Research Article

Analysing land use/land cover changes and its dynamics using remote sensing and GIS in Gubalafito district, Northeastern Ethiopia

Gebeyehu Abebe[1] · Dodge Getachew[2] · Alelgn Ewunetu[3]

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Abstract
Mapping and quantifying the status of Land use/Land cover (LULC) changes and drivers of change are important for identifying vulnerable areas for change and designing sustainable ecosystem services. This study analyzed the status of LULC changes and key drivers of change for the last 30 years through a combination of remote sensing and GIS with the surveying of the local community understanding of LULC patterns and drivers in the Gubalafto district, Northeastern Ethiopia. Five major LULC types (cultivated and settlement, forest cover, grazing land, bush land and bare land) from Landsat images of 1986, 2000, and 2016 were mapped. The results demonstrated that cultivated and settlement constituted the most extensive type of LULC in the study area and increased by 9% extent. It also revealed that a substantial expansion of bush land and bare land areas during the past 30 years. On the other hand, LULC classes that has high environmental importance such as grazing land and forest cover have reduced drastically through time with expanding cultivated and settlement during the same period. The grazing land in 1986 was about 11.1% of the total study area, and it had decreased to 5.7% in 2016. In contrast, cultivated and settlement increased from 45.6% in 1986 to 49.5% in 2016. Bush land increased from 14.8 to 21% in the same period, while forest cover declined from 8.9 to 2% in the same period. The root causes for LULC changes in this particular area include population growth, land tenure insecurity, and common property rights, persistent poverty, climate change, and lack of public awareness. Therefore, the causes for LULC changes have to be controlled, and sustainable resources use is essential; else, these scarce natural resource bases will soon be lost and will no longer be able to play their contribution in sustainable ecosystem services.

Article Highlights

- Forest cover and grazing lands declined rapidly.

- Fluctuating trends in cultivated and settlement, bush land and bare land.
- Population pressure and associated demand are the main causes behind LULC changes in the study area.

✉ Gebeyehu Abebe, gebeyehuabebe2010@gmail.com | [1]Department of Natural Resources Management, Debre Berhan University, P.O. Box 445, Debre Berhan, Ethiopia. [2]Department of Geography and Environmental Studies, Debre Berhan University, Debre Berhan, Ethiopia. [3]Department of Geography and Environmental Studies, Woldia University, Woldia, Ethiopia.

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1 Introduction

Land is a vital natural resource for human survival and the base for all terrestrial ecosystem services [1, 2]. However, land degradation in the form of land use/land cover (LULC) changes has been a severe problem in the world [2, 3]. LULC changes have gained as the main cause of ecosystem service change at global scale and Africa is experiencing substantial changes across the continent [4–7]. In recent decades, African grassland, woodland, bush land and other vegetation covers have been transformed into agriculture and settlement area [8, 9]. In Africa, 5% of woodlands and grasslands and 16% of natural forest cover has disappeared during the period from 1975 to 2000; and more than 50,000 km^2 of natural vegetation has lost per year [10]. The majority of vegetation cover has been changed into agricultural and settlement land covers [10]. LULC changes and its dynamics in Ethiopia have followed a similar trend, with significant implications for natural resource degradation and loss of ecosystem service [11–14]. The major LULC changes in Ethiopia occurred in highly populated areas, mainly in the highland areas of the country [11, 13, 15].

LULC changes are the result of a multidimensional interaction among institutional, socioeconomic and environmental dynamics [16–18, 33]. Limited technology and livelihood options have aggravated the competition between different uses, and government policy and tenure insecurity have also played a significant role [7, 13, 17]. Several studies reported that deforestation and encroachment of cultivated land into marginal areas were the major causes of land degradation, particularly in the highland areas of the country [13, 19, 20]. For instance, Bewket [19] and Abate [20] reported that, a serious trend in land LULC changes resulted from the areal expansion of agriculture and settlement at the expense of forest cover in the northern part of Ethiopia. In addition, LULC changes and land degradation showed to be the main cause of rural poverty and a threat to sustainable resource utilization in the study area as elsewhere in Ethiopia [21–23]. In Ethiopia, deforestation is a continuous process, and it is a cause of biodiversity loss, changing climate conditions, desertification, and soil erosion [7, 12]. The natural forest that cover more than 40% of the country at the beginning of the twentieth century, reduced to 2.36% in 2000 as a result of population growth [7]. The population size of the country has more than doubled in the last three decades from 40 million in 1984 [24] to over 73 million in 2007 [25] and it is projected to over 130 million by the year 2030. More than 85% of the population live in rural areas [25] and highly depend on subsistence agriculture to sustain their livelihood and this result in an increasing resource demand in the country [26].

LULC changes plays a significant role in spatio-temporal environmental stability since it has a linkage with local, regional, and global climate conditions, carbon cycle, biodiversity stability, clean water, agriculture, and food security [27–29]. Thus, it is vital for understanding of the environmental change process and the problem that must be solved if living conditions and standards are to be improved sustainably [30]. This enables public agencies and private organizations to know what is happening and to make comprehensive plans for their future intervention and design effective land management policies and decisions [4]. Hence, timely information on LULC changes and its dynamics is extremely important for understanding the relationships and interactions between human and natural phenomena for better management of natural resource bases which are the main sources of livelihood for the rural poor [1, 7, 31]. This calls for global attention for continuous evaluation of the LULC changes [2, 7, 32].

Recently, geographical information systems (GIS) and remote sensing have been extensively used for LULC mapping and change detection across the world [6, 16, 33–35]. Moreover, advances in remote sensing such as the use of digital image processing algorithms have increased the use of satellite imageries such as Landsat data in studies concerned with LULC changes across multiple spatial and temporal scales [35, 36]. In this regard, several image classification algorithms have been developed and used for mapping LULC changes at a range of spatial scales [37]. The image classification algorithms differ in their rationality and level of complexity, and they include: (1) unsupervised (K-means and ISODATA); (2) supervised (minimum distance, parallelepiped and maximum likelihood) classification, and (3) non-parametric (fuzzy classification, nearest-neighbor classification, and machine learning algorithms such as random forest, support vector machines and neural networks) [38, 39]. Among these methods, supervised classification is one of the most commonly used techniques [40, 41]. Multiple remote sensing features such as spectral, spatial, multi-temporal and multi-sensor information could be used in the image classification [38].

