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Analyze of spatial extent and current condition of land use land cover dynamics for the period 1990–2020 Wayu-Tuka district, western Ethiopia

Jembere Bekere [a,*], Feyera Senbeta [b], Abren Gelaw [c]

[a] (Environment & Natural Resource Mgt) Geography Department & Env'tal Studies, Arba Minch University, Ethiopia
[b] (Centre for Environmental and Development) Department of Environmental and Sustainable Development, Addis Abeba University, Ethiopia
[c] (Environment & Natural Resource Mgt), Geography Department and Env'tal Studies, Arba Minch University, Ethiopia

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ABSTRACT

LULC variation has increased in many parts of the world recent years. Analyzing LULC is valuable to ability to grasp for spatial extent, patterns and impacts of the dynamics. This research examines the magnitudes and trends of LULC dynamics of Wayu-Tuka District, Western Ethiopia for a period of 1990–2020. Data were acquired from Landsat images (i.e, TM from 1990 to 2000, ETM+ from 2010 and OLI 2020). LULC classes were classified (from Landsat images) to develop land use land cover change maps for the study area. Landsat images were grouped via supervised classification method and maximum likelihood classifier (MLC). Accuracy scores and kappa a coefficient was used to confirm the accuracy categorized for LULC classes. Forest, settlement area, cultivated area, water body, and bare land are the main land use land cover categories identified in the study area. At the study district, forest coverage decreased progressively within the past three decades (1990–2020) from 12.4% in 1990 to 2.6% in 2020. The settlements, cultivated lands and water bodies have been explained by a average rate of 0.41% per year and forest land has been reduced by 0.33% per year. The study identified the major drivers of land use/land cover dynamics such as expansion of agricultural land, extraction of fuel woodland, illegal settlements and illegal logging was the key factors of LULC changes in the field of the study. In expressions of historical and current LULC, the analysis indicated that in the three decades years' viewpoint; changes in agriculture land expansion and expansion of settlement land have had a strong impact on the LULC dynamics. The few remaining forest area coverage of the District shall be completely vanished unless measures are taken to curb these declining trends. Therefore, relevant stakeholders should take integrated actions to rehabilitate degraded landscapes through afforestation and reforestation programmes.

1. Introduction

Since time immemorial, humankinds have changed or modified LULC to improve their well beings and quality of life. Land use/land cover change have recently emerged as a major driver of worldwide environmental change, with the result that natural ecosystems have further transformed into human-dominated landscapes [1,2]. According to Ref. [3] Land use is defined as services,

* Corresponding author.
E-mail addresses: biftuadugna1@gmail.com (J. Bekere), feyeras@yahoo.com (F. Senbeta), abren_mokonen@yahoo.com (A. Gelaw).

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actions and inputs, often related to people, taking place in the country and representing present usage, while land cover defines things that can be observed on the earth's surface as natural and anthropogenic topographies. LULC change/dynamic refers to the modification and/or conversion of one LULC class (e.g., forest) to another one (e.g., agriculture, woodland or shrub cover) [4,5]. However, Land conversion due to housing, economic development, and transportation expansion has recently resulted in changes in the spatial extent and current state of LULC worldwide [6,7]. LULC change analysis has been and continues to be used to realize how land has been used in the earlier, what types of changes can be expected in the future, and the factors and processes behind the changes [6,8]. Today, remote and geographic information system represents a powerful instrument for analyzing LULC changes [9]. Recently, Geospatial Information System, and remote sensing are applied systematically around the world for LULC mapping and change detection [10–12]. Therefore, analyses of changing aspects of LULC are useful to see the scale, developments and drivers of the dynamics and the processes behind the changes.

Africa suffers from significant LULC variation from corner to corner of the continent, where its land use/land cover, particularly grasslands, forests, shrub land areas, and extra vegetation area were converted into agricultural area besides inhabited places in the last decades [13–16]. Although the processes of LULC dynamics are frequent in Sub-Sahara countries of Africa, the magnitudes/rates, trends and impacts of the land use changes as well as its driving forces reveal spatiotemporal variations across countries [15,17]. This so because, LULC changes in Sub-Sahara countries of Africa together with Ethiopia is based on the complex interplay of various factors of socioeconomic issues alongside the performers of the driving forces and the country itself [18–20]. LULC is not consistent throughout Ethiopia, making it challenge to determine broad trends in LULC change in mentioning unstudied areas [21,22]. In developing countries such as Ethiopia; LULC changes were supported by the multifaceted interplay for diverse actors, drivers, and Ethiopia [20,22].

The current trends in LULC dynamics have revealed a significant change in settlement areas wherever it occurs [15]. Thus, understanding the spatial extent and current condition of land use/land cover changes, and arrangements were a serious concern and require appropriate investigation [23]. Adequate information about LULC dynamics is critical to recognize the relationship and interactions between human and natural occurrences in order to properly manage the natural resources that are the major livelihood of the rural poor in least developed countries [24,25]. According to Ref. [26], land-use change analysis of forest loss due to agricultural transformation shows that the relationship between population growth, increased demand for agricultural land, and forest loss goes back thousands of years. Depending on the type of disturbance and alteration, forest loss may progress from closed forest areas to

