Spatio-Temporal Analysis of Forest Cover Change by Using GIS and Remote Sensing Techniques; a Case of Geba Watershed, Western Ethiopia

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Abstract
Forest cover change was the serious environmental problem in the world. The forest cover around Geba watershed was declined substantial. The declining of this forest cover in the study area does not get research attention. This study analyze the Spatio-temporal forest cover change of the study area over the period 1990 to 2020 using Landsat image TM of 1990, ETM+ of 2003 and OLI/TIRS of 2020. The land use/land cover change (LULCC) detection results reveals that agricultural land is highly increase from 1786.6km^2 (37.2%) in 1990 to 3163.2km^2 (65.8%) 2020. Whereas; dense forest was dramatically decreased 2129.2km^2(44.3%) in 1990 to 1127.8km^2 (23.5%) in 2020. Agricultural land was increased by the rate of 45.9km2/year while dense forest was decreased by the rate of 33.4km2/year. Our finding reveals that dense forest and open forest are decreased over the study period whereas; agricultural land and settlement are increased from 1990 to 2020. The declining trend of forest cover change is associated with agricultural expansion in the periphery of the forest. Timber and charcoal production, and firewood harvesting for energy consumptions are the major driving factors for declining of forest in the study area. Generally, our results recommend the importance of participatory forest management and community awareness creation to sustain Geba watershed.
Keywords: Spatio-temporal, forest cover change; Land use/Land cover change, Land use/Land cover
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1. Introduction

Forest degradation was one of the alarming environmental problem in the worldwide (Mitchell *et al*., 2017; Mengist and Soromessa, 2019; Ranagalage *et al.,* 2020). The pressure on forest resource is increasing from agriculture sector to feed the rapid population growth (Mitchell *et al.,* 2017; Deribew and Dalacho, 2019; Negassa *et al.,* 2020). The main cause for deforestation in the developing countries is expansion of cultivated land to forest land, timber and charcoal production and wood harvesting (Declee *et al.,* 2014; Muhati *et al.,* 2018). Similar to other developing countries, the expansion of agricultural land, overgrazing and settlements on forest resources are the main driving forces for the declining of forest coverage in Ethiopia (Kindu *et al*., 2013; Tesfahunegn, 2016; Kindu *et al.,* 2016; Abrha *et al.,* 2017). To amendable of climate change through absorbing carbon dioxide and alleviates worldwide climate change forest has high significant role (Negassa *et al.,* 2020). However, about 141,000ha (1.1%) forest was declined per year from 1995 to 2010 in Ethiopia (FAO, 2010).

To monitor LULCC with development and to determine its nature, extent and rate of LULCC with forest cover over space and time through to mapping of LULCC (Forkuo and Frimpong, 2012; Deribew and Dalacho, 2019; Negassa *et al.,* 2020). To get important information for effective forest management was from exact and appropriate forest cover change detection (Shimizu *et al.,* 2019). Several scholars has been conducted on the studies of forest damages and deforestation in Ethiopia (Daye and Healey, 2015; Tolessa *et al.,* 2017; Feyissa and Gebremariam, 2018; Minta *et al.,* 2018; Belay and Mengistu, 2019; Geeraert *et al.,* 2019; Deribew and Dalacho, 2019; Negassa *et al.,* 2020). Geba watershed was high suitable for production of different crops and the farmer expands agricultural land on marginal land such as steep lands and areas covered by vegetation (Mekuriaw, 2019). The researches were limited to provide information on Spatio-temporal forest cover change in the study area. Therefore, the present study attempt to analyze Spatio temporal forest covers changes using GIS and remote sensing.

2. Methods and Materials

2.1. Description of the study area

Geba watershed was located in upper Baro river basin, geographically, bounded between 7^{0}53’30” to 8^0 44’ 30”N and 35^{0}24’0” to 36^{0}18’0” E. Administratively, Geba watershed is existed in Ilu Aba Bor Zone of Oromia National Regional State, Western Ethiopia. The elevation of the study area ranges between 2582.5m to 798.9m above the sea level (**Figure 1**). Geba watershed covers an area of 4805.3Km^2.

