Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2016, Volume 5, Issue 4, pp. 1688-1701
ISSN 2320 - 0243, Crossref: 10.23953/cloud.ijarsg.53

Research Article **Open Access**

Multi-temporal Analysis of Vegetation Dynamics Over Three Decades for Sustainable Management of Woody Vegetation: The Case of Abaya-Gelana Area, Borena Zone, Southern Ethiopia

Birhane Gebrehiwot

Department of Land Administration, Dilla University, Gedeo, Ethiopia

Publication Date: 21 April 2016

DOI: https://doi.org/10.23953/cloud.ijarsg.53

Abstract Up-to-date and reliable land use/land cover (LULC) information forms an essential component of local and regional planning. So, the aim of the present study is to analyze and quantitatively evaluate LULC changes in Abaya-Gelana area between 1986 and 2015 using remotely sensed data and techniques. To realize the aforementioned objective, cloud free orthorectified multispectral land sat 5 thematic mapper (TM) acquired in 1986 and land sat 8 operational land imager (OLI) acquired in 2015 were used for LULC change detection. In addition to the land sat images, collateral information was obtained from topographic maps, field data, and Google earth images. After digital image processing and visual interpretation of the land sat images, supervised classification with maximum likelihood algorithm was applied and LULC maps for 1986 and 2015 were produced. Finally, post-classification comparison was made to analyze LULC changes over the past three decades. The results of the change detection analysis show that there is obvious deforestation problem in the study area which is manifested by the reduction of bushland by 46.89% and an increase in bareland by 253.34% within 29 years. Besides, a reduction in grass land, a remarkable increase in cultivated land, urban expansion, an increase in water surface are among the major LULC changes over the past three decades.
Keywords *LULC Change; Land Sat Images; Maximum Likelihood Algorithm; Post-Classification Comparison; Supervised Classification*

1. Introduction

1.1. Background of the Study

Forests are increasingly recognized for the wide range of products and essential ecosystem services they provide at all spatial scales. According to Ellen (2010), forested catchments which account for three quarters of the earth's accessible freshwater resources reduce its quality as forest conditions worsen. Forest area is declining across the globe due to logging activities and conversion of habitats to croplands. Agricultural expansion accounts for up to 43% of tropical forest losses (Ellen, 2010). Specifically, a study conducted by FAO on global forest land-use change from 1990–2005 indicate that next to South America, Africa had the second highest net forest loss which is 1.6 million hectares annually during the study period (Lindquist et al., 2012). As a result, conversions of land use/land cover (hereafter LULC) from one to another have become recognized as a major cause of global environmental changes.

Similarly, deforestation and the resulting environmental degradation is a major problem in Ethiopia and after several years of deforestation, the remaining forest is estimated to be about 12 percent of the country's surface area (Zenebe, 2007). Likewise, Ellen (2010) points out that within a quarter of a century (1955-1979), over 77% of the country's forested area was disappeared and continued at the rate of 8% (about 140,000 hectares) annually. In addition, conversion of rangelands into cultivated land is one of the main challenges affecting the management of rangelands in Ethiopia (Elias et al., 2015) which has led to a severe land degradation in the Ethiopian highlands (Binyam, 2015). On the other hand, scientific information regarding growth rates, natural regeneration, or other related forest dynamics is lacking in the country (Desta, 2001).

Other studies also indicate that majority of the Ethiopian population is dependent on fuel wood for its energy consumption. JICA (2012) states that while the electricity coverage in Ethiopia reached 41%, the main source of energy for 85% of the Ethiopian population is still fuel wood. Among other things, the dependence of urban centers for their fuel on the rural hinterlands has also aggravated deforestation problems (Barnes et al., 2004).

As far as the study area is concerned, there is a continuous supply of fire wood and charcoal to the surrounding towns especially to the Dilla town which is located at the eastern part of the study area. In addition, there is conversion of rangeland into agriculture because many people who were pastoralists in the past are becoming agro-pastoralists and small scale farmers. Besides, investors have also taken large area of rangeland for crop production. However, although deforestation is evident in the study area, little prior knowledge exists with regard to the rate and the spatial pattern of deforestation over time (BoFED of National Regional Government of Oromia, 2015). On the other hand, at global level, the last few decades have witnessed considerable developments in the use of remotely sensed data as a means to follow-up and scrutinize the changes imposed on the environment (Ayache et al., 2015). Since up-to-date and reliable LULC information forms an essential component of local and regional planning (Campbell and Randolph, 2011), the aim of the present study is to analyze and quantitatively evaluate the LULC changes in Abaya-Gelana area over the past three decades using remotely sensed data and techniques.

2. Materials and Methods

2.1. Description of the Study Area

In the Federal Democratic Republic of Ethiopia, the administrative structure divides the regional states into divisions called *Woredas*. A *Woreda* is an administrative division equivalent to a district. It is composed of a number of subdivisions, which are the smallest administrative units called *Kebeles*. So in this study, a *Kebele* refers to a peasant association (PA) within a *Woreda*/district.