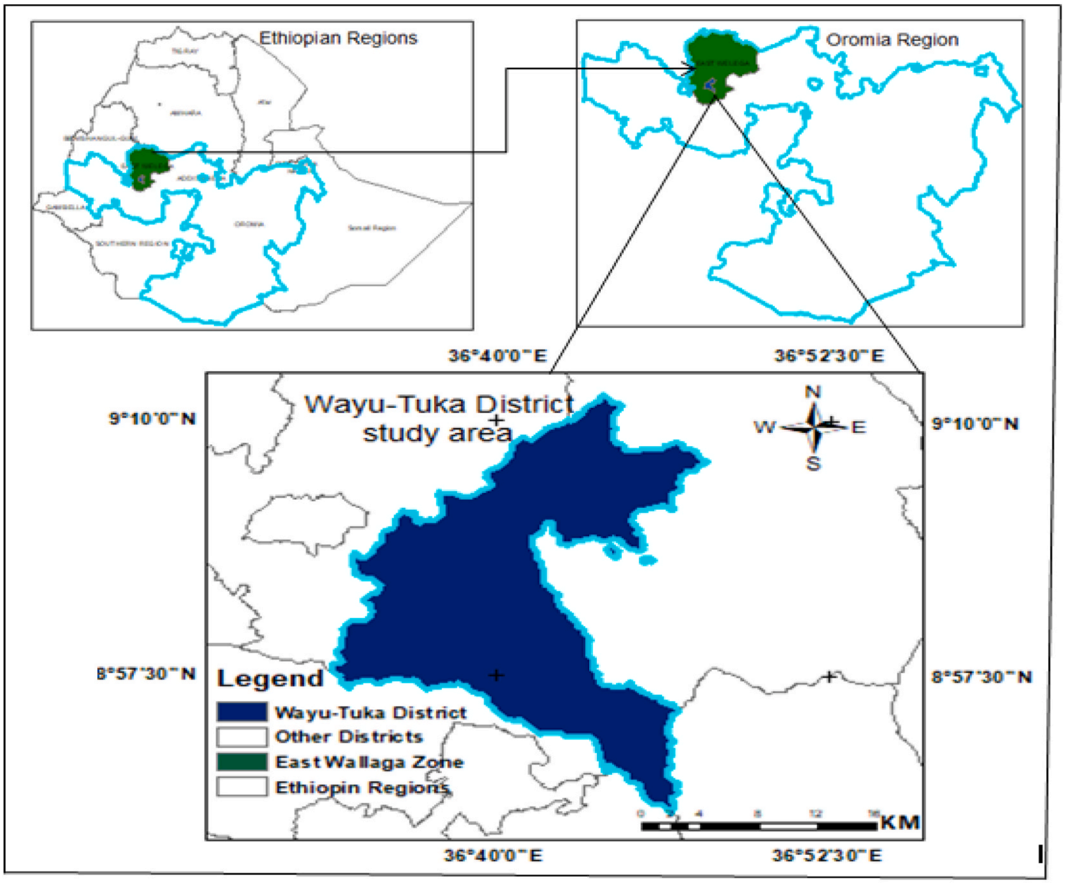

Fig. 1. Location map of the Wayu-Tuka district (Source: self-designed based on Ethiopia GIS database, 2022).

selectively dispersed forests, and then to clear cutting, or from closed forest areas to clearcutting [27,24,28].

Like elsewhere in Ethiopia, LULC dynamics caused by anthropogenic activities are commonly observed in Wayu-Tuka District (East Wollega) Western Ethiopia where this research was conducted. A recent study conducted western Ethiopia showed an expansion of agricultural land from 24.8% in 1991 to 33.5% in 2019, and where forest cover has declined from 37.4% in 1991 to 20.1% in 2019 [29]. The spatial extent and the current state of the LULC dynamics in the district, as in the other parts of the country, are strongly influenced by anthropogenic activities. Therefore, the LULC dynamics requires a thorough investigation of the ongoing LULC changes in the study in order to provide efficient policies and management alternatives for supportable natural use and management [30]. As a result, the study examined the spatial extent and current status of land use/land use cover change in Wayu-tuka District of East Wollega Zone, Ethiopia over four time periods: 1990, 2000, 2010 and 2020.

2. Field of study and approaches of the research

2.1. Study area description

The study area, Wayu-Tuka District is located in the East Wollega Administrative zone of the Oromia National Region State, approximately 322 km at West of Addis Abeba. The district is bounded to the north and east with Sibu Sire district, to the south is the area of Leka Dulacha, while to the west is Guto Gida. The study district is located specifically between 8° 51′ 30″ and 9° 10′ 30″ north latitudes and 36° 32′ 0″ and 36° 50′ 0″ east longitude (Fig. 1). The district contains hills and high peaks such as Komto and Gara-achani. This region, which lies at elevations of approximately 3,350, 3,140, and 2350 m above sea level, also includes Tuka. Wayu-Tuka is made up of 12 Kebeles (the smallest administrative unit in Ethiopia), 10 rural communities and 2 urban areas. Its total area is 54,590.4 ha.

2.1.1. Climate

The East Wollega Zone has three agro ecological separations; of these, 11% are highlands, 49% midlands and 40% lowlands (EWARDO, 2009). The zone receives between 1000 and 2400 mm of annual rainfall and an annual temperature between 140 °C and 260 °C. In the Wayu-Tuka district, on the other hand, about 2158 mm of precipitation fell annually and annual average temperature was about 190^{o}c. According to Nekemte Meteorology Station Agency (NMSA, 2014), the documented climate data indicates yearly precipitation of the study area is about 2200 mm, and that the area also had a minimum and maximum average temperature in the area in 2010 was about 2200 mm, and in 2014 12.5^{o}c and 25.5^{0}c respectively.

2.1.2. Vegetation

The foremost vegetation type observed in the study area is African mountain vegetation, highland forests, semi-deciduous low-mountain forests, some riverine types, and plantation forest types. According to Ref. [29], the plantation of the study place fits to moist ever popular montane forests; a forest type acknowledged occurring in southwestern Ethiopia.

2.1.3. Relief and soil

Soil in the study area is deep, and well located, suitable to oxidized soil and humus; among them, the main soil types and their ranges in this area are clay (17,371.68 ha), sandy soil (10,133.49 ha) and clay (1447.64 ha), suitable for agricultural planting, for instance crop cultivation: production of corn, sorghum and teff in the district (WARDO, 2009 E C.).

One type of Ultisols was recovered from volcanic ejecta around Nekemte in Guto Gida district, which coincides with the research area of Wayu-Tuka district; Oxisols soils are present in the western and southwestern parts of Oromia, such as Wollega, Ilu Ababora and Jima [31,32]. In addition, it has been stated that dry Vertisols and Inceptisols are found in western Ethiopia and southwestern Wallaga; the soil is deep and belongs to oxidized soil and Ultisols. For example (WARDO, 2009) mentioned that the main the soil types of the district and their spatial distribution is 17,371.68 ha of clay, 1447.64 ha of clay soil suitable for agriculture such as crop cultivation: the area produces maize, sorghum and teff (Fig. 2).

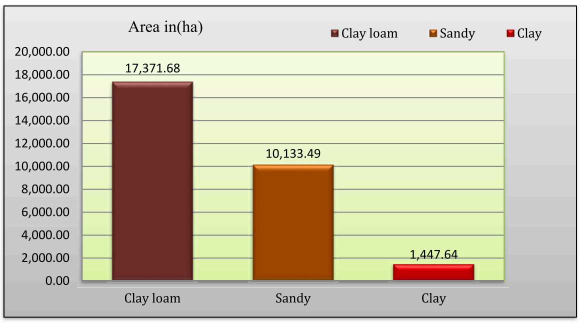

Fig. 2. Types of soil and their cover in the study area (Sources: WARDO, 2009 E C).

2.1.4. Economic activities and population characteristics

Subsistence agriculture is the most important accomplishment of the district; cereal production and animal husbandry. The 2007 Population and Housing Census found that Wayu-Tuka District had a population of estimated at 66,194. With 66,194 of whom 32,391 were men and 33,803 were women. Dwell in the urban area 3019 male 1514, female 1505 and in the rural male 30,877, female 32,298 for more clarification (Fig. 3).

2.2. Research method and materials

2.2.1. Sources of data, processing, and classification of images

Data sources for land use/land cover in the Wayu-Tuka district were acquired from satellite imagery captured four time periods.

To this end, 1990 Landsat Multispectral Scanner (MSS), 2000 Thematic Mapper (TM), 2010 Enhanced Thematic Mapper plus (ETM+), and 2020 Operational Land Imager (OLI) are available from the United States Geological Survey (USGS) http://earthexplore.usgs.gov Free download. Information for LULC such as woodland cover, settlement area, cultivated area, water body, and vacant place from Landsat consecutively and datasets created using the composite change approach conditions by selecting optimal pixels from all available archived Landsat data [33,32].