Remote sensing and GIS offers a powerful tool for LULC changes analysis; however studies of LULC changes based solely on remote sensing and GIS may not be relevant or dependable for specific environmental application at local level. Integrated, research on LULC changes requires a combination of agent-based systems and narrative perspectives for an in-depth understanding of biophysical states [42, 43]. The use remote sensing and GIS integrated with the information from the local community can yield deeper insights into LULC changes and the drivers of changes. As a result,

there is a growing need for the integration of scientifically proven knowledge with farmers' local knowledge of the state of land resources evaluation [42–44].

Therefore, this study evaluates the trend and status of LULC changes and key drivers of changes over the past 30 years in the Gubalafto district through a combination of remote sensing and surveying of local understanding of LULC patterns and drivers. The specific objectives include (1) to quantify the extent, trend, and rate of LULC changes in the period of from 1986 to 2016; (2) to obtain local people's perspectives on LULC changes; and (3) to identify key drivers of LULC changes in the district. Research on the LULC changes and its dynamics will help in the design of sustainable land management strategies and practices to ensure sustainability in the natural resources and ecosystem in the Gobalafto district.

The remainder of the manuscript is organized as follows. The materials and methods are described in detail in Sect. 2. The results are presented in Sect. 3. A detailed discussion is provided in Sect. 4, and a summary of the main conclusions is stated in Sect. 5.

2 Materials and Methods

2.1 Description of the study area

Gubalafto district is located in North Wollo administrative zone of the Amhara national regional state, Ethiopia. It lies between 11^0 34' 54" N and 11^0 58' 59" N latitude and between 39^0 12' 9" E and 39^0 45' 58" E longitude. The study area has three agro-ecological zones: low land that ranges from 1500–1800, mid-altitude ranges from 1900 to 2200 and highland ranges 2300–3300 masl. The annual rainfall ranges from 300 to 400 mm on average. The district experiences a bimodal rainfall pattern with two short rainy seasons. The first season—spring *(belg)* starts in March and lasts until May while the second—summer *(mahar)* starts from July till September. The latter rains provide most of the annual rainfall [45]. See Fig. 1. According to the 2007 national population and housing census, the population of the district was 139, 825, of which 70,750 are males and 69,075 are females [46]. The urban population constitutes 4, 886 (3.5%) of the total population. Agriculture, including crop farming and animal husbandry, is the basis of livelihoods in the district and it is characterized by rain fed, small scale and labor intensive activities.

Fig. 1 A map showing location of the study area
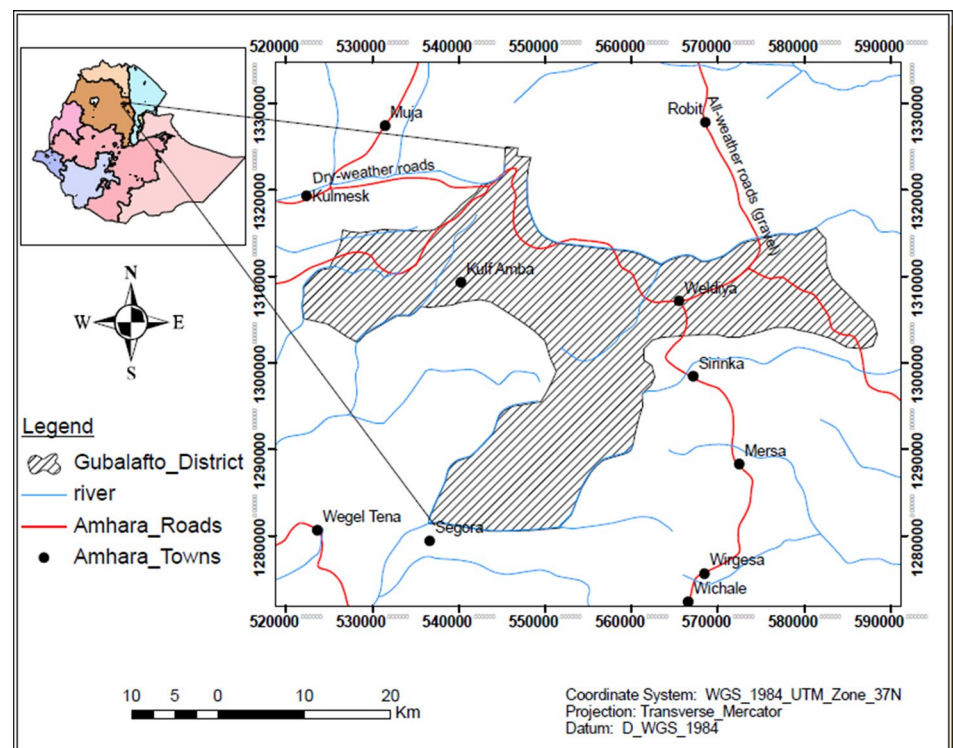
2.2 Land use/land cover classification scheme and data sources

Based on the researchers' prior knowledge of the study area and a brief reconnaissance survey with additional information from Gubalafto district agricultural office, a classification scheme was developed for the study area (Table 1). Then an extensive field observation was performed using topographic map 1:50,000, digital camera and Garmin GPS 72.

