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Spatio-temporal Pattern of Deforestation: The Case of Anbessa'chaka' Forest, Benishangul-Gumuz Region, Northwestern Ethiopia

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Abstract

The study seeks to analyze the spatio-temporal pattern of deforestation of Anbessa'chaka' forest, which is located in Benishangul-Gumuz region, Ethiopia. Satellite images taken between 1989 and 2019 were analyzed using ARC-GIS and ERDAS 2018 to attain the objective of the study. The results show that over 95% of the land area of Anbessa'chaka' was under natural landscape in 1989 with 35.6% under dense forests, 31.8% under open forest, and 27.3% under shrub land. Only about 5% of the total area was under cultural landscape, with 4% agricultural and 1% settlement area. In 2004, dense forest, open forest, and shrub covered about 13.8%, 18%, and 16% respectively, and agricultural and settlement areas covered 33.8% and 18.4% respectively. In 2019, the shares of dense forest, open forests, and shrub lands became 7%, 13.8%, and 18.4% respectively. Agricultural and settlement areas covered 36% and 25% respectively. Dense forest decreased from 35.6% to 13.8% between 1989 and 2004 at a rate of 21.8% and from 13.8% to 6.9% between 2004 and 2019 at a rate of 6.9%. Open forest and shrub decreased at rates of 18% and 9% respectively over the last 30 years. In contrast, agricultural and settlement areas were increased by 32% and 24% respectively over the same period. It is anticipated that Anbessa'chaka' will be completely deforested and changed into cultural landscape in the near future if the current rate of deforestation continues. Thus, the study recommends research into the root causes of deforestation of the forest so as to take appropriate measures that can reverse it.

Keywords: /Anbessa'chaka'/Deforestation/Forest/Land cover change/Land use/Pattern/

1. Introduction

According to FAO-UN (2011) estimate, the world's total forest area is about 4.1 billion ha, that is about 31% of the total land area. This is equivalent to 0.52 ha per person although forests are not distributed equally among countries of the world. And, the largest proportion of the world's forests (45 percent) is found in tropical area followed by the boreal, temperate, and subtropical domains. It is also noted that the world has lost about

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175 million ha forest since 1990, which is equivalent to the total area of Libya. However, the rate of net forest loss declined from 7.8 million ha per year in the decade 1990–2000 to 5.2 million ha per year in 2000–2010 and 4.7 million ha per year in 2010–2020 (FAO-UN, 2011). This is also true of Ethiopia where initially there was high rate of deforestation and then relative decline since recent past.

The total natural forest cover of Ethiopia in the 1900s was estimated to be about 40% of the total land area of the country (EFAP, 1994). This was declined to about 11% in 2010 (FAO, 2010) and about 3% in 2015 (FDRE, 2015). However, the most recent information shows that land area under forest had increased to 15.7% (MEFCC, 2018). According to Mongabay statistics (2018), the forest cover of Ethiopia was about 10.7% of the total land area of the country. Despite variation in the figures from the two sources, it seems that forest cover is improving perhaps due to afforestation measures taken by the state. In Benishangul-Gumuz region (BGR), high forests, woodlands, and shrubs cover 1.7%, 8%, and 5% respectively (FDRE, 2015).

Man-made and natural forest fires are reported among the factors for forest degradation in Ethiopia (FDRE, 2015). Fire is the most important centuries-old cause of deforestation. People used it to clear farmlands and as human population increases, the demand for farmlands increases leading to further deforestation (FAO, 2010). Grazing forest areas and logging trees from the forest are also important causes of deforestation. Generally, forest resources are under immense pressure from deforestation and forest degradation due to over exploitation of forest resource, overgrazing, resulting in habitat loss, prevalence of invasive species and pollution (Yitebtu & Eyob, 2014). Resettlement programs have also aggravated deforestation especially in BGR and Gambella region (Mekonen *et al*., 2021). Wildfire is one of the most serious causes of deforestation in these regions (Semeneh, 2014). Like in all parts of Ethiopia, the forest of the region has been decreased from time to time.