Satellite image from Land sat MSS, TM and ETM which were captured in 1990, 2000, 2010 and 2020 satellite imagery was enough to show changes and trends in Land Cover in the LULC classification. These Landsat satellite images were processed and obtained from (path 170; raw 54) which contain sensor types such as the MSS, ETM+, TM, and finally the OLI (http://earthexplore.usgs.gov for land in the study area Use/Land Cover Classification. The Ethiopian Mapping Authority (EMA) used to decide the rate of change in forest cover ended the past three decades Table 1: Summaries of satellite data types, sources and properties of the Landsat imagery used in this study.

The numbers of pixels/training sample points used for LULC-type classifications for each Landsat image were taken from the type of satellite data are presented in Table 2.

For LULC classification; the ground truth data used imagery from Google Earth and Landsat visual clarification through high-resolution images as a reference [32,34,35]. According to previous findings [18,36], the visual explanation of reference images is based on components that support identify LULC characteristics, such as location, size, shape, color, texture, hue, and pattern of geographic features. In addition, carefully selected training points (which were constant throughout the study periods) were chosen, taking into account the well-defined time intervals in the study. Finally, it was possible to obtain all defined LULC classes and training example points are listed in Tables 2 and 3, respectively.

Table 4: Described LULC classification arrangement for LULC categories this research and the description was based specifically on a research place. On behalf of every land use land cover type, schemes for land use/land cover groups (woodland, settlement land, cultivated area, water bodies, and undeveloped land) were briefly described (Table 4).

The image preprocessing involved correcting the distortions of images and improving the quality of the image data. For this purpose, Landsat imagery is first georeferenced with Universal Transverse Mercator (UTM-WGS84). The LULC classes of each image for the period (1990–2020) Classify using Maximum Likelihood Classifier for supervised classification technique using ArcGIS 10.8 (Fig. 4).

2.2.2. Accuracy assessment

Approving [9] indicated that an accuracy assessment was performed because classification errors could have been occurred in the

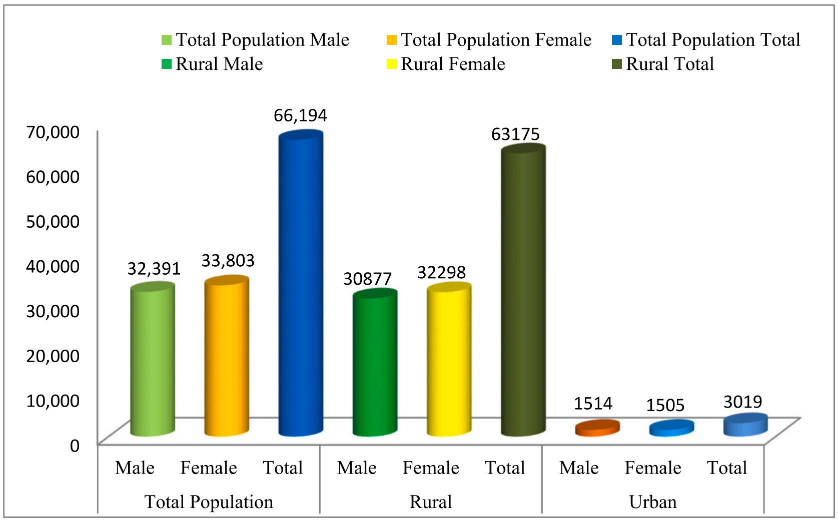

Fig. 3. Population of Wayu-Tuka district (Source: Ethiopian Census 2007).

Table 1
Sources and properties of Landsat TM, ETM+ and OLI imagery.

N0	Platform	Sensor Type	Path/Row	Resolution	N0 of Bands	Acquisition Date	Source Cloud c.
1	Landsat 5	MSS	170/54	30 m	7	February 1990	USGS <10%
2	Landsat 7	TM	170/54	30 m	7	January 2000	USGS <10%
3	Landsat 7	ETM+	170/54	30 m	9	February 2010	USGS <10%
4	Landsat 8	OLI	170/54	30 m	11	January 2020	USGS <10%

Source: Adopted from http://earthexplore.usgs.gov) (2020)

Table 2
Number of pixels used for classification of Wayu-Tuka district LULC classes.

N0	LULC Classes	Number/Counts of Pixels (Training Sites)			
		MSS (1990)	TM (2000)	ETM+ (2010)	OLI (2020)
1	Forest	3039	3079	2753	288
2	Settlement	399	381	817	387
3	Cultivated land	306	1079	647	782
4	Water body	275	87	158	38
5	Bare-land	631	406	168	340

Source: Own Summary, 2022

Table 3
Ground truth data used Google Earth as a reference for LULC classifications.

Landsat image	Ground truth data							Nopixels/Training sample
		Forest	Setl.	Cul.ld	WB	BL	Total (user)	
Multispectral Scanner (MSS) (1990)	Forest	**4**	0	2	0	0	**6**	3039
	Settlement	2	**6**	1	0	0	**9**	399
	Cultivated land	0	0	**8**	0	0	**8**	306
	Water body	0	0	0	**3**	0	**3**	275
	Bare land	0	0	0	0	**4**	**4**	631
Total (Producer)		**6**	**6**	**11**	**3**	**4**	**30**	
Thematic Mapper (TM) (2000)	Forest	**7**	0	0	0	0	**7**	3079
	Settlement	1	**6**	1	0	0	**8**	381
	Cultivated land	0	1	**7**	0	0	**8**	1079
	Water body	0	0	0	**2**	1	**3**	87
	Bare land	0	0	0	0	**4**	**4**	406
Total (Producer)		**8**	**7**	**8**	**2**	**5**	**30**	
Enhanced Thematic Mapper Plus (ETM+) (2010)	Forest	**6**	0	1	1	0	**8**	2753
	Settlement	1	**5**	1	0	1	**8**	817
	Cultivated land	1	0	**6**	0	0	**7**	647
	Body of water	0	0	0	**3**	0	**3**	158
	Bare ground	0	0	0	0	**4**	**4**	168
Total (Producer)		**8**	**5**	**8**	**4**	**5**	**30**	
Operational Land Imager (OLI) (2020)	Forest	6	0	1	0	0	7	288
	Settlement	0	**6**	2	0	0	**8**	387
	cultivated land	0	0	**7**	0	0	**7**	782
	Water body	0	0	0	**3**	1	**4**	38
	Bare land	0	0	0	1	**3**	**4**	340
Total (Producer)		**6**	**6**	**10**	**4**	**4**	**30**	

NB: Setl. = Settlement, Cul.ld = farmland, WB = bodies of water, and BL = bare land.
(Source: Own summary, 2022)

Table 4
The main LULC classes of Wayu-Tuka district, eastern Wallaga.