Extensive field observation and GPS control points (GCPs) sample collection was conducted in the month of February (I.e., in the same season to the date of image acquisition) to select representative training sites for each LULC class (Table 2) and to collect training samples used for image classification and validation (accuracy assessment). Hence, a total of 380 GCPs for each year were obtained, of which 80% (304 GCPs) were used for image classification and the rest 20% (76 GCPs) for validation. Historical black and white aerial photos in combination with raw satellite imaging data through visual interpretation were used as reference data to collect sample points for classifying the Landsat images of 1986 and 2000. Along with training data collection, site observations were carried out with transect walks, and the observations were used for refining the training sites and verification of classified images. In this study, multi-temporal Landsat satellite images of the study area were freely downloaded from the USGS' Earth Explorer portal (https://earthexplorer.usgs.gov/) for three study periods: Landsat 5 TM 1986, Path and Row: 168/052, and Landsat 7 ETM + 2000 Path and Row: 168/052. Landsat 8 OLI 2016, Path and Row: 168/052. Except the thermal infrared, all the visible and infrared spectral bands were included in the image classification.

In addition, Focus Group Discussions (FGDs) and Key Informants Interviews (KIIs) were carried out to obtain information on important issues such as trends and causes of LULC dynamics and environmental change in the study area. Thus, major causes of the LULC dynamics were explored using 46 key informant interviews and focus group discussions, including from local communities, government officials and Non-governmental organizations(NGOs) working in the study area. The key informants from each rural kebele were selected considering age (I.e., elders of age 60 and above), living in the study area for more than 30 years as well as their readiness to participate in the interview. Government officials and experts from Gubalafto agricultural office, and Gubalafto district Environmental Protection, and Land Administration office were selected for KIIs because of

Table 1 LULC Classification Scheme/Description of LULC types in the study area

LULC type	Brief description
Cultivated & Settlement	Includes areas allotted to crop cultivation, mostly of cereals in subsistence farming and the scattered rural settlements included within the cultivated fields
Forest cover	This refers to areas covered by trees forming closed or nearly closed canopies which include patches of natural forest and eucalyptus plantation. In the study area, forests are found mainly in small patches in mountain gorges
Bush land	This refers to land covered by small trees, bushes and shrubs; in some case mixed with grasses, less dense than forests. Bush lands are mainly found in marginal soils in the study area
Grazing land	This class refers to an area covered with grass that is used for grazing, usually communal. In the study area, grazing lands (grass lands) are found mainly in the high land areas
Bare land	This refers to areas with no vegetation cover or degraded agricultural lands. In the study area, bare land mainly found in mountainous areas which is mainly covered by bare soil and exposed rocks
No Data*	This refers to areas covered by clouds and shadows in which the image areas are contaminated with clouds and shadows. Since the study area is mountainous and the contamination is so high, the attempt to remove cloud covers and shadows was less successful

* It does not refers the actual LULC rather it indicates no data availability (clouds and shadow)

Table 2 List of Landsat images used in this study

Landsat series	Sensor	Spatial resolution(m)	Wave length range(μm)	Selected bands	Path/row	Acquisition date	Percentage of scene cloud coverage
5	TM	30	0.45–0.90	1–4	168/052	18/02/1986	3.00
7	ETM+	30	0.45–0.90	1–4	168/052	03/02/2000	9.00
8	OLI	30	0.45–0.885	2–5	168/052	06/01/2016	14.10

their knowledge about the LULC dynamics in the study area. The KIIs with each individual took about one hour. Moreover, the study included seven FGDs, each having five members from both sexes. Each FGD lasted two hours. In addition, secondary data sources, such as official reports, published works and public statistics were utilized to document the scale of the major causes behind LULC dynamics in the study area.

2.3 Data processing and analysis

Image preprocessing corrects image distortions, removes noise and increases the interpretability of an image's data. In this study, pre-processing of the images like atmospheric and geometric corrections, suitable band selection, sub-setting, layer stacking and image enhancements (such as histogram equalization and focal analysis) were applied before performing the classification of the remote sensing data [6, 16, 31, 47]. Atmospheric correction of the top of atmosphere (TOA) reflectance to surface reflectance removes atmospheric interference and it is required to implement the LULC changes detection [1, 6, 35]. Therefore, to obtain surface reflectance data, Landsat images were atmospherically corrected using FLASH algorithm in the ENVI software tools. To combine time series image data sets for change detection at pixel level, L5 TM and Landsat 7 ETM + images were registered to their corresponding Landsat 8 OLI image based on automated image-to-image registration approaches using a set of ground control points (GCPs). Spatial enhancement technique (I.e. focal analysis) was applied on Landsat 7 ETM + image in order to improve the image quality. The images were geo-referenced (Universal Transverse Mercator-UTM, WGS84) from the data set provider. Then, the land sat images of each study year was independently classified with supervised classification technique using ground truth data on existing LULC. Maximum likelihood classifier (MLC) algorithm was applied to classify the LULC types in ERDAS Imagine 2014 software. However, classification errors in the area

estimates may occur due to the spatial and spectral resolution of the satellite image used [48]. Thus, accuracy assessment of the classified images plays a vital role in evaluating dependability of extracted information from classification [49]. Hence, the accuracy of the classification results was tested using the data for validation. Finally, the post classification comparison was employed using separately classified Landsat images and then a comparison was made for the LULC maps of 1986–2000, 2000–2016 and 1986–2016.

3 Results

3.1 Land use/land cover classification

Five major LULC types (cultivated and settlement, forest cover, bush land, grazing land and bare land) were classified for the years of 1986, 2000 and 2016 (Table 3). The results confirmed that the total land area of the study area was 94954.3 ha. The areal coverage and percentage of each LULC for the three periods including 1986, 2000 and 2016 are summarized in Table 3.The LULC classification for the TM 1986 image shows that the majority of the study area was under cultivated and settlement covering for about 43,275.1 ha (45.6%). Bare land and bush land covered an area of 17,297.83 ha (18.2%) and 14,095.5 ha (14.8%) respectively, whereas the aerial coverage of grazing land and forest cover were 10,536.6 ha (10.1%) and 8482.73 ha (8.9%) from the total area of the district (Table 3 and Fig. 2). Similarly in 2000, the greatest share of LULC, from all classes was cultivated and settlement, which covers an area of 54,590.4 ha (57.6%). Bare land and bush land covered an area of 15,181.63 ha (15.9%) and 12,068.4 ha (12.7%) respectively. The least aerial coverage was forest cover and grazing land, which accounts for only 6454.91 ha (6.8%) and 5872.66 ha (6.2%) respectively (Table 3 and Fig. 3).