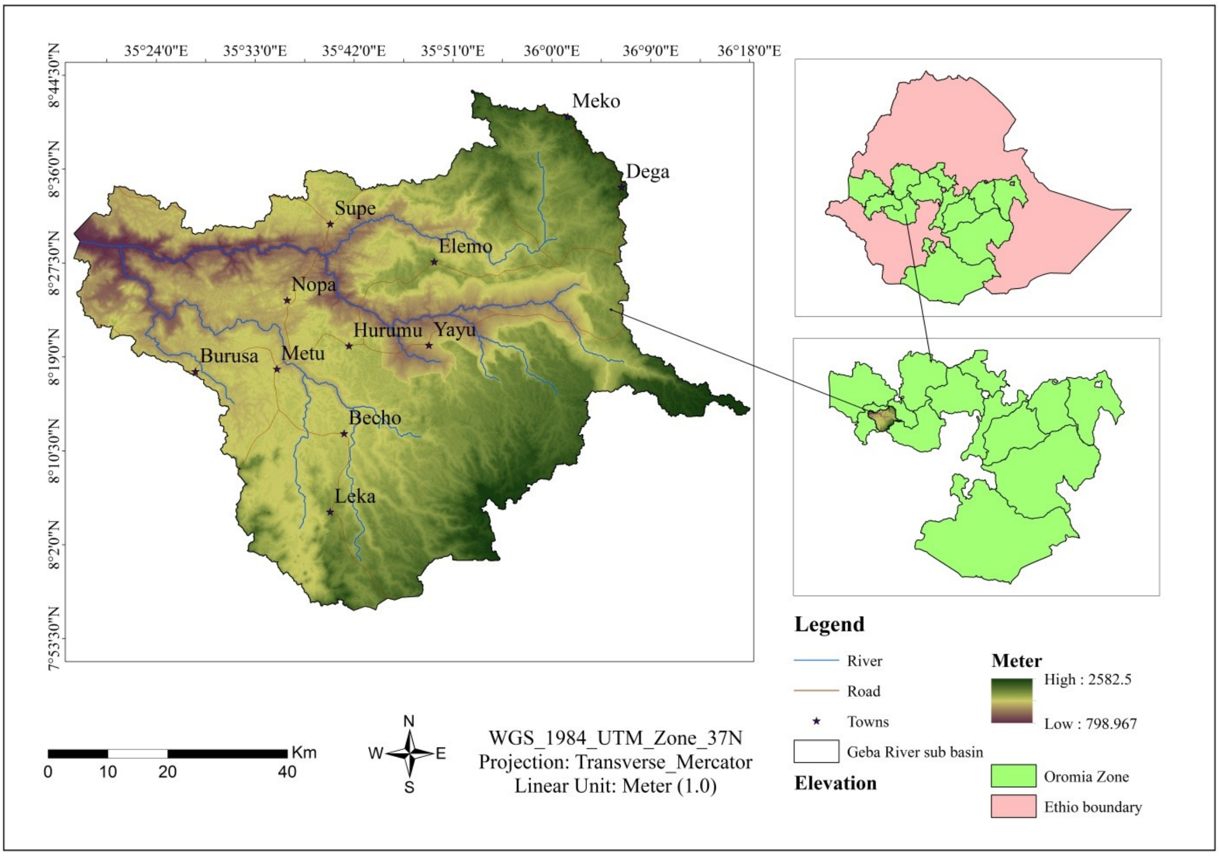

Figure 1: Location map of the study area

2.2. Data Sources

2.2.1. Remote sensing data acquisition and processing

For this research, to analysis spatio temporal forest cover change of Geba watershed, landsat image of 1990, 2003 and 2020 was used. For image processing ERDAS Imagine 2015 software was used. According to (Churches *et al.,* 2014; Wu *et al.,* 2017) stated that, Land use/land cover types of three years (1990, 2003 and 2020) of the study area was classified by using supervised classification method with maximum likelihood algorithm to achieved for spatio temporal forest cover changes of Geba watershed. Landsat TM of 1990, Landsat ETM+ of 2003 and Landsat OLI/TIRS of 2020 were used for land use/land cover classification (**Table 1**; **Figure 2**).