In BGR, deforestation has become a serious challenge today. The growing demographic pressure and subsequent demand for additional farmlands have caused high rate of deforestation (Semeneh, 2014). Unplanned large-scale agricultural land investments are the likely causes of deforestation in most parts of the region (Tsegaye, 2013). Anbessa‘chaka’ forest is one of the popular forest areas of the regions, which is facing serious level of deforestation due to the surrounding resettlements since the 1970s. ‘Chaka’ is an Amharic term to mean forest used to call the forest area under study. It was observed that the forest was under severe rates of deforestation but studies that tried to show the spatio-temporal pattern of deforestation are scarce. Available studies focused on different issues of forests in the region. For example, Solomon *et al.*, (2010) studied the structure of the Erythrocebus Patas monkey in Anbessa‘chaka’. Semeneh (2014) studied deforestation and its protection strategy in Beles sub basin and estimated the pattern and magnitude of deforestation and identified the triggering factors of deforestation. Semeneh (2014) further examined the Land Use/Land Cover change in Bamboo forest in the region. Mekonen *et al*., (2021) studied the impact of resettlement program on Anbessa‘chaka’ forest and revealed that resettlers had deforested the area mainly for agricultural purposes. Semeneh (2014) studied the determinants of bamboo deforestation in the region. However, none of these studies focused on the spatio-temporal aspect of Anbesa‘chaka’ forest, which is one of the popular and extensive forest areas in the region. This motivated the authors to conceive the problem and undertake the study.So, understanding the magnitude of deforestation in quantitative and qualitative terms is essential to design appropriate policy decision. The aim of the present study was therefore to show the spatio-temporal pattern of deforestation that took place in Anbessa‘chaka’ forest over the last 30 years using satellite image.

2. Literature Review

The definition of forest varies from one organization to another; however, the definition of Food and Agricultural Organization (FAO's) is frequently used. Accordingly, forest is defined as land with a tree crown cover of more than 10% and an area of more than 0.5 hectare; the trees should be able to reach a minimum height of 5 meter at maturity (FAO, 2001). According to this definition, forest includes high forests, woodlands, and bamboo forests. Likewise in the present study, deforestation is defined as high forest being converted into other land-use types.

Globally very few landscapes remain without significant alteration by human activities (UNDESA, 2021). Most landscapes have experienced land cover change, which has become a major topic of discussion in sustainable management of natural resources (Kadıoğullarıh, 2013; Batunacun *et al.*, 2018; Hu *et al.*, 2018) and, sustainable development (Hu *et al.,* 2018) since recently. Land cover change has had considerable effect on forest ecosystem, biodiversity, soil conservation, and global climate (Xu et al., 2007; Karnieli *et al.,* 2008). Human activities are the main causes of land cover 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; Wakeel *et al.*, 2005, Cayuela *et al.*, 2006). So, understanding the spatial and temporal extent and distribution of deforestation as a result of the change is vital to the study of environmental degradation at various levels (Ojima *et al,*. 1994). Accordingly, environmental analysts recognized that land cover analysis is a fundamental tool for assessing environmental and ecological consequences of human activities (Yang, 2001; Flamenco-Sandoval *et al*., 2007).

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; Başkent *et al.*, 2008; Keleş *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'chaka' forest have experienced deforestation due to mainly human activities (McKee, 2007; Mathewos, 2019).

Deforestation is an important outcome for land cover change elsewhere in the world (Batunacun *et al*., 2018; 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). Forest structure and composition are essential ecosystem characteristics (Batunacun *et al.*, 2018; de Quesada & Kuuluvainen, 2020) which are disrupted 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).