LULC Class	Definition and Description of the LULC Classes
Forest	Consisting of trees with over 3 m heights and nearly closed canopies, and found in small patches
Settlement	Built-up areas having scattered rural homesteads and villages, schools, churches and market sites
Cultivated land	Cropland used for growing dominantly cereals, which are meant largely for subsistence consumption
Water body	Refers to streams (stream courses), ponds and marshy/wetland areas
Bare-land	Areas devoid of vegetation and abandoned from farming, and hilly sites with bare-soil and exposed rocks

Source: Own Summary, 2022

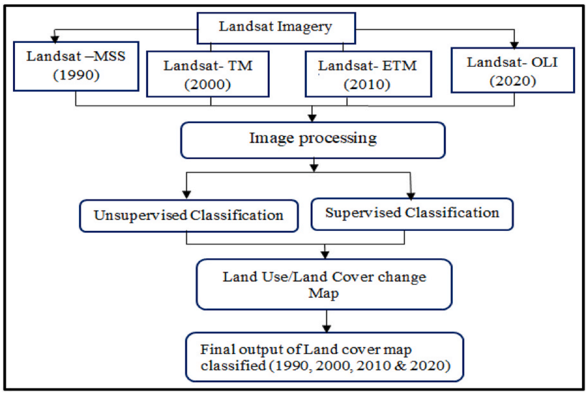

Fig. 4. Flowchart methods for the LULC change (1990–2020) (Source: Own Design, 2022).

detection of the LULC change types of the research extent, consistent with spatial and spectral determination for satellite imagery. The purpose of the accuracy assessment is to quantitatively evaluate the effectiveness with which pixels are classified into the correct land cover class [37]. In addition, when selecting pixels for accuracy assessment, emphasis is placed on areas that can be clearly identified in high-resolution Landsat images, Google Earth and Google Maps [38,37]. In addition, assessing the accuracy of classified Landsat images also plays a crucial role for assessing the reliability of classification information [21,32]. Therefore, the accuracy of the classification results should be tested against the validation data.

For these images, producer accuracy, user accuracy, over-all accuracy, and kappa coefficients are evaluated for every one images (Table 5). Producer accuracy (PA) and user accuracy were calculated to verify the accuracy of LULC type classification. PA is the ratio of correctly classified pixels in a class to the total number of column pixels in that class multiplied by 100; while UA is the ratio of correctly classified pixels in a class to the total number of row pixels in the same class, multiplied by 100 [38]. The kappa coefficient estimate is a measure of the agreement between a classification map and reference data. The kappa coefficient (Ḱ) is defined as [16,36]:

$$\acute{K} = \frac{\text{observed accuracy} - \text{chance agreement}}{1 - \text{Chance agreement}} \tag{1}$$

Normally, the Ǩ value is between 0 and 1. The Kappa coefficients are calculated using the follow formula [39].

$$R = \frac{N \sum_{1}^{k} x_{ii} - \sum_{1}^{k} (x_{i+} x_{x+1})}{N^2 - \sum_{1}^{k} (x_{i+} x_{x+1})} \tag{2}$$

Where: N is the total number of observations in the entire error matrix, k is the total number categories or classes, xii is the number of correctly classified observations for a given category, $xi+$ and $x+i$ are the number of marginal values associated with the category Total for row i and column i.

To confirm reliability for the LULC results, the overall precision, the ratio of the gathered diagonals pixels grouped by numeral to the number of reference pixels multiplied by 100, was also evaluated [40].

According to Ref. [41], the criteria for the agreement of the kappa coefficient statistics are defined: Lowly if kappa <0.4, good if $0.4 <$ kappa <0.75, and excellent if $K > 0.75$. As a result, the kappa coefficient is assessed almost perfectly and showed strong agreement with the classified images of the 1990, 2000, 2010 and 2020 land cover maps. They were found to be accepted for further analyzed LULC changes and are suitable for further investigation.

Table 5
The LULC types of Wayu-Tuka district 1990, 2000, 2010 and 2020.

No.	LULC Type	1990		2000		2010		2020	
		Area (ha)	P (%)	Area (ha)	P (%)	Area (ha)	P (%)	Area (ha)	P (%)
1	Forest cover	5015.6	12.4	3321.9	8.2	1665.6	4.1	1054.9	2.6
2	Settlement	9017.99	22	10,461.88	26	13,931.58	34.2	14,842	36.6
3	Cultivated land	14,788.51	37	21666.78	54	20,917.08	52	22,792.31	56.5
4	Water body	214.0	0.5	885.4	2.2	121.9	0.3	1535.7	3.8
5	Bare-land	11,392.5	28.2	4092.6	10.1	3792.4	9.4	203.7	0.5
	Total	**40,428.6**	**100.0**	**40,428.6**	**100.0**	**40,428.6**	**100.0**	**40,428.6**	**100.0**

Source: Own Analysis via ArcGIS 10.8 (2022)

2.2.3. Methods of data analysis

The magnitude and rate of LULC change classes were analyzed using Landsat imagery data Free download at http://earthexplore.usgs.gov. The images are processed using ArcGIS 10.8 software. First, the imagery was converted to Universal Transit Mercator co-ordinates and geo-referenced to Ethiopia's chosen datum from WGS-84. Histogram equalization is used to improve image quality. Satellite imagery was then first geo-referenced; supervised and unsupervised classifications were employed to indicate the types and areas of the different land use and land cover categories of the study area for each period considered. This study employed a descriptive continuous mixed study design approach, using maximum likelihood techniques for supervised classification, using ArcGIS 10.8 software to classify land cover categories.

The spatial extent for forest cover type, e.g. forest, settlement, cultivated area, water body, and bare area classifications is shown in Table 5. According to Refs. [36,42], there is a general assumption that the accuracy of the country's assessment process coverage classification depends on several factors such as grouping pattern, image data employed, the pre-processing and post-processing methods, the justification of the data collection, and the validation methods [43]. The results were determined for each LULC type