Table 1: Remote sensing data used in the study

Date of Acquisition	Sensor	Path/Row	Multispectral band	Spatial Resolution	Source
1/20/1990	TM	170/054	1 to 5and 7	30*30	USGS
1/15/2003	ETM+	170/054	1 to 5 and 7	30*30	
1/20/2020	OLI/TIRS	170/054	1 to 5 and 9	30*30	

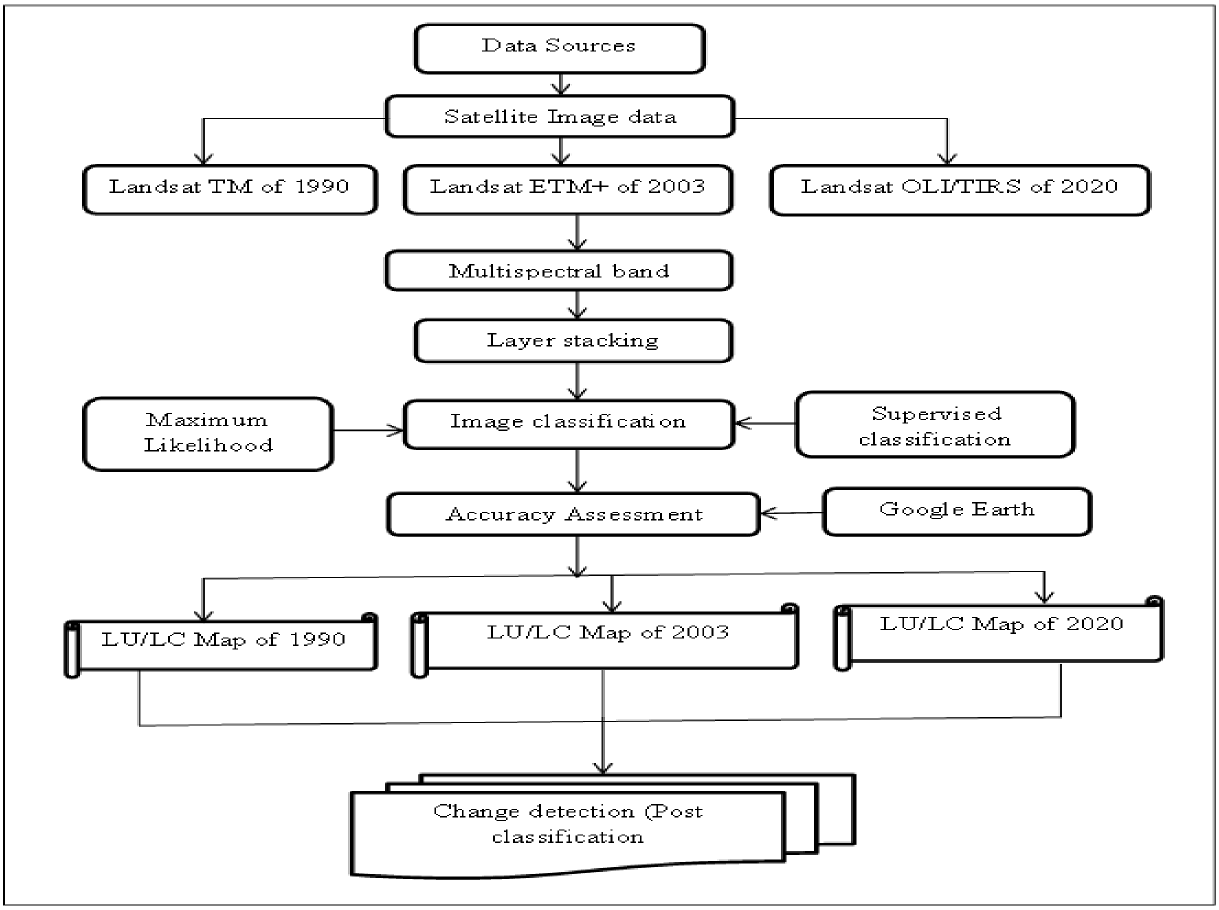

Figure 2: Flow diagram of the study

2.3. Land use/Land cover analysis

Land use/Land cover (LULC) types were classified according to Deribew and Dalacho (2019) and Negassa *et al.* (2020); these images were classified into five LULC classes; dense forest, open forest, agricultural land, settlement and water body (**Table 2**).

