



# Analysis of land use/land cover changes and their causes using landsat data in hangar watershed, Abay basin, Ethiopia

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## Abstract

This study analyzed land use/land cover (LULC) changes and their causes for the last 30 years from 1987 to 2017, covering an area of about 7673.87 km<sup>2</sup> in Hangar Watershed, Ethiopia. The LULC maps were produced from three Landsat images of 1987 (Landsat-5 TM), 2001 (Landsat-7 ETM+) and 2017 (Landsat-8 OLI\_TIRS) through pixel-based supervised image classification. The results indicated that there were an expansion in cultivated land (by +24%, +6%, and +28%) and built-up area (by +22%, +19%, and +37%) for LULC of corresponding years 1987–2001, 2001–2017 and 1987–2017. Whereas, there was a decrease in the forest (by –20%, –15% and –32%), rangeland (by –28%, –13% and –37%), grassland (by –65%, –6% and –67%) and water body (by –2%, –54% and –55%) for LULC of 1987–2001, 2001–2017 and 1987–2017 correspondingly. The major causes of these changes were identified as population expansion associated with increasing agricultural expansion, big tree clearing for building and wood extraction for fuel. The extraction of wood for fuel and building should be limited and legally managed, awareness of land use/land cover change hazard should be given for the community so that they shift the trends of land use and land cover change towards increasing vegetation covers which in turn can balance sediment yield.

**Keywords** Anthropic impact · Environmental changing · ERDAS imagine · Landsat images · Sediment yield

## 1 Introduction

Land use/land cover (LULC) changes influence climate and weather conditions from local to global scales (Oki et al. 2013). The Land-use and Land cover conversion, such as from forest to various land-use types is a collective experience in most areas of Eastern African countries including Ethiopia, were ranked as the highest in Africa at a rate of 0.94% (1990–2000) and 0.97% per year (2000–2005) due to increasing human and livestock population in protected areas (Garedew et al. 2009). For example, in Ethiopia, the estimated forest area in 1955 was 17 million ha, but by 1979, it dropped dramatically to 3.4 million ha (Hailemariam et al. 2016). The growing human population is responsible for the

expansion of agricultural fields that has been one of the main modes for personal conversion and modification of the environment (Piao 2007).

In Ethiopia, land use for human activities, such as agriculture, construction and urbanization, has been influenced by an increase in the human population in urban areas and the depopulation of rural areas (Hamza and Iyela 2012). However, the rural population is currently overgrowing too and consequently inducing many effects on the natural resources such as very dynamic land use and land cover (Ellis et al. 2010). With the fast growing of population, the uncontrolled agricultural activities to bring more land to agriculture have deteriorated the environment (Wu and Zhang 2012). As studies carried out in different parts of Ethiopia for instance; in Ethiopian highlands (Muluneh and Arnalds 2011); in the tropical highland watershed (Bewket and Abebe 2013); in the bale mountain (Hailemariam et al. 2016); in the Andassa watershed (Gashaw et al. 2017); in Lake Tana watershed (Hassen and Assen 2018) and in Northern Ethiopia (Birhane et al. 2019) showed that croplands have expanded at the expense of natural vegetation, including forests and shrublands. As

