GIS and Remote Sensing based land use/land cover change detection: The case of Kility Watershed

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Abstract: The land cover and land use changes are caused by both, natural and anthropogenic factors. This study was conducted in kility Watershed, Amhara Region, North western Ethiopia. The objective of this study was to detect and analyse LULC changes in the watershed. The study has used ArcGIS10.3 and ERDAS IMAGINE 15, Landsat images of 1986 and 2002; Sentinel 2 image for 2019 to analyse land cover and land use changes of Kility watershed. In addition, the survey was conducted to detect the land use class and their drivers of changes.

The Maximum Likelihood Algorithm of Supervised Classification has been used to generate land use and land cover maps. For the accuracy of classified Land Use/Land Cover maps, a confusion matrix was used to derive overall accuracy and results were above the minimum and acceptable threshold level. Post classification comparison change detection method was employed to identify gains and losses between Land Use/Land Cover classes.

The satellite image results showed that Bush land decreased in the first period but increased in the second and the entire study periods. Grassland increased in the first period and increased in the entire periods. Agricultural land is the most converted cover type during the second study period. In the 33 years, forest lands expanded by over 8.48 % of the original forest cover what was existed at the base year. Settlement area which was not found in the first two study years satellite image result have 1.46 % proportion in 2019 Land Use/Land Cover classification.

Key words: Kility; Watershed; Image Classification; GIS; Land Use/Land Cover Change; Remote Sensing

1. Introduction

Land use is the intended employment of land management strategy placed on the land cover by human agents to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging and mining among many others (Zubair, 2006). On the other hand, land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin*et al.*, 2003; Baulies and Szejwach, 1997 cited in Bireda Alemayehu, 2015). The land use/land cover pattern of a region is an outcome of natural and socio–economic factors and their utilization by man in time and space (Bireda Alemayehu, 2015)

Roughly 40% of earth's land surface is under agriculture, and 85% has some level of anthropogenic influence (Sanderson *et al.*, 2002 cited in Bireda Alemayehu, 2015). Therefore, large-scale land cover change is largely a rural phenomenon, but many of its drivers can be traced to the consumption demands of the swelling urban population (Carr, 2004 cited in Bireda Alemayehu).

Land is becoming a scarce resource due to immense agricultural and demographic pressure (Zubair, 2006). Hence, information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use system to meet the increasing demands for basic human needs and welfare by understanding the relationships and interactions between humans and the natural environment. Land use/land cover change has become a central and important component in current strategies for managing natural resources and monitoring environmental changes (Rawat, 2013). The information of Land Use Land Cover also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population.

In Ethiopia, too, fast population growth and uneven spatial distribution of population have been affecting resource use, leading to its gradual deterioration (Bireda Alemayehu, 2015). Population growth leads further to unnecessary natural resource exploitation such as forest clearing both for farming and settlement purposes, short fallow periods, and land fragmentation which has a direct adverse effect on agricultural output(Mamo, 1990; Teferra, 2009 cited in

Bireda Alemayehu, 2015). Most of the population of Ethiopia is settled on the highlands, with the northern and central highlands being the oldest settled regions of the country. These regions are the most exploited and environmentally degraded areas in the entire country.

Kiliti Watershed is located in Dangila Woreda, North Western part of the country. The watershed is one of the exploited and degraded areas of the region. Because of small land holding size and shortage of land in the watershed, ploughing steep slopes with marginal output is common practice which has led to land and other natural resources degradation.

RS data have been one of the most important data sources for studies of LULC spatial and temporal changes. The availability of time-series dataset is essential to understand and monitor the change process, in order to characterize and locate the evolution trends at a detailed level. In fact, multi-temporal RS datasets, opportunely processed and elaborated, allow mapping and identifying landscape changes, giving an effective effort to sustainable landscape planning and management (Dewan*et al.*, 2009). In particular, by means of the integration RS and GIS techniques, it is possible to analyze and to classify the changing pattern of LULC during a long time period and, as a result, to understand the changes within the area of interest.

2. Objectives

2.2 General Objective

The general objective of this study is to detect and analyse LULC changes in Kility watershed by integrating RS and GIS techniques.

