International Journal of Horticulture and Forestry Research

Vol.3, No.1, pp.12-26,2022

Published by European Centre for Research Training and Development UK (www.eajournals.org)

Mapping Forest Cover Change of Duli Kebele, Kellem Wollega, Ethiopia

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Citation: Bezu A., Usmane I.A., Girma T., Ahmed I A. (2023) Mapping Forest Cover Change of Duli Kebele, Kellem Wollega, Ethiopia, *International Journal of Horticulture and Forestry Research*, Vol.3, No.1, pp.12-26

ABSTRACT: *Currently Land use/land cover change has become part of the global science agenda, because the existing forest lands have been destroyed and changed into other land use/land cover type and this had resulted into various calamities that has been regulated by forest such as desertification, flooding, loss of biodiversity, and others. The influence of the land use /land cover change was observed everywhere in the glob including Duli area where the area is previously known by dense forest cover and the coverage were declining now a day from time to time. Hence, the current study was initiated to analyze the dynamics of forest coverage over the past thirty years (1990-2020. For the analysis of the forest coverage dynamics GIS and remote sensing techniques were used. To quantify the magnitude and directions of Land use/land cover change, multi-sensor and multi-temporal Landsat images were accessed from United States Geological Survey. The obtained images were processed and analyzed to generate the information of Land use/land cover change. As a result of analysis from the total area of Duli kebele about 70% were covered by forest. However, through time the forest area has been converted to other land uses/land cover such as grassland, cultivated and settlement. The majority of the converted forest area was changed to grassland, followed by cultivated and settlement. The study revealed that in 1990 the forest cover of Duli kebele was 1509 ha but at the end of the study period (2020) the forest area was reduced to 1356 ha which is the loss of 153 ha of forest. This implies that from the existing forest area 7 % were converted into other land use land cover type. Based on the results it is possible to conclude that the forest resource of the area will be lost in the near future if the current trend is continued. Hence, government and the local community should work in cooperation in order to maximize benefit obtained from forest as well as to sustain the forest resource.*

KEYWORD*:* Duli, Gergeda, forest, land use, land cover, GIS and Remote Sensing

INTRODUCTION

Forests are important sources of livelihood for millions of people and contribute to the national economic development of many countries. Despite their crucial importance in livelihood and

climate regulation, forest resources all over the globe are subjected to enormous pressure resulting in deforestation and degradation due to the increase in human and cattle population and widespread rural poverty FAO, (2011). For instance, since 1990 FAO (2015) has estimated that about 129 million hectares of forests have been lost. The depletion of forests has many ecological, social and economic consequences, including the extinction of biotic communities leading to reduction in biodiversity, soil erosion, global warming and loss of income to forest dwellers Solomon et al, (2018); Chakravarty,(2012).

Forests are globally threatened precious natural resource, especially in Ethiopia where about 12% or less of land area is covered by forest. Loss of forest cover may be due to a number of factors, such as the cutting of timber for fuel wood and the expansion of agriculture. At the same time, changes in household tree planting practices, among other things, may be increasing forest cover in some degraded areas. By drawing upon a Geographic Information Systems (GIS) analysis of forest cover within four Regional States - Tigray, Amhara, Oromia and the Southern Nations, Nationalities, and Peoples region (SNNP) - this study aims to explore the relationships between governance institutions, access to forests, and population pressures, and changes in forest cover in Ethiopia.

Due to the combined stresses of population pressure and limited access to alternative resources, Ethiopian forests are under significant strain. According to the Food and Agriculture Organization of the United Nations (FAO), forest area accounted for approximately 12% of Ethiopia's total land area in 2005 (FAO, 2010). Earth Trends (2003) suggests forest cover in Ethiopia may be substantially less, as little as 5%. By any measure forest cover in Ethiopia is low compared to the 20.8% average for East Africa; and Ethiopia's forest cover is expected to continue decreasing in coming years. Deforestation, along with other forms of land use change, is a substantial contributor to economic and environmental problems, ranging from global climate change to local food and energy scarcity. Forests provide numerous ecosystem services, or benefits provided by proper ecosystem functioning. Some ecosystem services provided by forests include erosion control, nutrient cycling, and maintenance of biodiversity, water purification, control of desertification, carbon sequestration, and climate stabilization. Deforestation alone was responsible for nearly 25% of worldwide anthropogenic CO2 emissions during the 1990s (Houghton, 2003).

Improvement of forest management practices are estimated to be capable of reducing worldwide CO2 emissions substantially (Sohngen, 2009). Inextricably linked to ecosystem services, deforestation plays a role in a variety of social concerns, such as poverty and energy availability (Alem et al., 2010; Burgess et al., 2010). Rural and poor communities internationally, including those in Ethiopia, depend on forests for sources of energy, food, timber and income (Burgess et al., 2010). Even urban areas depend heavily on forest resources: Alem et al. (2010) found that nearly one million trees must be cut annually to account solely for the amount of charcoal that is brought to Addis Ababa, the capital city of Ethiopia. (Homeier & Homeier, 2009).