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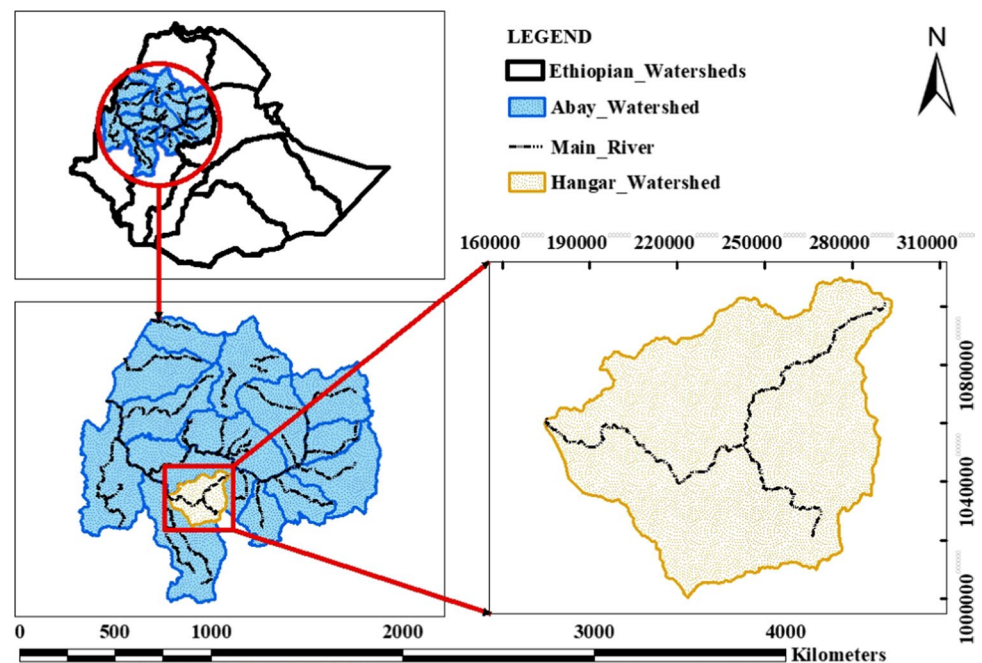
a result, identifying the controlling factors of LULCs and monitoring their dynamics and impact is fundamental to the definition of measures for environmental protection and sustainability (Belay et al. 2014). According to Miheretu and Yimer (2018), socio-economic and biophysical variables act as the driving forces of land-use changes. The effects of human activities are immediate and often radical, while natural effects, such as climatic changes experienced for a long period, results in a decrease in evapotranspiration and water recycling, which causes a reduction in rainfall. The area of Hangar Watershed is mostly covered by villages of a particular area called Anger Gute. The particular features that differentiate Anger Gute from other villages of Gida Ayana district are the settlement of people who came from different parts of the country searching for land for their livelihood. The day-to-day life of the community settled there depends on land to meet their needs. The clearance of forest for agriculture, fuel and timber production for construction resulted in unbalance nature of the land cover and land use. Bare land is highly prone to erosion, which contributes to the silting up of rivers and the reduction in the volume of water resources. Hangar River is the tributary of Didessa catchment that feed Abbay basin. This part of the basin is very important due to the location of the place where different water resources development is undertaking, like the Grand Renaissance dam and other project schemes. Hence, the analysis of change in land use and land cover helps the concerned environmental management entities to take care of forests understanding the impacts that deforestation has

on hydrology and water resources availability. Thus, in this study the land use/land cover was classified by ERDAS imagine 2015 software with maximum likelihood classification algorithm and analyzed changes over 30 years (1987–2017) in a landscape of Hangar-Nekemt area, Ethiopia. The causes of these changes identified mostly as the effects of human activities. The results of this study will be an input to model the hydrological responses of Hangar watershed to the changes in land use and land cover, soil erosion and reduction of water resources.

## 2 General description of the study area

The study conducted in Hangar Watershed, which is part of the Didessa catchment, located in the East Wollega Administrative Zone of the Oromia National Regional State, situated in South-West part of Blue Nile River Basin. The district is located between  $36^{\circ} 31' 41''$  to  $37^{\circ} 06' 50''$  East longitude and  $9^{\circ} 41' 58''$  to  $9^{\circ} 59' 56''$  North Latitude (Fig. 1). The regional geology of the study area developed from three types of geological terrains. These are Quaternary sediments, Paleozoic to Mesozoic rock, Precambrian rock (from youngest–oldest). The study area receives heavy rainfall from June to September and experiences a limited amount of rainfall for the remaining seven months. In the study area, the average maximum temperature experienced in the months of February, March, and April whereas, the average minimum temperature occurred in the months of September, October and November.