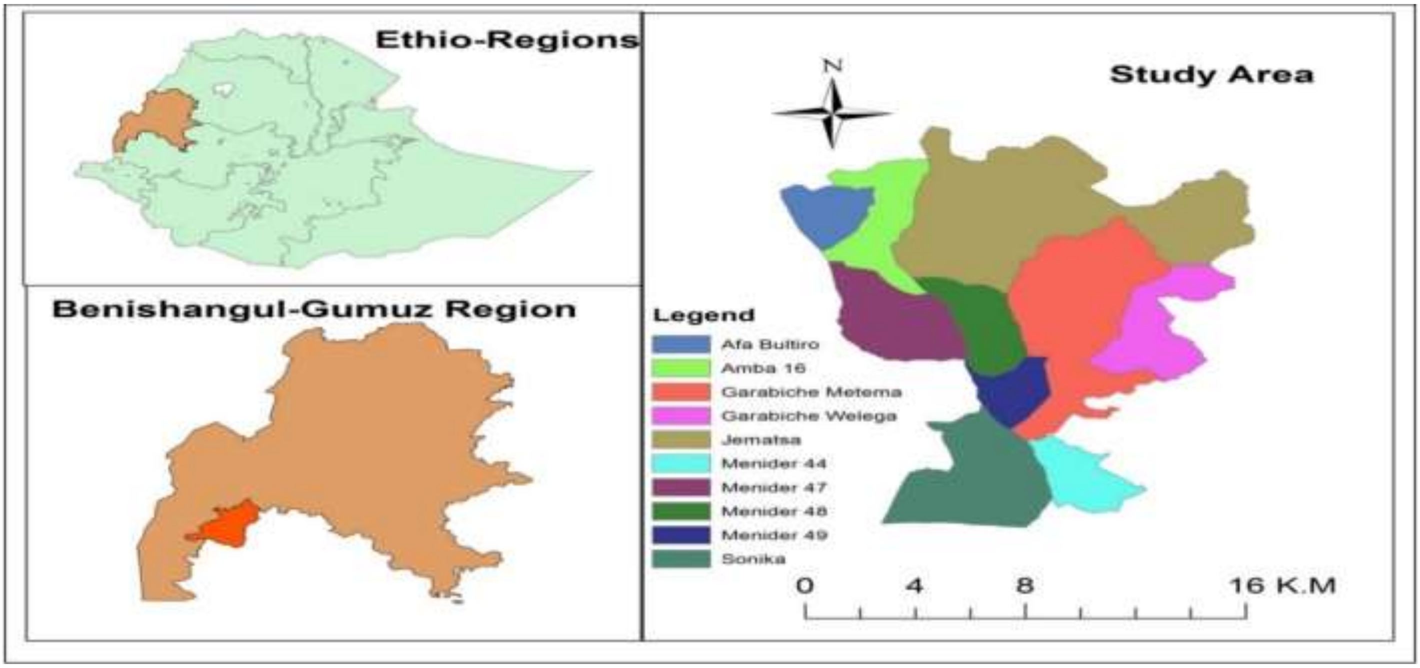

Figure 1: Location map of Anbessa‘chaka’ forest (Source: Own work using Arc GIS Software, 2021)

In Ethiopia, forest losses of 140,000 hectares each year are driven by conversion into agricultural lands, 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‘chaka’ forest, one of the popular high forests of Ethiopia, has been exposed to deforestation over the last three to four decades. But, research that shows the level of deforestation is scarce, and the type and nature of land cover changes that the study area has undergone. While most previous studies dealt mainly with bamboo forest, a previous study examined plant diversity in Anbesa‘chaka’ forest (Tamene, 2016). In addition, a brief survey of some forest areas in Assosa zone was conducted and attributed deforestation to wild fire, overgrazing, and timbering (FARM-AFRICA, 2011). This shows that there is a gap in literature as there was no study conducted on the spatio-temporal pattern on the forest. Therefore, understanding the spatio-temporal pattern of deforestation in quantitative and qualitative terms is essential to design appropriate policy decision as well as to narrow literature gap.

3. Methodology

3.1. Study Area

Anbessa‘chaka’ forest is a natural forest land which is found in Benishangul-Gumuz region, Ethiopia. It is located between 90 53′ 24″ N -90 55′ 40″ N and between 340 39′ 09″ E - 340 50′ 55″ E. Recently, it has an estimated total area of 15,072 ha. However, originally it had an area of about 44,569 ha (Figure 1). The topography of Anbessa‘chaka’ forest is very flat except for few hilly areas in the western part of the forest near the main asphalt road from Addis Ababa (capital city of Ethiopia) to Asossa town (administrative capital of Benishangul-Gumuz regional state). Its elevation ranges from 1292m to 1563m asl with the highest and lowest peaks in the western eastern parts respectively.

Anbessa'chaka' forest is characterized by monomodal rainfall distribution with the rainy season extending from March to November (Tamene, 2016). Its average annual rainfall is about 1381mm and its mean monthly temperature is about280C (Herrmann *et al.*, 2007). Anbessa'chaka' forest is also characterized by Combretum-Terminalia woodland, which is dominated by Oxytenanthera abyssinica (lowland bamboo) that stands with scattered Combretum – Terminalia woodland vegetation. The rest of the forest is flat wooded grass land with very small slope variation (FARM-AFRICA, 2011).

Anbessa'chaka' forest has been under rapid rate of deforestation since the implementation of resettlement schemes in 1980s which brought re-settlers from northern Ethiopia to the area. At present, the forest is surrounded by 10 large villages listed in Figure 1. Since then, the forest has been under serious threats 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).

3.2. Methods

To measure the extent of deforestation, land cover types of the forest were mapped as the spatial database from satellite images obtained from three Landsat series. The images for the period of 30 years were derived from Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for1989, 2004, and 2019 respectively. The year 1989 is chosen as a base because resettlement programs started in the first half of 1980s in the study 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) from Google Earth to evaluate the Anbessa'chaka' forest cover change from1989 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 cm. 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 60m as compared to the TM′s 120 m spatial resolution. The ETM+ also contains 15 m 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.