The current study was conducted in two *woredas* namely Abaya and Gelana which are located in the Oromiya Regional State, Borena zone. It was a single *Woreda* (district) in the past but they have been administratively split into two and each of them formed an independent *woreda* currently. The geographic coverage of the study area extends from $5^0$44'10" to $6^0$40'10"N and from $37^0$44'10" to $38^0$19'40"E (Figure 1). It is bordered by Hagere Mariam *Woreda* in the south, and in the west, north and east by the Southern Nations Nationalities and Peoples Region (SNNPR). Specifically, it is bordered by lake Abaya in the west. According to the central statistical agency of Ethiopia (1994), the total surface area of Abaya-Gelana is 3240 square kilometers and estimated numbers of human population in 2009 for Abaya and Gelana *woredas* were 110,086 and 81210 respectively (BoFED of National Regional Government of Oromia, 2015). The capital center of Abaya *woreda* is Guangua town which is found at 365 kilo meters south of Addis Ababa along the Addis Ababa-Moyale international road and the capital of Gelana *woreda* is Tore town which is located to the south west of Guangua town.

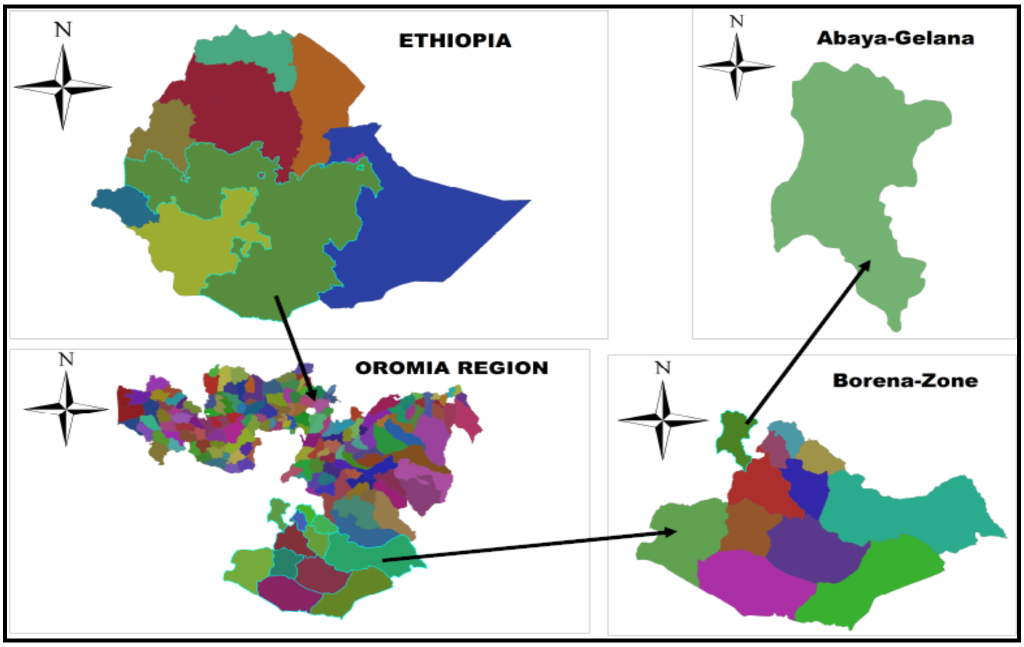

Figure 1: *Location Map of the Study Area*

The elevation of Abaya *woreda* ranges from 1100 to 2060 meters above sea level and it has two types of agro-climatic zones, 'Weyna Dega' or midland (about 40%) and 'Kola' or lowland (about 60%). Its average annual rainfall ranges from 900 mm to 1200 mm and its temperature ranges from 16^{o}C to 28^{o}C. Likewise Gelana *woreda* has elevation ranges of 1280 to 1860m above sea level. Generally, the study area has bi-modal rainy seasons from the mid of March to the end of May and from the mid of September to the end of November (BoFED of National Regional Government of Oromia, 2015).

The study area is covered by different types of vegetation, predominantly shrubs, bushes, and grass including natural and plantation forests which are protected by the government. The major land uses are shrub land, forest, water, swamp, cultivated and barelands. Crops such as maize, barley, teff, sorghum, haricot bean, wheat, enset (ensete ventricosum) and chickpea are grown in the study area. However, in both *woredas*/districts, there are problems regarding up to date, reliable and adequate information on the existing condition, current level of exploitation, and degradation of natural resources (BoFED of National Regional Government of Oromia, 2015).

2.2. Methods of Data Collection

In this study, different types of data collection methods were employed. These are remote sensing, GIS, and field data collection methods.