**Fig. 1** The geographical location of the study area



### 3 Materials and methods

#### 3.1 Data collections and sources

The 12.5 by 12.5 m resolution Digital Elevation Model (DEM) was downloaded from the website of Alaska satellite facility (<https://asf.alaska.edu/data-sets/sar-data-sets/alos-palsar/>) for watershed delineation. The map in which the study watershed is located was obtained from East Wollaga Zone, municipality office. The three Landsat images (Landsat-5, Landsat-7, and Landsat-8) collected from the United States Geographic Survey (USGS) center (<https://earthexplorer.usgs.gov/>) with zero cloud cover. As much as possible, the acquisition dates of the obtained Landsat data made in the same season of the years to minimize the impacts of a seasonal variation in vegetation pattern and distribution throughout the year. The images identified by the Landsat grid describing path ( $p$ ) and row ( $r$ ) for which the Hangar watershed covered with 170 paths and 53–54 rows (Table 1). Landsat-5 TM sensor, Landsat-7 ETM+ sensor, and Landsat-8 OLI\_TIRS sensor have 7, 8, and 11 bands, respectively. For TM and ETM+ sensors, bands (1–5 and 7) have a spatial resolution of 30 m (Tekleab et al. 2014). The band 6 of the TM sensor has a spatial resolution of 120 m. Bands of (6.1 and 6.2) for Landsat-7 ETM+ sensor have 60 m spatial resolution (Hassen and Assen 2018). OLI and TIRS on Landsat-8 coincidentally collect data, and the observatory transmits the data to the ground system where it will be archived, processed to Level 1 data products containing well-calibrated and co-registered OLI and TIRS data, and made available for free distribution to the general public (Irons et al. 2012). One sensor, the Operational Land Imager (OLI), collect image data for nine shortwave spectral bands over a 185 km swath with a 30 m spatial resolution for all bands (1–7, 9) except a 15 m panchromatic band (band 8) (Enderle and Weih 2005). The other instrument, the Thermal Infrared Remote Sensor (TIRS), collect image data for two thermal bands (10 and 11) with a 100 m resolution over a 185 km swath (Blackett 2014). Both sensors offer technical advancements over earlier Landsat instruments (Irons et al.

2012). The ground truth data, which was used during LULC classification and accuracy assessment, were collected using Global Positioning System (GPS) by setting the representative ground control points for selected villages of Hangar watershed. Since the study area of the watershed is large, the reading of coordinates was taken for selected villages from all direction. To reduce the uncertainty during LULC classification and accuracy assessment, primary data was collected in different seasons of the year in March and October. Post site observation was carried out during which the major causes of land use/land cover changes were identified.

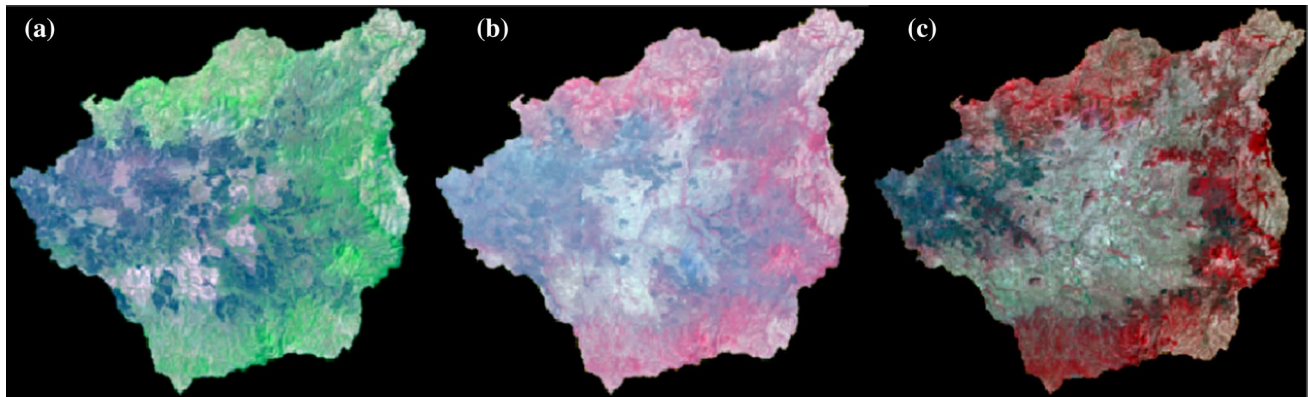
#### 3.2 Landsat image pre-processing and other data analysis

