

Land Use Land Cover (LULC) Change Detection Using Geospatial Technique in Anbessa Forest, Benishangul-Gumuz Region, Ethiopia

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Abstract

Background: LULC analysis using satellite images for detecting the changes across a given landscape is a very crucial tool for understanding the nexus between forest ecosystems and human activities. LULC pattern of Anbessa forest had undergone fast changes over the last 30 years, but no research measured the level of the changes. The present study was aimed at detecting the LULC change pattern of Anbessa forest using data from satellite images between 1989 and 2019.

Methods: We examined the LULC changes of Anbessa forest using satellite image data over the period of 1989 – 2019 using geospatial technique.

Results: The results show a 29% and 18% decrease in land area under dense and open forests respectively over a period of 30 years. Conversely there is 32% and 25.6% increase in the land under agricultural land and settlement areas respectively. A relatively small average decrease of 8% in shrub land was found although there was a decrease from 1989 to 2004 and an increase from 2004 to 2019.

Conclusion: The fact that there is a decrease in natural and open forests and an increase in agricultural and settlement areas implies there had been fast degradation of natural forests of Anbessa forest due to human activities. Thus, there should be an intervention project that ensures the sustainability of the forest.

Keywords: Forest, LULC, change detection, image data

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INTRODUCTION

Globally only very few landscapes remain without significant alteration by human activities (Yang, 2001). Most landscapes have experienced land use land cover (LULC) change, which has become a major topic in, sustainable management of natural resources (Kadioğullari, 2013) and, sustainable development (Hu et al., 2018) since recently. LULC change has had considerable effect on forest ecosystem, biodiversity, soil conservation and global climate (Johnson et al., 1997; Xu et al. 2007; Karnieli et al., 2008). Human activities are the main causes of LULC changes through ever increasing population pressure and the resulting demand for agricultural land, wood, charcoal and firewood production from forests, overgrazing and indiscriminate cutting of trees (Kennedy & Spies 2004; Wakee et al., 2005; Cayuela et al., 2006). So, understanding the spatial extent and distribution of LULC change is vital to the study of environmental changes at various levels (Ojima et al. 1994). Accordingly, environmental analysts recognized that LULC analysis is a fundamental tool for assessing environmental and ecological consequences of human activities (Yang, 2001; Flamenco-Sandoval et al., 2007). But, what is LULC change?

LULC change refers to conversion of one type of LULC to another (Turner & Meyer, 1994). It also refers to human modification of the terrestrial surface of the Earth, and reflects the role of human activities on natural resources and the environment (Shah & Sharma, 2015). Whereas land cover denotes the biophysical attributes of the Earth's surface, land use refers to the human purpose or intent applied to these attributes (Batunacun, et al., 2018). Forest cover is one of the LULC types for which both attributes are considered in detecting the changes in Anbessa forest, which is dominantly wood grassland at present (Tamene, 2016). The structure of forest ecosystem refers to the spatial characteristics of ecosystem including the size, shape,

composition, and spatial arrangement (Kadioğulları, 2013). The environmental and economic functions of forest ecosystems therefore, depend on these characteristics, are affected by LULC changes and, need proper management (Shah & Sharma, 2015). Thus, the sustainability of the services of forest ecosystems depends on their health and stability.

Forest ecosystems provide not only conducive environment for human survival but also home for numerous animals. Forests harbor two thirds of all the terrestrial animal and plant species (World Bank, 2004). Their environmental and economic functions such as timber, fuel wood, fodder, water and soil protection, carbon sequestration, oxygen production, recreation, aesthetics, biodiversity, and habitat for wildlife species are described in vast literature (Köchli & Brang 2005; Keleş et al. 2008; Başkent et al. 2008). Specially, their economic functions such as contribution to food security in general (Shriar, 2002) and being a major source of wild foods in particular are paramount (Guyu & Muluneh, 2015). However, forests of Ethiopia including Anbessa forest have experienced LULC changes due to mainly human activities (McKee, 2007; Mathewos, 2019).

Deforestation is an important cause of LULC elsewhere in the world (Lambin et al., 2001) and also in forest areas of Ethiopia (McKee, 2007; Mathewos, 2019). The major drivers of deforestation in Ethiopia are settlements, agriculture (both small scale and commercial), extraction of construction materials, grazing, and firewood and charcoal collection (McKee, 2007). In the present study, deforestation is thus defined as high forest being converted into other land-use types. Forest structure and composition are essential ecosystem characteristics (Quesada & Kuuluvainen, 2020) which are disturbed by deforestation. The regular and periodic assessments of forest cover change in tropical regions are therefore carried out to recognize previous patterns, assist proper planning and predict future trends (Shah and Sharma, 2015).