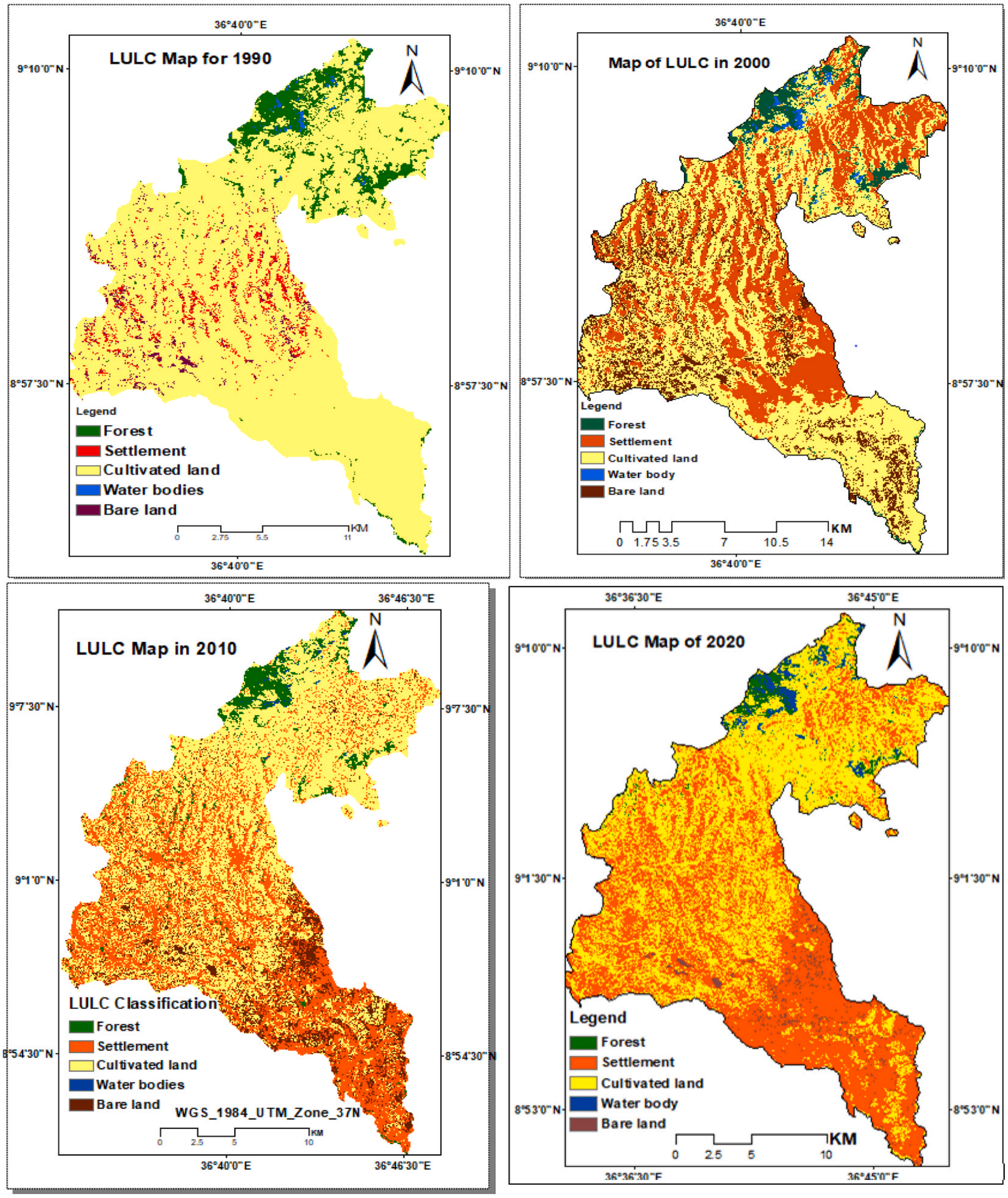

Fig. 5. LULC change graph from 1990 to 2020 in Wayu-Tuka district (Sources: Landsat image).

for the years 1990, 2000, 2010, and 2020 considering the total forest cover, settlement, cultivated land, water body, and bare land areas. Magnitude (A) of change hectares (ha), and percentage (%) of a LULC class from one (initial) period (P1) to the next (final) period (P2) was calculated using the following technique [2]:

$$A = \frac{(A2 - A1)}{A1} * 100 \tag{3}$$

where "A" is the area change of an LULC class from period one (P1) to period two (P2), A1 is the area of the LULC class in period one (P1), and "A2″ is the surface of the same LULC class in the second period (P2). Fig. 4 shows the flowchart of the LULC generation methodology.

The annual rate change of each LULC class (for the 10-year interval/periods) 1990–2000, 2000–2010, 2010–2020, and 1990–2020) was calculated using the following technique:

$$R = \frac{(A2 - A1)}{n} * 100 \tag{4}$$

where: R is the change in annual interest rate of a LULC class from period one (P1) to period two (P2), A1 is the area of the LULC class in the first period (P1), A2 is the area of the same LULC class in the second period (P2), "n" means distance between periods in years. The trends (increase and/or decrease) in the dynamics of the five LULC classes over time periods such as 1990–2000, 2000–2010, 2010–2020 and 1990–2020 were interpreted based on the results (magnitudes) derived from equation (1) were obtained. 3 and Eq. (4) (above).

3. Results and discussion

3.1. Status of LULC classes in wayu tuka district in 1990, 2000, 2010 and 2020

Based on satellite imagery analysis and field surveys, five (5) the most important LULC types were acknowledged in the study area (Table 5). The spatial extent and current status of LULC dynamics by LULC type (forest, settlement, Farmland, bodies of water and uncultivated land/bare land) in 1990, 2000, 2010, and 2020 were classified (Table 5 and Fig. 5).

The cultivated area in the study area is about one-third of the total area of the whole region (37%, or 14,788.51 ha) in 1990, while bare land, settlement and forest cover accounted for a corresponding proportion of 22% (9017.99 ha), 26% (10,461.88 ha) and 12.3% (5015.6 ha) accounted for about two-thirds (60.3%) of the area of Wayu-Tuka District at the same time (1990). The proportion of water bodies (1990) to the total area of the whole region (0.5%) is insignificant (Table 5).

The year 2000 was the period when cultivated the largest proportion of land to total area of Wayu-Tuka District, about 54% (21666.78 ha); whereas the area of the settlement (26% or 10,461.88ha) in the year 2000 showed a slight decline from its extent during early days (1990). In fact, the year 2000 was also a period of "bare land" and "forest" coverage, at the rate of 10.1% each (4092.6 ha) and 8.2% (3321.9 ha), revealed significant shrinkage from their area extents during 1990. On the contrary, the area share (%) of water body (2.2% or 885.4 ha) of the district showed increase in the year 2000 (Table 5).

In 2010, cultivated land (52% or 20,917.08 ha) and settlement (34.2% or 13,931.58 ha) accounted over six-seventh (86.2%) of the total area of the Jurisdiction. And the bare ground area was about 9.4% (3792.4 ha) of the study area in 2010, forest cover constituted only 4.1% (1665.6 ha) simultaneously (2010). To proportion (part extent) water body was insignificant in 2010 (Table 5).

In 2020, Landsat image-based analysis revealed cultivated land is the largest land use type fraction (%) at approximately 56.5% (22,792.31 ha), and this was also reflected LULC categories in this area over the years 1990, 2000 and 2010 with the largest area percentage. The spatial extent of settlement land was about 36.6% (14,842 ha) end of period this result. Water body and forest cover constituted about 3.8% (1535.7 ha) and 2.6% (1054.9 ha) in the study District in 2020, separately. The extent of bare-land area (0.5% or 203.7 ha) has become insignificant in 2020 (Table 5).