Since the study area could not be covered with one image, more images of DEM were downloaded and mosaicked with the aid of Arc GIS before extracting the area of interest. After Landsat images of the selected year acquired, bands of similar spatial resolution were combined through layer stacking. As one image could not cover the study area, a two-layer stacked image was mosaicked for each year's images. Because of their low spatial resolution, 60 m, 100 m, and 120 m (Isik et al. 2013) not used for the analysis of land use and land cover change. Since ETM+ and OLI\_TIRS have multispectral images of 30 m and a panchromatic image of 15 m spatial resolution, image fusion (pan-sharpening) techniques done to improve the visualization of images for better analysis of LULC (Öztürk et al. 2013). Clipping the mosaicked image with shapefile of the watershed was done using ERDAS imagine 2015 through Subsetting to reduce the size of an image to the area of interest (Fig. 2). The collected primary data were imported to ERDAS imagine software by arranging its X and Y coordinate properly during both satellite image classification and accuracy assessment. After independent image classification and accuracy assessment of each reference year, the change detection process made from the generated LULC map. The land use/land cover change detection performed using the following formula (Kindu et al. 2013).

$$\text{Percentage of land use and land cover change} = \frac{(\text{Area of final year} - \text{Area of Initial year})}{\text{Area of initial year}} \times 100 \quad (1)$$

**Table 1** Summary of spatial datasets used in this study

Year	Sensor	Bands	Spatial resolution	Path_Row	Producer	Acquisition date
1987	TM	1–5, 7	30 m	170_053	USGS	1/22/1987
	TM	1–5, 7	30 m	170_054	USGS	1/22/1987
2001	ETM+	1–5, 7 and 8	30 m and 15 m	170_053	USGS	2/5/2001
	ETM+	1–5, 7 and 8	30 m and 15 m	170_054	USGS	2/5/2001
2017	OLI	1–7, 9 and 8	30 m and 15 m	170_053	USGS	1/8/2017
	OLI	1–7, 9 and 8	30 m and 15 m	170_054	USGS	1/8/2017



**Fig. 2** Subset images of (a) Landsat-5 (TM), (b) Landsat-7 (ETM+) and (c) Landsat-8 (OLI\_TIRS)

The causes of land use/land cover changes that identified after site visitation were indicators of the changes observed during change detection.

The overall flowchart of the Landsat image pre-processing and classification were shown in Fig. 3.

## 4 Results and discussions

### 4.1 Land use and land cover classification

Image classification is the process of assigning defined land use and land cover classes for pixels of a continuous raster image (Guide 2010). For this study, Landsat images classified by a pixel-based supervised image classification with a maximum likelihood classification algorithm. During image classification for each reference year, the collected terrestrial data were used. Finally, for Hangar watershed, six classes of land use/land cover were identified as Forest, Rangeland, Grassland, Cultivated land, Built-up area, and Waterbody (Table 2).

### 4.2 Accuracy assessment

The Land use/land cover map prepared through supervised classification by utilizing the present land use and land cover data of the field-collected by GPS, information of the past times from elders living at the study area, and Google Earth as a reference data. Finally, image classification accuracy evaluated and summarized by kappa coefficients (Tables 3, 4, 5). Kappa value typically lies between 0 and 1 where, the value higher than 0.8 denotes a firm agreement and values between 0.75, and 0.8 are very good indicators of the

classified image (Viera and Garrett 2005). For this study, overall Kappa statistics are 0.8129, 0.8533, and 0.8432, respectively (Tables 3, 4, 5).

### 4.3 Land use/land cover change detection

During 1987–2017, a significant amount of LULC changes occurred in the watershed. For example, the percentage increase in cultivated land was by +24% from 1987 to 2001 and by +6% from 2001 to 2017 periods. Similarly, the extent of the built-up area increased between 1987 and 2001 periods by +22% and the increment continued between 2001–2017 years (by +19%). Conversely, areas covered by forest decreased by –20% between 1987–2001 years and by –15% between 2001–2017 periods. Range Land, grasslands, and Waterbody showed a similar trend throughout the 1987–2001 and 2001–2017 periods (Table 6 and Fig. 4).