2.2.1. Remote Sensing and GIS Data Collection

Cloud free orthorectified multispectral land sat 5 TM image which was acquired on January 18/1986 and Land sat 8 OLI image acquired on January 05/2015 were downloaded from the USGS website. These images were selected for the study as the land sat program has the longest continuous timeseries of similar remotely sensed data which is a critical component in the analysis of changes in LULC since the 1970s (Williams et al., 2006). The time of acquisition of the images was in a similar time of the year to minimize the effects of seasonality so as to keep the data quality. In addition, topographic maps with the scale of 1:50,000 and 1:250,000 which were produced in 1979 were obtained from the Ethiopian Mapping Agency (EMA) and they were found to be useful in reconstructing the past image of the study area.

Table 1: *Remotely Sensed Data Used for the Study*

Type of Sensor	Path/row	Spatial Resolution	Date of Acquisition	Source of Data
Landsat 5 Thematic mapper (TM)	168/056	30m X 30m	January 18/1986	USGS archive
Landsat 8 operational land imager (OLI)	168/056	30m X 30m	January 05/2015	USGS archive

2.2.2. Collection of Ground Truths / Land Cover Samples

To improve the satellite image interpretation and accuracy of LULC classification, a detailed field observation was conducted in order to take representative ground truths for each land cover class and the location of each ground truth data was recorded with Global Positioning System (GPS). Finally, during the training stage, these ground truth data were overlaid as training areas or land cover samples so as to train the software.

2.3. Methods of Data Analysis

2.3.1. Digital Image Processing and Visual Image Interpretation

Image enhancement and transformation techniques were applied in order to make the image ready for visual interpretation. Specifically, normalized difference vegetation index (NDVI), principal components analysis (PCA) and spectral ratio were applied using EARDAS Imagine 2013 and ENVI 4.5 softwares so as to accurately interpret the image. Finally, visual image interpretation was applied by overlying the ground truth data on the current image to improve the accuracy of image interpretation, classification, and change detection results. Similarly, the previous (1986 image) was interpreted by comparing its spectral reflectance with the one acquired in 2015. Moreover, the topographic map with 1:50,000 scale was found useful in interpreting the 1986 image because the map was produced in 1979 which is very close to the image acquisition time. In addition to EARDAS Imagine 2013 and ENVI4.5 softwares, ArcGIS 10.1 was used in order to integrate the various spatial data with GIS.

2.3.2. Training Stage and Digital Image Classification

After digital processing and visual interpretation of both the 1986 and 2015 land sat images, training areas were overlaid as region of interests using the ground truth data as reference. Accordingly, supervised classification was adopted to match the spectral classes to their corresponding information classes using EARDAS imagine 2013 software. Supervised classification was selected because it does not suffer from the problem of matching spectral classes to their corresponding information classes on the final map (Campbell and Randolph, 2011). As the quality of the training process determines the success of the classification stage and the value of the information generated from the entire classification effort, representative and complete samples were taken carefully for all information classes (Lillesand et al., 2004).

In order to distinguish between similar land cover classes and to achieve better accuracy of classification, masking technique was applied for the agroforestry and urban classes, because the spectral reflectance of agroforestry was similar with the forest class and the spectral reflectance of urban was similar with bare land reflectance. Finally, the images were classified using Gaussian maximum likelihood classification algorithm.

2.3.3. Accuracy Assessment

"A classification is not complete until its accuracy is assessed (Lillesand et al., 2004)." For that reason, the accuracy of the classification was assessed using error matrix (confusion matrix) which is one of the most common means of expressing classification accuracy. As a result, by comparing with 137 ground truth data, an overall accuracy of 93.88% and 94.44% was achieved for the 1986 and 2015 images respectively.

2.3.4. Change Detection

Ideally, change detection procedures require data acquired by the same (or similar) sensor and be recorded using the same spatial resolution, viewing geometry, spectral bands, radiometric resolution, and time of the day. However, in reality, it might be difficult to find images which fulfill all these requirements. Due to these difficulties, one way of discriminating changes between two dates of imaging is to employ post-classification comparison (Lillesand et al., 2004). Thus, in order to compensate for variations of sensor characteristics, post-classification change detection approach was applied (Figure 2).