Performing land use change detection is an important tool to understand the extent of land cover loss and gain over time. Understanding the characteristics, extent and pattern of land use land cover change (LULCC) is an important supporting tool for decision making processes (Armenteras et al. 2019; Abebe et al. 2019; Yan et al., 2018; Tolessa et al. 2017). Therefore, studying the rate of LULCC support a decision making processes. Due to world population boom and advancement in science and technology, the natural resources are overexploited for the sake of economic activities with high severity in developing countries. Agricultural expansion into the forest land, timber logging, charcoal production and firewood harvesting are the major drivers of deforestation in Africa (Muhati et al. 2018). Forest depletion is a common problem in different parts of Ethiopia due to people dependence on forest for energy consumption as well as forest goods and services for survival. According to Erena et al. (2011) and Dinkayehu (2006) explained that Komto protected forest priority area is one of the remnant forest in Ethiopia threatened by forest over utilization in the form of charcoal extraction and timber production (Negassa et al., 2020).

Objectives

- To determine the temporal forest cover changes of the study area over the past thirty years
- To generate information on forest cover change through image analysis and provide evidence for policy makers

METHODOLOGY

Description of Study Area

The study area is located in Duli kebele, Anfillo District, Kellem Wollega zone, Oromia Regional State, Ethiopia (Figure 1). It is located about 672 km west of Addis Ababa, 35 Km northwest from zonal capital, Dembidolo and 20 Km east of Mugi town which is the capital of the district. It covers an area of 2516 ha. The study area lies between 8° 39′00″ and 8° 43′ 00″ North Latitude, and 34° 39′ 30″, and 34° 41′ 00″ East Longitude.The area is humid and moderately hot climate. The mean annual temperature is about 17.5 °C and the mean minimum and maximum temperature are 15 °C and 20 °C, respectively. The altitude of the study area lies between 2107 and 2493 m above sea level and receive 913.80 mm mean annual rainfall（Raga and Seid, 2017).