In Ethiopia, forest losses of 140,000 hectares each year are driven by conversion into agricultural lands, and unsustainable forest management, underpinned by poor governance, uncertain land tenure and a rapidly growing population (Lawrence *et al.*, 2010). The average annual deforestation rate is 1% which is high compared to other Sub-Saharan African countries (0.6%) (Tamene, 2016). Anbessa forest, one of the popular high forests of Ethiopia, has been exposed to deforestation over the last three to four decades. But, there is no research that shows the level of deforestation, and the type and nature of LULC changes that have so far occurred in the forest. A previous study examined plant diversity in the forest (Tamene, 2016). Therefore, understanding the level of LULC changes in quantitative and qualitative terms is necessary to design appropriate intervention strategies. Therefore, the aim of the present study was to detect the level of LULC change that had occurred in Anbessa forest over the last 30 years using geospatial techniques so as to understand the spatial and temporal dynamics of the size and pattern of forest cover changes.

MATERIALS AND METHODS

Study Area

Anbessa forest is located in Bambasi district, Benishangul-Gumuz region, Ethiopia. Astronomical location of the forest ranges from 9° 53' 24.3" N -9° 55' 40.8" N and from 34° 39' 09.0" E - 34° 50' 55.3" E. Since recently, the estimated total area of the forest has become 15,072 ha (Tamene, 2016). However, originally it had total area of about 50,213ha (Figure 1). The topography of Anbessa forest is very flat except for few hills in the western part of the forest near the main asphalt road from Addis Ababa (Capital city of Ethiopia) to Asossa (capital town of Benishangul-Gumuz region). Its elevation ranges from 1292m to 1563m a.s.l. with the highest peak in the western side and the lowest in the eastern side.

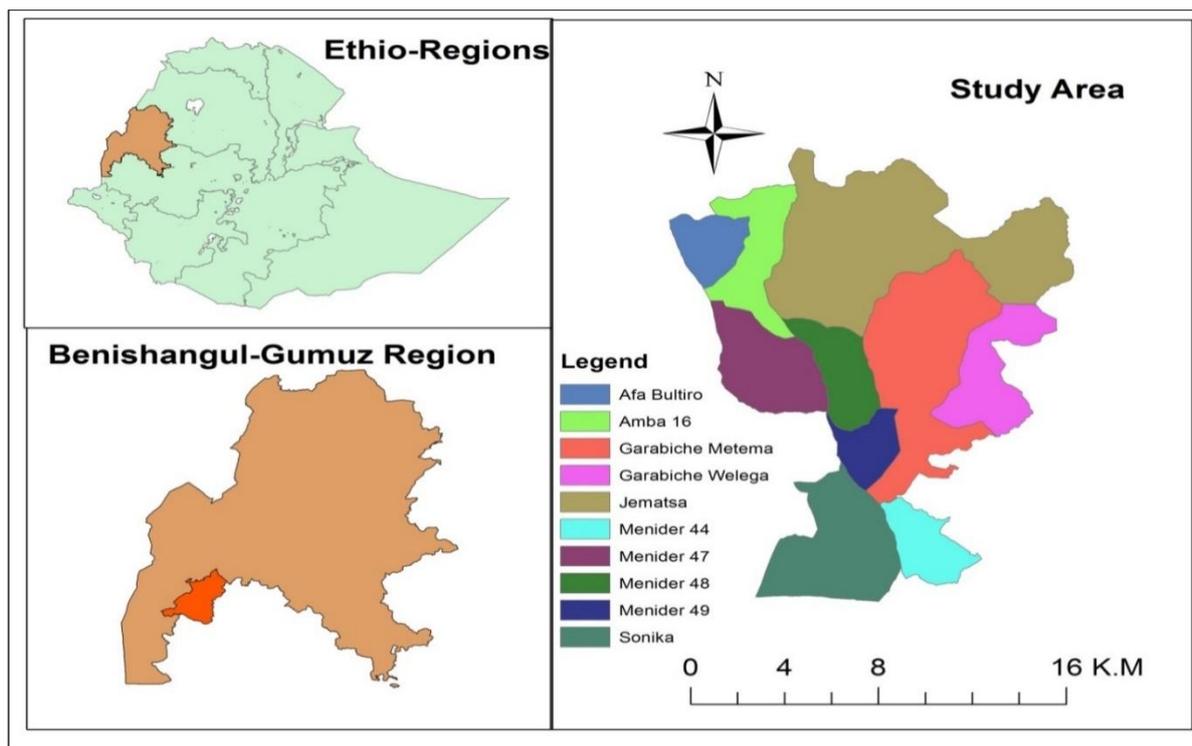


Figure 1. Location map of the study area

As part of the western lowlands of Ethiopia, Anbessa forest is characterized by unimodal rainfall distribution

with the rainy season extending from March to November (Tamene, 2016). Its average annual rainfall is 1381.42 mm and the mean monthly temperature is 28.37⁰C. Hydrologically, Anbessa forest is found in the Blue Nile river basin. There are a number of big and small rives which are tributaries of Blue Nile, such as Dabus, Afa, Selga, Shosha, Mutsa, Nifiro, Abakidi, Eshama, Chilonya and many small streams which pass through or near by the forest (Herrmann et al., 2007).