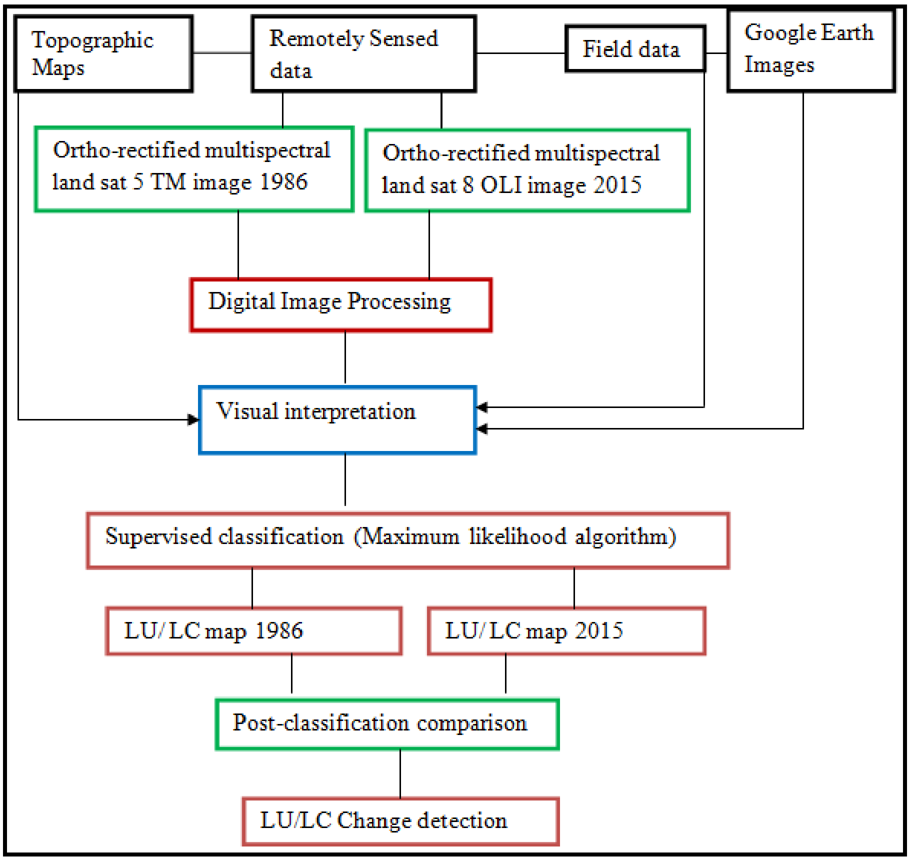

Figure 2: *Flow Chart of Digital Image Analysis and LULC Change Detection*

3. Results and Discussion

3.1. Land use/Land Cover Classes of the Study Area in 1986 and 2015

The total surface of the study area is 257,442.20 hectares. However, in order to keep the quality of the information, cloud free area of 238,385.11 hectares (92.6%) was considered in the current study. The LULC classes were defined based on the Global Forest Resources Assessment (2010) and by considering the biophysical characteristics of the study area (Table 2). Accordingly, the 1986 image was classified into seven (Figure 3) while the one acquired in 2015 was divided into eight LULC classes (Figure 4).

Table 2: *Description of the LULC Classes of the Study Area*

No	LU/LC Class	Description
1	Agroforestry	Refers to the complex land use pattern with natural and plantation trees at the top, enset in the middle, coffee in the lower layer and other herbaceous plants on the ground layer. In some parts of the study area, it is mixed with small parcels of cereals, pulses, vegetables, root crops, and scattered rural settlements where it is impossible to map each layer separately.
2	Annual crops	Refers to rainfed and irrigated crops mainly maize, wheat, barely, teff, and haricot bean out of the agroforestry area.
3	Bareland	Degraded or devegetated land including rock outcrops
4	Bushland	Land composed of bush or shrubs mainly acacia species which are lower than 5 meters in height.
5	Forest	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent. It also includes areas with young trees that have not yet reached but which are expected to reach a canopy cover of more than 10 percent and tree height higher than 5 meters.
6	Grassland	Land cover dominated by grass and herbs with scattered trees and shrubs mainly used for grazing purpose.
7	Urban	Refers to towns including residential areas, infrastructures such as roads, various institutions, factories, and cemetry.
8	Water	Refers to water bodies mainly lakes and rivers.