Table 3 Areal coverage of LULC types at different periods in the Gubalafto District

LULC types	1986		2000		2016	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Cultivated and Settlement	43275.1	45.57	54590.4	57.59	46995.7	49.49
Forest Cover	8482.73	8.93	6454.91	6.79	1979.73	2.08
Bush land	14095.5	14.84	12068.4	12.70	19887.6	20.94
Grazing Land	10536.6	11.09	5872.66	6.18	5377.05	5.66
Bare Land	17297.83	18.21	15181.63	15.98	19842.21	20.89
No Data*	1266.54	1.33	786.3	0.82	872.01	0.92
Total	94954.3	100	94954.3	100	94954.3	100

* Clouds & shadows cover

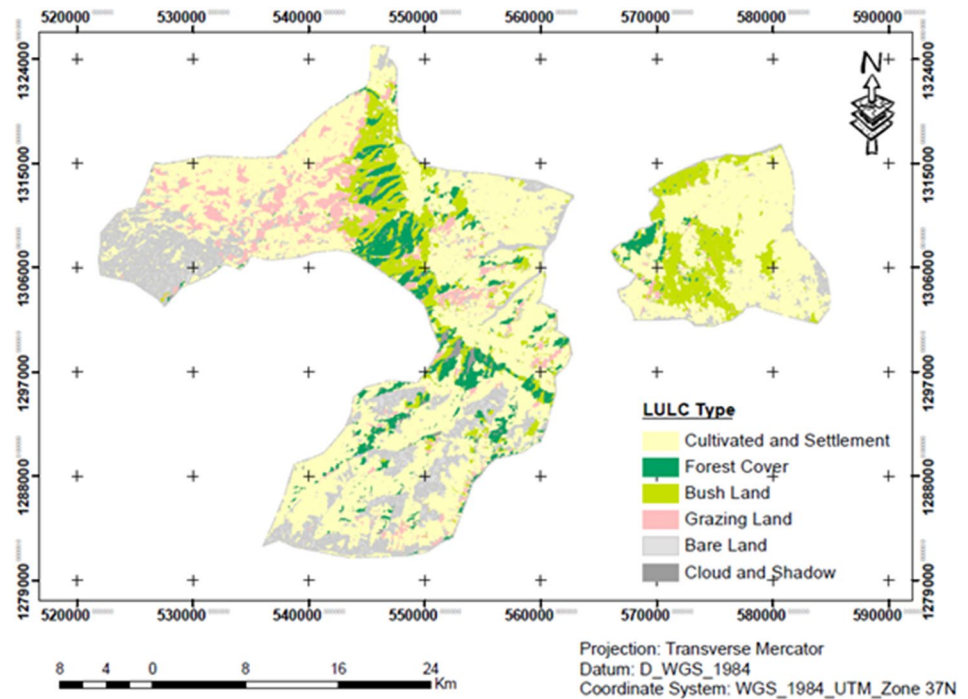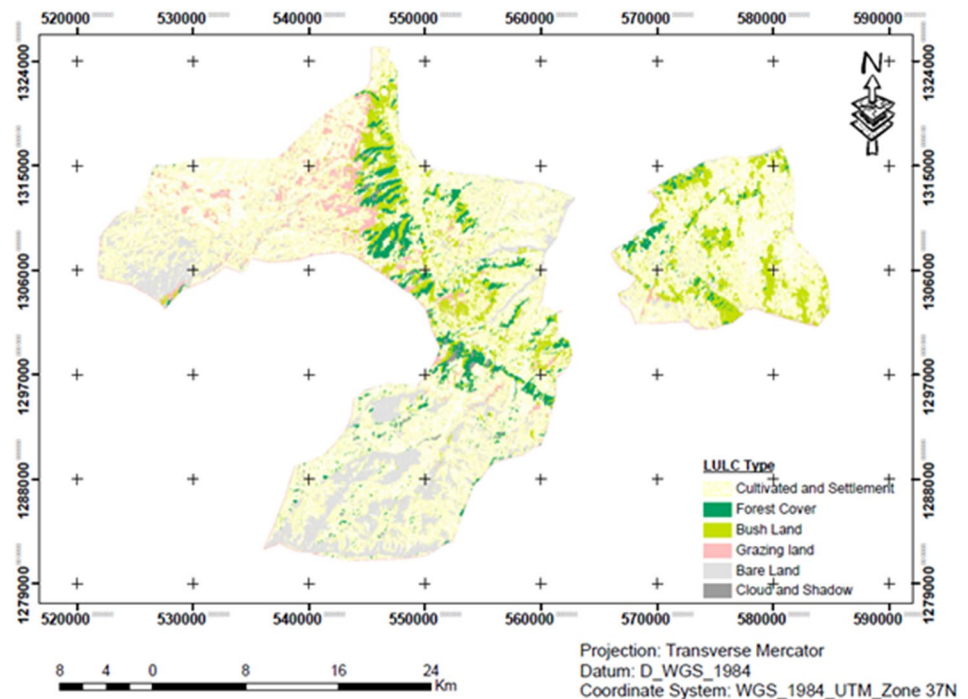**Fig. 2** LULC map of Gubalafto District in 1986



Fig. 3 LULC map of Gubalafto District in 2000

The results of LULC classification for the OLI 2016 image also shows that the greatest share of LULC from all classes goes to cultivated and settlement areas, which covers 46,995.7 ha (49.5%) of the total area of the district. Bush land and bare land covered 19,887.6 ha (20.9%) and 19,842.21 ha (20.9%) respectively. The least area was covered by grazing land and forest which was 5377.05 ha (5.7%) and 1979 ha (2%) respectively from the total size of the district. Cultivated and settlement still covered the largest area in 2016, which depicts conversion of other LULC classes to cultivated and settlement purpose (Table 3 and Fig. 4).

