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Assessment and Mapping of Land Use Change by Remote Sensing and GIS: A Case Study of Abaya Chamo Sub-basin, Ethiopia

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ABSTRACT

Population pressure, lack of awareness and weak management are considered as the real reasons for the deforestation and degradation of natural resources in Ethiopia. Land use land cover (LULC) classification has been widely studied in remote sensing and GIS for the purpose of agricultural, ecological and hydrological processes. This study applied supervised classification method with maximum likelihood classification algorithm in ArcGIS 10.1 software to identify land use land cover changes observed in Abaya Chamo sub-basin, Ethiopia by using Landsat 4-5TM and Landsat-8 OLI/TIRS images for the years 1995, 2000 and 2017. The LULC classification of the sub-basin was classified into seven major classes. It was found that barren soil, farmland, Lake Abaya and vegetation area had been increased within two decades and the annual rate of change was 0.08%, 0.45%, 0.25% and 0.37% respectively, but grass and shrubland, and woodland area has been decreased by an annual rate of change of 0.48% and 0.10% respectively. In the current situation because of deforestation and expansion of farmlands the sub-basin lakes are under stress by surface runoff, sediment yield and groundwater extraction. Hence, proper planning, management, decision and implementation are required to use the natural resources sustainably or else the natural resources will soon be lost.

INTRODUCTION

Land use land cover (LULC) change is two separate phrases considered as a critical device to survey global change in various spatio-temporal scales (Islam et al. 2017). Land use refers to the manner by which land has been utilized by humans and their natural surroundings, for the most part with an accent on the useful part of land for economic tricks. While land cover refers to the physical attributes of the earth's surface caught in the dissemination of forest, bare soil, vegetation, agriculture, water, and others, including those made exclusively by human exercises, e.g. settlements. The LULC illustration of a basin or sub-basin is a result of natural and socio-economic causes and their use by the human beings in time and space. Data on LULC and conceivable outcomes for their optimal utilization are fundamental for the selection, management, planning and implementation of land use strategies to meet the expanding demands for essential human needs and welfare (Rawat & Kumar 2015).

Complete information of LULC change is valuable for recreating historical LULC and for forecasting future changes and in this manner may help in elaborating sustainable management practices intended for conserving fundamental landscape functions (Hietel et al. 2004). The essential drivers of LULC change and their interrelationship with the hydrological regimes must be distinguished to generate projections of future land use and management decision results under a scope of environmental, economic, and social scenarios (Tadele 2009). As of now, enhanced comprehension of procedures of LULC change has prompted a move from a view denouncing human effect on nature as driving generally to a deterioration of earth system processes to accentuation on the potential for efficient use of resources and ecological restoration through basin or sub-basin management. This change reproduces the advancement of the research study questions, methods, and scientific worldview (Victor & Ausubel 2000). Thus, general declarations about effects of LULC change and land-water interactions should be consistently addressed to decide if they represent the best accessible data and whose interests they support in decision-making processes (Bewket 2003, FAO 2002).

LULC change studies that have been done at various parts of Ethiopia showed that croplands have expanded at the expense of natural vegetation, including woodlands and shrublands; for example, north Ethiopia (Tegene 2002), north-western Ethiopia (Hurni et al. 2005), west Ethiopia (Abate 1994), south-western Ethiopia (Argaw 2005) accounted the impact of LULC change in causing significant gullies and quantified the rate development and their consequences for the livelihoods of individuals in eastern and central highlands of Ethiopia (Tadele 2009).

The growth of population has contributed significantly to land degradation, poverty and food insecurity in the northern part of Ethiopian highlands. The fundamental reason for affecting land cover in the Abaya-Chamo sub-basin is the rapid population growth and consequential pressure on the land use ecosystems by the development of settlements, clear-cutting, and development agricultural areas. The majority of the observational confirmation indicated that LULC changes and socioeconomic dynamics have a solid relationship; as population growth increases, the need for fuelwood, grazing land, cultivated land; settlement zones additionally increment to take care of the developing demand for energy and food, and domestic animals population. In this way, population pressure, lack of awareness and weak management are considered as the real reasons for the deforestation and degradation of natural resources in Ethiopia (Tadele 2009).

Abaya Chamo sub-basin is one of the naturally gifted and tourism place in Ethiopia. The natural resources are lakes (Lake Abaya & Lake Chamo), national park (Neche Sar National Park), more than forty springs in one place, natural forest and different kinds of endemic birds and wild animal species. In recent years the land cover of the sub-basin was dramatically changed due to population growth, settlements, deforestation and expansion of agricultural lands around the lakes and affected the lake water level and water quality due to sedimentation. Therefore, the study area was selected because of the above reasons to sustain the natural resources of the sub-basin. The study considered 1995 as the baseline period and examined the LULC change from 1995 to 2017.