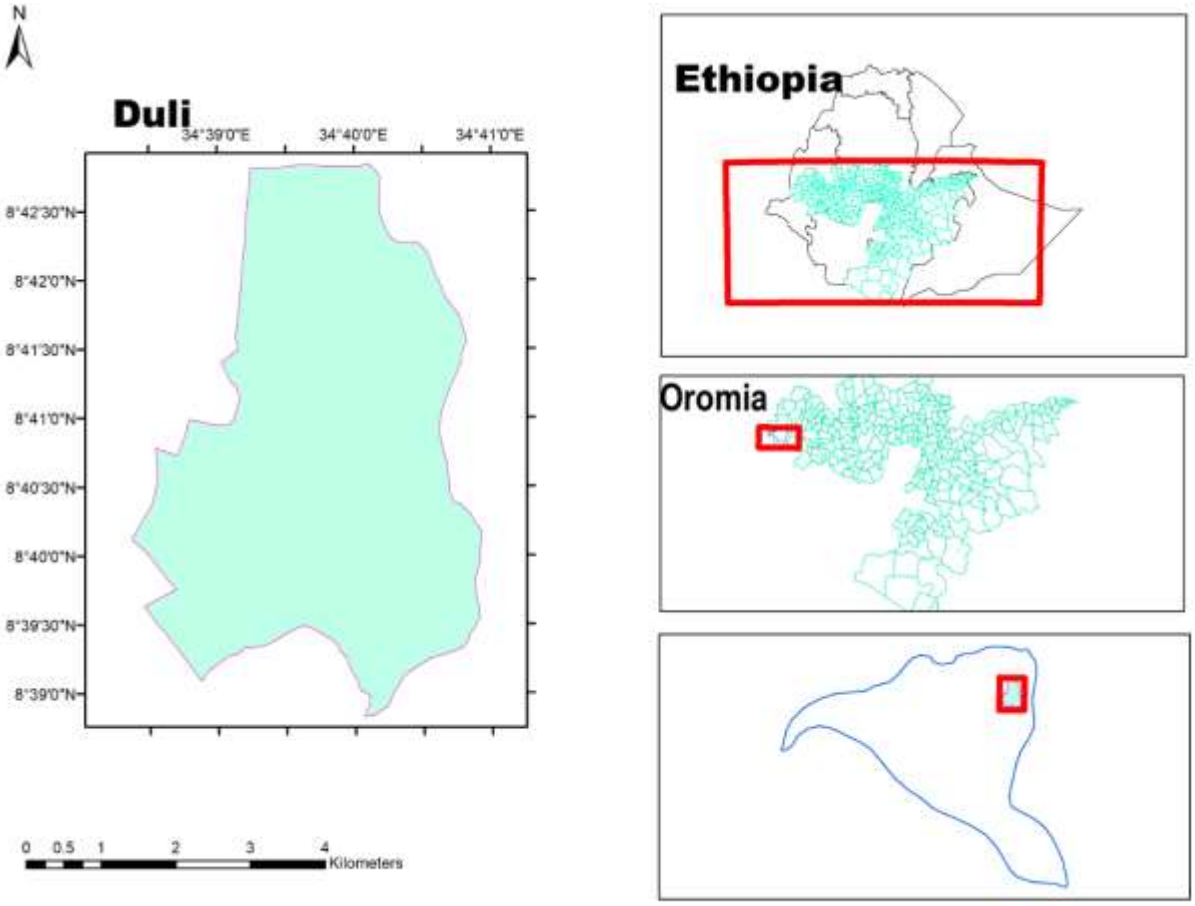


Figure 1. Study area

Data Collection

Acquisition of Satellite Images

Cloud-free Landsat satellite images captured in the dry season of the past thirty years (1990, 2000, 2010 and 2020) were acquired from the U.S. Geological Survey's Earth Resources Observation and Science (USGS). The years of study were selected based on major changes in political systems. The technical details of the satellite data that were used in the present study are given in Table 1. For making classification accurate and precise, google earth pro and ESRI 2020 land use map were used. For accuracy assessment, separate 30 points from each point were collected.

Table 1. Details of satellite data used in the study.

No.	Satellite	Date of Acquisition	Pixel Resolution (m)	No of Bands Used
1	Landsat	1990	30	7
2	Landsat	2000	30	7
3	Landsat	2010	30	7
4	Landsat	2020	30	11

Image processing

this study used remote sensing data for forest cover change in Duli kebele which is part of Gergeda state forest for the period of 1990-2020. The image processing task was carried out using ENVI version 5.2 integrating with Esri's ArcGIS platform. Landsat imagery pre-processing was conducted such as Radiometric correction, Image sub-setting (resizing), Layer stacking, Geometric correction and cloud detection methods were performed for noise removal as suggested by (Lin et al. 2015; Wang, 2016). Supervised image classification methods were performed for forest cover change detection techniques. Images were classified into four LULC classes; such as forest, cultivated land, grassland, and settlement.

Data Analysis

Satellite Image Analysis

To improve the interpretability of the images, appropriate preprocessing procedures including radiometric calibration, atmospheric correction (haze reduction and histogram equalization) were performed using ENVI 5.2 by employing supervised image classification methods as suggested by Rogan and Chen, (2004). Through employing image classification, a total of four land use/land cover classes were identified. All the four classes were identified in all images and represented the years under investigation in a consistent manner. The four classes were forest, cultivated land, grassland and settlement. Using training samples, maximum likelihood supervised classification was performed. After completing classification of each period, post classification was employed to identify the area changed during study period.

Accuracy Assessment

Accuracy of the image classification was assessed using Kappa statistics. Comparison was carried out by creating an error matrix. The accuracy assessment reflects the real difference between our classification and the reference map or data (Lillesand et al. 2004; Negassa et al., 2020; Pouliot et al. 2014; Tsutsumida and Comber 2015; Disperati and Virdis 2015). If the reference data is highly inaccurate, assessment might indicate that classification results are poor. Producer's accuracy is the map of accuracy from the point of view of the map maker (the producer). This is how often are real features on the ground correctly shown on the classified map or the probability that a certain land cover of a given area on the ground is classified as such. It is also the number of reference

sites classified accurately divided by the total number of reference sites for that class (Eq. 1). In principle, all the output maps have to meet the minimum 85% accuracy (Anderson et al., 1976; Solomon et al, 2018).

$$\text{Producer Accuracy} = \frac{\text{Total number of pixels in a category}}{\textit{Total no of pixels of that category derived from the reference data (row total)}}$$

Eq. 1

$$\text{User's Accuracy} = \frac{\text{Total number of pixels in a category} n(n-1)x^2}{\text{Total no of pixels of that category derived from the reference data (column total)}}$$

Eq. 2

RESULTS

Forest Cover Change during 1990-2000

The majority of the study area (Duli kebele) which is about 70% was covered by dense forest and the area is part of Gergeda Protected Forest Priority Area, and it has been administered by Oromia Regional Government, Oromia Forest and wildlife Enterprise in collaboration with local community. According to Raga and Seid, (2017) the forest, was invariably under extreme pressure from settlement, land-use change or conversion in to farming and grazing, coffee plantation by the local community, excessive wood harvesting, and neglect in terms of forest management and protection.

The forest cover change during 1990-2000 was fundamental that the coverage was degraded from one thousand five hundred nine (1509) he to one thousand four hundred fifty-nine (1459) he which was fifty (50) he within ten years. This implies that the forest degradation rate was five (5) hectare per year (table 2 and table 2). However, one thousand three hundred fifty-one (1351) hectare remain forest land. Moreover there are other land uses that converted to forest area. For instance fifteen hectare of cultivated, ninety-two hectare of grass and no area of settlement were changed to forest land during the period.