Table 2: Descriptions of LU/LC classes used in the study area

LU/LC classes	Description
Agricultural land	Areas used for cultivation, both annuals and perennials and areas used for grazing including partially wet lands
Open forest	Areas covered Collected predominantly of redevelopment forest from the previous disruption
Settlement	Areas allotted for permanent residential, commercial areas, institution and infrastructures
Dense forest	The area which are covered by dense forest
Water body	Areas covered with mainly reservoirs and rivers

2.4. Classification accuracy assessment

According to Congalton (1991), by dividing all pixels correctly classified by the total number of pixels in the matrix the overall accuracy index is produced (Eq 1). The amount of agreement between two maps stacking into account all elements of error matrix is measured by kappa coefficient (Khat) (Mishra et al., 2019) (Eq 2).

Overall accuracy= $\frac{Sum\ of\ the\ diagonal\ elements}{Total\ number\ of\ accuracy\ sites\ (pixels)}*100$ (Eq 1)

$Khat = \frac{Obs-exp}{1-exp}$ (Eq 2)

2.5.. Spatio-Temporal Forest Cover Change

To determine the magnitudes of change in terms of forest cover change, the amount of changed area and extent of change should be analyzed (Yared and Sisay, 2019). Moreover, to demonstrate the magnitude of the changes between a given periods the percent of change and rate of change were computed (Abraham *et al.,* 2016; Eyasu *et al.,* 2019; Abebe *et al.,* 2019; Negassa *et al.,* 2020) (Eq 3).

$$Rate\ of\ change\ (\frac{km2}{year}) = \frac{A2-A1}{Z} \quad (3)$$

Where, **A2** is an area of LULC (Km^2) in time 2, **A1** is an area of LULC (Km^2) in time 1; **Z** is Time Interval between A2 and A1 in years

To perform LULCC detection post classification was employed (Yang *et al*., 2012). To indicate the overall LULCC between 1990 and 2020 the LULCC matrix was produced.

3. Result and Discussion

3.1. Analysis of forest cover changes (1990 to 2020)

Landsat images of thematic mapper of 1990, enhanced thematic mapper plus of 2003 and operational land imager of 2020 were used to analyze spatio temporal forest cover changes in the case of Geba watershed. Those landsat images of the three years were classified into five LULC classes, like agricultural lands, dense forest, open forest, settlement and water body. According to Mekuriaw (2019) confirmed at Geba watershed, LULC of the study area was changed due to land use/land cover LULC conversion, such as dense forest, open forest and water bodies converted to agricultural land and settlements. This is the main reason of rapid population growth and agricultural land was expanded on open forest and dense forest by cutting and clearing of forest to get food and shelter from there.

In most place of Ethiopia forest cover was declined due to human activity for different purpose (Abera et al., 2020). The decreasing trends of forest coverage in Ethiopia are confirmed by numerous studies (Tolessa *et al.,* 2017; Minta *et al.,* 2018; Feyissa and Gebremariam, 2018; Geeraert *et al.,* 2019; Belay and Mengistu, 2019; Deribew and Dalacho, 2019; Negassa *et al.,* 2020). The result revealed that, forest coverage was declined from LULC classes of the study period. The LULC types of the study area were changed from the result of change detection analysis. This result is in consistent with result of (Mekuriaw, 2019) in Geba watershed. Agricultural land and settlement were increased in all study period, while dense forest, open forest and water bodies were decreased from 1990 to 2020. According to Negassa *et al.* (2020) stated that in Komto forest protected area, Forest coverage of Geba watershed was declined by human activities due to agricultural expansion to forest land, production of charcoal, harvesting of fire wood, human settlement was expanded to forest and built shelter from product of forest. Other land use land cover types such as agricultural land and settlements are increased, besides dense forest and open forest was decreased in the study area **(Figure 3).**