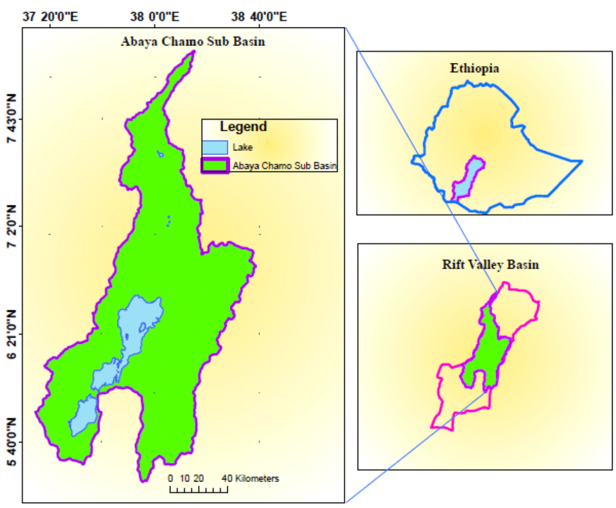

Fig. 1: Location map of Abaya Chamo sub-basin.

MATERIALS AND METHODS

Study area: Abaya Chamo sub-basin is located in the Ethiopian Rift Valley Basin (Fig. 1). The sub-basin is geographically located between 5°51.5'N to 8°8'N latitude and 37°16.3'E to 38°39.3'E longitude (Bekele 2007). In the sub-basin, climate varies from tropical to alpine and the rainfall pattern is bimodal. The rainfall seasons for the catchment around Lake Chamo and southern part of Lake Abaya are March to May and September to October. For the catchment northern part of Lake Abaya, the rainfall seasons are July to October, and for the rest, catchment part are April to May and October (Tiruneh 2005).

Data used: In this study both satellite data and ground truth data are used. Landsat4-5TM (Thematic Mapper) and Landsat-8 OLI/TIRS (Operational Land Imager/Thermal Infrared Sensor) were obtained from the website of the United States Geographical Survey (USGS). The Landsat satellite image data of the three acquisition years 1995, 2000 and 2017 were acquired from path 168 and 169 and row 54, 55 and 56 for the months of December and January. Imagery having cloud could significantly decrease the precision of the LULC classification work. Consequently, we could not choose imageries of the similar month along the whole study period (Islam et al. 2017). Because of this reason, imageries of December and January with less than ten percent cloud cover were the main source of data acquisition months. The information about the satellite data used in this study is given in Table 1. The ground truth data points collected by Geographical Positioning System (GPS) are used as reference data for image classification.

Image processing: Landsat8 OLI/TIRS and Landsat4-5TM images consist of band 1 to 7 and band 1 to 5 and 7 respectively with 30 m spatial resolution. The three composite bands (band 6, 5, 4 for Landsat8 and band 5, 4, 3 for Landsat4-5TM) are converted into a single layer by ArcGIS 10.1. This process was done for all three acquisition years. From the layer file, the study area was masked by using the sub-set tool. The sub-set image was then re-projected to UTM (Universal Transverse Mercator) zone 37 N. For LULC classification, supervised classification method with maximum likelihood classification (MLC) algorithm was applied in the ArcGIS 10.1 software. The method is widely used and convenient for LULC change evaluation (Afify 2011, Butt et al. 2015, Dewan & Yamaguchi 2009a, b, Ghebrezgabher et al. 2016, Rawat et al. 2013, Jayanth et al. 2016, Mosammam et al. 2017, Sinha et al. 2015). The MLC algorithm considers both the co-variances and variances of the class signatures when appointing every cell to one of the class represented in the signature file.

Every single satellite data were examined by assigning per-pixel signatures and separating the sub-basin into seven major classes on the bases of the specific Digital Number (DN) value of various land use elements. For every one of the pre-processed LULC type, training samples were chosen by drawing up the boundaries of polygons around the representative places. Spectral signatures for the particular land cover types obtained from the satellite imagery were confirmed by using the pixels encased by these polygons (Butt et al. 2015). An acceptable spectral signature is the one that makes sure that there is negligible confusion between the LULC to be mapped (Gao & Liu 2010). After that MLC algorithm was processed to supervise the Landsat images classification. To enhance classification precision and decrease of misclassifications, post-classification modification was utilized for simplicity and adequacy of the method. Visual investigation was very significant to improve the quality of LULC classification. Subsequently, visual investigation, reference point data, and additionally local knowledge, impressively enhanced the outcomes acquired using the supervised algorithm (Butt et al. 2015).