There is no significant variability in the vegetation type due to low level of variations in its altitude. In general, Anbessa forest can be characterized as Combretum-Terminalia woodland. The forest is dominated by *Oxytenanthera abyssinica* (lowland bamboo) which stands with scattered Combretum – Terminalia Woodland vegetation. The rest of the forest is flat wooded grass land with very small slope variation.

Significant level of deforestation on Anbessa forest has started since the implementation of resettlements schemes in 1980s which brought settler Amhara ethnic group from northern Ethiopia to the area. At present, the forest is surrounded by 10 large villages of this type namely: Amba 16, Jematsa, Garabiche Welega, Sonka, Village 44, and Village 47 (Figure 1). Since then, the forest has been under serious pressure from deforestation due to the increasing number of population around it and the resulting demand for arable agriculture, grazing land and production of charcoal, firewood and timber. As a result, it is a typical area that faces many ecological problems (Tamene, 2016).

Data

Forest resource maps had been traditionally prepared from forest inventories involving aerial photography and fieldwork. However, the modern technology, Geographic Information System (GIS) technique and Remote Sensing (RS) from Satellite platforms offer an alternative and economic tool for forest mapping (Shah & Sharma, 2015). In the present study too, LULC types were mapped as the spatial database from satellite images obtained from three Landsat series.

The images over the period of thirty years were derived from Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIR) for 1989, 2004 and 2019 respectively. The year 1989 is chosen as the base because settlement programs started in the first half of the year in the area and satellite data are available for the study area since then. The Landsat satellite images for these years were acquired from the U.S Geological Survey (USGS) via Google Earth to evaluate the forest cover change over the period of 1989 to 2019. The wave length of the Landsat TM sensor ranges from the visible to the thermal infrared portion of the electromagnetic spectrum and

has a spatial resolution of 30 meter. After six bands of the TM (excluding thermal band) were considered for layer stacking, TM band 4, 3 and 2 were combined to make conventional false color composite image.

The Landsat ETM+ was introduced in Landsat 7 and its data covered the visible, near-infrared, shortwave, and thermal infrared spectral bands of the electromagnetic spectrum. ETM+, which improved the version of TM sensor, has thermal band with an improved spatial resolution of 60metercompare to the TM's 120meter spatial resolution. The ETM+ also contains 15m panchromatic band. After six bands of the ETM+ (excluding thermal band) were considered for layer stacking, ETM+ band 4, 3 and 2 were combined to make conventional false color composite images.

NASA successfully launched the Landsat Data Continuity Mission on 11 February, 2013. The satellite was renamed Landsat 8 and operation has been transferred to the USGS. Data collected since April 11, 2013 by the OLI and TIRS on board Landsat 8 are available for download. Of its 11 bands, only those in the very shortest wavelengths (bands 1– 4 and 8) sense visible light whereas all the others are in parts of the spectrum those we cannot see. The true-color view from Landsat is less than half of what it sees. As a result, the images need to be contrasted and enhanced (stretched). Following this recommendation, histogram equalization was run to enhance the image and a good result was found. Over seven bands of the Landsat 8 (excluding thermal band) were considered for layer stacking, and band 5, 4 and 3 were combined to make conventional false color composite images with a spatial resolution of 30 meters.

Image Processing and Presentation

The LULC change was detected using post classification cross-tabulation approach in ARC-GIS and ERDAS. The images were processed in three phases: pre-processing, image classification, and post-classification and change detection.

In the first phase, radiometric and atmospheric corrections were performed to correct atmospheric conditions from sensors' scanning errors as well as distortions from solar angle and sensors' angle in the Landsat images. Then, all images from each study year were clipped to match with the study area and buffer zone boundaries.

In the second phase, image classification and land cover change detection were performed. Supervised classification method was applied to three Landsat images (1989, 2004 and 2019) using the Maximum Likelihood Classification method (MLC) - a well-known parametric classifier for supervised classification (Otukey & Blaschke, 2010).

In the third phase, post classification process and change detection was performed to assess the changes through the entire land cover during the study period for both the forest covered area and degraded zone. Land cover maps were produced for each year for which satellite images were used. In this process, the forest classes were identified and given names as dense forest, open forest, shrub land, agricultural land and settlement. The results are presented qualitatively in maps and quantitatively in tables, and are synthesized by drawing conclusion.