2.3 Specific Objectives

- to produce LULC maps of the study area for years 1986, 2002, 2019
- to analyze the dynamics of LULC changes as well as its spatial distribution and patterns within 1986, 2002, 2019
- to quantify gain and losses of land cover classes, examine land use transitions and assess spatial trends of changes;

3. Materials and methods

3.1 Description of the Study area

The Kility watershed is found in Dangla woreda in Awi Zone in Amhara region and it extends between 36^{0}45’37.09” E to 36^{0}49’26”Eastlongitude and 11^{0}13’51” to 11^{0}16’18” North latitude and covers total area of 1759 ha as shown in Figure 1. The climatic condition in water shed is Weyna-dega (midland with 1500-2500m altitude). The altitudinal variation of the study area generally ranges from 2072-2343 m above sea level. The mean annual rainfall and temperature for the watershed is 2379 mm and 18°C, respectively.

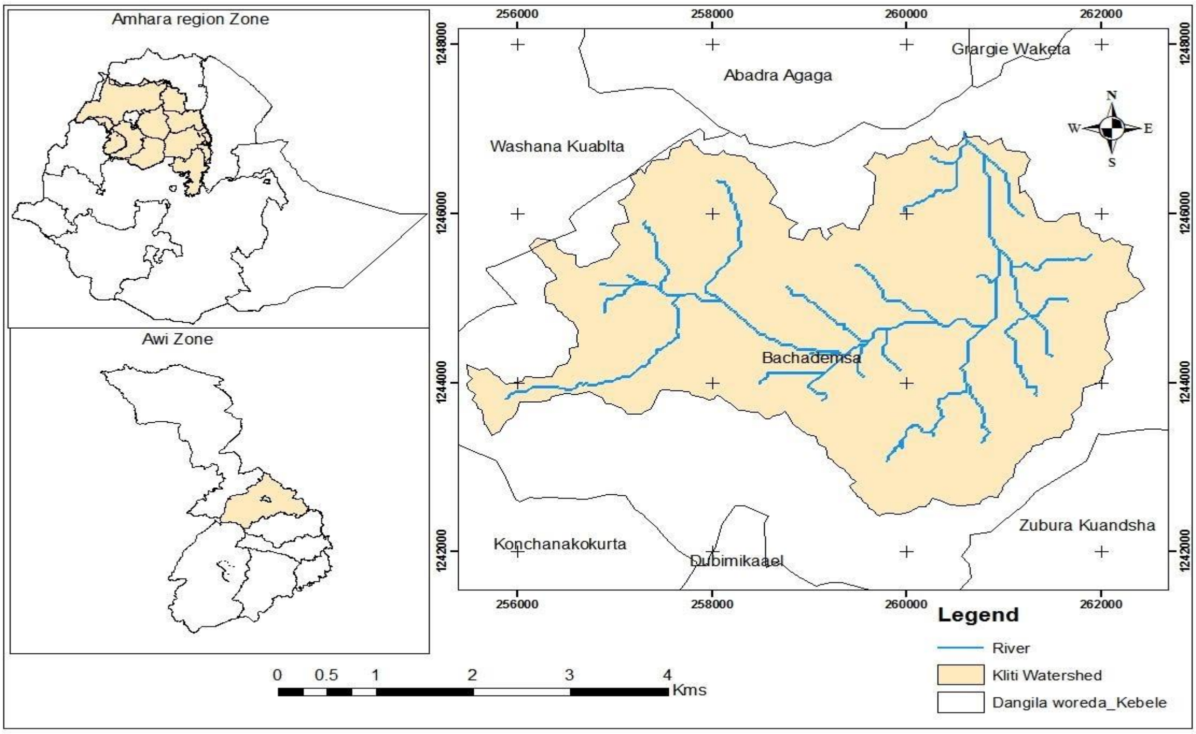

Figure 1: Location map of Kility watershed

3.2 Methodology

3.2.1 Data Acquisitions

In this study, both primary and secondary data were collected. Primary data were generated from the analysis of satellite images and preliminary field survey using handheld GPS (Garmin 64). Satellite data for 1986 and 2002 years (Table 1) consisting of multi-spectral data acquired by LandSat-TM satellite which was acquired from GLOVIS website (http://glovis.usgs.gov) and Satellite data for 2019 year consisting of multi-spectral data acquired by sentinel-2 which was acquired from European Space Agency (ESA) (https://scihub.copernicus.eu/). During image selection, cloud and unwanted shade free imagery were set as criteria as their presence could substantially reduce the accuracy of the classification work Field investigation was required to take the representative ground control points (GCPs) from each of the currently identified land use types. The GCPs were used for the preparation of signatures for supervised classification image classification and overall accuracy assessment of the classification results. Totally 125 ground truth points were collected. Secondary data such as Digital Elevation Model (DEM) were collected from ANRS Plan Commission with 20m resolution to delineate study area watershed.

Table 1: Details of satellite data acquisition

Sensor	Path/ Row	Cloud cover (%)	Resolution (pixel size)	Acquisition time
Landsat – TM	170/52	0	30 × 30 m	Jan, 1986
Landsat – TM	170/52	0	30 × 30 m	Jan, 2002
Sentilel-2		0	10× 10 m	Jan, 2019

3.2.2 Image processing