To enhance the accuracy of vegetation distribution in this study the Normalized Difference Vegetation Index (NDVI) was used. For the purpose of LULC change study, it is the most widely used pointer for the vegetation distribution. The NDVI quantifies vegetation by measuring the difference between wavelength of near-infrared and red bands, and its value always ranges from -1 to 1. When the value of NDVI is lowest, moderate and high indicates urbanized area or barren soil/rock, sparse vegetation, and dense vegetation respectively (USGS 2015). The NDVI is calculated by the following equation.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad ...(1)$$

Where, NIR- The near-infrared wavelength; Red- The wavelength of red band

A non parametric Kappa test was used to measure the LULC classification accuracy (Butt et al. 2015). Kappa accuracy assessment was done for the 2017 LULC image by using ArcGIS 10.1. The accuracy assessment of the study area LULC was carried out using 225 ground truth reference points and visual interpretation. Kappa test was calculated by the following equation (Stehman 1996).

$$\hat{K} = \frac{N\sum_{i=1}^{M} X_{ii} - \sum_{i=1}^{M}(X_{i+}X_{+i})}{N^2 - \sum_{i=1}^{M}(X_{i+}X_{+i})} \quad ...(2)$$

Where, N- The total number of pixels; M- The total number of groups in error matrix; X_{ii}- The marginal distribution of pixels in row and column; X_{i+}- The total marginal distribution (row); X_{+i}- The total marginal distribution (column)

RESULTS AND DISCUSSION

The overall achieved accuracy of classification image and Kappa coefficient were 85.33% and 81.55% respectively for LULC classification of 2017 image. The value of Kappa

Table 1: Satellite data information (Source: https://earthexplorer.usgs.gov/).

Satellite Data	Sensor	Acquisition date	Spectra Bands	Resolution (m)	Source
Landsat-8	OLI/TIRS	28-12-2017	Multi-spectra	30m	USGS
Landsat4-5	TM	03-01-2000	Multi-spectra	30m	USGS
Landsat4-5	TM	14-01-1995	Multi-spectra	30m	USGS

Table 2: Accuracy assessment error matrix.

LULC	BS	FL	G/SL	LA	LC	V	WL	TU	UA (%)	PA (%)
BS	52	8	2	0	0	0	0	62	83.87	91.23
FL	3	44	3	0	0	5	0	55	80.00	75.86
G/SL	2	4	40	0	0	0	0	46	86.96	88.89
LA	0	0	0	7	0	0	0	7	100	100
LC	0	0	0	0	4	0	0	4	100	100
V	0	2	0	0	0	29	2	33	87.88	80.56
WL	0	0	0	0	0	2	16	18	88.89	88.89
TP	57	58	45	7	4	36	18	225		

Overall Accuracy=85.33%; Kappa Coefficient=81.55%

Note: BS=Barren Soil, FL=Farm Land, G/SL=Grass and Shrub Land, LA=Lake Abaya, LC=Lake Chamo, V=Vegetation, WL=Wood Land, TU=Total User, TP=Total Producer, UA=User's Accuracy and PA=Producer's Accuracy.

coefficient is greater than 80% shows strong agreement between the ground truth reference point data and the classified image (Landis & Koch 1997, van-Vliet et al. 2011). The error matrix in Table 2 shows the accuracy and Kappa statistic result of 2017 supervised LULC classification of Abaya Chamo sub-basin.

The results of classified LULC map of Abaya Chamo sub-basin of years 1995, 2000 and 2017 is given in Fig. 2. Change of grass, shrub and woodland areas to farmland, urban and industrial development and local energy consumption affects the natural land cover (Wagesho et al. 2012). The LULC assessment of each class of 1995 and 2000, 2000 and 2017 and 1995 and 2017 listed in Table 4 showed that there has been a change in LULC during the study period of 22 years. Relative with the baseline period 1995 the LULC result was decreased with respect to the area in Abaya Chamo sub-basin in grass and shrubland and woodland whereas, the LULC area of barren soil, farmland, lakes and vegetation was increased. Based on 1995, 2000 and 2017, LULC classification results (Table 3), the highest coverage was grass and shrubland, but the percentage of the coverage was decreased by 0.49% annual rate. The second largest coverage is farmland and it was increased by 0.45% annual rate. The reason for this increment is due to population growth and expansion of farmland in the highland areas and around the lakes.