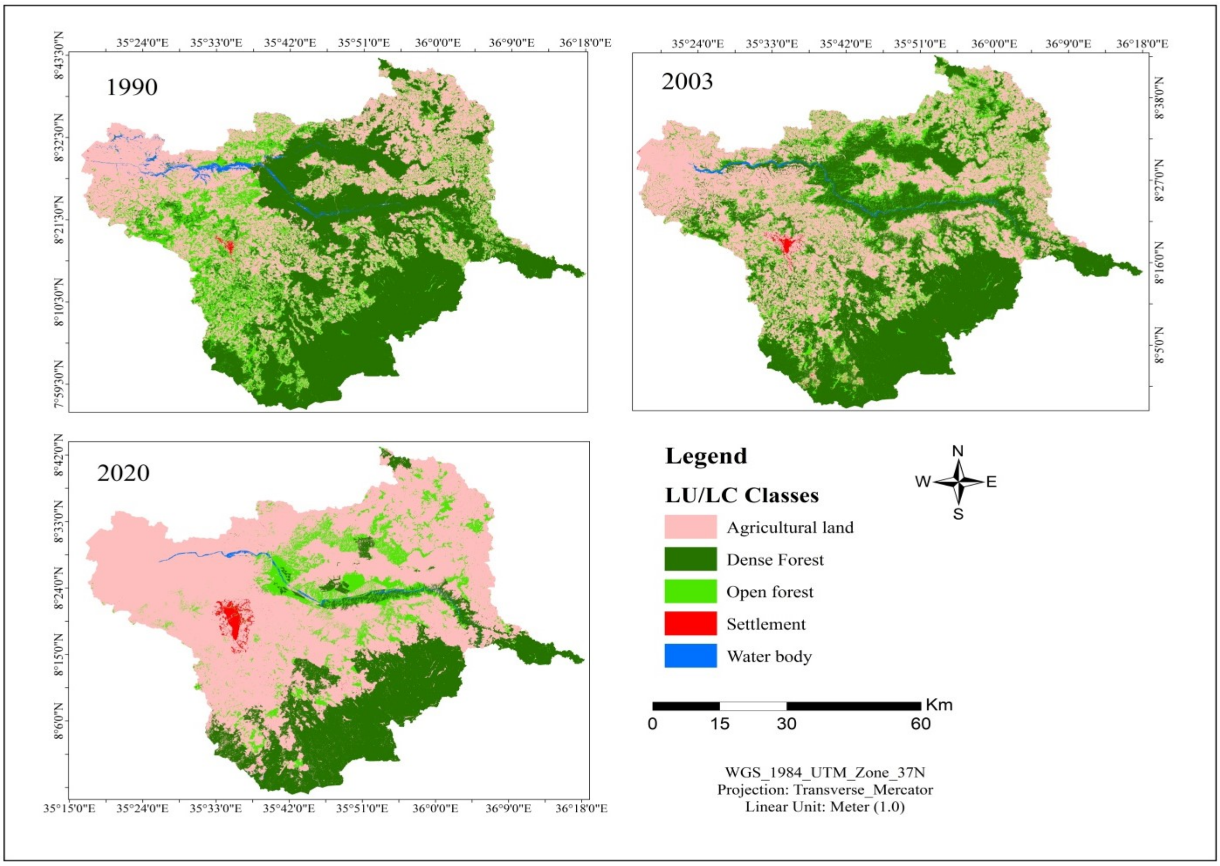

Figure 3: Land use/Land cover map of 1990, 2003 and 2020

In 1990, the highest amount of the Geba watershed was dominated by dense forest 2129.2 km^2 (44.3%), whereas agricultural land, open forest, water body and settlement represented 1786.6km^2 (37.2%), 841km^2 (17.5%), 41.8km^2 (0.9%), 6.5km^2 (0.1%), respectively. This result is in consistent with the finding of Negassa *et al.* (2020) conducted in Komto forest protected area. By the year 2003, the areas of agricultural land settlement were increased by 2006.6km2 (41.8%) and 16.1km^2 (0.3%), respectively. The result revealed that the coverage of dense forest, open forest and water body were decreased by 2011.5km^2 (41.9%), 750.5km^2 (15.6%) and 20.5km2 (0.4%) respectively. The finding is in agreement with (Deribew and Dalacho, 2019). Similarly, in 2020, the area of dense forest and open forest were decreased by 1127.8km2 (23.5%) and 457.2km^2 (9.5%), whereas the coverage of agricultural land and settlement were increased by 3163.2km^2 (65.8%) and 37.3km^2 (0.8%), respectively. From the analysis of land use/land cover (LU/LC) change, we found the agricultural land was expanded quickly at the expense of dense forest and open forest, as well as other land use/land cover over the last three decades (30 years) in the study area (**Table 3**).