Image processing and performing supervised image classification helps to extract information from imageries. ERDAS Imagine 14 software was used for image processing. Layer stacking of this software was used to convert three bands (5, 4, 3 for sentilel-2and 4, 3, 2 for Landsat TM) into a single layer. The sub-setting of satellite images wasperformed for extracting watershed area from images. Radiometric correction, Histogram equalization were performed used of image interpretation. To analyse the change detection within the three-time images have different spatial resolution. After image classification resample pixel size were applied for 2019 Sentinel classified image in to 30 meter resolution.

Both unsupervised and supervised image classification techniques were applied. Unsupervised classification was done before field work. For the supervised image classification training areas were established based on the ground truth taken during field work and Google Earth imagery of the study area. For a single class a minimum of 20 training areas were taken to create signatures. All scenes were then classified using supervised classification method and maximum likelihood technique.

3.2.3 Land use land cover data classification schemes

Based on the prior knowledge of the study area and additional information from previous research, physical site observation and interviewing the local community in the study area, for 1986 and 2002 years four different types of land use and land cover have been identified while in 2019 additional settlement class include in Kility Watershed. These are Forest Land, Grazing land, Bush Land and Agricultural land (Table 2). In this study, land use land cover classification system developed by Anderson, et al., (1976) was used as basis of the classification. Each land use/land cover description was stated as follows in the table.

Table 2: Characteristics of each land cover class identified in Kility watershed

Land cover class	Description
Forest	It represents both natural and fragmented plantation forest areas that are stocked with trees capable of producing timber or other wood products
Agricultural land:	Areas used for crop cultivation (both annual and perennials), scattered rural settlements, some pastures and plantations around settlements. Sparsely located settlements were included here as it was difficult to separate them from agricultural lands.
Grazing land	Areas used for grazing as well as bare lands (or rocks) with little or no grass cover
Bush land	Areas covered with small trees, bushes and Bushs, mainly ranged from closed canopy to open canopy areas are considered as Bush land.
Settlement	Includes Residential or cluster of villages

Source: Anderson*et al.*, (1976)

