

The LULC changes have severely aggravated environmental problems. The LULC changes have increased degraded lands, soil erosion, sediment and nutrient loads to water bodies. Beside, a decline in livestock number and products, crop yields, and fish population in Lake Abaya were implications of LULC changes.

The study suggests that the assessment of the impact LULC changes on adverse implications in the Bilate catchment are well-represented by evidence from remote sensing and informants. However, the lack of evidences on local LULC change and change consequences; and lack of concern about LULC changes in the catchment need urgent attention to improve our understanding of the variations in the future. Most people do not have concern about LULC change.

The results provided evidence on the relative influences of how the adverse implications in Bilate catchment respond to the changes in LULC. This could help to plan and implement proper land management interventions. If the degraded sloppy lands are rehabilitated, indigenous tree plantations are based on decisions, local community conscious about LULC changes, soil and water conservation works properly implemented the groundwater recharge increase. Accordingly, the surface runoff which washes the topsoil, sediments and nutrients into the water bodies is reduced. Besides, Lake Abaya should be buffered with suitable management approaches. This study proposes future studies on change detections on environmental restoration and agricultural productions (crop, livestock and fish conditions). Overall, to ensure sustainable land use, it is recommended that all responsible bodies have the commitment and work closely with communities through participatory approaches. These can assist to restore the present land covers change trends in Bilate catchment.

Declarations

Author contribution statement

Hailu Gisha Kuma: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Fekadu Fufa Feyessa & Tamene Adugna Demissie: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

The Landsat images that support the findings of this study are available from the following open sources from USGS, https://earthexplorer.usgs.gov.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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