Table 2. Land use/land cover change matrix

LU/LC Classes		2000				
		Cultivated	**Forest**	**Grass**	**Settlement**	**Total**
1990	**Cultivated**	274.59	15.3	18.09	16.47	324.45
	Forest	34.29	1351	121.68	2.16	1509.12
	Grass	128.88	92.61	89.64	0.9	312.03
	Settlement	6.12	0	0	13.95	20.07
	Total	443.88	1459	229.41	33.48	**2165**

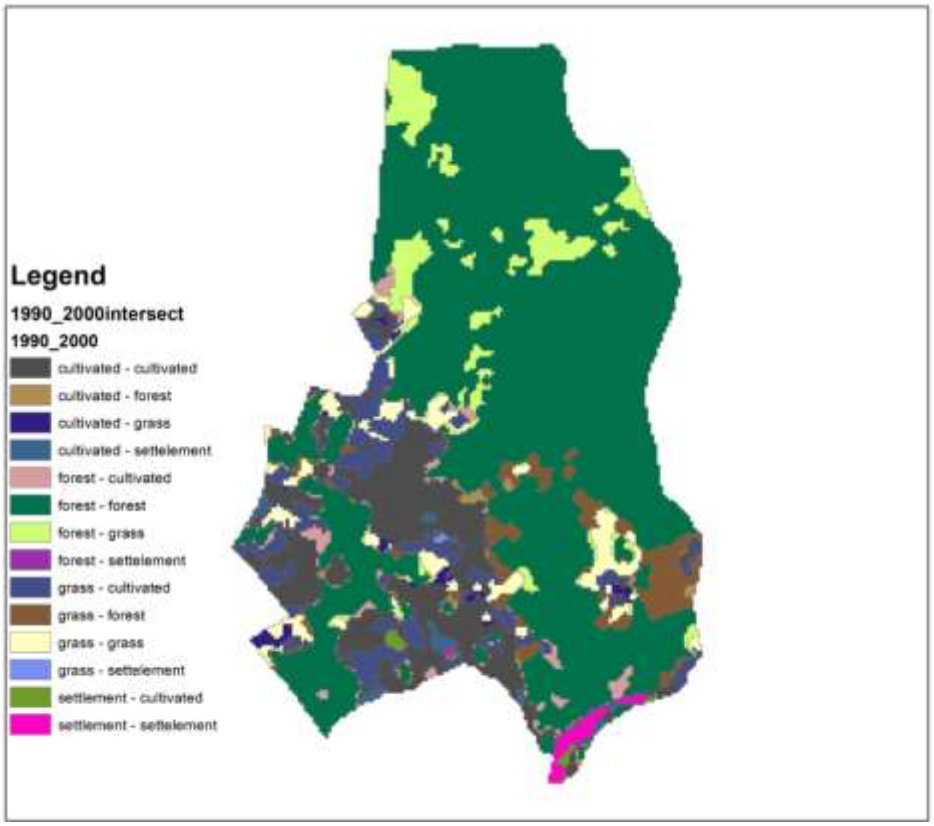


Figure 2. Forest cover change during 1990-2000

	1990		2000		2010		2020	
LULC Classes	**Area (ha)**	**Area (%)**	**area (ha)**	**Area (%)**	**area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Forest	1509.30	69.70	1458.00	67.34	1444.68	66.71	1356.66	62.65
Cultivated	324.00	14.96	444.00	20.51	433.44	20.01	432.54	19.97
Grass	312.00	14.41	230.00	10.62	248.58	11.48	298.53	13.79
Settlement	20.00	0.92	33.00	1.52	39.06	1.80	77.76	3.59
Total	2165.30	100.00	2165.00	100.00	2165.76	100.00	2165.49	100.00

Table 3. Rate of forest cover change

1990_2000		2000_2010		2010_2020		1990_2020	
Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
51.30	2.36	13.32	0.64	88.02	4.06	152.64	7.05