Nowadays the expansion of farmlands by private farmers and agricultural investors around Lake Abaya and Lake Chamo has significantly increased. Relative to 1995, in 2000 and 2017 the expansion of farmlands was observed around Lake Chamo catchment in Sile, Ailgo, Wozeqa and Gumaide Mazoria (South part of Lake Chamo) areas and around Lake Abaya catchment in Chano, Lante, Mirab Abaya and Bilate areas. In the previous period the areas around the lakes are covered by shrubland and woodland. Due to the expansion of farmland in the sub-basin, the rate of runoff and sediment yield to the lakes was increased. The increased runoff and sediment yield have been affecting the surface area and water level of Lake Abaya and Lake Chamo. Relative to the baseline period 1995, the surface area of Lake Abaya and Lake Chamo increased by 3.26% and 4.94% in 2000 and 5.59% and 4.20% in 2017 respectively. The annual surface area change rate of Lake Abaya and Lake Chamo is 0.25% and 0.19% respectively.

In the current period, agricultural investors around Lake Chamo used the groundwater and stream flow for irrigation purpose. The mismanagement of water used around the rivers and groundwater and withdrawals for the purpose of irrigation are the factors that affect the Lake Chamo water. The inflow rivers to Lake Chamo are Kulfo, Sile, Sago and Wozeqa. Especially in dry season 100% of water from the rivers is used for irrigation purpose. Relative to 2000, the

Table 3: LULC classification of Abaya Chamo sub-basin from 1995 to 2017.

LULC Feature	LULC in 1995		LULC in 2000		LULC in 2017	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Barren Soil	3128.55	16.82	3131.58	16.84	3183.85	17.12
Farm land	4843.18	26.04	4897.11	26.33	5325.78	28.63
Grass & Shrub land	6971.49	37.48	6837.69	36.76	6228.52	33.49
Lake Abaya	1040.71	5.60	1074.65	5.78	1098.91	5.91
Lake Chamo	294.90	1.59	309.48	1.66	307.27	1.65
Vegetation	1606.96	8.64	1614.53	8.68	1738.80	9.35
Wood Land	530.60	2.85	524.53	2.82	518.92	2.79

Source: USGS Landsat4-5 and Landsat8 OLI/TIRS satellite imageries from 1995 to 2017 and data extraction and classification done by authors using ArcGIS 10.1 software.

Table 4: LULC change assessment of Abaya Chamo sub-basin from1995 to 2017.

LULC Feature	LULC:1995-2000		LULC:2000-2017		LULC:1995-2017		Annual Rate of Change
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	
Barren Soil	3.03	0.10	52.27	1.67	55.30	1.77	0.08
Farm land	53.93	1.11	428.67	8.75	482.60	9.96	0.45
Grass & Shrub land	-133.80	-1.92	-609.17	-8.91	-742.97	-10.66	-0.48
Lake Abaya	33.93	3.26	24.27	2.26	58.20	5.59	0.25
Lake Chamo	14.58	4.94	-2.20	-0.71	12.37	4.20	0.19
Vegetation	7.57	0.47	124.27	7.70	131.84	8.20	0.37
Wood Land	-6.07	-1.14	-5.61	-1.07	-11.68	-2.20	-0.10

Note: (-) sign indicates decrease of LULC change magnitude.