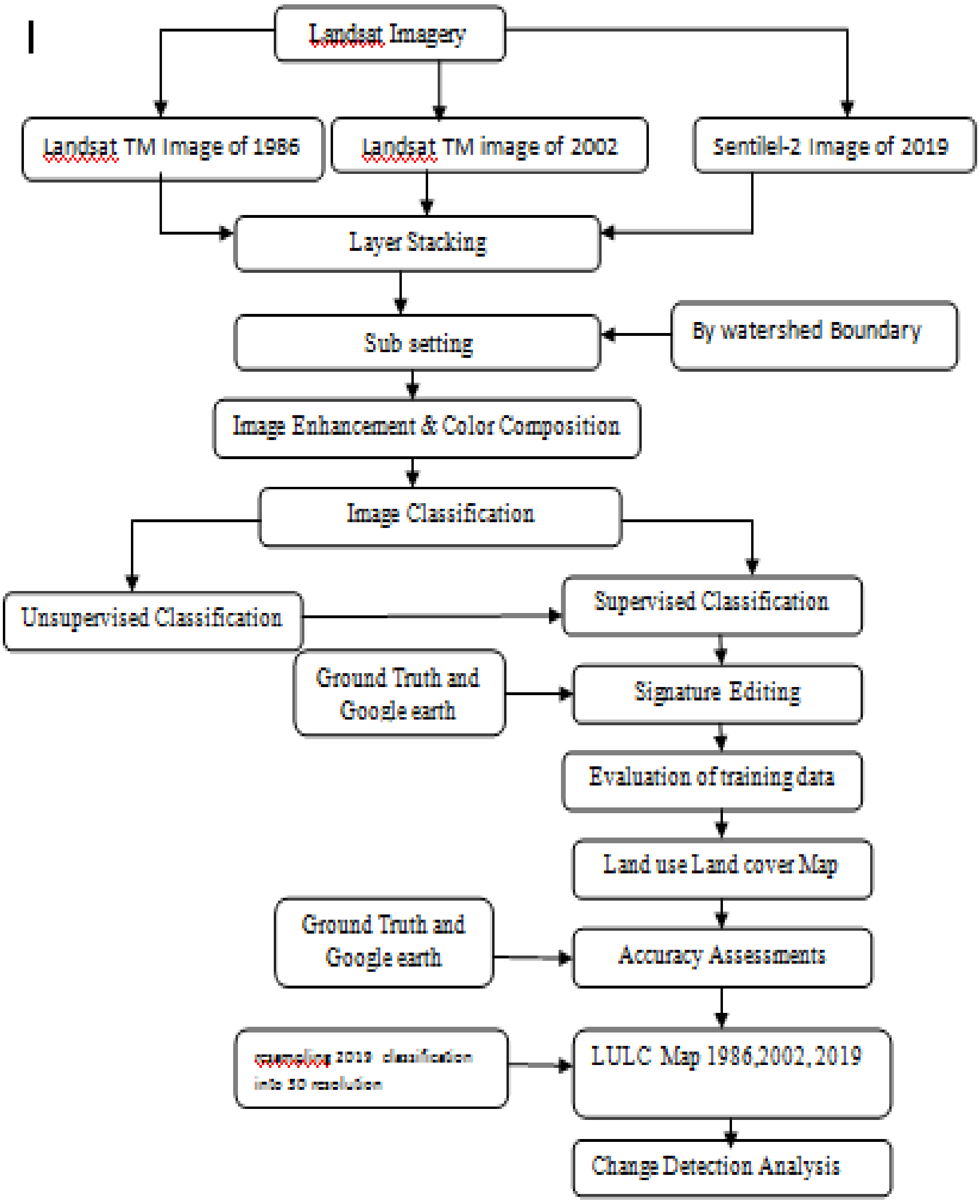

Figure 2: General Procedure of the Study

3.2.4 Accuracy assessment

Accuracy assessment is the comparison of a classification with ground-truth data to evaluate how well the classification represents the real world. In this study, accuracy assessment of the resultant classified images was carried out to determine the quality of information derived from the data which is collected by using GPS from ground truth and Google earth. The total points used for accuracy assessment for 1986, 2002 and 2019 years were 60, 50 and 97, respectively. This assessment was carried out using an error matrix. In addition, Kappa statistics along with total accuracy of the classified images were also performed to measure the extent of classification accuracy from the report section of ERDAS Imagine 15.

4. RESULTS AND DISCUSSION

As indicated in the classification scheme **Agricultural land**, **Grassland**, **Bush land**, **Forest** and **Settlement area** are the major LULC classes for the study periods.