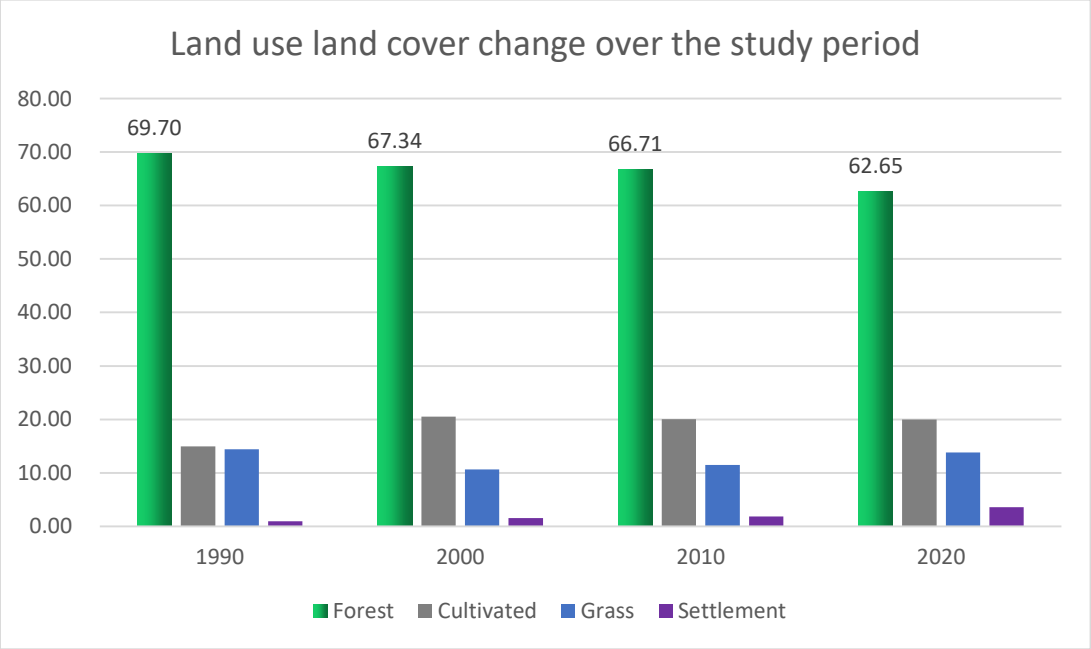


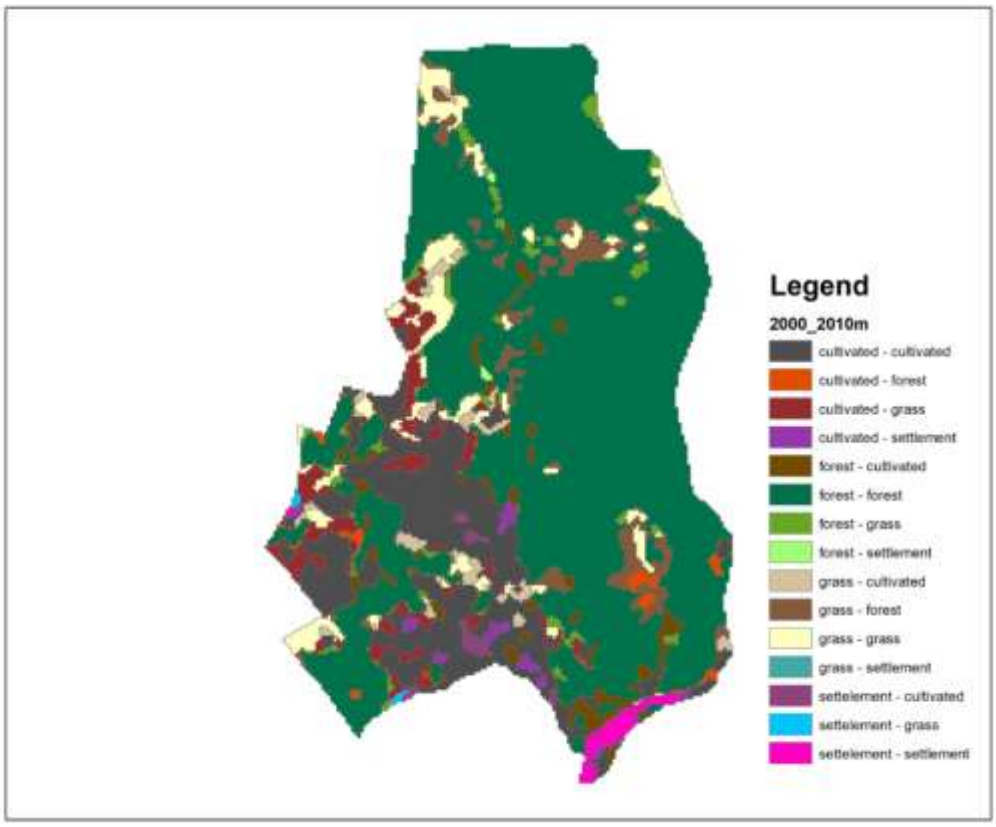
Figure 3.**Percentage** of land covers change over the study period

Forest Cover Change During 2000-2010

During the second period (2000-2010) relatively there is slower rate of deforestation as compared to the first period (1990-2000). In which the forest area was 1459 hectare in 2000 and reduced to 1444.68 hectare in 2010, which is 14 hectare were lost during the period (table 2). This implies the net about one hectare were lost each year during the period. The highlighted diagonal represented area that didn't changed during the period (table 3)

Table 4. Land use/land cover change matrix

LU/LC Classes		2010				
		Cultivated	**Forest**	**Grass**	**Settlement**	**Total**
2000	**Cultivated**	319.95	19.53	87.3	17.1	443.88
	Forest	68.4	1342.35	45.72	2.52	1459
	Grass	32.94	82.8	113.22	0.45	229.41
	Settlement	12.15	0	2.34	18.99	33.48
	Total	433.44	1444.68	248.58	39.06	**2165**



Forest Cover Change during 2010-2020

The third period (2010-2020) of the study showed the declining of forest cover from about one thousand four hundred forty-four (1444.68) hectare to one thousand three hundred fifty-six (1356.66) hectare with net deforestation of about eighty-eight (88) hectare of forest land during the period (table 2). This implied that annually about 8.8 hectare was converted in to other land uses and this is by far more deforestation has occurred during the period as compared to the previous period.