RESULTS

Spatial Pattern of Anbessa Forest Cover in 1989, the Reference Year

The1989 LULC map after the Supervised Classification yielded the spatial extent of different land cover classes (Figure2).There was a clear association between settlement and agricultural lands in the forest. Spatially, these land use types largely found in northwestern and north central with close proximity to dense forests and open forests. The eastern half of Anbessa forest area that extends from North through Northeast and Southeast to South was occupied by settlement and agricultural lands.

On the other hand, dense forest cover was found largely in western half of the forest area although significant distribution of this type of forest cover extended from southern via southeastern and central to northern parts. Open forest covers were also found in north, north central, northwest, central, northeastern, eastern and southeastern parts of the forest. Open forests are generally associated with the shrub lands (Figure, 2). In general, dense and open forests covered more area than other types of LULC. This implies that deforestation was very smaller than the next decades.

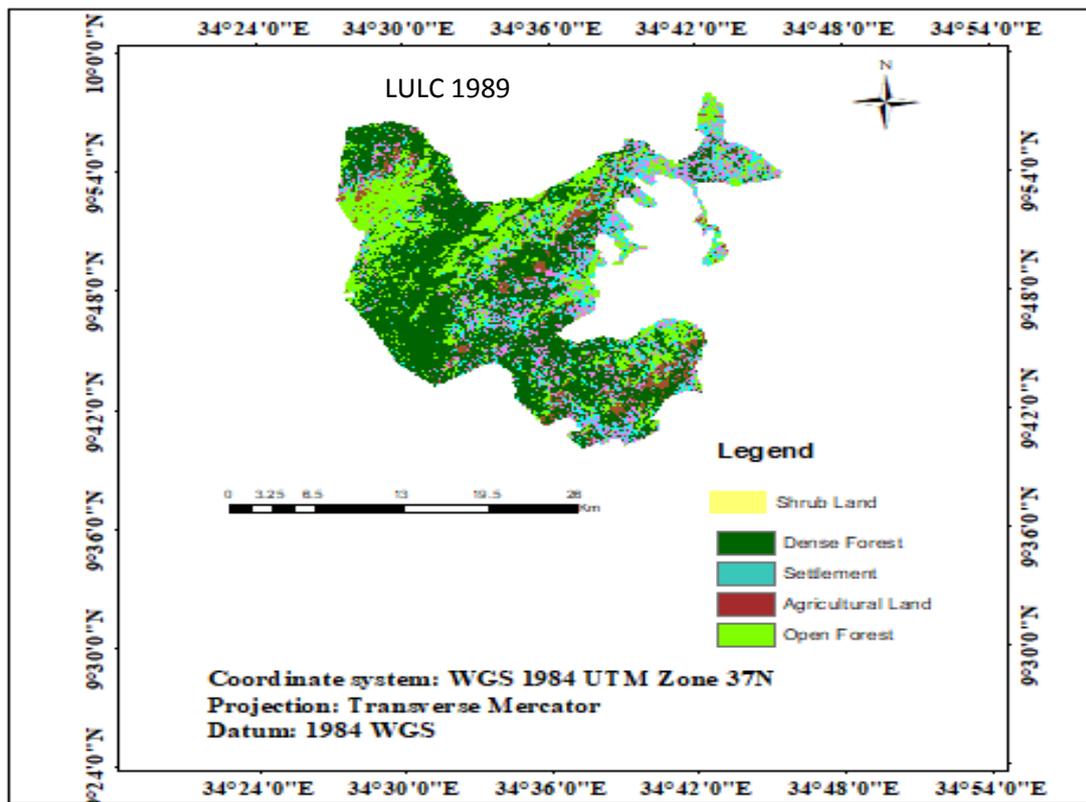


Figure 2 Land use land cover map of Anbessa forest in 1989

The amount of LULC types is also measured quantitatively for clear detection. The dense forests covered the highest part of Anbessa forest area accounting for 15,884ha (35.63%) followed by open forest with 14,177.2ha (31.80%) and shrub land with 12,184.7ha (27.33%). The smallest LULC types were agricultural land and settlements constituting about 1,724ha (3.9%) and 599 (1.34%) respectively (Table 1).

Table 1. Percent distribution of LULC classes of Anbessa forest in 1989

	Land Use Land Cover Class					Total
	Dense Forest	Open Forest	Shrub Land	Agri.Land	Settlemen t	
Area (ha)	15884.04	14177.16	12184.72	1724.00	599.08	44569.00
(%)	35.63	31.80	27.33	3.90	1.34	100.00

Source: Computed from Landsat data using ERDAS

Spatial Pattern of LULC Classes of 2004 and its Change from 1989

The supervised classification procedure applied to the 2004 image shows the largest land cover map for agricultural land and settlement as compared to other LULC classes (Figure 3). There was sharp decrease in the land cover under dense forest, open forest and shrub lands from 1989 to 2004. In contrast, areas under settlements and agricultural lands increased over the same period. Dense forest cover gave way to open forest, shrubs and agricultural lands. Some areas of open forests also gave way to shrub lands, settlements and agricultural lands. As a result, small pocket areas of dense forests remained by 2004 and were confined to central, southwestern and south central parts of Anbessa forest area. In other words, most of dense forests were deforested and converted into open forest, shrub, settlement and agricultural lands (Figure 3).