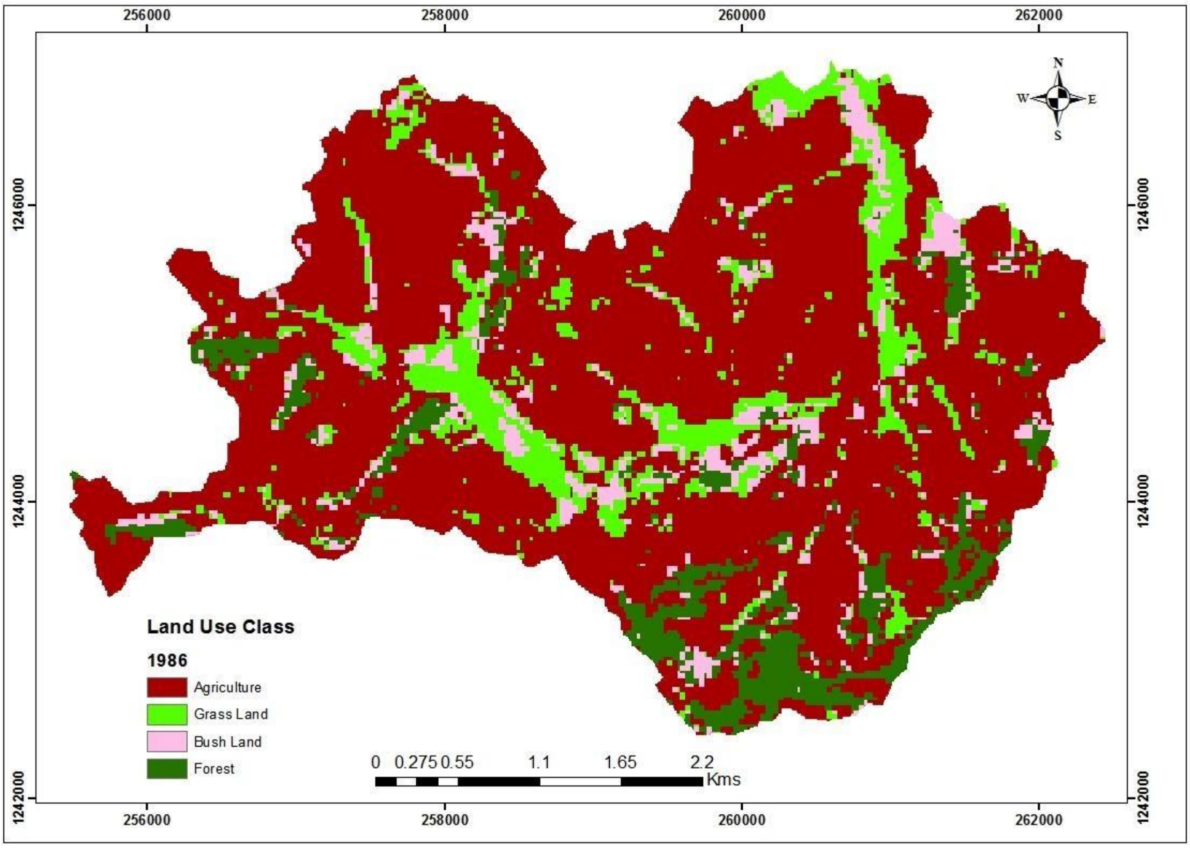

Figure 3: Land Use Land Cover map of 1986

The classification result of the 1986 image revealed that Agriculture land constituted the largest proportion of land in the watershed with a value of 73%, followed by grass land which accounts for 11%. Forest land and bush land constituted 11 % and 7 %, respectively (Table 3).