National Aeronautics and Space Administration (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 TIR Son 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; hence 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 obtained. 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 30m.

The land cover change was analyzed using post classification cross-tabulation approach using ARC-GIS and ERDAS 2018. 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 (MLC) method - a well-known parametric classifier for supervised classification (Otukei & Blaschke, 2010).

In the third phase, post classification process and change detection were performed to assess the changes in land cover during the study period for both the forest covered area and degraded zone. And land cover maps were drawn for each year under consideration. 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 to draw conclusion. In fact, observations of the forest area were made to appreciate the ground situation although they were not used in this study.

4. Results

4.1. Forest Cover Change

The land cover map yielded the spatial and temporal extents of different land cover types (Figures 2, 3 & 4). The maps show the spatial distributions and temporal variations of each land cover types from 1989 to 2019. The dark green map shows that Anbessa'chaka' forest was covered by dense forest in 1989 (Figure 2).

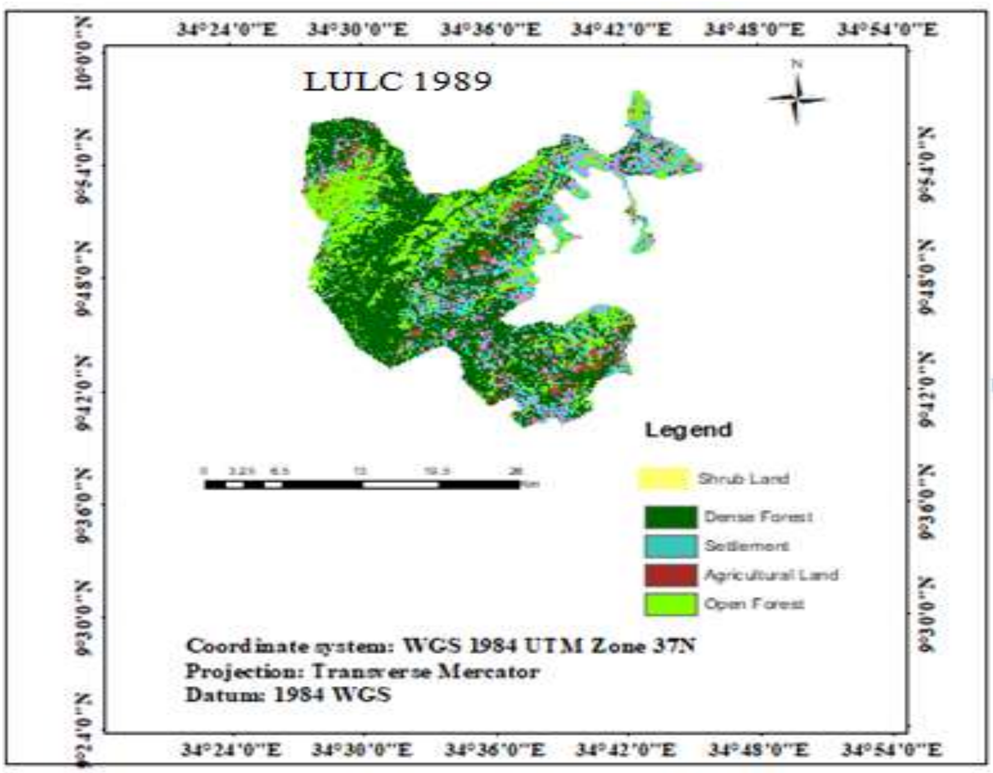

Figure 2: Anbessa 'chaka' forest cover situation (1989)

The map in Figure 3 shows that a very small area of the forest (as shown with dark green) was left in 2004, i.e. after a period of 15 years. In 2004 open forests, shrubs as natural landscape, and agricultural land, and settlement areas as a cultural landscape dominated Anbessa'chaka' forest.