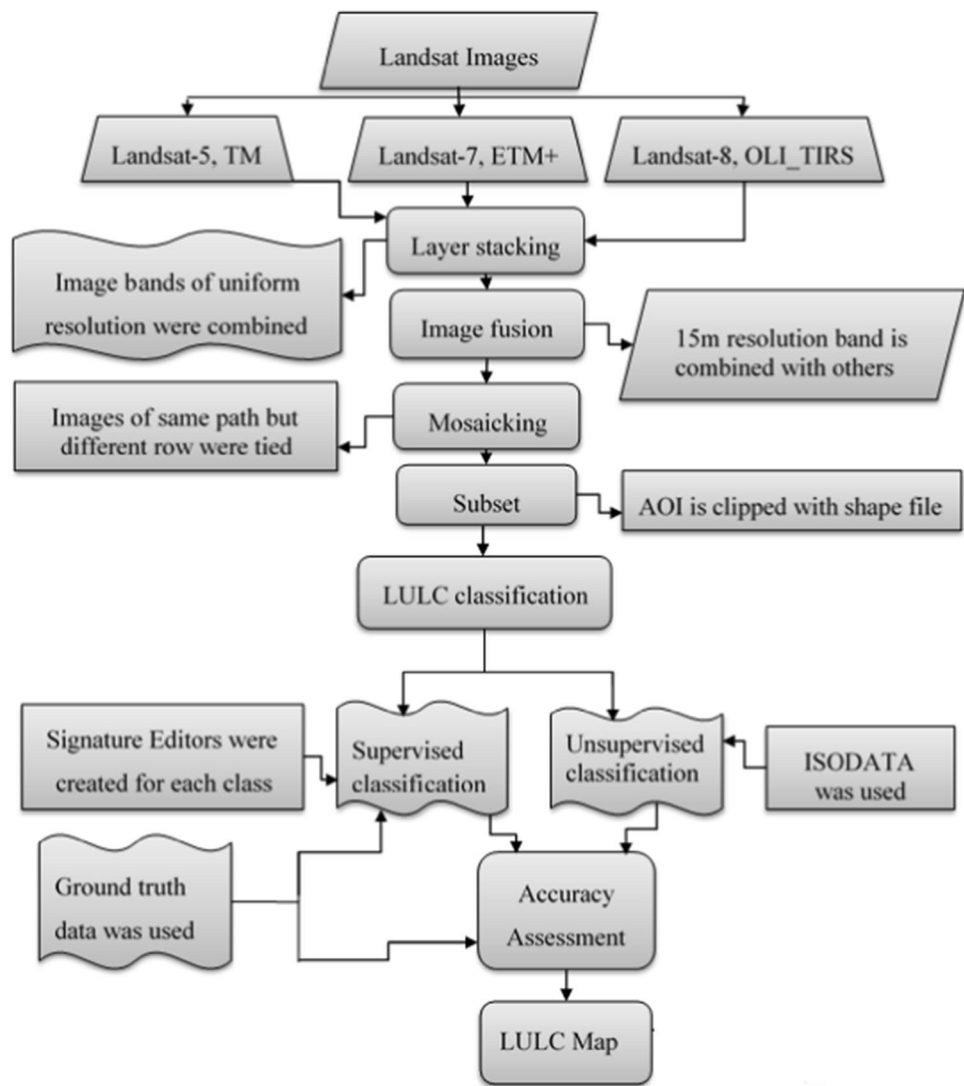
The Landsat images of the Watershed area pre-processed and classified using ground truth data. The maps of Classified LULC prepared using the Arc map. The LULC states of the Hangar watershed through 1987–2017 periods shown in Fig. 5.