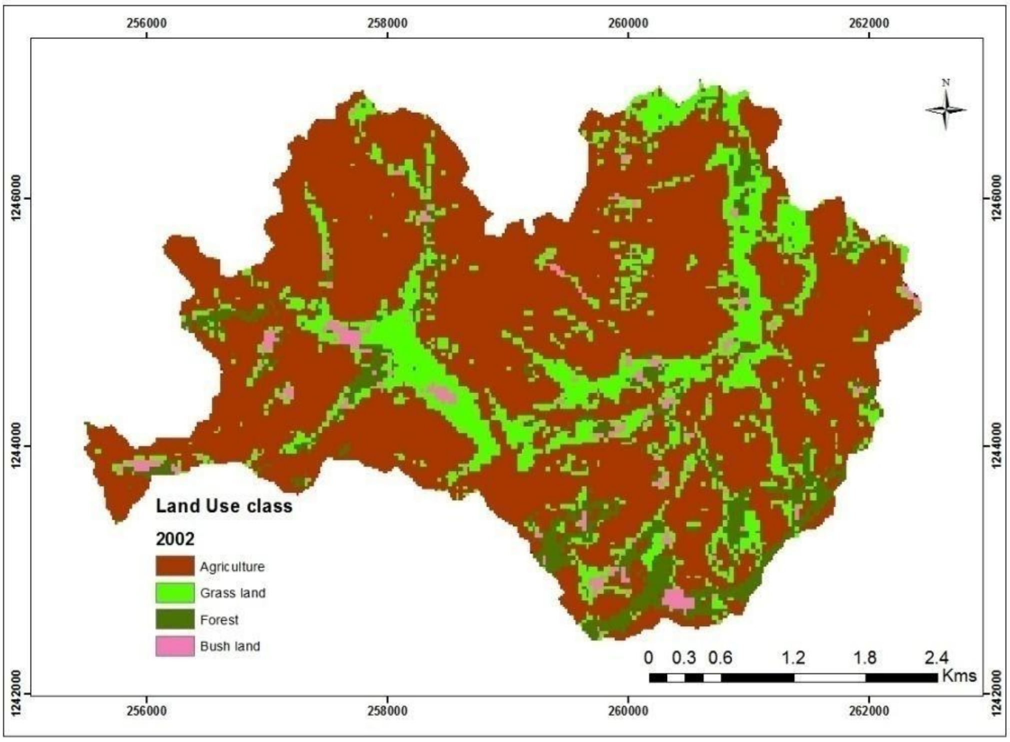

Figure 4: Land Use Land Cover map of 2002

As shown in Figure 4 for the 2002 image of the watershed, the proportion of land allocated for Agriculture land is all most the same as the first year. Furthermore, grassland expanded (due to free grazing) and covered 17% of the study area. However, the proportions of forest and bush land have been decreased (due to deforestation) to 7% and 2%, respectively (Table 3).