Fig. 5 below shows that the LULC classification of four (5) maps for 1900–2020 from left to right. The first map indicated LULC classification by TM 1990 images; the results show that the larger space of land use/land cover types is 37% for cultivated land, 28.2% for bare land, and 22% for settlement areas. Cover the entire study area; the forest part was 12.4%, while the water area was 0.5%. The result of the TM 2000 Landsat LULC array also indicated that the most LULC classes, starting with the overall grouping, are cultivated land and then cover 54% and 26%, respectively, of the total research area with settlement area. Among LULC classified; the proportion of undeveloped and wooded areas was 10.1% and 8.2%, respectively. The lowest occupancy was recorded in a body of water that covers 2.2% of all take classes in the study area. Also for ETM 2010 land use/land classification result, the map offered highest proportion of LULC classes of any drive; cultivated land area and residential area accounted for 52% and 34.2% respectively. Bare land and forested areas accounted for 9.4%, and 4.1%, separately. The smallest surface is covered with water bodies, which accounted for 0.3% of all categories in the field of study. Finally, the results of the LULC classification of the OLI 2020 map also showed that the largest part for all classified LULC drives; As with ETM 2010, the proportion of cultivated and settlement area accounts for 56.5% and 36.6% of the total area of the district. Water and forest cover is 3.8% and 2.6% respectively. Finally, the least area covered by OLI in 2020 was bare land, even covering 0.5% of the total class in the field of study (Fig. 5).

3.2. Results of the accuracy assessment

Assessing the accuracy of the classification of LULC categories is valuable because the value of the accuracy assessment helps to understand the level of confidence in the results used for the Landsat image-based classification of the five LULC types in the Wayu-Tuka district in the years 1990 and 2000, 2010 and 2020. The results of producer accuracy, user accuracy, overall accuracy and kappa coefficient of the LULC category for four time periods (i.e. 1990, 2000, 2010 and 2020) are shown in Table 6.

As shown in Table 6, the estimated accuracy values (levels) showed variations between the five LULC classes during the period, and the accuracy assessment values for every land use/land class show that the period-to-period variation increased over the three decades under study (i.e., 1990–2020). Referring to the 1990, LULC classes of Wayu-Tuka District, for example, the estimated values of PA (66.7%) and UA (66.7%) of the forest, UA (66.7%) of the settlement and PA (72.7%). It turned out that the number of cultivated areas is relatively small. Here again, the UA values for water body (66.7%) and settlement (75%) were relatively low in 2000. The UA population level (62.7%) (for 2010) was found to be the lowest of all values from the five LULCs - the classifications in all four investigated periods. The maximum accuracy for all five LULC classes was 100% (Table 6).

An assessment was also made of the overall accuracy levels and kappa coefficients for the classified LULC classes of the Wayu-Tuka District in all four periods studied. The overall accuracy of the LULC classes was 80% (for 2010) and above in all four periods, which corresponds to the minimum accuracy level of the Landsat image-based classified LULC classes of the study area [38,42,44]. Kappa coefficients of the classified LULC classes were 0.75 (for 2010) and 0.79 (for 2020); and in the other periods the coefficients were >0.80 (Table 5). The kappa coefficient (K) is expressed as poor if the coefficient <0.40, good if 0.40 < k < 0.75, and excellent if k > 0.75 [45].

3.3. Magnitude, trends, and drivers of LULC dynamics

Analyzing the historical and current dynamics of the LULC types is significant for understanding the level of degradation and/or sustainability of natural resource uses in the study place. Magnitudes and trend LULC changes in the study area of 1990–2000, 2000–2010, 2010–2020 & 1990–2020 are organized in Table 7.

As illustrated in Table 7, forest and bare-land of the study area exhibited decline by the respective magnitudes of change of 33.8% (1693.7 ha) and 64.1% (7299.9 ha) in the period 1990–2000. Whereas, cultivated land, 13.8% (1443.89 ha) and water body, with the respective magnitude of change of 73.2% (9766.5 ha) and 313.7% (671.4 ha), in the initial phase studied (1990–2000)) gave an increase. Here, decrease in settlement land is unique; this is because, settlement area is expected to increase persistently in Sub-Sahara countries of Africa [46].

In 2000–2010, settlement and cultivated land showed contradicting trends of change each other and from their respective trends of change (shown) during the previous period (1990–2000) accounted in by this study (Table 7). While settlement experienced an increase by about 64% (8910.4 ha), cultivated land shrink by about 9.5% (2194 ha) in the period 2000–2010. In fact, in rural dominated areas like study area, part of the cultivated land of individual households is used for the construction of new houses when adolescents establish new families. In such cases, cultivated land may decline due to conversion to settlement, and this could be one reason for the contradicting trend of change between settlement and cultivated land in the second 10-years' period (2000–2010) studied. Forest coverage and bare land in the study area had continued to decline by 49.9% (1656.3 ha) and 7.3% (300.2 ha) in the years 2000–2010 respectively (Table 7). As a matter of fact, the surface water resource (water body) of the study area also experienced a high magnitude of decline by 86.2% (763.5 ha) in the same period (2000–2010).

The result of the LULC change detection for period 2010–2020 also revealed a seemingly unique trends and magnitudes of changes in settlement, cultivated land, water body, and bare land for land use/land cover classes. The area of settlement revealed a high magnitude of change and increasing trend in 2010–2020; whereas, cultivated land (alike the earlier period i.e. 2000 – 2010) had continued to decline by 29.3% (6124.8 ha) in 2010–2020. Forest coverage in the study area also continued to shrink by 36.7% (610.7 ha) in the same period (2010–2020). Again, bare-land, with a magnitude of decline of 94.6% (3588.7 ha) and water body, with a magnitude of increase of about 1159.8% (1413.8 ha), experienced high magnitudes of change in the final period (2010–2020) considered by this study (Table 7).

The result of the dynamic detection analysis showed that forest cover in research district practiced a net loss by about 79% (3960.7 ha). Similarly, the part extent for bare land coverage of the study place also exhibited a net shrinkage (decrease) by about 98.2%

Table 6
The producer accuracy (PA) and user accuracy (UA) (%) for 1990–2020.

N0	LULC	1990		2000		2010		2020	
	class	PA (%)	PU (%)	PA (%)	PU (%)	PA (%)	PU (%)	PA (%)	PU (%)
1	Forest	66.7	66.7	87.5	100.0	75.0	75.0	100.0	85.7
2	Settlement	100.0	66.7	85.7	75.0	100.0	62.5	100.0	75.0
3	Cultivated land	72.7	100.0	87.5	87.5	75.0	85.7	70.0	100.0
4	Water body	100.0	100.0	100.0	66.7	75.0	100.0	75.0	75.0
5	Bare-land	100.0	100.0	80.0	100.0	80.0	100.0	75.0	75.0
6	Overall accuracy	83.3	–	86.7	–	80.0	–	83.3	–
7	Kappa coefficient	0.80	–	0.83	–	0.75	–	0.79	–

Source: Own Summary of Results of the Landsat Images' Analysis Using ArcGIS 10.8, 2022

Table 7
Area (A) in hectare (ha) and Percent (%) of LULC changes in 4 periods within 1990–2020.