### 4.4 Causes of Land use/Land cover changes

After the analysis of classified satellite images, an interview with selective group revealed that permanent agriculture and livestock grazing, commercial big trees cut for building, wood extraction for fire and expansion of villages to small towns and towns to cities are the four major identified causes of land use/land cover changes. This finding is consistent with results from previous studies in different parts of Ethiopia (Teshome 2011; Kidane et al. 2012; Warra et al. 2013; Kindu et al. 2013) where they confirmed



**Fig. 3** Flowchart of the Landsat image pre-processing and classification



**Table 2** The classified land use/land cover of the study watershed

Land use/ land cover type	Description
Waterbody	Rivers, streams
Range land	Include areas covered with small trees, less dense forests and bushes, and shrubs
Forest	Areas covered with a dense growth of trees included here
Cultivated land and settlements	Include areas used for perennial and annual crops, irrigated areas, and the scattered rural settlements
Grassland	Areas used for Livestock grazing, as well as bare land that has very little or no grass cover (exposed rocks) but with the same tone on the aerial photographs, included here
Built-up area	Areas used for construction sites, both zone and worda’s towns and also roads, were classified here due to their similar reflectance

that deforestation or reduction of land covers such as forest, rangeland, grassland, and water body increased with high rate. Cleared areas immediately occupied by settlers and partly converted to farmlands (+ 28%) (Table 6). Geist

and Lambin (2001) stated that the expansion of cultivation and grazing accounted for 96% of the cases causing deforestation. They have emphasized that agricultural expansion is the most critical cause of tropical deforestation.

**Table 3** Accuracy assessment of classified LULC of Hangar watershed in 1987

1987 Classified image (22- Jan-1987)	Reference data						Row total	User's accuracy (%)	Kappa coefficient
	RNGB	PAST	CULT	FRST	URBN	WATR			
RNGB	16	0	0	0	0	0	16	100	1
PAST	0	12	1	2	1	0	16	75	1
CULT	1	0	13	1	0	1	16	81	1
FRST	1	1	0	14	0	0	16	88	1
URBN	0	1	0	3	11	1	16	69	1
WATR	0	0	0	1	0	15	16	94	1
Column total	18	14	14	21	11	17	96		
Producer's accuracy (%)	88.89	85.71	93	67	100	88		Overall classification accuracy = 84.38%	Overall kappa statistics = 0.8129

**Table 4** Accuracy assessment of classified LULC of Hangar watershed in 2001

2001 Classified image (05- Feb-2001)	Reference data						Row total	User's accuracy (%)	Kappa coefficient
	RNGB	PAST	CULT	FRST	URBN	WATR			
RNGB	15	0	0	0	0	0	15	100	1
PAST	0	14	1	0	0	0	15	93.33	0.9167
CULT	1	0	13	0	1	0	15	86.67	0.8442
FRST	0	0	0	14	1	0	15	93.33	0.92
URBN	0	3	0	1	11	0	15	80	0.7692
WATR	1	1	0	0	1	12	15	73.33	0.68
Column total	17	18	14	15	15	12	90		
Producer's accuracy (%)	88.24	77.8	100	93.33	100	73.33		Overall classification accuracy = 87.78%	Overall kappa statistics = 0.8533

**Table 5** Accuracy assessment of classified LULC of Hangar watershed in 2017

2017 Classified image (08- Jan-2017)	Reference data						Row total	User's accuracy (%)	Kappa coefficient
	RNGB	PAST	CULT	FRST	URBN	WATR			
RNGB	11	0	1	0	0	2	14	78.57	0.75
PAST	0	12	0	1	1	0	14	85.71	0.831
CULT	1	1	10	1	1	0	14	71.43	0.6712
FRST	0	0	0	13	1	0	14	92.86	0.9104
URBN	0	0	0	0	14	0	14	100	1
WATR	0	0	0	1	0	13	14	92.86	0.9155
Column total	12	13	11	17	17	13	84		
Producer's accuracy (%)	91.67	92.31	90.91	76.47	82.35	100		Overall classification accuracy = 86.90%	Overall kappa statistics = 0.8432