Table 3: Land use/land cover areas in 1990, 2003 and 2020

	1990		2003		2020	
LU/LC Types	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Agricultural land	1786.6	37.2	2006.6	41.8	3163.2	65.8
Dense Forest	2129.2	44.3	2011.5	41.9	1127.8	23.5
Open forest	841.0	17.5	750.5	15.6	457.2	9.5
Settlement	6.5	0.1	16.1	0.3	37.3	0.8
Water body	41.8	0.9	20.5	0.4	19.7	0.4

The overall classification accuracies for the study period; 1990, 2003 and 2020 were 86.3%, 84.8% and 87.6% with the kappa statistics of 0.86, 0.82 and 0.85 respectively. The kappa statistics values greater than (>) 0.80 (80%) represents a strong agreement and a value between 0.60 (60%) and 0.80 (80%) represents a substantial agreement (Landis and Koch, 1977).

3.2. Rate of Forest cover change during 1990 to 2020

The result shows that dense forest, open forest and water body were decreased by the rate of 33.4km2/year, 12.8km2/year and 0.7km2/year from 1990 to 2020. Whereas, the agricultural land settlement were increased by the rate of 45.9km2/year and 1km2/year over the 30 years (**Figure 4**). Our study report that forest cover area declined rapidly in the Geba watershed, which in agreement with previous studies (pillikkaa *et al.,* 2018; Minta et al., 2018; Geeraert *et al.,* 2019; Negassa *et al.,* 2020).

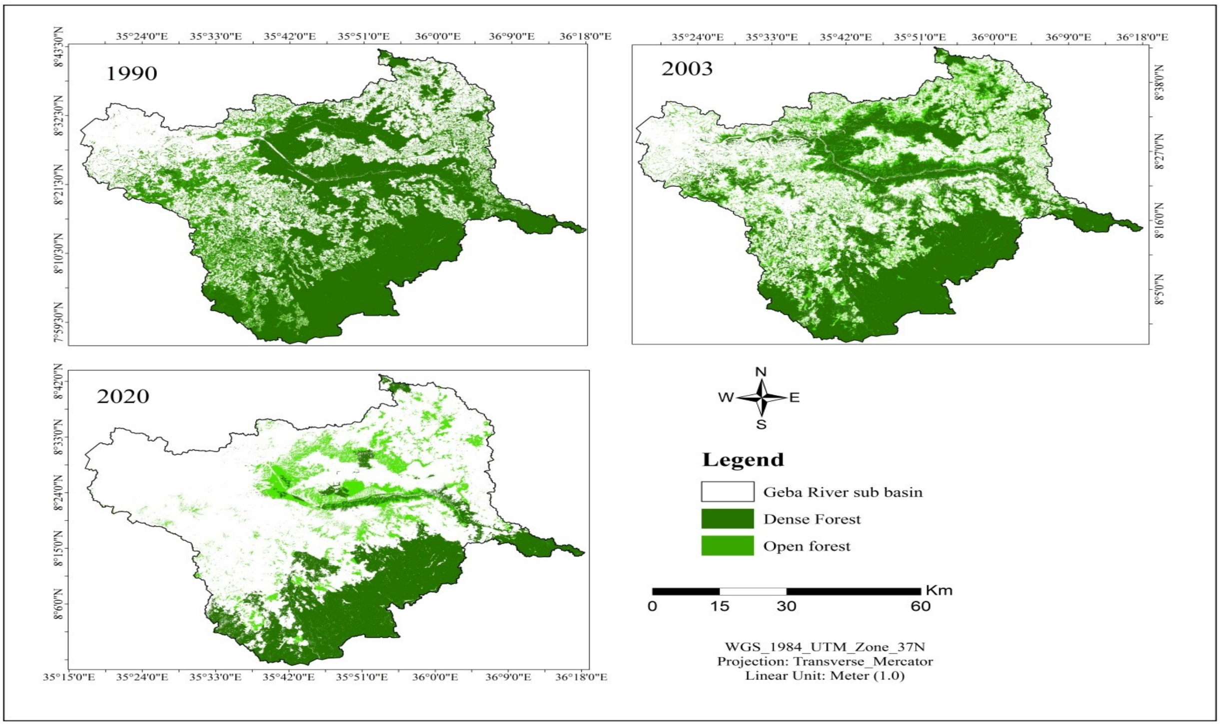

Figure 4: Forest covers map of 1990, 2003 and 2020

3.3. Trends of Forest cover change

The study shows that dense forest and open forest were decreased by 1001.4km^2 and 383.8km^2. Whereas, agricultural land and settlement were increased 1376.7km^2 and 30.8km^2 respectively (**Figure 5**). Our finding is in line with previous studies (Deribew and Dalacho, 2019; Negassa *et al.,* 2020).