LULC	1990	2000	2010	2020	1990–2000		2000–2010		2010–2020		1990–2020	
Classes	A (ha)	A (ha)	A (ha)	A (ha)	ha	%	ha	%	ha	%	ha	%
Forest	5015.6	3321.9	1665.6	1054.9	−1693.7	−33.8	1656.3	49.9	−610.7	−36.7	−3960.7	−79.0
Settlement	9017.99	10,461.88	13931.6	22842.0	1443.89	16	3469.7	33.2	8910.4	64.0	13824.0	153.3
C. land	13344.6	23111.1	20917.1	14792.3	9766.5	73.2	2194.0	−9.5	6124.8	−29.3	1447.7	10.8
Water	214.0	885.4	121.9	1535.7	671.4	313.7	−763.5	86.2	1413.8	1159.8	1321.7	617.6
Bare-land	11392.5	4092.6	3792.4	203.7	−7299.9	−64.1	−300.2	−7.3	3588.7	−94.6	11188.8	−98.2
Total	**40428.6**	**40428.6**	**40428.6**	**40428.6**	**0**	**0.0**	**0**	**0.0**	**0**	**0.0**	**0**	**0.0**

Source: Own Analysis via ArcGIS 10.8 (2022) (Note: C = Cultivated)

(11,188.8 ha) in the period 1990–2020 (Table 7). Here, it should be noted that the decline in bare-land does not necessarily mean an increase in land degradation since a bare-land in the context of Wayu-Tuka District encompasses areas devoid of vegetation and abandoned from farming as well as hilly and rugged landscapes with bare-soil and exposed rocks. On contradictory, the area of settlement, water body, and cultivated land (each) of the study area revealed a net increase by the respective magnitudes of change of 118.3% (12,380.1 ha), 617.6% (1321.7 ha) and 10.8% (1447.7 ha) in 30 years (1990–2020). However, the magnitude of net increase in the cultivated land (1447.7 ha) of the study area in the three decades accounted (1990–2020) was very small; and, this was different from the high magnitude of net increase in cultivated land, which was shown by some of the recent studies conducted in different regions of Ethiopia [13,27,47,39]. While settlement and cultivated land increased by the respective annual rate of 0.49% (412.7 ha) and 0.65% (48.3 ha), in the three decades studied (1990–2020), the bare land decreased annually by 2.6% (132 ha), 3.3% and (373 ha) (Table 8).

The analysis of LULC changes showed that there were differences in the range and rate changes from LULC to different periods in the study area (Table 8). For three decades, i.e. 1990-2020; the area of forest land and bare soil decreased 9.8% and 27% respectively. The share of these years decreased by 0.33% or 0.9% per year. On the contrary, the settlement area, cultivated land area and water area increased by 30%, 4%, and 3% individually on the forested areas and the bare land areas (Table 8). In the last 30 years; Settlement, cropland, and water bodies have expanded 0.41% per year on average with 8522 per year being absorbed by other types Change in land use/land cover in the study area. Conversely, area of the forest has been shrinking in 0.3% per year, reduction 132.72 ha each year. The reason for the forest decline may be due to the expansion of managed forest areas, due to illegal logging of forests, poor land management practices and political unrest in the zone accelerated. The finding also agrees with the finding of many researchers in Ethiopia [8,15,19,40]. In addition, the research result at the Huluka River Basin of the National Regional State of Ethiopia revealed that the forest area 59.3% reduction between 1979 and 2017 (164.52 ha/year), and was mostly converted to arable land. Although the acreage of the study area increased between 1990 and 2000 (by 73.2%), this LULC class has declined as the magnitude of changes over the last two decades, for example in the years 2000–2010 (by −2194 ha), has gradually increased in 2010–2020 (by −6124.8 ha).

The opposite trends of change of the cultivated land, and settlement area in the period 2000–2010 and 2010–2020 imply that settlement expansion was one of the driving forces behind the decline of cultivated land at study district for the last two decades (2000–2020). In a broader sense, actions such as the conversion of croplands (used for growing annual crops) to the cultivation of perennial crops or agroforestry and expansion of urban built-up area, infrastructures (e.g. road, schools, health centers, etc.) and rural settlement at the cost of farmlands could be among the main reasons for the decline in cultivated areas. This study findings are in accordance with other reports in southern Ethiopia where the decline (and limited level of increase) of cultivated land demonstrated [17].

The declining trend the forest area of the study area contradicts with 'green legacy' efforts Ethiopian government since four years ago. The depletion of the forest resource, such attributed to unsustainable harvesting of forest products and services for fuel-wood and construction materials, medicinal values, erosion control service, the biodiversity conservation (e.g. coffee seeds and seedlings source) benefit, the water quality and quantity regulation benefit, the aesthetic value, the carbon sink, air quality control and air conditioning services and other benefits [48]. The bare-land of the study area also exhibited a declining trend throughout the three decades studied such as 1990–2000 (by −7299.9 ha), 2000–2010 (by −300.2 ha) and 2010–2020 (by −3588.7 ha) (see Table 8).

The expansions of settlement (i.e. urban built-up area, infrastructures and rural residential houses) and cultivated land were among the main direct causes of the declining trend and shrinkage of forest cover and bare-land in Wayu-Tuka District in 30 years (1990–2020); and, this (in turn) was underlain by the high rate of population growth that induced an increase in peoples' demand for more agricultural land, residential houses and socioeconomic infrastructures in the District [13,15,22,40].

Fig. 5 presents the trend line of magnitude and rate of change in LULC four different periods (1990–2020). The green line with a red marker showed that magnitude and land-use change rates per year whereas the blue line stacked with a blue marker displayed the magnitude, and rate of LULC change area percentage of 1990–2020 (Fig. 6).

3.4. Historical and current LULC

A focal group discussion, key informant interviews, and interviews with local community and others relevant stakeholder were organized for additions to satellite image analysis learn about history and current changes in research area. The following survey questions are posed to a sample of HHs from the study area. For example, how have you seen the forest land size of households in the

Table 8
Magnitude and rate LULC change in Wayu-Tuka District on four different periods.

No	LULC types	**Area and percentage the land use/land cover classes for year**								
		1990–2000		2000–2010		1990–2010		1990–2020		
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	%/yr
1	Forest	−1693.71	−4.2	−1656.36	−4.1	−3350.07	−8.3	−3960.72	−9.8	−0.33
2	Settlement	−1444.32	−4	+4914.05	+8.2	+3469.73	+12.2	+12380.1	+14.6	+0.49
3	Cultivated land	+9766.53	+17	2194.02	−2	−7572.58	+15	11865.26	+19.5	+0.65
4	Water bodies	−671.4	+1.7	763.56	−1.9	92.16	−0.2	1321.65	+3.3	+0.1
5	Bare land	7299.9	−18	299.72	−1	7600.05	−19	11188.8	−27	−0.9

Source: Own Analysis via ArcGIS 10.8 (2022)

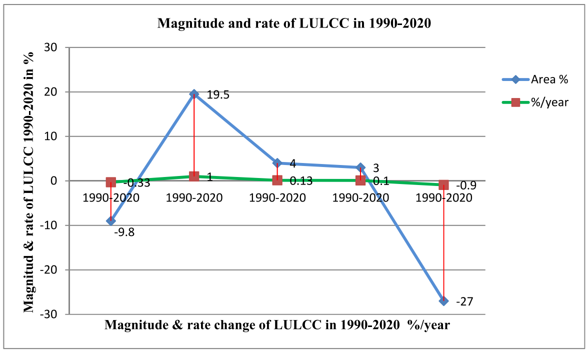

Fig. 6. Magnitude & rate change of LULC change for 1990, 2000, 2010 and 2020 year (Source: Own summary the result of ArcGIS 10.8, via Excel, 2022).

study area change over time earlier 30 years? If you believe that forest cover is declining, what factors contributed to the decline? What were/are the key drivers for LULC changes in your village?