The classification accuracy was assessed for the recent image (2016) with an overall accuracy and kappa

Fig. 4 LULC map of Gubalafto District in 2016
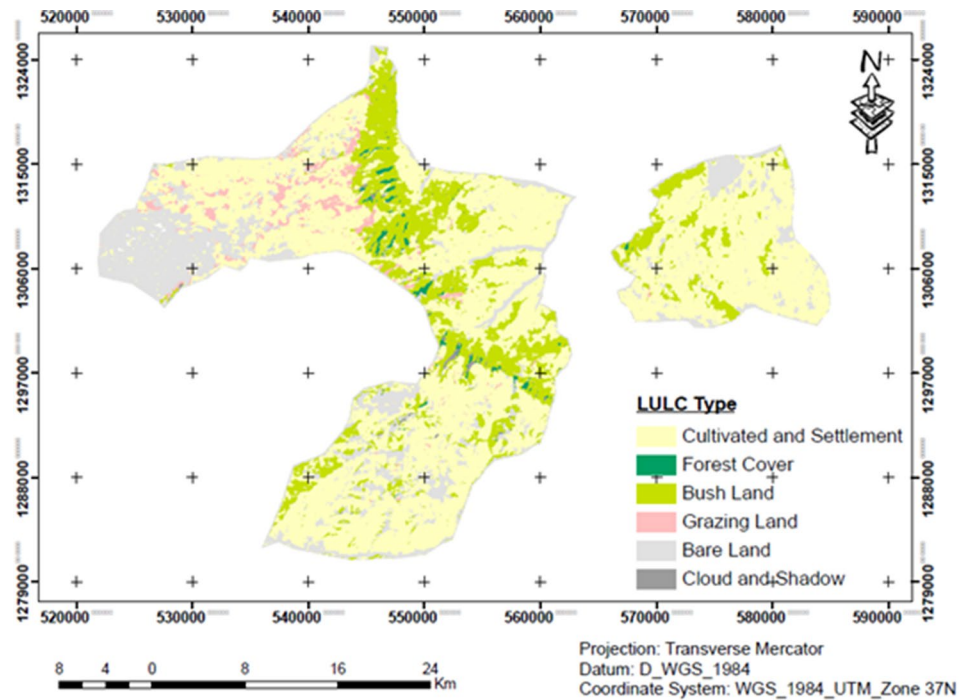
coefficient of 86.96% and 0.754 respectively (Table 4). Ismail and Jusoff [50] defined the agreement criteria for Kappa statistics as: poor when Kappa < 0.4, good when 0.4 < Kappa < 0.7 and excellent when K > 0.75. Accordingly, the LULC classification for 2016 in this study denotes excellent. The overall accuracy of this study is consistent with that of Tadese et al. [17] and Reis [51] who reported a satisfactory overall accuracy of 86.6% and 87.1% respectively. Hence, the Kappa statistics of this study showed a strong agreement for the recent classified image and the overall accuracy was within the acceptable range for further LULC changes analysis [52].

3.2 Land use/land cover changes and its dynamics

3.2.1 Extent, rate and trends of land use/land cover changes

The extent and rate of changes of each LULC for the three periods including 1986, 2000 and 2016 are summarized. Considering, the pattern of changes in LULC between 1986 and 2000, cultivated and settlement increased by 26% compared with the previous amount of cover. In contrast, grazing land showed a reverse trend, reducing by 44% during the same period of time. Forest cover and bush land showed a similar pattern of change and decreased by 24% and 14% respectively between 1986 and 2000 (Table 5). Bare land also showed declining trend, by approximately 12% in the same period. In general, the pattern showed a tendency towards more land being brought under cultivated and settlement, at the expense of other LULC types.

Table 4 Accuracy assessment of LULC classification, 2016

LULC	CS	FC	BuL	GL	BrL	Total
CS	38	0		0 2	2	42
FC	0	4		0 0	0	4
BuL	3	0		17 0	0	20
GL	0	0		0 4	0	4
BrL	0	0		0 0	6	6
Total	41	4		17 6	8	76
Overall Classification Accuracy 86.96%			Overall Kappa statistics 0.754			

CS = Cultivated & Settlement, FC = Forest cover, BuL = Bush land, GL = Grazing Land, BrL = Bare Land

Table 5 Extent and rate of LULC changes between 1986 and 2000 in Gubalafto district

LULC Types	1986	2000	Change between 1986 and 2000		Average rate of change	
	Area(ha)	Area(ha)	Area(ha)	%	Ha/yr	%
Cultivated and Settlement	43275.1	54590.4	+11315.3	+26.1	+808.24	+1.9
Forest Cover	8482.73	6454.91	−2027.82	−23.9	−144.84	−1.7
Bush land	14095.5	12068.4	−2027.1	−14.4	−144.79	−1.0
Grazing Land	10536.6	5872.66	−4663.94	−44.3	−333.14	−3.2
Bare Land	17297.83	15181.63	−2116.2	−12.2	−151.16	−0.9
No data*	1266.54	786.301	−	−	−	−
Total	94954.3	94954.3	−	−	−	−

*Clouds and shadows cover

In contrast, more and more land under grazing land, bush land and forest cover became degraded.

The extent and rate of LULC changes between 2000 and 2016 are presented in Table 6. From 2000 to 2016, bush land and bare land area has increased by 65% and 31% respectively. On the other hand, forest covers and cultivated and settlement reduced by 69% and 14% respectively during the same period. Likewise, grazing land has declined by 8% in this period (Table 6). Unlike to the previous period, cultivated and settlement declined while bare land has shown a remarkable expansion. This indicates that, the increasing agricultural areas in the previous periods mostly result in land degradation in the mountains steep slope areas, which means some cultivated areas, were converted to bare land and abandoned from cultivation during the period 2000–2016. This is observed during field surveys in which the cultivated land before 2000 has been transformed to bare land and abandoned as wasted land. Key informants also confirmed that, large areas of marginal lands were used for cultivation until the 1980s. Currently, this land feature had exhausted and cannot be used for agriculture unless rehabilitated with intervention measures. In this respect,

area closure and soil and water conservation works is fostered by the government through active participation of the local community.