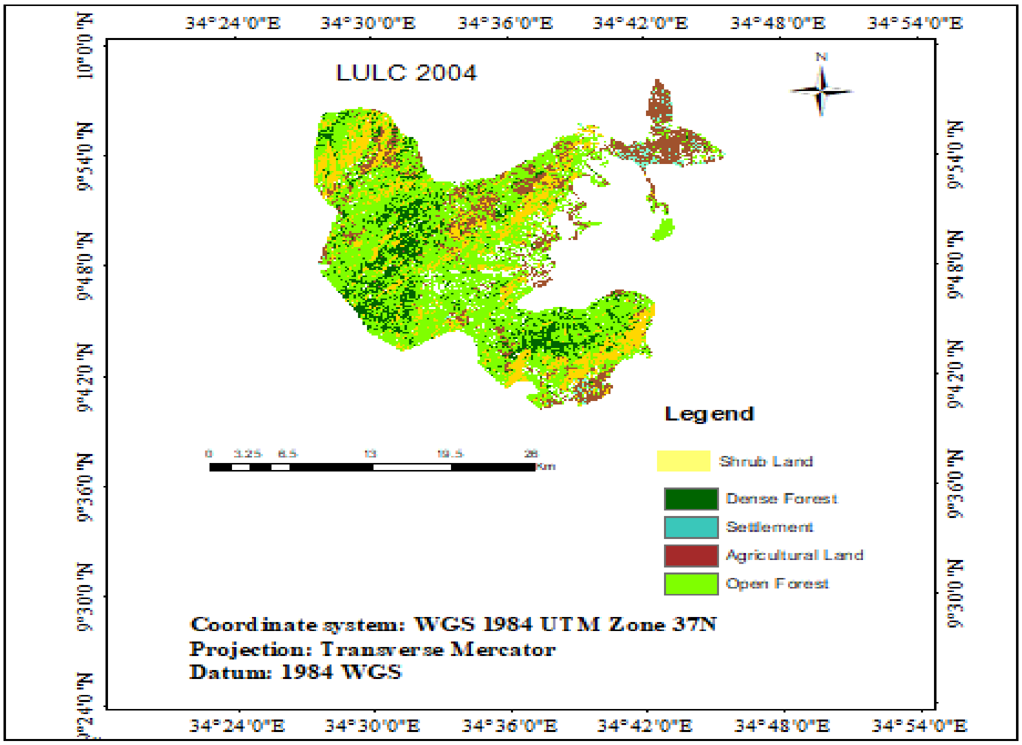

Figure 3: Anbessa 'chaka' forest cover changes (1989 – 2019)

In 2019, high domination of cultural landscape (i.e. agricultural and settlement) is indicated by the yellow color. This shows that deforestation had been mainly driven by agriculture and settlement areas and reached its peak currently. Better way of understanding the spatial and temporal magnitudes of deforestation of Anbessa'chaka' is analyzing the areas deforested over a period of 30 years quantitatively (Figure 4).