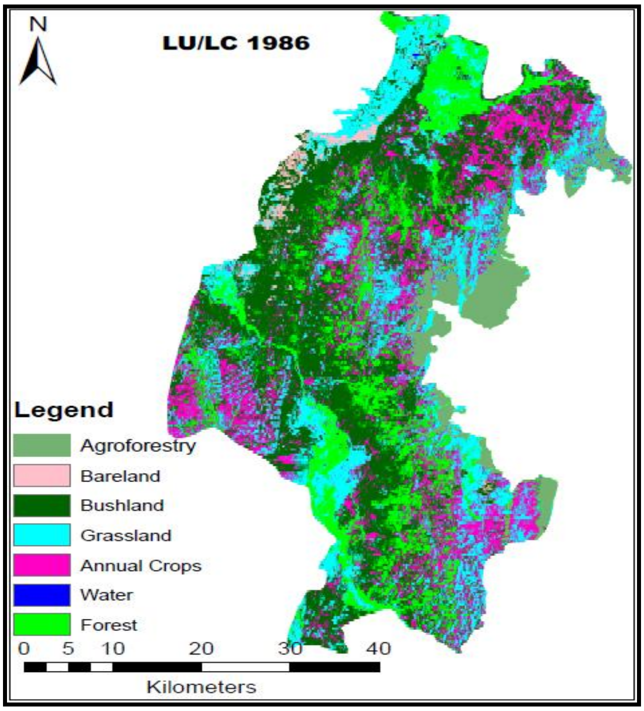

Figure 3: *LULC Classes of the Study Area in 1986*

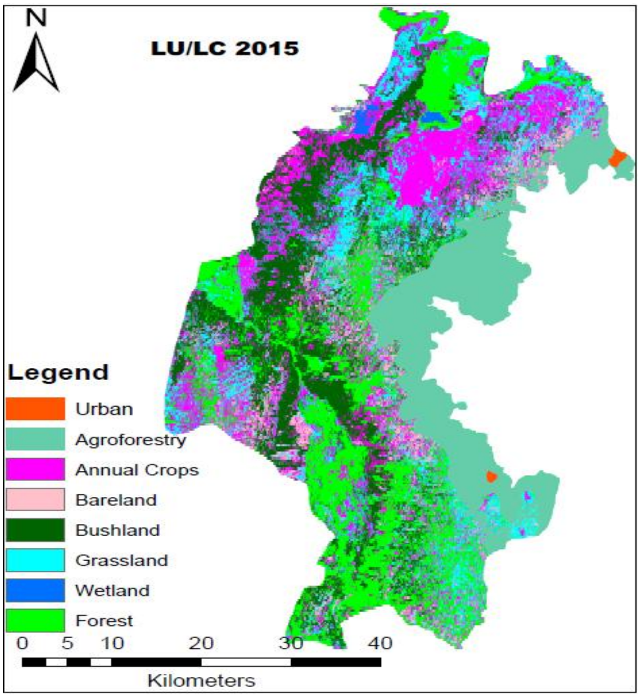

Figure 4: *LULC Classes of the Study Area in 2015*

Table 3: *Surface Area of LULC Classes in 1986*

No	LU/LC Class	Area (inha)	Percent
1	Agroforestry	12780.22	5.36%
2	Annual crops	40467.54	16.96%
3	Bareland	5284.98	2.22%
4	Bushland	88891.12	37.29%
5	Forest	38273	16.06%
6	Grassland	52527.51	22.04%
7	Water	160.74	0.067%
	Total	**238385.11**	**100%**

Table 4: *Surface Area of LULC classes in 2015*

No	LU/LC Class	Area (inha)	Percent
1	Agroforestry	38579.87	16.18%
2	Annual crops	51108.8	21.44%
3	Bareland	18674.19	7.83%
4	Bushland	47209.59	19.80%
5	Forest	38961.76	16.34%
6	Grassland	42359.31	17.77%
7	Urban	381.89	0.16%
8	Water	1109.7	0.47%
	Total	**238385.11**	100%

3.2. Change Detection Results

The result of the post classification comparison by subtracting the surface area of each LULC class in the 1986 from that of the 2015 is shown below (Table 5).

Table 5: *LU/LC Changes between 1986 and 2015*

No	LU/LC Classes	Area (ha) 1986	Area (ha) 2015	LU/LC change (2015-1986)		Rate of change	
				Area (ha)	Percent	Area (ha/yr)	Percent
1	Agroforestry	12780.22	38579.87	25799.65	201.87%	889.64	6.96%
2	Annual crops	40467.54	51108.8	10641.26	26.30%	366.94	0.91%
3	Bareland	5284.98	18674.19	13389.21	253.34%	461.70	8.74
4	Bushland	88891.12	47209.59	-41681.53	-46.89%	-1437.29	-1.62
5	Forest	38273	38961.76	688.76	1.80%	23.75	0.06
6	Grassland	52527.51	42359.31	-10168.20	-19.36%	-350.63	-0.67
7	Urban	0	381.89	381.89	381.89%	13.17	3.45
8	Water	160.74	1109.7	948.96	590.37%	32.72	20.36

3.3. Major LU/LC changes between 1986 and 2015

Over the past three decades, there is a remarkable change in the agroforestry class (Table 5). The area of land under agroforestry has increased by 201.87% within the past 29 years with average annual increment of 6.96%. Likewise, the land area covered with annual crops which consist of mainly maize, teff, barley, wheat, and haricot bean has also expanded although at relatively lower rate as compared to the agroforestry. Within three decades, the surface area of annual crops has raised by 26.30% with an average annual expansion of 0.91%. Generally cultivated land including both agroforestry and annual crop classes has expanded from 53,247.76 hectares in 1986 to 89,688.67 hectares in 2015 which has risen by 168.43% between the two study periods.