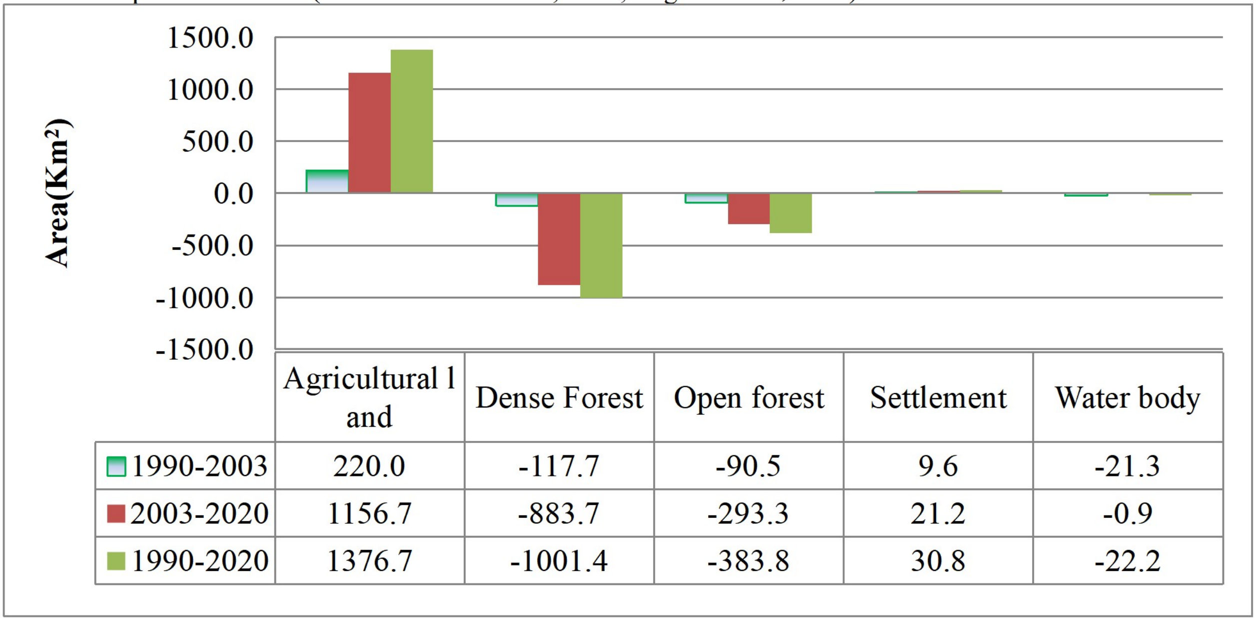

Figure 5: Trends of land use/land cover in study area

3.4. Land use/Land cover conversion of Geba watershed from 1990 to 2020

The major LULC in Geba watershed was presented in (**Figure 6**). The result shows that dense forest and open forest converted to agricultural land by 647km2 and 750.4km2 from 1990 to 2020 respectively. Whereas, 2847.2km^2 were unchanged in all LULC types from 1990 to 2020. Detail of the results was presented in (**Table 4**). This finding is consistent with previous study (Negassa *et al.,* 2020).