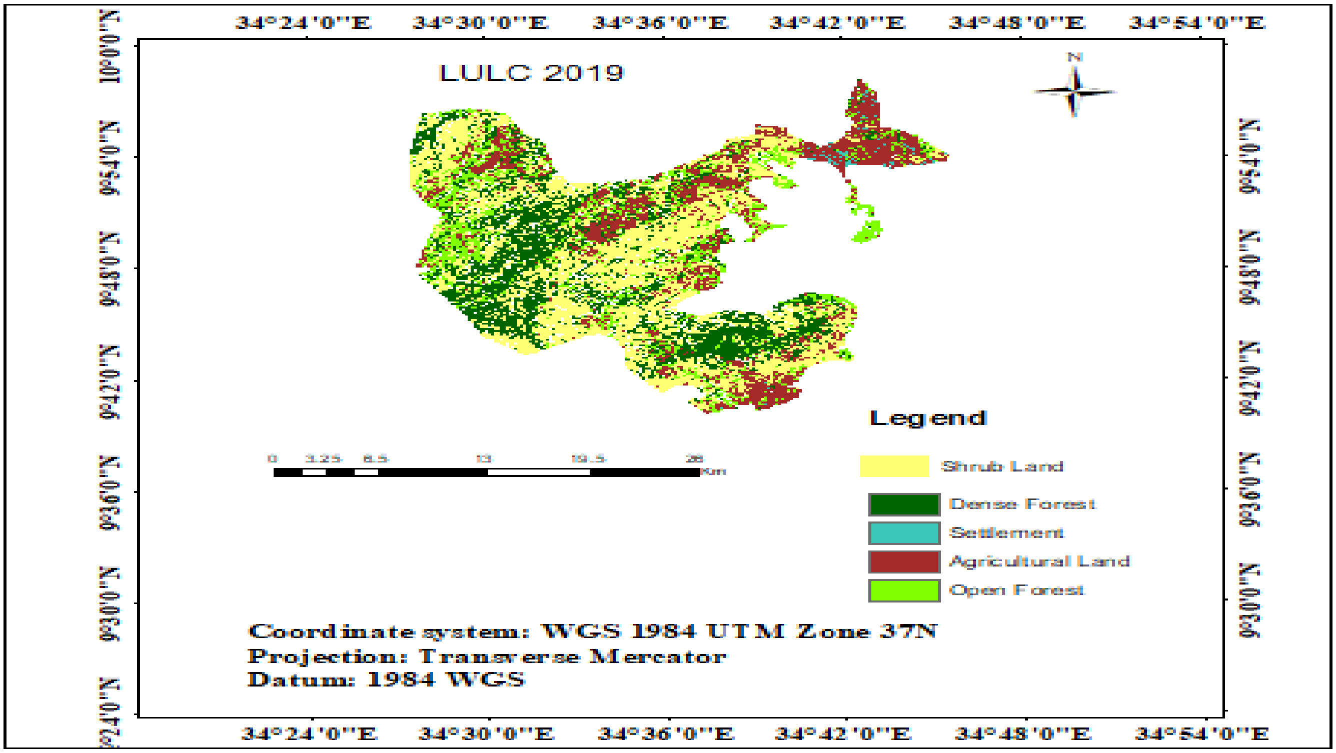

Figure 4: Anbessa'chaka' forest cover changes (2019)

Computation of the land cover change for three different years (1989, 2004, and 2019) reveals that there had been fast rate of deforestation in the study area. This is confirmed with the quantitative results in Table 1.

Table 1: Distribution of different land covers types during 1989, 2004, and 2019

Land cover types	Years					
	1989		2004		2019	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
Dense Forest	15884.1	35.6	6135.1	13.8	3091.1	6.9
Open Forest	14177.2	31.8	8003.5	18.0	6170.3	13.8
Shrub Land	12184.7	27.3	7152.2	16.1	8190.5	18.4
Agricultural Land	1724.0	3.9	15058.5	34.0	16020.4	36.0
Settlement	599.1	1.4	8219.7	18.4	11096.8	24.9
Total	44569.0	100.0	44569.1	100.0	89138.1	100.0

Source: Computed from Landsat data using ERDAS

There was a decrease in land cover under dense forest, open forest, and shrub land from 1989 to 2019 giving ways to agricultural and settlements. The land under agriculture and settlement increased over the same period of time. As shown in Table 1, the largest area of Anbessa‘chaka’ forest (35.6%) belonged to dense forest followed by open forest (31.8%), and shrub land (27.3%) in 1989. This means that about 95% of the area was under natural landscape with very minimum human interference during the year. Only 4% of the total area was under agriculture and 1% under settlement. In 2004, the proportions of area under the dense forest, open forest, and shrub land were about 14%, 18%, and 16% respectively. The shares of agricultural and settlement area during the same year were about 34% and 18% respectively. Moreover, in 2019 the respective shares of area under land cover types mentioned above were about 7%, 14%, and 18% respectively (Table 1).

4.2. Temporal Pattern of Deforestation of Anbessa‘chaka’

Table 1 show that there had been a decreasing trend in the dense forest coverage from 35.6% to 13.8% between 1989 and 2004. This means that the natural dense forest of Anbessa‘chaka’ forest had dwindled by 21.8% from 1989 to 2004 and by 6.9% from 2004 to 2019. This implies that the forest was shrunk by 29% over the last 30 years. Similarly, open forest and shrub land decreased at rates of 18% and 9%, respectively during the same period. In contrast, agricultural land and settlement areas increased at rates of 32% and 24% respectively over the period of 30 years (Table 2). With the current rate of changes in the land cover types and given the low practice of forest land management and administration, Anbessa‘chaka’ forest is expected to lose all the natural forest and changed into cultural landscape within the coming decade.

Table 2: Land cover change under each land use type between 1989 and 2019

Land cover types	Period					
	Land cover change (1989-2004)		Land cover change (2004-2019)		Land cover change (1989-2019)	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
Dense Forest	-9,748.9	-21.9	-3044.1	-6.8	-12793.0	-28.7
Open Forest	-6,173.7	-13.9	-1833.3	-4.1	-8006.1	-18.0
Shrub Land	-5,032.6	-11.3	+1038.5	+2.3	-3994.1	-9.0
Agri. Land	+13334.5	+30.0	+961.9	+2.2	+14296.4	+32.1
Settlement	+7,620.6	+17.1	+2877.2	+6.5	+10497.8	+23.6

Source: Computed from Landsat using ERDAS

At present, observation of Anbessa‘chaka ’forest shows that trees and shrubs are found on the hilly area in southwestern part. Most areas are already deforested and being changed into farmlands and settlements. Between 1989 and 2019, the area under dense forest declined by 28.1% (21.9% between 1989 and 2004 and 6.8% between 2004 and2019). Land under open forest decreased by 13.9% between 1989 and 2004 while the figure was 4.1% between 2004 and 2019 while it decreased by18% between 1989 and 2019. Overall, the rate at which land under forest cover decreased decreases from 11989 to 2019 (Table 2). This is also proved with the results of the rate of deforestation computed in Table 3. The rate of deforestation is computed for each period of 15 years and overall period of 30 years.