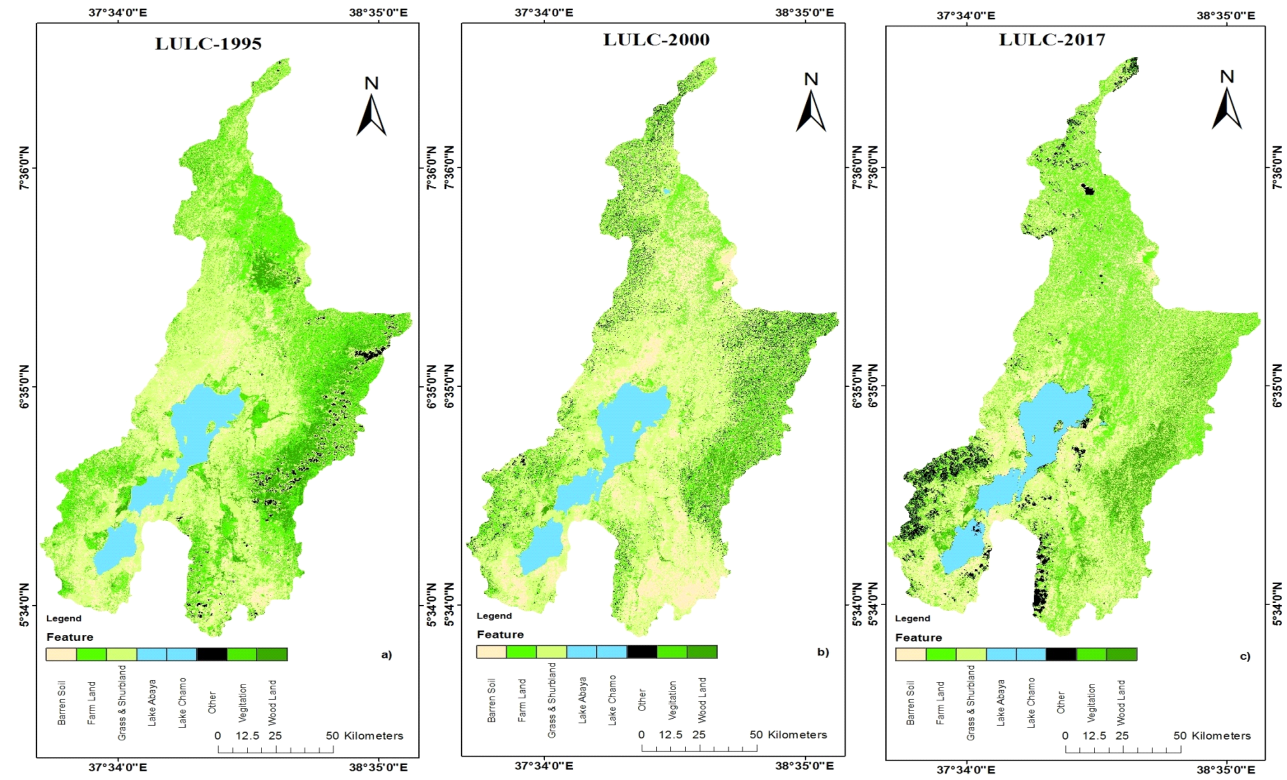

Fig. 2: LULC classified map of Abaya Chamo sub-basin a) 1995, b) 2000 and c) 2017.

surface area of Lake Chamo was decreased by 0.71% and the result shows that the groundwater withdrawals and other factors affected the surface area of the lake.

The study area has high potential in the production of banana, mango and avocado. Due to the expansion of these products in the sub-basin vegetation cover was increased by 0.37% annual rate. On the other hand, woodland cover was decreased by 0.10% annual rate because of deforestation for the purpose of farmland expansion, energy consumption and construction of urban and rural area. The third largest LULC feature is barren soil with 16.82%, 16.84% and 17.12% coverage respectively, during the study period.

Supervised LULC classification of satellite imagery with the ground truth reference point data interpretation is an effective option for LULC study and multi-temporal change evaluation of land use (Islam et al. 2017). The overall achieved accuracy of classification image along with the Kappa value for supervised LULC was acceptable to identify the changing scenarios of Abaya Chamo sub-basin.

CONCLUSION

Grass and shrubland, and woodland areas have been degraded severely and converted into various land uses like farmlands and barren soils. Based on the result of this study grass and shrubland, and woodland coverage has been reduced by 10.99% and 2.20% respectively during 2017. In Abaya Chamo sub-basin there are two lakes, the Lake Abaya and Lake Chamo. Because of deforestation and expansion of farmlands around the lakes and highlands of the study areas, the rate of runoff and sediment yield to the lakes was increased. The increase of this rate affected the surface area and water level of the two lakes. The surface area of Lake Abaya was increased during the study periods, but the surface area of Lake Chamo was decreased during 2000 to 2017 by 0.71%. Generally, expansion of farmland, mismanaged use of stream water and groundwater abstraction near to the lakes are the factors that affect the lake water in Abaya Chamo sub-basin. Policy makers, organizations, institutions, regional and federal bureau and authorities, private users and other concerned bodies are responsible to take an appropriate plan, management and decision for sustainable use of lake water.

In this study, during classification of images uncertainties are associated with cloud cover but the overall achieved accuracy of classification image was acceptable. From this assessment, it can be concluded that Abaya Chamo sub-basin had experienced a major change in LULC the past two decades. To prepare the LULC change analysis by using these methods the process takes less time with high accuracy and the cost is low. Thus, this study shows that remote sensing and GIS are significant methods for LULC classification.

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