Table 4: Land use/land cover conversion from 1990 to 2020

	LU/LC Classes	**2020**					
		Agricultural land	Dense forest	Open forest	Settlement	Water body	Total
1990	Agricultural land	1732.1	21.3	20.6	10.5	1.7	1786.2
	Dense Forest	647.0	1072.3	393.6	7.0	9.2	2129.0
	Open forest	750.4	32.4	39.6	17.6	0.8	840.8
	Settlement	0.0	0.0	0.0	3.2	0.0	3.3
	Water body	33.1	1.6	3.3	0.0	8.0	46.0
	Total	3162.6	1127.6	457.2	38.3	19.7	**4805.3**

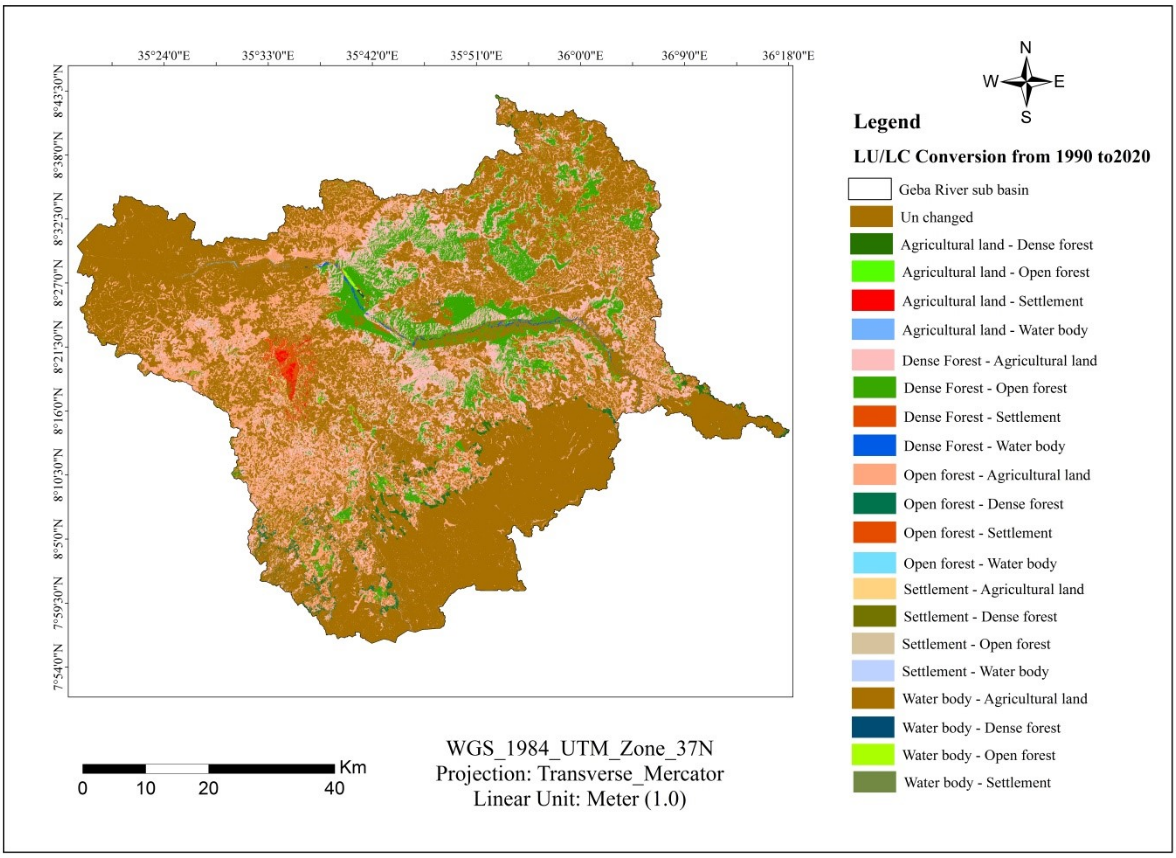

Figure 6: Major Land use/Land cover conversion from 1990 to 2020

4. Conclusions

In the present study, spatio-temporal forest cover change of Geba watershed is analyzed by using Geospatial technologies. Three years of landsat images were used to classify LULC types of the study area. The results of the study shows that forest cover area is the important extents that occurred over the past three decades (30 years). Dense forest and open forest were declined by 1001.4km^2 and 383.8km^2. In contrast, agricultural land and settlement were increased 1376.7km^2 and 30.8km^2 respectively from 1990 to 2020. Results shows that the main driving forces of forest cover change was agricultural expansion, timber production, charcoal production, firewood harvesting and built up area expansion over the forest cover change. Finally, this study recommends policy intervention to protect Geba watershed from deforestation and degradation.

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