According to local sources, expansion of cultivated, settlement, and most areas bare land, while area expansion of forest areas was small (Table 9). The results of the study area are consistent with the results performed in different parts of the countries [2,10]. In the title "Analysis of current and future forecast of LULC in Mayang Forest Biosphere Reserve, Southwestern, Ethiopia", it was stated that during this period (1987–2017), a total of five LULC types were identified in the study area, woodland, cropland and settlement land, grassland and bodies of water have been identified. In 2017, the forest area decreased to 77.8%, and the cultivated land area, settlement area, and grassland area increased by 17.4%, 3.4% and 1.4%, respectively. However, the water body did not show any significant changes and this are almost results agree of this study (Table 9). The results of this study are also consistent with those of other studies recognized by Ref. [17]. An analysis of land use and land cover change dynamics of the Beressa watershed in the north-central highlands of Ethiopia mentions that the analysis assumes 31 years of land use change between 1984 and 2015; area increased 67.5% and 14.5%, respectively. However, between 1999 and 2015, the number of pasture and wasteland areas declined rapidly by 51.4% and 65.8%, respectively. In the past 31 years, the expansion of agricultural fields, settlement areas, forest areas and water bodies increased at the rates of 71.6%, 16.8%, 5.7% and 3.7%, respectively, while the proportion of pasture land and Wasteland at rates of 43% and 54.8%, respectively, as shown by these results. Also, a study in Gubalafto district in north-eastern Ethiopia found that patterns show a tendency to clear and settle more land at the expense of other land uses and land cover types [9].

The respondents of the study area replied that for the question how you see the forest land size of HHs in this village for last 30 years? About 83.7% of the respondents' replied that the status of forest land size over the last 30 years decreased, 6.3% increased and 10% said no change (Table 9). This result corroborates with the result of analyzed landsat of LULC which stated that the forest coverage has decreased by 0.3% per year annual reduction 132.72 ha (Fig. 4). As to the factors that aggravated for destruction, the majority of the respondents (60.2%) mentioned expansion of farmland as cause.

3.5. Major drivers of LULC

The changes in LULC are the result of many complex and numerous factors [48–50]. Therefore, the main determining factors that have contributed to changes in LULC over three decades (i.e., 1990–2020) were analyzed. Previous studies have shown that the main responsible factors differ according to the type and size of the area [51]. In this study, the main drivers of land use/land cover change in the study area were: agricultural land, increased demand for firewood, building materials, illegal settlement of forests, illegal logging for commercial purposes, etc. (Table 10). Based on information on household heads living in and around the study area; Land use is changing mainly due to the expansion of agricultural land, increasing demand for firewood and illegal colonization of forests. The result of this research is also consistent with other study results from [60]. Land use/land covers change and their drivers in the Shenkolla watershed, south-central Ethiopia; showed that agricultural area increased over a 44-year period (1973–2017).

The chief reasons for a major change and a crucial deterioration in the historical and current condition of LULC change in the study area were conversion of land cover from forest to expansion and colonization agricultural and settlement land. The results of the focus group discussion showed that the LULC has changed over the last three periods and the analysis obtained from Landsat satellite imagery were almost similar to the field evidence obtained (i.e. the result of the ground truth data and focus group discussion). With reference to expressions of historical and current land use land cover change analysis shows that in the last three decades, population changes, agricultural area expansion, and urban area expansion have had a strong impact on LULC dynamics. This aspect is consistent with other work from Ethiopia [46] in the title Land use/cover change dynamics in NE Ethiopia. For interviews with the main informants were conducted involving older people who knows and lives in the study area; there has been a long-standing effort to develop more reliable information on changes and drivers of land-use change. Result selected households surveyed showed that LULC for the last three domains, changes in settlement land expansion, population size and agricultural area expansion had a strong impact on forest decline.

In terms of the drivers behind the decline of forests lies a specific trend, namely the increase in agricultural production is crushing

Table 9
Forest land size of HHs for last 30yrs.

Status of forest land size for last 30yrs	Frequency	Percent	Cumulative Percent
Decreasing	185	83.7	83.7
Increasing	14	6.3	90.0
No change	22	10.0	100.0
Total	221	100.0	

Source: Analyzing Survey Questions Using SPSS, 2022

Table 10
Major drivers (causes) of LULC.

Major drivers of LULC	Frequency	Valid Percent	Cumulative Percent
Expansion of agricultural land	119	53.8	53.8
increasing demand for firewood	48	21.7	75.6
building material	6	2.7	78.3
illegal settlement of forests	21	9.5	87.8
illegal logging for trade	21	9.5	97.3
Other	6	2.7	100.0
Total	221	100.0	

Source: Survey question analyzed using SPSS, 2022

forests through a number of mechanisms; it relocates the agricultural land expansion, causes disturbance and illegal expansion of settlement land within forests. Some results which were similar with this result described in different parts of Ethiopia [29, 57, 60].

4. Conclusions

This study evaluated the dynamics of LULC types between 1990 and 2020. The study result showed that forest, settlement, cultivated land, water body, and bare soil are the main types of land use and land cover in the study area. The extent of the area and the current condition analysis of LULC changes using three decades of Landsat imagery. The result revealed that LULC was different during the different time periods in the field of study. The district's forest resources are being depleted continuously and at a decreasing rate for three consecutive decades of the study period 1990–2020. Loss of forest cover means population within the study area is currently facing a shortage of numerous products and services derived from the forest ecosystem. The conversion the increase in forested area may be due to the expansion of cultivated land into forest land, accelerated illegal logging of forests, weak land management and political instability. Finally, the results of this study also show that settlements, cultivated land, and water bodies have grown at an average annual rate of 0.41% over the past 30 years, with an annual removal of 8522 ha from other land use/cover type bare land/soil in the study area. Contrary, forest area decreased by 0.33% per year, or 132.72 ha per year. These indicate that settlement expansion (i.e. rural housing units, urban built-up and socio-economic infrastructure) has been the most important direct cause of the decline in cultivated land over the last 30 years (2000–2020). Therefore, stakeholders (e.g. government, NGOs, local communities) should: (i) be aware of the scale and severity of forest degradation for local communities; (ii) adopt integrated measures such as afforestation, reforestation and land closure to restore the forest cover and its Ecosystem services in the study area and beyond.

Author contribution statement

Jembere Bekere: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data, Feyera Senbeta: Conceived and designed the experiments, Abren Gelaw: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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