The agroforestry area is located in the eastern part of the study area bordered by the Gedeo zone. The Gedeo people are famous for their management of indigenous agroforestry. So the agroforestry practice at the immediate border of the Gedeo zone shows the cultural dissemination to previously pastoral areas of the study area. The most common vegetation species in the agroforestry class include Millettia ferruginea, Cordia africana, Croton macrostachyus, Ficus sur Forssk, Erythrina brucei, Ficus vasta, Enset (Ensete ventricosum), Coffee (Coffea arabica), Banana (Musa paradisiaca), Avocado (Persea americana), and Mango (Mangifera indica). In some parts, these trees are combined with small parcels of cereal crops such as maize, wheat and barley. The farmers keep diversified trees species to play various roles in the agroforestry system. Some of these trees such as Erythrina brucei, Millettia ferruginea, Cordia africana, Ficus sur Forssk and Ficus vasta are preferred for coffee shade. In addition to their role as a shade for coffee, the farmers witnessed that Erythrina brucei and Millettia ferruginea are also preferred for soil fertility enhancement as they are nitrogen fixing plants. Enset (ensete ventricosum) is used as a stable food in the agroforestry area while tree crops such as coffee, avocado, mango, and banana are grown for fruit production for market and household consumption. Specifically, coffee production in the agroforestry area is primarily market-oriented. Other tree species such as Croton macrostachyus are also grown for firewood. These diverse multipurpose trees species and the enset fulfill production and protection purposes which act as cornerstones, holding the whole agro-ecosystem intact (Tadesse, 2002). Due to the cultivation of integrated and diversified species, farmers in the agroforestry area are less vulnerable for hazards such as drought as compared to the cereal crop producers.

Figure 5: *Typical Agroforestry Site in Foge kebele, Abaya district*

In 1986, the landuse/landcover of the study area was dominated by bush land (37.29%) and grassland (22.04%) as shown in (Table 3 and 5), but in 2015 it is dominated by cultivated land (37.62%) which is the combination of agroforestry and annual crops (Table 4 and 5). Over the past three decades, the decline in grass land and bushland is evident but the rate of change is higher for bushland (Table 5) since it is primarily cleared for market-oriented charcoal making (Figure 6) but also for agricultural expansion by both small scale farmers and agricultural investors. Similarly, Worku and Csaplovics (2015) found that about 52 % of woodland area was converted to other land uses, primarily cropland in the northwestern part of the country between 1972 and 2010.

In the study area, the bushland class predominantly consists of thorny acacia species which are highly preferred by the local community for charcoal production. Different groups of the local community including children are engaged in market-oriented charcoal making for income generation (Figure 6). Charcoal making is an attracting business in the study area due to high demand for charcoal in the nearby towns. Firewood collection is also another factor contributing to the diminishing of the bush land (Figure 7) as the main source of energy for 85% of the Ethiopian population is still fuel wood (JICA, 2012). After they fell the trees, they use the branches for fire wood while the stem and root parts are used for charcoal making (Figure 6 and 7). While charcoal is produced primarily for sale, firewood wood is collected for both domestic consumption and for market.

Figure 6: *Traditional Method of Charcoal Making in Gololcha Kebele, Abaya district*

Some studies in other parts of the Borena zone indicate that there is an increase in the bushland area due to bush encroachment of invasive acacia species which resulted in the decline of forage production and also prohibited human and livestock access to the underlying grass (Dessalegn et al., 2003; Berhanu and Suryabhagavan, 2014). In contrast, the bush encroachment in the study area has created employment opportunity and majority of the local community are engaged in market-oriented charcoal production from the bushland. This job opportunity is created mainly due the geographic location of the study area which is bordered by Dilla town in east. Huge amount of charcoal and fire wood is continuously supplied to the town (Figure 7) and those engaged in this activity claimed that the price of charcoal and fire wood is rising from time to time due to shortage of wood for charcoal production. Consequently, the area of the bush land has declined from 88,891.12 hectares in 1986 to 47,209.59 hectares in 2015 which is a reduction by 46.89% within 29 years. Similarly, Elias et al. (2015) reported a reduction of bushland in other parts of the Borena zone mainly attributed to agricultural expansion.

Figure 7: *Supply of Firewood and Charcoal from Abaya district to Dilla town*

On the other hand, the increase in cultivated lands (Figure 8) and decline in grass lands in the current study is consistent with the findings of Mesele et al. (2006) who found dramatic declines in the extent of grasslands while a five-fold increase in croplands in Yabelo district of the Borena zone. Similarly

Elias et al. (2015) found a remarkable increase in cultivated land in some parts of the Borena rangeland due to the conversion of woodland, bushland, and grassland. Thus the significant increase in cultivated lands probably indicates that the pastoral communities in the study area are shifting from heavier livelihood dependence on livestock to crop production to cope up with population pressure and food insecurity (Mesele et al., 2006). Previous pastoralists are becoming agro-pastoralists or there is a change from pastoralism to mixed farming system. The people have started stable life instead of moving with their animals from one place to another place. As a result, they keep both cultivated lands and livestock together.

Figure 8: *Area Cleared for Agricultural Investment*

Bareland categories in this study include non–vegetated and non-agricultural lands including rock outcrops and degraded areas. The surface area of the bare land class has shown an increase within the study period (Table 5) which could be the indication of land degradation (Berhanu and Suryabhagavan, 2014; Elias et al., 2015).