Table 5. Landuse/land cover matrix between 2010 and 2020

LU/LC Classes		2020				
		Cultivated	**Forest**	**Grass**	**Settlement**	**Total**
2010	**Cultivated**	276.66	45.99	70.38	39.96	432.99
	Forest	17.01	1242.18	181.35	4.05	1444.59
	Grass	128.34	67.05	46.17	6.93	248.49
	Settlement	10.44	1.26	0.63	26.73	39.06
	Total	432.45	1356.48	298.53	77.67	**2165**

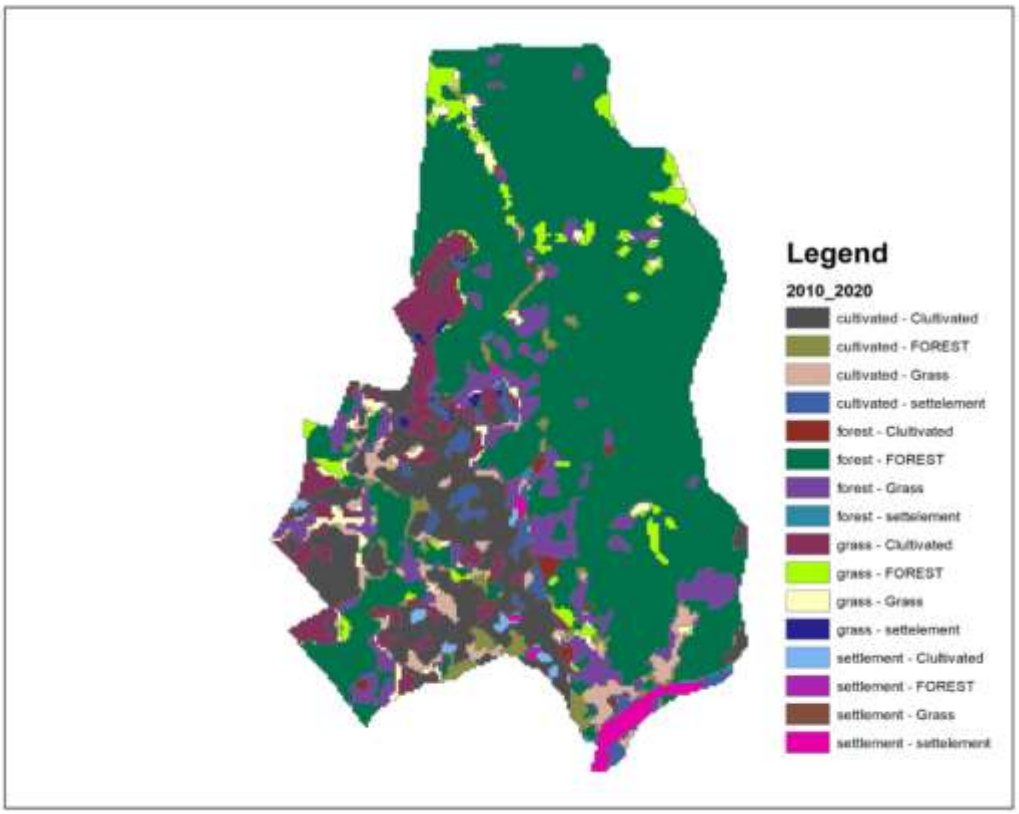


Figure 4. Land use/ land cover matrix during 2010_2020

Forest Cover Change During 1990-2020

The forest cover change during the past 30 years (1990-2020) was resulted in high deforestation rate that resulted in the loss of forest area from 1509 hectare in 1990 to 1356.39 hectare in 2020, this resulted in 153 hectare loss in thirty years (table 2). This indicated that the loss of the existing forest of five hectare per annum. This also indicated that seven percent of the forest has been changed to other land use.

The forest degradation of the area was continuously increasing during the study period and cultivated land grassland and settlement area were increasing significantly. Hence the forests were cleared and converted to cultivated land grassland and settlement area Table 6. Land use land cover change matrix

		2020				
		Cultivated	**Forest**	**Grass**	**Settlement**	**Total**
1990	**Cultivated**	235.98	27.99	25.56	34.74	324.27
	Forest	50.5	1232.28	212.76	13.5	1509
	Grass	142.83	95.4	60.03	13.41	311.67
	Settlement	3.15	0.72	0.18	16.02	20.07
	Total	432.45	1356.39	298.53	77.67	**2165**