Table 3: Rate of deforestation of Anbessa‘chaka’ between 1989 and 2019

Land cover type	Period					
	Land cover change (1989-2004)		Land cover change (2004-2019)		Land cover change (1989-2019)	
	Area change (ha)	Rate (ha/year)	Area change (ha)	Rate (ha/year)	Area change (ha)	Rate (ha/year)
Dense forest	-9,749.0	-649.9	-3044.1	-202.9	-12793.0	-426.4
Open forest	-6,173.7	-411.6	-1833.1	-122.1	-8006.9	-266.9
Shrub land	-5,032.6	-335.5	+1038.5	+69.2	-3994.1	-133.2
Agri. land	+13334.5	+889.0	+961.9	+64.1	+14296.2	+476.6
Settlement	+7,620.7	+508.1	+2877.2	+191.8	+10497.8	+349.9

Source: Computed from Landsat using ERDAS

The result shows that the rate of deforestation in dense forest area of Anbessa‘chaka’ was 649.93 ha/year between 1989 and 2004, and became 202.94 ha/year between 2004 and 2019. The overall rate of deforestation over the period of 30 years was 426.43 ha/year (Table 3). This shows that almost all of the dense forest areas are completely deforested and changed into agricultural and settlement areas. This is in line with our observation of the forest area where only few pocket areas on and around the hilly part of the forest has few forest covers whereas the rest of the forest is now deforested. Similarly, the rates of deforestation of open forest between 1989 – 2004, 2004 – 2019 and 1989 – 2019 were 411.66 ha/year, 122.12 ha/year, and 266.90 ha/year respectively. On the other hand, shrub land was deforested at a rate of 335.5 ha/year between 1989 and 2004 but increased its area by a rate of 69.23 ha/year between 2004 and 2019. The later was perhaps due to the fact that open forest areas were changed into shrub land due to human activities such as cutting of larger trees for firewood and charcoal purposes. However, ultimately the shrub land was deforested at a rate of 133.2 ha/year over a period of 30 years (Table 3).

In contrast, the land under agriculture and settlement increased at fast rates. Agricultural land increased at an average rate of 888.97 ha/year between 1989 and 2004 and 64.1 ha/year between 2004 and 2019. The average rate of increase of land under agriculture between 1989 and 2019 was 476.55 ha/year. Similarly, while the land under settlement increased at an average rate of 508.1 ha/year between 1989 and 2004, the land under settlement increased at 191.81 ha/year between 2004 and 2019, and at 349.9 ha/year between 1989 and 2019 respectively (Table 3). This shows that although some pocket areas of the original area of Anbessa‘chaka’ has forest trees, it has likely been entirely converted into agricultural and settlement lands.

4. Discussion

Anbessa‘chaka’ is a popular forest in Benishangul-Gumuz region, Ethiopia which lacks attention from the government and deforested indiscriminately. Our knowledge of literature regarding Anbessa‘chaka’ forest proved only one previous study that examined plant diversity in it (Tamene, 2016). In the present study we examined the spatial and temporal extent of deforestation of Anbessa‘chaka’. To understand clearly the extent of deforestation, we classified the forest area into five basic types of land cover, which is similar exercise with other studies in Ethiopia (McKee, 2007; Yitebtu & Eyob, 2014; Mathewos, 2019; Barana *et al.*, 2020; Milkesa *et al.*, 2020). These include dense forest, open forest, shrub land, agricultural land, and settlement. The five land cover types are examined for over the period of 30 years.