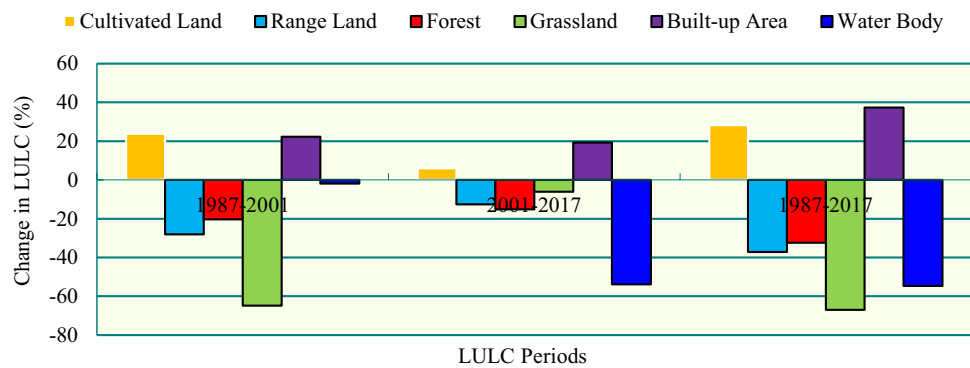
The increase of the built-up area (+ 37%) (Table 6) in this study watershed also coincides with other research findings in Ethiopia such as Belay and Mengistu (2019) in Muga watershed, Upper Blue Nile basin and Gashaw et al. (2018) in the Andassa watershed. Conversion of natural

vegetation cover to other land use types such as farmlands, grazing lands, human settlements, and urban center causes loss of biodiversity, deforestation and soil degradation as observed by Miheretu and Yimer (2018). In addition, the results of this work also suggest that the observed change

**Table 6** Analysis of LULC change between 1987–2001, 2001–2017 and 1987–2017

LULC categories	1987	2001	2017	1987–2001		2001–2017		1987–2017	
	Coverage	Coverage	Coverage	Rate of change		Rate of change		Rate of change	
	Area (ha)	Area (ha)	Area (ha)	%	(ha/y)	%	(ha/y)	%	(ha/y)
Cultivated land	374,506	490,832	521,895	24	8309	6	19,441	28	4913
Range land	300,338	216,036	188,712	- 28	- 6022	- 13	- 1708	- 37	- 3721
Forest	38,088	30,332	25,741	- 20	- 554	- 15	- 270	- 32	- 412
Grassland	41,792	14,689	13,794	- 65	- 1936	- 6	56	- 67	- 933
Built-up area	10,089	12,973	16,078	22	206	19	194	37	200
Water body	2574	2525	1167	- 2	- 4	- 54	- 85	- 55	- 47
Total	767,387	767,387	767,387						