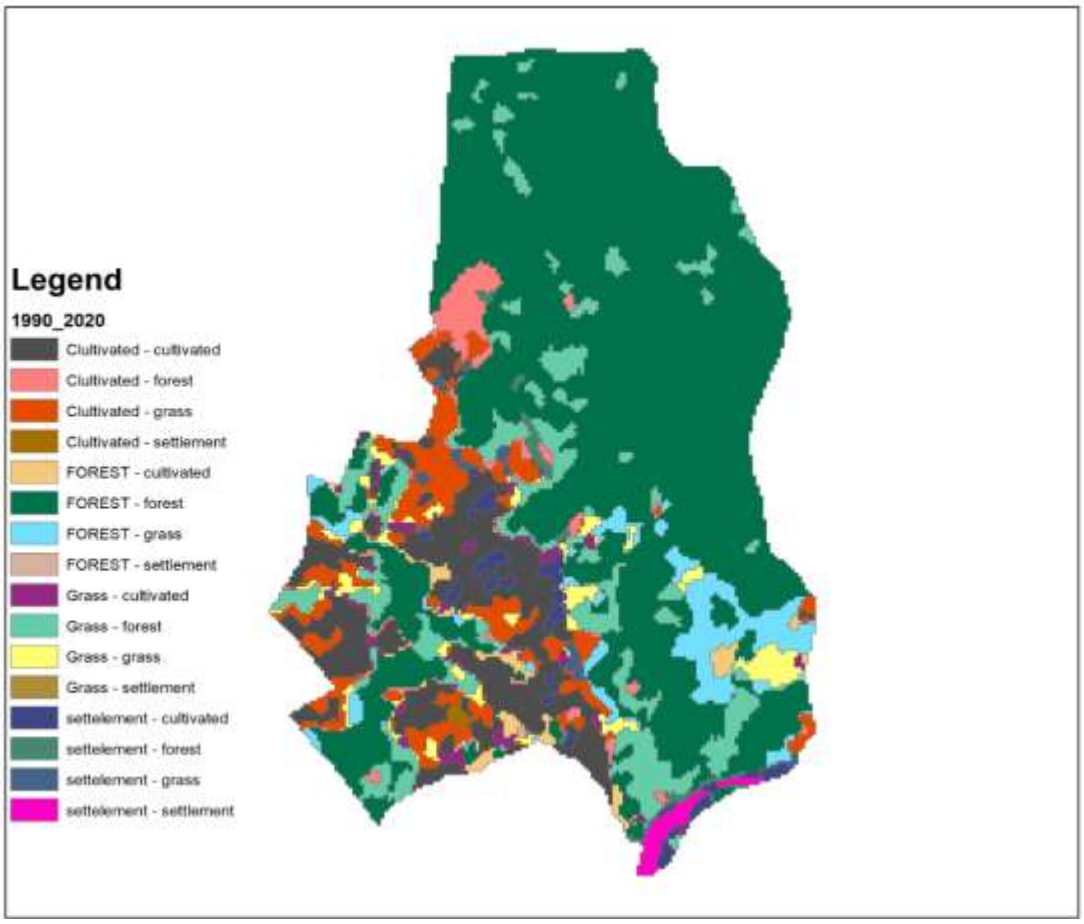


Figure 5. Land use land cover change matrix

Table 7. Forest cover change intersection

LULC Intersection	1990_2000	2000_2010	2010_2020	1990_2020
Forest - Settlement	2.16	2.52	4.05	0.72
Forest - Cultivated	34.29	68.4	17.01	27.99

Forest – Forest (unchanged)	1350.99	1342.35	1242.18	1232.28
Forest - Grass	121.68	45.72	181.35	95.4

Forest Cover Change Matrix

The post image classification result indicated that the class to which the land use land cover changed to. Before the study period (1990), out of the total study area (2165) hectare, forest coverage was about one thousand five hundred and nine (1509) hectare. However, at the end of study period (2020) the area of the forest reduced to one thousand three hundred fifty-six (1356) hectare (table 3). During the past thirty years the majority of the forest land was changed into grassland (212 ha), whereas fifty and half (50.5) hectare was changed to cultivated land, and thirteen and half (13.5) was goes to settlement. However the remaining about one thousand two hundred and thirty- two (1232.28) hectare was remained a forest which is indicated in table 3 highlighted in the diagonal arrangement.

Accuracy Assessment

Accuracy assessment is used to validate the technique by which the overall accuracy of satellite image classification as compared to the actual condition. The overall accuracy, producer and user accuracy and kappa coefficient were computed for all supervised. The result of this study shown the overall accuracy of 90.32%, 90%, 93.9%, and 94.74% for 1990, 2000, 2010 and 2020, respectively.Whereas, the Kappa Coefficient 0.85, 0.87, 0.91, and 0.91 for 1990, 2000, 2010 and 2020, respectively (table 8).