Another important LULC in the study area is the forest class which consists of mixed natural and plantation vegetation species such as Olea europaea, Juniperus procera, Combretum molle, Croton macrostachyus, Acacia and Ficus vasta. Although reduction of the forest land as a result of deforestation activity is observed in some parts of the study area, there is a slight net increase in this class due to area closure or enclosure of previously degraded communal lands for rehabilitation with natural regeneration and reforestation programs (Figure 9). Area enclosure was introduced in order to protect degraded lands from anthropogenic interference and further degradation which is implemented on mountains and hillsides. As a result, previously degraded lands are being rehabilitated by natural regeneration and reforestation which resulted in a slight gain in the area of forest land. Similarly, Bokutache (2011) also reported the existence of area closures and Elias et al. (2015) found slight gains of woodland vegetation on mountain escarpments in the Borena zone.

Figure 9: *Area Closure at Semero Kebele, Abaya District with Emerging and Diversified Vegetation Species*

The urban class which refers to the permanent settlement in particularly two emerging towns has a total area of 381.89 hectares in 2015. These two small towns are newly emerged and it was absolutely impossible to map them using the land sat image in 1986.

Other changes in land use/land cover in the past three decades are the increase in number and surface area of water bodies. One of the reasons behind the increase in the surface area of water bodies is due to the over flow of the Abaya lake, which is one of the largest rift valley lakes in the country located in the western border of the study area. As a result of the overflow, a new small lake is formed around the Abaya lake (Figure 10). Consequently, more than 2000 households were displaced from their original settlement in 2013. In addition, there was an increase in the surface area of another previously existing lake. The overflow and expansion of these lakes might be associated with the accumulation of sediment as a result of soil erosion from the upper stream as Seleshi (2007) reported that the major challenges in the Abaya and Chamo lakes basin are deforestation, over grazing, poor tillage, severe soil erosion, and flooding of areas surrounding the rivers.

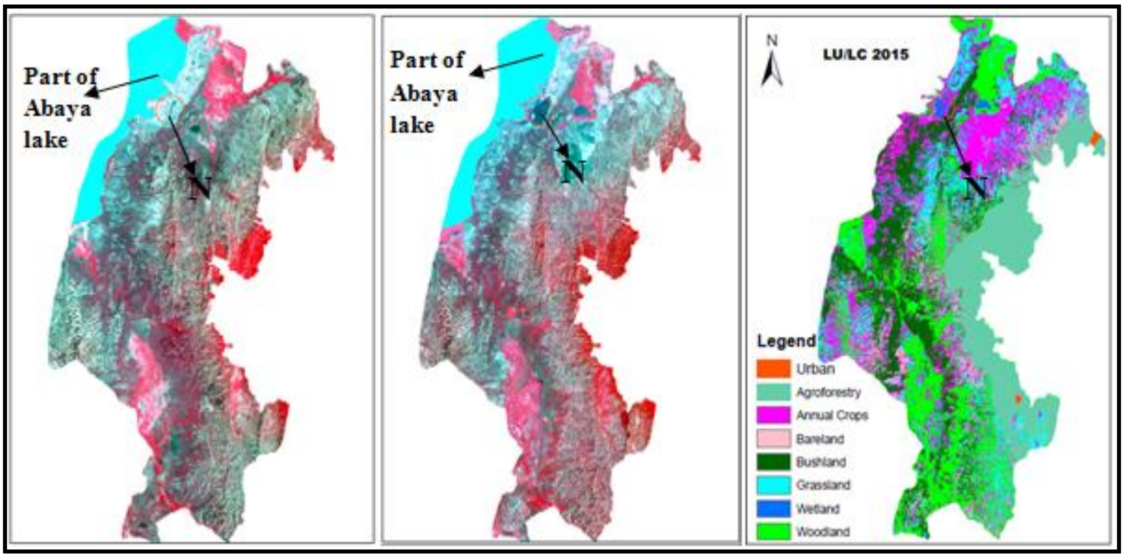

Figure 10: *The Location of the New Lake Formed by the Overflow of the Abaya lake is labeled 'N'*
a) Land sat 5 TM 1986 b) Land sat 8 OLI 2015 c) Classified image 2015

4. Conclusion

In the study area, there is obvious deforestation problem as a result of charcoal making, firewood collection, and agricultural expansion which is manifested by the reduction of bushland by 46.89% and an increase in bare land by 253.34% within 29 years. Similarly, there is reduction in grass land mainly due to conversion into agricultural lands. As a result, a remarkable expansion of cultivated land including agroforestry and annual crops was observed over the past three decades. Perhaps, the reduction in grassland and the rise in the area of cultivated land is the manifestation of livelihood change from high dependence on livestock husbandry to mixed farming system.