Taking into consideration the overall study period, bush land has shown a remarkable areal increment, an increase of 41%. Cultivated and settlement and bare land have shown relative increment in coverage, increased by 9% and 15% respectively in the same period. In contrast, forest cover and grazing land have diminished harshly, reduced by 77% and 49% respectively in the same period (Table 7).

Generally, the result demonstrated a series of LULC changes in the study area for the last 30 years (1986–2016). The results showed that bush land became more important in the study area and has shown a significant expansion for the past 30 years. To the contrary, to a greater extent land covered by grazing land and forest had transformed to other LULC areas and declined severely. In addition, more and more land became degraded and was abandoned. The expansion of cultivated and settlement area at the expense of forest cover and grazing land were found to be consistent with LULC changes reported elsewhere [9, 20, 53].

Table 6 Extent and rate of LULC changes between 2000 and 2016 in Gubalafto district

LULC Types	2000	2016	Change between 2000 and 2016		Average rate of Change	
	Area(ha)	Area(ha)	Area(ha)	%	Ha/yr	%
Cultivated and Settlement	54590.4	46995.7	−7594.7	−13.9	−690.43	−1.3
Forest Cover	6454.91	1979.73	−4475.18	−69.3	−406.84	−6.3
Bush land	12068.4	19887.6	+7819.2	+64.8	+710.84	+5.9
Grazing Land	5872.66	5377.05	−495.61	−8.4	−45.06	−0.8
Bare Land	15181.63	19842.21	+4660.58	+30.7	+423.69	+2.8
No data*	786.301	872.01	−	−	−	−
Total	94954.3	94954.3	−	−	−	−

*Clouds & shadows cover

Table 7 Extent and rate of LULC changes between 1986 and 2016 in Gubalafto District

LULC Types	1986	2016	Change between 1986 and 2016		Average rate of Change	
	Area(ha)	Area(ha)	Area(ha)	%	Ha/yr	%
Cultivated and Settlement	43275.1	46995.7	+3720.6	+8.6	+148.82	+0.3
Forest Cover	8482.73	1979.73	−6503	−76.7	−260.12	−3.1
Bush land	14095.5	19887.6	+5792.1	+41.1	+231.68	+1.6
Grazing Land	10536.6	5377.05	−5159.55	−48.9	−206.38	−1.9
Bare Land	17297.83	19842.21	+2544.38	+14.7	+101.78	+0.6
No Data*	1266.54	872.01	–	–	–	–
Total	94954.3	94954.3	–	–	–	–

*Clouds and shadows cover

3.2.2 Land use/land cover change matrix

According to Abate [20], an important aspect of change detection is to determine what is actually changing to what category of LULC type (i.e., which LULC type is changed to the other type of LULC class). LULC changes matrix depicts the direction of change and the LULC type that remains as it is at the end of the period. Thus, to clearly understand the source and destination of major LULC changes, change matrix for each period was analyzed. The results of the study shows that, about 76.5% of the area that was covered with cultivated and settlement in 1986 remained the same in 2000. The remaining 23.5% had changed to other LULC types by 2000 (Table 8). In contrast, conversion of other LULC types to cultivated and settlement reached about 49.6% compared with 23.5% that was lost to other LULC types. On the other hand, only approximately 49.6% of the area that was covered with forest cover in 1986 was still under the same cover in 2000. The rest 50.4% was transformed to other LULC types in 2000. The area that was changed from other LULC types to forest cover was small and accounted for only 26.5% compared to the amount of forest cover lost to other LULC

types. Of the total bush land, grazing land and bare land in 1986; 40%, 33.1% and 52.8% respectively remained unchanged in 2000(Table 8), whereas the remaining largest portion of these LULC changes to other LULC types.

As illustrated in Table 9, about 57.6% of the area that was covered with cultivated and settlement showed no change between 2000 and 2016. However, conversion of other LULC types to cultivated and settlement accounted about 28.5%, covered by mostly grazing land and bush land. Of the total forest cover in 2000, 19.3% remained unchanged in 2016. The rest 79.7% was changed to other LULC types in 2016. About 47% of the area that was covered with bush land in 2000 was still under the same cover in 2016.The remaining 53% was altered to other LULC types in 2016: 42% to cultivated and settlement, 5% to bare land, 3% to grazing land and 2% to forest cover. Similarly, of the total grazing land in 2000, 35% remained unchanged in 2016, while the remaining 65% of this LULC type was changed to other LULC types in 2016: 43% to cultivated and settlement, 11% to bush land and 11% to bare land. About 45% of bare land showed no change, while the remaining 55% of this LULC was changed to other LULC types between 2000 and 2016 (Table 9).

Table 8 LULC conversion matrix of the Gubalafto District between 1986 and 2000

		LULC Type in 2000 (ha)						
		CS	FC	BuL	GL	BrL	No Data	Total
LULC Type in 1986 (ha)	CS	33120.1	966.38	3667.46	1038.73	4475.36	7.1	43275.13
	FC	3054.19	4203.73	895.83	51.8	48.05	229.16	8482.76
	BuL	6809.07	621.68	5639.22	606.67	417.95	0.91	14095.49
	GL	4745.85	11.55	1186.7	3491.65	1100.83	0.04	10536.62
	BrL	6768.72	37.35	670.43	682.25	9137.57	1.52	17297.84
	No Data	92.17	614.23	8.73	1.94	1.91	547.56	1266.54
	Total	54590.1	6454.92	12068.37	5873.04	15181.66	786.29	94954.38

CS = Cultivated & Settlement, FC = Forest cover, BuL = Bush land, GL = Grazing Land, BrL = Bare Land