**Fig. 4** The analysis of Land use/land cover changes from 1987 to 2017



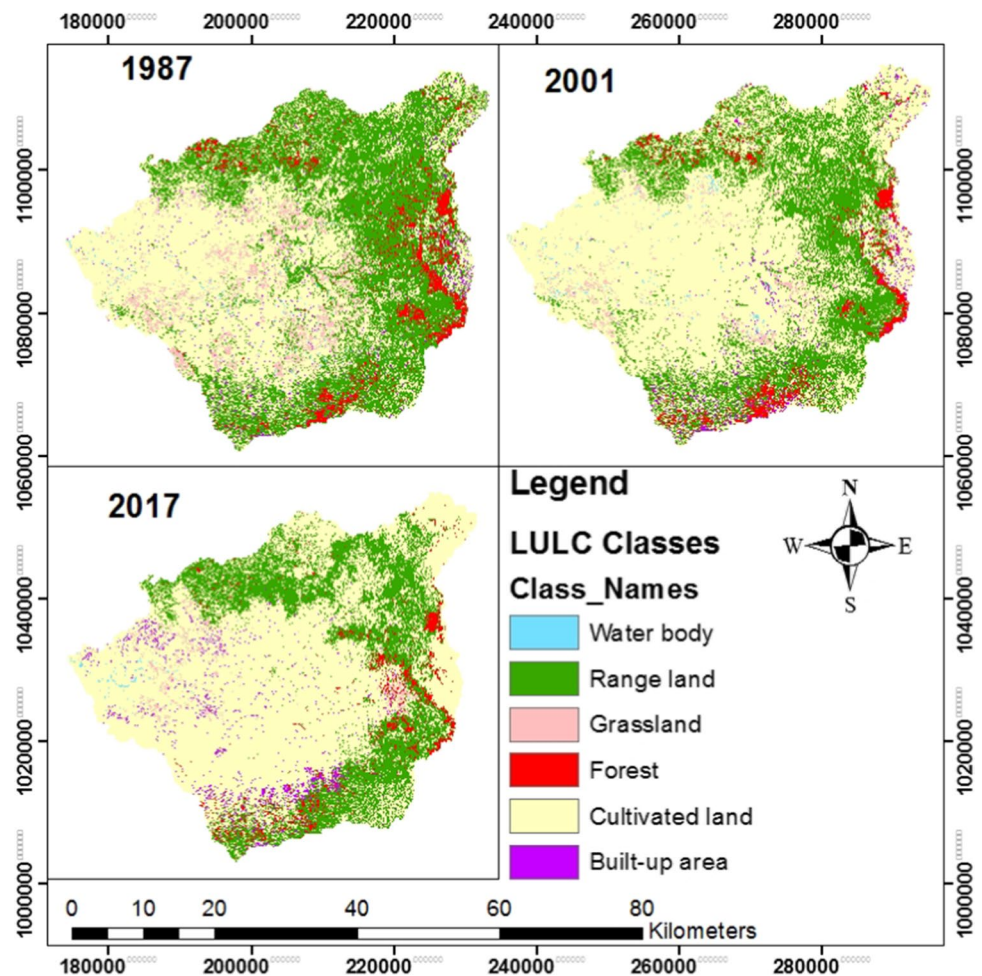
in land use/land cover can facilitate the remobilization of sediments, the increase in the solid load carried by rivers and the silting up of water bodies. In the inhabited areas, the impermeability of the soils facilitates the surface runoff of the water, especially in periods of intense rain, reducing the infiltration and the feeding of the underground water sheets; so it can also result in a reduction of the water resources and the availability of drinking water.

### 5 Conclusion

The land use and land cover change have significant impacts on the functioning of socioeconomic and environmental systems. In Ethiopia, most parts of the regions are vulnerable to problems concerning food production that mostly affects rural livelihood, mainly due to an increase in population in addition to inappropriate management of resources. This study was carried out in the East wollega zone of Ethiopia, specifically the Hangar watershed that is located in a rural agricultural area. Landsat images acquired from the website of the United States geographic survey and its assessment accomplished through image pre-processing and classification by different components of ERDAS imagine software. Generally, the analysis of

classified Landsat images of 1987 (Landsat-5 TM), 2001 (Landsat-7 ETM+) and 2017 (Landsat-8 OLI\_TIRS) showed that cultivated land and built-up area expanded. With the consequent decrease of forest, rangeland, grassland and water body. The major causes of the changes identified in this work are; agricultural expansion and cattle grazing, population expansion associated with the increase in the extraction of wood for fuel and the felling of large trees to obtain timber for building. From these changes, the increase in sediment volume transported by rivers and cumulated in the watershed with the consequent loose of the availability of drinking water is expected because: (1) uncovered land is more exposed to runoff that contributes to sediment yield than land covered by vegetation; (2) Soil can be easily eroded from the agricultural area and deposited in water bodies and; (3) paved terrains due to urban expansion, facilitate surface runoff by reducing the volume of infiltrated water and the supply of underground water reservoirs. Therefore, the cutting of trees for the expansion of areas destined to agriculture, the use of wood for fuel, the construction of houses and overgrazing should be limited; a legal replacement strategy can be adopted by planting trees to compensate for their felling to reduce the loss of fertile soil, the remobilization of sediments and the loss of water resources.

**Fig. 5** Land use/land cover map of the study area in 1987, 2001 and 2017



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