There is a general theory that states human or cultural interventions are the main causes of environmental changes (Johnson *et al.,* 1997; Yang, 2001; Xu *et al.,* 2007; Batunacun *et al.,* 2018). Huge number of studies also documented a decreasing trend in areas under natural forests and an increasing trend in areas under cultural landscapes (Johnson *et al*., 1997; Yang, 2001; Xu *et al.,* 2007; Karnieli *et al*., 2008; Hu *et al.,* 2018; Mathewos, 2019). Our study goes in line with the theory and those studies as initially the three types of land cover (i.e. dense forest, open forest, and shrub land) were generally in their natural settings and later replaced by the cultural landscapes (agriculture and settlement). As stated in a previous study on the forest area, this was due to the expansion of agricultural and settlement areas into the forest (Mekonen *et al.,* 2021). Moreover, a study by Semeneh (2014) indicated that forest fires contributed to deforestation in BGR, where Anbesa‘chaka’ is a part. In line with this, we observed that in 1989 the largest proportion of the forest area (i.e. 95%) was covered by natural forests (i.e. dense forest, open forest, and shrub land) as opposed to only 5% of the forest areas under agriculture and settlement. As time went on, in 2004 the total area of the natural landscape constituted about 48% of the total land area of the forest while the larger share (i.e. about 52%) went to agriculture and settlement areas each with proportional share of 34% and 18% respectively. In 2019, the share of the natural landscape further declined to about 39% while the remaining 61% went to agriculture and settlement lands. This shows that initially little or no deforestation took place on Anbessa‘chaka’ forest but later it had been changed into cultural landscapes since the 1984/85 resettlement scheme due to drought that occurred in the northern part of Ethiopia (Tamene, 2016). This goes in line with Milkesa *et al.* (2020), which had shown that existing forests were changed into agricultural and settlements in Komto protected forest. The present finding is also similar with the findings of Barana *et al.* (2020) in which dense forests and woodlands were changed into cultivated and settlement areas in Southern Nations Nationalities and People’s region.

According to the supervised classification procedure applied to the1989,2004, and 2019 images, the largest land cover for dense forest, open forest, and shrub lands (i.e. natural landscape as a whole) was mapped during initial time, i.e. 1989 (Figure 2). We remember that the second half of the 1980s was the time when people from northern Ethiopia begun to resettle by the government because of drought. Since then, the rate of deforestation has been very fast and at present the forest is already at risk of complete disappearance although the government reports the presence of the forest. Deforestation of dense forests alone took place at the rate of 649.9 ha/year between 1989 and 2004 and at 202.9 ha/year between 2004 and 2019 and today forest cover is almost none. In contrast, the area under agriculture increased at average rates of 889.0 ha/year and 64.1 ha/year during 1989 – 2004 and 2004 – 2019 respectively and settlement increased at 508.1 ha/year and 191.8 ha/year during the same periods of time respectively. As the result of this high rate of deforestation, the forest area is now at the eve of complete deforestation unless strict intervention measures are taken. The overall decreasing trend in forest covers in Anbessa’chaka’ forest is in line with Mekonen et al (2021) in which forest cover changes were mainly attributed to settlement and agriculture land expansion. This shows that the main force for forest cover change is human activities of different types. Conversion into cultivated and settlements is the main process in the present study area. As this study was limited to forest cover change of Anbessa’chaka’, further study on the root causes of the changes is essential.

5. Conclusion and Recommendations

The supervised classification produced five land cover types namely dense forest, open forest, shrub land, agricultural land, and settlement area for the year 1989, 2004, and 2019. The land cover map shows that there was a sharp decrease in the land area under dense forest, open forest, and shrub land covers from 1989 to 2019. In contrast, areas under settlements and agricultural lands grew over the same period. Dense forest cover gave way to open forest, shrubs, and finally to agricultural and settlement areas. As a result, small pocket areas of dense forests remained by 2019 and were confined to central, southwestern, and south-central parts of Anbessa‘chaka’ forest. In other words, most of dense forests were deforested and converted into open forest, shrub lands, settlement areas, and agricultural lands. As deforestation proceeded in the next decades, little forests have survived on and around hilly areas of Anbessa‘chaka’ forest at present. Therefore, high rate of deforestation over the last 30 years had degraded the forest of Anbessa‘chaka’ leaving it as an agricultural and settlement lands. Thus, we recommend an immediate intervention measure that averts the existing spatio-temporal pattern so as to work towards the rehabilitation of forest area. Meanwhile, we also recommend research that examines the root causes of deforestation of Anbessa‘chaka’.

Abbreviations:

Arc-GIS: Arc-Geographic Information System; ETM+: Enhanced Thematic Mapper Plus; LULC: Land Use Land Cover; MLC: Maximum Likelihood Classification; NASA: National Aeronautics and Space Administration; OLI/TIRS: Operational Land Imager/ Thermal Infrared Sensor; TM: Thematic Mapper; USGS: United States Geological Survey.

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Guyu Ferede is the principal researcher who conceived the research idea; reviewed literature, and wrote the draft manuscript.

Aduwa Anjulo collected satellite image and analyzed it. Both authors reviewed the draft manuscript and agreed on the final paper that it can be published.

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