Table 9 LULC conversion matrix of the Gubalafto District between 2000 and 2016

		LULC Type in 2016 (ha)						
		CS	FC	BuL	GL	BrL	No Data	Total
LULC Type in 2000 (ha)	CS	31418.3	283.69	9311.72	2350.68	10973.77	252.22	54590.39
	FC	861.11	1248.65	3443.32	21.22	626.77	253.83	6454.90
	BuL	5061.95	223.37	5681.93	410.329	659.45	31.35	12068.38
	GL	2506.93	10.74	620.11	2053.62	666.98	14.28	5872.66
	BrL	7091.43	9.19	622.37	530.6645	6840.28	87.72	15181.66
	No Data	42.62	200.61	208.40	1.15746	100.13	233.38	786.30
	Total	46982.34	1976.27	19887.86	5367.671	19867.37	872.79	94954.29

CS = Cultivated & Settlement, FC = Forest cover, BuL = Bush land, GL = Grazing Land, BrL = Bare Land

Taking into consideration the overall study period, the result confirmed that about 59% of the area that was covered with cultivated and settlement in 1986 remained the same in 2016. The remaining 41% had changed to other LULC types by 2016: 21% to bare land, 16% to bush land and 3% to grazing land (Table 10). In contrast, conversion of other LULC types to cultivate and settlement amounted 50% compared with only 41% that was lost to other LULC types. Furthermore, approximately 42% of the area covered with bush land in 1986 was still under the same cover in 2016. The rest 58% was transformed to other LULC types in 2016: 46% to cultivated and settlement, 4% to grazing land, 7% to bare land and 1% to forest cover. Of the total forest cover and grazing land in 1986, 14% and 26% respectively remained unchanged, while the remaining largest portions of these LULC were changed to other types of LULC (Table 10). Thus, it is evident that the two LULC types are most at risk of undergoing change in the study area.

4 Discussion

The results from this study demonstrated five major LULC types (I.e., cultivated and settlement, forest cover, bush land, grazing and bare land) in the Gubalafto district (Table 3). Cultivated and settlement, and bare land constituted the main land cover types, though the former has been by far the most dominant from 1986 to 2016 in the district. Of the total area, cultivated and settlement covered about 46.6 in 1986 and 49.5% in 2016 and bare land covered about 18.2% and 21% in the respective years. The accuracy assessment result of recent (2016) LULC classification in this study shows excellent. The overall accuracy of this study is consistent with that of Tadese et al. [17] and Reis [51] who reported a satisfactory overall accuracy of 86.6% and 87.1% respectively. In addition, the Kappa statistics of this study showed a strong agreement for the recent classified image and the accuracy was within the acceptable range for further LULC changes detection assessment [52].

The results have shown several LULC changes occurred for the last 30 years (1986–2016) in Gubalafto district

Table 10 LULC conversion matrix of the Gubalafto district between 1986 and 2016

		LULC Type in 2016 (ha)						
		CS	FC	BuL	GL	BrL	No Data	Total
LULC Type in 1986 (ha)	CS	25376.2	186.33	7051.55	1320.88	9173.64	166.43	43275.03
	FC	1565.53	1203.27	4312.72	87.39	1077.53	236.28	8482.73
	BuL	6520.91	191.29	5904.65	509.61	932.14	36.88	14095.47
	GL	5101.99	18.28	1243.8	2726.48	1417.14	28.92	10536.6
	BrL	8377.79	21.52	997.52	724.77	7050.32	125.89	17297.83
	No Data	76.59	357.63	370.63	1.06	175.69	284.94	1266.54
	Total	47019.01	1978.32	19880.87	5370.19	19826.45	879.34	94954.2

CS = Cultivated and Settlement, FC = Forest cover, BuL = Bush land, GL = Grazing Land, BrL = Bare Land

(Table 7). The findings demonstrated that bush land became more important and has shown a significant expansion for the past 30 years, increase by 41%. Similarly, cultivated and settlement and bare land have shown relative increment in coverage, increased by 9% and 15% respectively during this period. In contrast, to a greater extent land covered by grazing and forest had transformed to other LULC and declined by 77% and 49% respectively during this period (Table 7). Studies conducted in different parts of Ethiopia also showed consistent results with this study. For instance, Gebrehiwot et al. [54] in Birr and the Upper-Didesa watershed, Gashaw et al. [55] in the Andassa watershed, Dibaba et al. [56] in Fincha catchment and Ewunetu et al. (31) in north Gojjam sub-basin. This is also consistent with the findings of Abate [20] who reported the expansion of cultivated land at the expense of forest cover and grass land between 1985 and 2003 in Borena district, Northeastern Ethiopia. In general, the results imply that bare land, cultivated and settlement expansion increased to produce more crops by increasing farm size, but it was at the expense of natural resource degradation and severe soil erosion. Furthermore, charcoal production and firewood collection are also among the sources of livelihood for the rural community in the study area as elsewhere in Ethiopia [9], however they are a cause of forest destruction in the study area.

The finding of this research indicated that more than half of the area that was covered with cultivated and settlement in 1986 remained the same in 2016. The remaining had changed to other LULC types during this period (Table 10). On the other hand, half of other LULC type conversion was to cultivate and settlement. Furthermore, less than half of the area covered with bush land in 1986 was still under the same cover in 2016, however, more than half of its part was transformed to other LULC types (Table 10). Accordingly, it is evident that forest cover and grazing land are most at risk of undergoing LULC changes in this study area. Comparable LULC changes dynamics were reported by previous studies in different parts of Ethiopia. For instance, Zeleke and Hurni [14] reported the expansion of agricultural lands at the expense of natural forest covers in northwestern Ethiopian highlands during 1957 to 1995. Similarly, Kindu et al. [52] reported that a remarkable conversion of forests covers and woodlands for cultivated lands from 1973 to 2012 inMunessa-Shashemene, south-central highlands of Ethiopia. Ewunetu et al. [31] and Teferi et al. [13] also reported that the highest gain of agriculture land was obtained from grazing and shrubland from 1986 to 2017 inthe north Gojjam sub-basin of upper Blue Nile and from 1972 to 2009 inthe Jedeb watershed respectively.