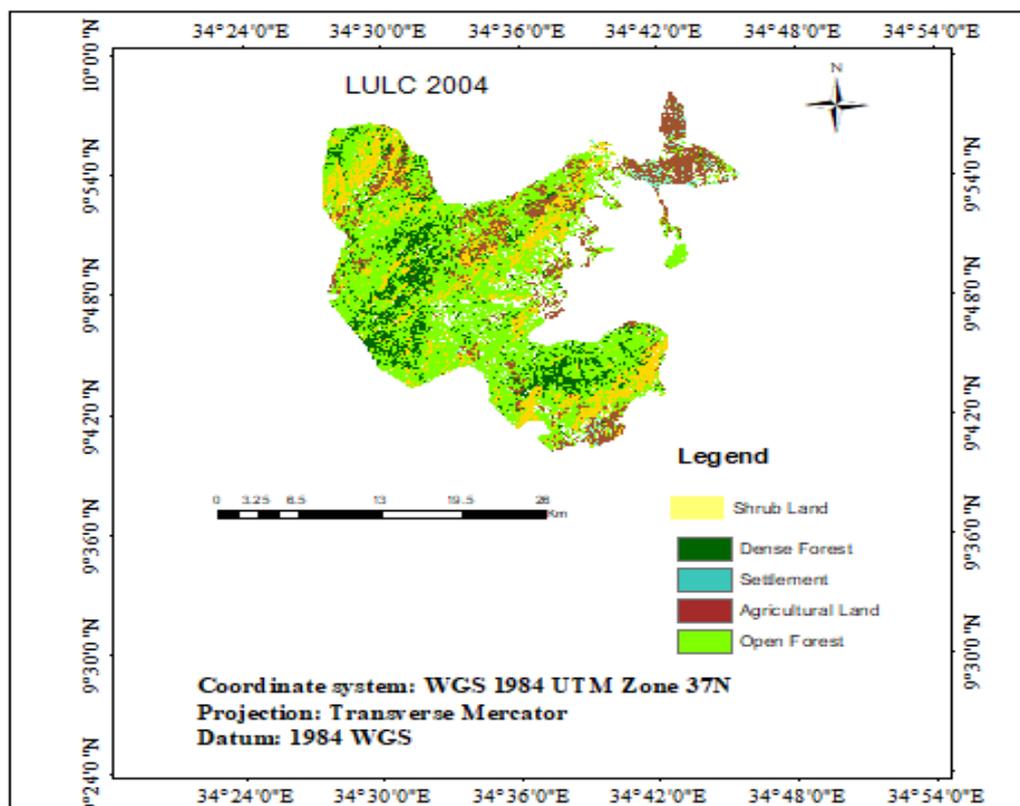


Figure 3 Land use land cover map of Anbessa forest in 2004

The extent of LULC change over this period is also measured quantitatively. The agricultural land, which was 1,724ha (i.e. only 3.9% of the total area of Anbessa forest in 1989) became 15,058.5ha (33.8%) in 2004. Similarly, settlement areas, which were 599.08ha (i.e. only 1.34% of the total area of the forest in 1989) became 8,219.72ha (18.4%) in 2004. In contrast, other types of LULC showed considerable decrease as they gave way to agricultural and settlement lands. Dense forest cover decreased from 15,884.04ha (35.6%) in 1989 to 6,135.10ha (13.8%) in 2004. Open forest cover decreased from 14,177.16ha (31.8%) in 1989 to 8,003.50ha (18%) in 2004. Shrub lands decreased from 12,184.72ha (27.3%) in 1989 to 7,152.18ha (16%) in 2004 (Table 2). This shows that the natural forest cover (i.e. dense, open and shrub lands) was converted into cultural landscape (i.e. agriculture and settlement). As a result, there was critical deforestation in Anbessa forest between 1989 and 2004.