In some parts of the study area, previously deforested and degraded communal lands are enclosed or legally protected from human and livestock interference. These enclosed areas mainly mountains and hillsides are being rehabilitated by natural regeneration and reforestation, which resulted in a slight gain of the forest land. Other important LULC changes observed in the study area include urban expansion and an increase in the water bodies mainly due the overflow of Abaya lake which resulted in the displacement of more than 2000 households from their settlement area.

References

Ayache, A., Ayad, N., Hellal, B., Benhanifia, K., and Gacemi, M. *Study of the Temporal Evolution of Land Use in the Steppe South of Tlemcen Province for the Period 1987 and 2010 using Remote Sensing and GIS Techniques.* International Journal of Remote Sensing & Geoscience. 2015. 4 (4) 28-34.

Barnes, D.F., Krutilla, K., and Hyde, W., 2004: *The Urban Household Energy Transition: Energy, Poverty, and the Environment in the Developing World.* World Bank.

Berhanu, K., and Suryabhagavan, K.V. *Multitemporal Remote Sensing of Landscape Dynamics and Pattern Change in Dire District, Southern Ethiopia.* Indian Society of Geomatics. 2014. 8 (2).

Binyam Alemu. *The Effect of Land Use Land Cover Change on Land Degradation in the Highlands of Ethiopia.* Journal of Environment and Earth Science. 2015. 5 (1) 1-12.

Bokutache Dida, 2011: *Range Enclosures in Southern Oromia, Ethiopia: An Innovative Response or Erosion in the Common Property Resource Tenure?* Future Agricultures.

Bureau of Finance and Economic Development of Oromiya Region, 2015. The National Regional Government of Oromia, Regional Statistics.

Campbell, B.J., and Randolph, H.W., 2011: *Introduction to Remote Sensing.* Fifth Edition. New York: The Guilford Press.

CSA, 1994: Central Statistical Agency of Ethiopia National Census Data.

Dessalegn Gurmessa, Sileshi Nemomissa, Girma Tadesse, 2003: Borana Rangeland Change from 1986-2003: The Application of Remote Sensing and GIS.

Desta Hamito, 2001: Research Methods in Forestry: Principles and Practices with Particular Reference to Ethiopia, Larenstein University of Professional Education, Deventer, the Netherlands.

Elias, M., Hensel, O., Richer, U., Hulsebusch, C., Kaufmann, B., and Wasonga, O. *Land Conversion Dynamics in the Borana Rangelands of Southern Ethiopia: An Integrated Assessment Using Remote Sensing Techniques and Field Survey Data.* Environments. 2015. 2 (3) 385-387.

Ellen, W., 2010: *Participatory Forest Management in Ethiopia, Practices and Experiences.* Food and Agriculture Organization Sub Regional Office for Eastern Africa (SFE), Addis Ababa.

Global Forest Resources Assessment, 2010: Terms and Definitions, Food and Agriculture Organization of the United Nations, Forest Resources Assessment Programme, Working Paper 144/E Rome.

Japan International Cooperation Agency (JICA, 2012). Energy Policy of Ethiopia, Country Report, Tokyo Japan June 24-July 14, 2012.

Lillesand, T.M., Kiefer, R.W., and Chipman, J.W., 2004: *Remote Sensing and Image Interpretation.* 5th ed. USA: John Wiley and Sons.

Lindquist, E.J., D'Annunzio, R., Gerrand, A., MacDicken, K., Achard, F., Beuchle, R., Brink, A., Eva, H.D., Mayaux, P., San-Miguel-Ayanz, J., and Stibig, H.J., 2012: *Global Forest Land-Use Change 1990–2005*. FAO Forestry Paper No. 169. Food and Agriculture Organization of the United Nations and European Commission Joint Research Centre, Rome.

Mesele, S., Heluf Gebrekidan, Lemma Gizachew, and Coppock, D.L., 2006: *Changes in Land Cover and Soil Conditions for the Yabelo District of the Borana Plateau, 1973-2003.* Research Brief 06-06-PARIMA. Global Livestock Collaborative Research Support Program. University of California, Davis. 4.

Seleshi Bekele. *Abaya-Chamo Lakes Physical and Water Resources Characteristics, Including Scenarios and Impacts.* Catchment and Lake Research. LARS 2007. 162-167.

Tadesse Kippie, 2002: *Five Thousand Years of Sustainability? A Case Study on Gedeo Land Use (Southern Ethiopia).* Heelsum. The Netherlands: Treemail Publishers.

Williams, D.L., Goward, S., and Arvidson, T. *Landsat: Yesterday, Today, and Tomorrow.* Photogram. Eng. & Remote Sens. 2006. 72 (10) 1171-1178.

Worku Zewdie and Csaplovics, E. *Remote Sensing Based Multi-Temporal Land Cover Classification and Change Detection in Northwestern Ethiopia.* European Journal of Remote Sensing. 2005. 48; 121-139.

Zenebe Gebreegziabher, 2007: *Household Fuel Consumption and Resource Use in Rural-Urban Ethiopia.* PhD Thesis, Wageningen University, Netherlands.