Like most parts of Ethiopia, the study area is inhabited by rural people in which their livelihood is depend on subsistence agriculture and thus the natural growth is relatively higher than urban areas [46]. Currently, the population of the study area has increased and its effect on the environment is devastating. Regarding this trend, FDG participants and key informants' interviews stated that population growth as the main cause of natural resource degradation in the Gubalafto district. Due to population growth, farm land owned by the parents is unceasingly shared by the number of children and, therefore, land fragmentation continues, nonetheless its size abjectly declining. This has caused for natural resources scarcity and has supported natural resource degradation in the district. Moreover, according to local respondents, population growth results in cultivated land expansion at the expense of natural vegetation and grazing land cover in the Gubalafto district. This finding is similar to recent studies conducted on other parts of Ethiopia, which have shown that population growth is the main cause in the LULC changes [11, 12, 23]. In this respect, different land uses compete with one another, and can reduce the quality of natural resource basses and land productivity.

Regime changes and land tenure insecurity were also described by the KIIs and FGDs participants as one of the main factors behind the LULC changes in the study area. They described the situation, during the Dergue regime (1974 -1991) there was large scale afforestation in most parts of the study area. However, in the early 1990s the plantation forests were inappropriately removed for different purposes such as house construction, settlement, fuel wood and charcoal making. Those tragedies of community plantations and natural forests in the absence of firm political control to enforce and maintain rules for protection of such common property have also resulted in massive forest decline elsewhere in the country [57–59].

The land tenure system of the country also plays an important role for LULC changes in the highlands of Ethiopia since the national land policy transferred land ownership from the individual to the government [52]. This is also true in the study area, as farmers do not own land but have only use right and hence they are reluctant to participate in soil and water conservation works with long-term environmental impacts. Previous study also demonstrated that land tenure insecurity led for short-term needs than long-term return and thus resulted in inappropriate land use and poor land management practices that accelerate LULC changes [58]. Agricultural growth is still based on areal expansion [20] and thus, there was mismanagement of land, including cultivating steep slope and marginal land, overgrazing and destruction of forest cover for different purposes.

On the other hand, the livelihood of many poor people relies on the sale of firewood, charcoal and dung cake. According to the KIIs and FGDs participants, in recent years, firewood and charcoal have become the most

commercialized energy sources for both the rural and urban poor in the Gubalafto district. This finding is similar to the finding of Ewunetu et al. [31], recently conducted in the north Gojjam sub-basin of upper Blue Nile. Generally, the main causes of LULC changes in the study area include population pressure, agriculture and settlement expansions to marginal mountain area, increasing wood demand for fuel, collection of farm implement and construction wood, charcoal production, livestock grazing and regime changes.

Similarly, climate change directly or indirectly affects LULC and the ecosystems by altering the pattern, distribution and practice of land [18]. On the other hand, LULC changes such as deforestation, cultivated land expansion and urbanization have a long term impact on hydrological processes such as rainfall pattern, evapotranspiration, runoff and infiltration [60]. In addition, LULC changes and its dynamics directly relate to biodiversity and productivity of land [61, 62]. Furthermore, LULC changes have enormous environmental and societal impacts [63, 64] and it affects both local and global systems by altering the interaction of energy, greenhouse gasses and water between land and the atmosphere [65]. For instance, in their study Traore et al. [66], attempted to assess the land use/land cover changes and their impacts on land surface temperature in Bangui city, Central African Republic. Their study reported that LULC changes related to urbanization process results in an increase in the land surface temperature (LST), in the Bangui city in the period from 1986 to 2017. In another study, Kafy et al. [67] attempted to evaluate the impact of LULC changes on the seasonal LST using multi-temporal Landsat images in the northwest part of Bangladesh; and the results showed an increasing seasonal LST trends in the study region for the years 2029 and 2039. Hence, sustainable land use planning and management should put in place for local communities with particular emphasis on close supervision of bare land restoration, forest and bush land conservation, making grazing lands available through restoration of degraded land and regulating further expansion of areas under cultivation.

5 Conclusions

The main aim of this study is to investigate LULC changes and their dynamics that occurred in the Gubalafto district between the years 1986 and 2016 using remote sensing and GIS. The result from digital image classification and change detection coupled with a field survey demonstrated that the study area had undergone a significant LULC change for the past 30 years. The general trend observed by the present study is a decrease in forest cover and grazing lands and corresponding fluctuating trends in cultivated and settlement, bush land and bare land. Generally, the observed LULC changes are mainly linked with the growing population and the associated demand for natural resources through fuelwood, charcoal production, and expanding cultivated and settlement areas in Gubalafoto district, Northeastern Ethiopia. These changes worsen biodiversity loss, land degradation, and disturbance of the hydrological cycle in the study area. Since there is no additional land to be brought for cultivation, large areas of a steep slopes which were once under forest cover and bush are now used for agriculture purposes and exposed to severe soil erosion. Hence, there is a risk of a decline in the extent of cultivated land in the near future. Because cultivation of marginal lands on steep slopes coupled with lack of appropriate land management practice may lead to severe land degradation and thus cultivated land could be converted towards bare land. The implication is that the recent tendency may lead to more land degradation. The findings of this study highlights, the need for a comprehensive assessment of human activities in the study area and the adaptation of sustainable LULC practices such as close supervision of bare land restoration, forest and bush land conservation, making grazing lands available through the restoration of degraded and impoverished lands and limiting further expansion of areas under cultivation. Thus, sustainable land use planning and management, proper implementation of forest, soil, and water conservation measures, and provision of alternative livelihood strategies should be put in place for local communities to reverse undesired situations associated with LULC changes in the study area.

Authors' contribution All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Gebeyehu Abebe. The first draft of the manuscript was written by Gebeyehu Abebe and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability All data generated or analyzed during this study are included in the manuscript file.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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