Table 2. Percent distribution of LULC classes of 1989 and the change from 1989

LULC Class	Years					
	1989		2004		LULC change (1989 – 2004)	
	Area (ha)	%	Area(ha)	%	Area(ha)	%
Dense Forest	15884.04	35.63	6135.10	13.77	-9,748.94	-21.86
Open Forest	14177.16	31.80	8003.50	17.95	-6,173.66	-13.85
Shrub Land	12184.72	27.33	7152.18	16.05	-5,032.54	-11.28
Agri. Land	1724.00	3.90	15058.51	33.79	+13,334.51	+29.89
Settlement	599.08	1.34	8219.71	18.44	+7,620.63	+17.10
Total	44569.00	100.00	44569.00	100.00		

Source: Computed from Landsat data using ERDAS

Spatial Pattern of LULC Classes of 2019 and the Change from 2004

Analyzing the pattern of LULC classes of the 2019, mapped from satellite images, is a crucial step to compare with maps of 1989 and 2004. The result showed that the change in LULC had continued to happen until 2019 (Figure 4). The northeastern part of the forest area was almost entirely converted into agricultural land.

Large part of northern, northcentral, central and southeastern part of the area was dominantly occupied by agricultural land. Settlements were also distributed almost all over the area of Anbessa forest. Most part of Anbessa forest had also gradually been changed into shrub lands.

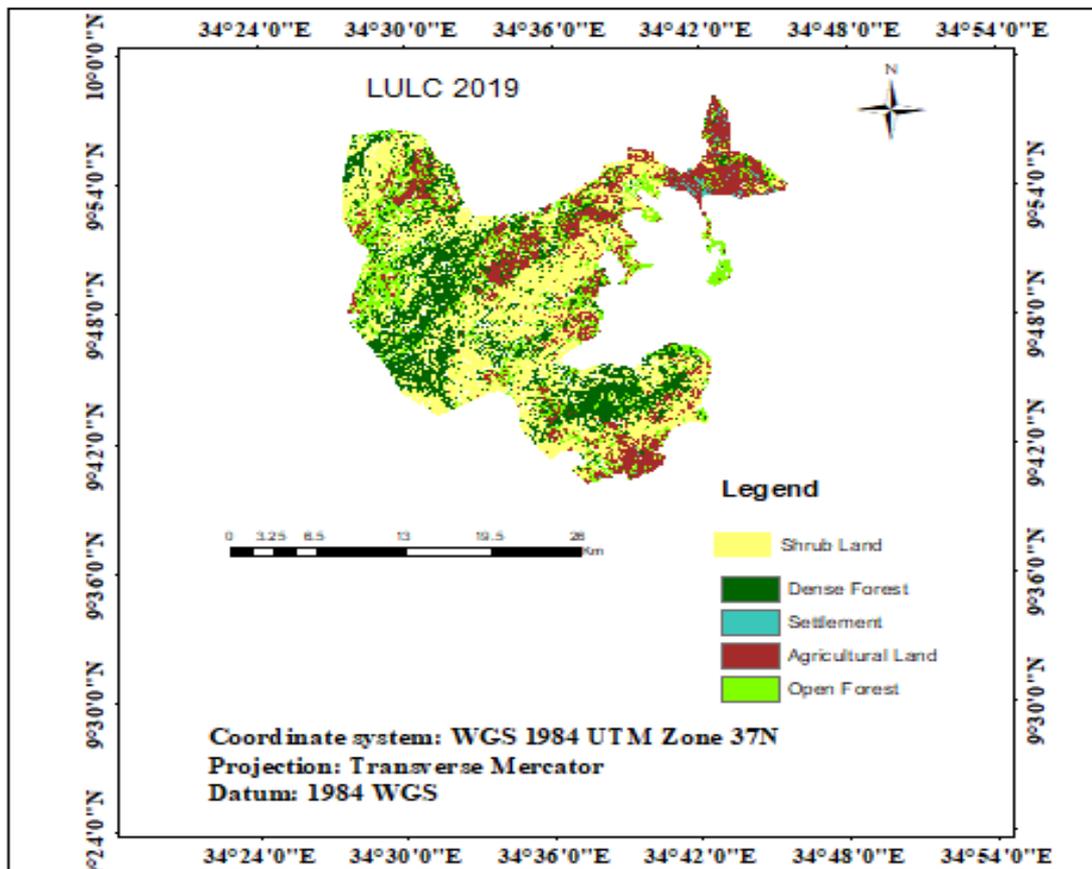


Figure 4. Land use land cover map of Anbessa forest in 2019

In contrast to agricultural, settlement and shrub lands, dense forest and open forest covers had decreased from 2004 to 2019. Dense forests likely divided Anbessa forest into two running from North through central part to Southwest. These forests were also found in central southeastern part of the forest area. Open forests were found in northwestern and western as well as northeastern fringes of the forest area. In addition, these classes of forest area were distributed throughout Anbessa forest (Figure 4).