Table 8. accuracy assessment

Land Class	**1990**		**2000**		**2010**		**2020**	
	Prod. Acc (%)	User Acc (%)	prod.Acc (%)	User Acc (%)	prod.Acc (%)	User Acc (%)	prod.Acc (%)	User Acc (%)
Forest	83.51	100	91	100	92	100	86	100
Cultivated	93	100	85.7	86	88.9	89	100	90
Grass	100	50.65	89	89	100	100	88.9	89
Settlement	100	67.19	100	80	100	80	100	100
Kappa Coefficient	0.85		0.87		0.91		0.91	
Overall Acc	90.32		90		93.9		94.74	

DISCUSSION

Forest Cover Change

As indicated above the forest cover of the area has been dramatically reduced during 1990-2000 study period and majority of the forest land was converted into grass land. This might be related to the expansion of town around the vicinity of the forest and they cleared the forest and used the

wood for construction and source of energy, hence the grass land was increase as a result. Similarly (Deribew & Dalacho, 2019) found that, rapid urbanization and expansion of settlements (6.2% net increase) may have further triggered LULC transitions, mostly gaining areas from forest land and agricultural. Moreover forest cover conversion rate indicated the highest acceleration during 2010-2020 than the past two decades, this might be attributed to the highly increasing of forest demand which might be related to alarmingly increasing human population. In the same manner (Deribew & Dalacho, 2019) found a 10% decrease in dense forest and open forest and an increase in cultivated and grassland between 2000 and 2016. Negassa et al. (2020) conducted on a nearby forest of komto and found that the total loss of open forest between1991-2002 was about 0.65 ha/year. The open forest declining trends was continued between the years 2002 to 2019 by 0.73 ha/year.

The second period of study was from 2000 to 2010 in which there was a slight forest cover change where forest cover change during the period was reduced by 13.32 hectare and 0.64% during the decade. The forest cover change during this period was the least all the study phases, this might be attributed to the active intervention of government (Oromia Forest and Wildlife Enterprise) on forest control. Because most forest boundary was delineated during this period (personal communication with site manager). Like to 1990-2000, the forest cover conversion in 2000 to 2010 study period was majorly converted to grassland, which might attributed to the increasing demands for wood and other forest products.

Whereas during 2010 to 2020, the forest conversion rate was the highest, in which about 88 hectare or around 4 % forest area were converted into other land use type. The alarmingly increasing rate of forest cover conversion was associated with the increasing demand for wood and other non-wood forest products. Babiso Badesso et al. (2020) reported that the forest cover change between 2000 and 2018 was dropped by 2% and its area coverage was reduced from 2451.65 to1714.69 hectare, which is primarily connected to intensive logging, expansion of agriculture and illegal forest settlement.

In generally over the study period (1990-2020) substantial amount of forest area was converted in to other land uses such as grassland, cultivated and settlement. This indicated that there is a high dynamics of land cover change which means the area that has been cleared and changed to grassland might back to the forest in other study period. Moreover, the result of the study indicated that the forest area coverage was reduced by 152.64 hectare and 7.05 % were changed into other land uses over the study period. In addition, this study revealed from the existing land use land cover of the area grass land was the most benefited from forest degradation because most of the degraded area of the forest were converted to grass land which account about ninety-five (95) hectare (table 7).

Moreover, the land classification accuracy assessment results indicated high result for overall accuracy and kappa statistics. Congalton and Green (2009) indicated that Kappa statistics more than 0.8 is strong agreement of ground truth with the classified. Since our Kappa in all study years

are more than 0.85, the error matrix report depicts classified maps met the accuracy requirements for forest cover change analysis.

CONCLUSION

The Ethiopian highlands have particularly experienced intense levels of land use/land cover conversions mainly due to human population pressures and consequent expansion of croplands, urbanization and household energy demands. Studies revealed that many protected forest priority area are one of the remnant forest in Ethiopia threatened by forest over utilization in the form of charcoal extraction and timber production. The Duli kebele forest is part of Gergeda protected forest priority area with highly diversified and high forest consisting of a total of 134 tree species out of which 11 are endemic species. The forest is one of the remnant forest of the country with area coverage of about 70% by forest. The forest also consisting of extremely productive116 genera, and 61 families were identified. The study revealed that forest coverage has been declining from time to time, hence, during the start of study period (1990) the forest area was about 1509 hectare. Whereas at end of study period (2020) the forest area was reduced to about 1356 hectare, which indicated that 153 hectare of very important forest area has been changed to other land use/land cover.

The percentage of forest area also showed significant reduction during the study period in which the percentage reduced from 69.70 % in 1990 to 62.65 % in 2020 with the change of 7.05 % during the study period (1990-2020). The degraded forest area has been changed to grassland cultivated land and settlement. However the majority of the forest cover change has been goes to grass land and the increasing of grassland is favored by compromising forest cover. Based on the result of the current study, the future likelihood of the forest resource of the area will be a great devastation and with the current trend the forest area will be changed to grassland and intern converted to cultivated land. Moreover, the result of Kappa statistics is more than the limit set by researchers and this indicates that the classification represents the true ground truth. The results of this study give a good explanation for addressing forest cover dynamics in the study area. Finally, the study recommends the intervention by government and local community to reverse the current forest degradation. Hence, the local governing organ and the community should work on:

- Developing and enforcing local forest conservation and utilization rule and regulations
- Developing and implementing Participatory Forest Management (PFM) approaches at local level
- Introduction and promotion of non-timber forest production (NTFP) practices

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