Table 3. Percent distribution of LULC of 2019 and the Change from 2004

LULC Class	Years				LULC (2004 – 2019)	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
Dense Forest	6135.10	13.77	3091.06	6.94	-3044.04	-6.83
Open Forest	8003.50	17.95	6170.26	13.84	-1833.24	-4.11
Shrub Land	7152.18	16.05	8190.53	18.37	+1038.35	+2.32
Agri. Land	15058.51	33.79	16020.35	35.95	+961.84	+2.16
Settlement	8219.71	18.44	11096.80	24.90	+2877.09	+6.46
Total	44569.00	100.00	44569.00	100.00		

Source: Computed from Landsat data using ERDAS

The area extent of each LULC class is quantified so as to clarify the changes. There was further decrease in the land use cover of the dense forest and open forests from 6,135.10ha (13.8%) in 2004 to 3,091.06ha (6.9%) in 2019 and from 8,003.50ha (18%) in 2004 to 6,170.26ha (13.8%) in 2019. In contrast, shrub land increased from 7,152.18ha (16%) to 8,190.53ha (18.4%); agricultural land from 15,058.51ha (33.8%) to 16,020.35ha (36%), and settlement areas from 8,219.71ha (18.4%) to 11,096.90ha (24.9%) between 2004 and 2019 (Table, 3). This shows that there is a linear decrease in dense and open forest area since 1989 while linear

increase agricultural land and settlement areas and variable changes in the area cover under shrub land over the same period of time.

DISCUSSION

As to our knowledge of literature regarding Anbessa forest, only one previous study examined plant diversity in it (Tamene, 2016). In the present study we classified the different LULC types and measured the spatial and temporal levels of changes in the forest area. The study classified the forest area into five basic types of LULC, which is similar exercise to other study in Ethiopia (McKee, 2007; Mathewos, 2019). These include dense forest, open forest, shrub land, agricultural land and settlement. The five land use types were examined over the period of thirty years.

The spatial map of the LULC of the forest during the reference year (1989) was in line with the general observation where dense forests had the largest area (Figure 2). There was a clear association between settlement and agricultural lands in the forest. This goes in line with the fact that human cultural interventions are the main causes of environmental changes (Yang, 2001; Johnson et al., 1997; Xu et al., 2007). Thus, it is natural that LULC changes start when human beings to encroach forests through their activities. This was true in Anbessa forest where the spatial and temporal pattern of changes had started since the 1984/85 resettlement scheme due to drought in the northern part of Ethiopia brought many people to this area (Tamene, 2016). Since then, the natural forest cover had shown a significant decrease giving ways to agricultural and settlement areas.

Generally, the study showed a general decline in the area of natural features and an increase in cultural features from 1989 to 2004 and then to 2019 (see Figure 5). Temporally, we observed a sharp decrease in the area of dense and open forests from 1989 to 2004 and then to 2019. Conversely, there had been a sharp increase in the share of land under agriculture and settlement over the same period of time. But, the experience of land under shrubs is a little bit different showing a decrease from 1989 to 2004 and then an increase from 2004 to 2019. Spatially in 1989, the largest and smallest shares of land were dense forests and settlement. In fact, the share of agriculture was also very small. Open forests and shrubs had also large area coverage. In 2004, the share of agricultural land grew high while it was almost proportionate for others. In 2019, agriculture covered the largest percent followed by settlement, open forest, shrub and dense forest (Figure 5). Such a negative and a positive change are documented in a number of studies (Xu et al. 2007; Karnieli et al., 2008; Hu et al., 2018; Mathewos, 2019). This clearly implies that there was low level of interference in the forest ecosystem via human activities such as agriculture until 1989. However, the subsequent years were accompanied by increased human interference followed by a fast decline in the natural forest co

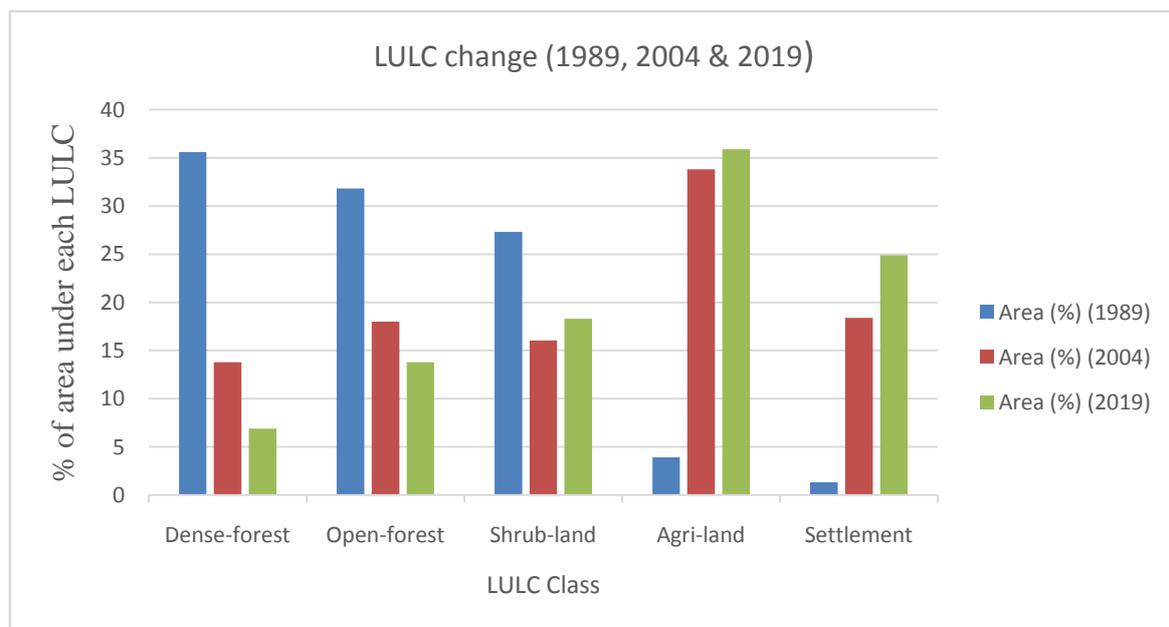


Figure 5. Trends in the changes in the area of each LULC from 1989 to 2019

The above facts are proved by observing the rate of changes in the LULC (Table 5). Negative changes were experienced by dense forest, open forest and shrub land covers. This implies that these classes of Anbessa forest had experienced a decrease in their areas. On the other hand, shrub lands showed fluctuations as they experienced negative change (-11.3%) between 1989 and 2004 and positive change (+2.3%) between 2004 and

2019 resulting in the negative general changes between 1989 and 2019. There were also positive changes in agricultural and settlement areas over the same period of time (Figure 4). So we can conclude that Anbessa forest had experienced a change from natural landscape to cultural landscape over the last 30 years.

Table 4. Land use land cover change between 1989 to 2019 by land use classe

Land Use Land Cover Class	Years					
	LULC change (1989-2004)		LULC change (2004-2019)		LULC change (1989-2019)	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
Dense Forest	-9,748.94	-21.86	-3044.03	-6.83	-12792.97	-28.69
Open Forest	-6,173.66	-13.85	-1833.24	-4.11	-8006.90	-17.96
Shrub Land	-5,032.55	-11.28	+1038.45	+2.32	-3994.09	-8.96
Agri. Land	+13334.51	+29.89	+961.85	+2.16	+14296.36	+32.05
Settlement	+7,620.64	+17.10	+2877.18	+6.46	+10497.82	+23.56

Source: Computed from Landsat data using ERDAS

The overall finding revealed that the increase in some classes of LULC gave way to the decrease in other LULC classes, for example, from 1989 to 2004 and from 2004 to 2019 (Table 4). The negative changes in the dense and open forests and positive changes in the agricultural and settlement lands (Table 5) were also our prior expectation. This goes in line with the general observation that human activities such as deforestation for settlements and agriculture are the main causes of LULC changes (Turner and Meyer, 1994; Yang, 2001; Shah and Sharma, 2015). This obviously shows that human cultural practices play significant role in LULC changes.

CONCLUSION

LUC analysis is a crucial instrument that provides information on the environmental changes at any scale. The findings of the analysis of LULC are useful for decisions makers to work towards sustainable environmental management and development. In this study, we used a long term series of satellite images (1989, 2004 and 2019) to analyze the changes that had occurred in Anbessa forest. Our findings showed that there had been fast changes in LULC between 1989 and 2019. The transition, from dense and open forests to agricultural and settlement areas, was considerable. This was followed by major decrease in the areas of natural dense and open forests and an increase in agricultural and settlement areas over 30 years. In general, although the average change in all types of LULC was negative, different directions of changes were observed. That is, there was a negative change in the land cover under dense and open forests and a positive change in land cover under agriculture and settlement while shrub lands experienced an initial decrease followed by an increase from 1989 to 2004 and to 2019 respectively. Thus, we concluded that Anbessa forest had faced critical environmental changes mainly due to encroachments through agriculture and settlements. We recommend an intervention projects that can avert the current trend of Anbessa forest degradation. More importantly, we also suggest further research into the root causes for the reliance of the surrounding community on Anbessa forest.

Abbreviations

LULC = Land Use Land Cover; TM: Thematic Mapper; ETM+: Enhanced Thematic Mapper plus; OLI/TIR: Operational Land Imager; USGS: United States Geological Survey; ERDAS: Earth Resources Data Analysis System

Ethical Approval and Consent to participate

Not applicable

Consent for publication

Not applicable

Availability of supporting data

Not Applicable

Competing interest

There is no competing interest

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Authors Contribution

Dr. Guyu F. conceived the research idea, developed the proposal along with research tools. Mr. Adwa run the image analysis. Then Dr. Guyu F. wrote the reports of the findings. Both of them read and proved the manuscript that it is the final research work.

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