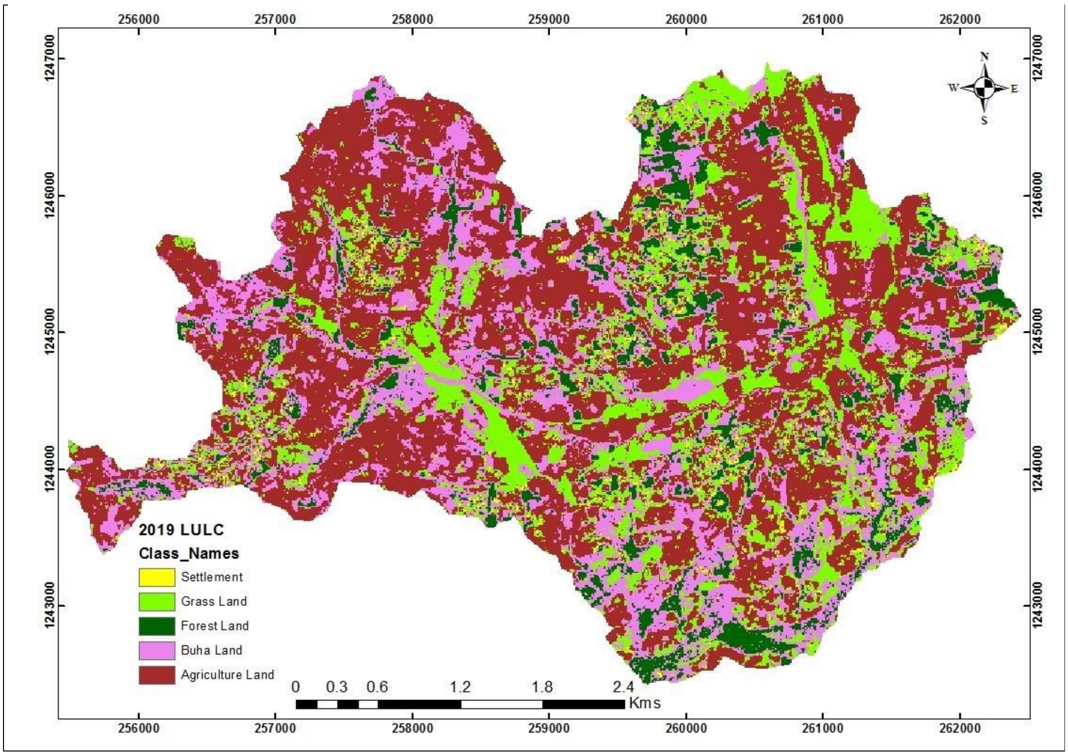

Figure 5: Land Use Land Cover map of 2019

Even if there is some decrement from the amount of 2002, the Agricultural land which covers 45.38 % of the landscape is the dominant class again in 2019. In contrast, the grassland increased to 19.01%. The forest coverage is increased to 8.48 % due to Rehabilitation and Plantation practices. Settlement which was not found on the previous classified images accounts 1.46 % in 2019.

Table 3: Results of the LULC classification for 1986, 2002 and 2019 images showing the area of each category and category percentages for Kility watershed

Land use class	1986		2002		2019	
	Area_ha	%	Area_ha	%	Area_ha	%
Grass Land	195.03	11.09	307.16	17.46	334.33	19.00
Agriculture	1288.59	73.25	1285.89	73.10	798.37	45.38
Bush Land	120.31	6.84	40.45	2.30	451.64	25.67
Forest	155.19	8.82	125.62	7.14	149.12	8.48
Settlement	-	-	-	-	25.66	1.46
Total	1759.12	100	1759.12	100	1759.12	100

4.1 Land Use Land Cover Change Scenarios

The LULC change scenario was developed for the change detection analysis to understand and quantify the trend of the land use land cover change from 1986 to 2002 and from 2002 to2019.

Table 4: Results of the LULC classification for 1986, 2002 and 2019 images showing the area changed and percentage at Kility watershed

LULC change	1986	2002	2019	2002 – 1986		2019 - 2002	
	Area_ha	Area_ha	Area_ha	Area_ha	%	Area_ha	%
Grass Land	195.03	307	334.33	112	57.44	45.84	14.93
Agriculture	1288.59	1286	798.37	-3	-0.23	-427.19	-33.22
Bush Land	120.31	40	451.64	-80	-66.67	325.52	813.80
Forest	155.19	126.26	149.12	-29	-18.71	32.62	25.89
Settlement	-	-	25.66	-	-	23.47	
Total	1759.12	1759.26	1759.12	0	100	0	100

The result over 1986 to 2002 has indicated that Bush and forest lands were decreased while grass land was increased. This was resulted from the deforestation for increased demand of trees for fuel wood and construction purposes and also the increasing of free grazing practice. The result from 2002 to 2019 also showed that an increasing of bush and Forest lands whereas, agriculture land has been declined. In other words, Agricultural land becomes changed in to Bush and Forest land uses system. This could be due to Rehabilitation of degraded areas by protecting free grazing practice and expansion of tree *plantation like Eucalyptus*. As a result, the spatial and temporal land use/land cover (LULC) in general and the Bush land coverage of the watershed in particular is changing.

4.2 Accuracy assessment

An accuracy assessment was done for Landsat-TM image classification (1986 and 2002 Land cover classification) and sentilel-2 image classification (2019 Land cover classification) using ground truth points collected during the field visit and Google Earth. Overall accuracy of 1986, 2002 and 2019 classification were 86.7%, 88.00% and 88.66%, respectively. As mentioned by Anderson *et al.* (1976) for a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be 85%. Therefore, the overall accuracies for the study period were above 85% based on Anderson's criteria. Similarly, Kappa coefficient was 0.77 which we believe is an acceptable accuracy. (Kappa coefficient >0.8: High accuracy, 0.4-0.8: Moderate accuracy, <0.4: Poor accuracy) (Congalton, 1999).

Table 5: Confusion Matrix for the LULC Map of 1986

	LULC class	Reference Data					
		Grass Land	Agricultur	Bush Land	Forest	Row Total	Users Accuracy
Classified Data	Grass Land	**12**	2	0	0	14	**85.71**
	Agriculture	0	15	1	0	16	**93.75**
	Bush Land	1	0	**16**	3	20	**80.00**
	Forest	1	0	0	**9**	10	**90.00**
	Column Total	14	17	17	12	60	
	Producers Accu.%	**85.71**	**88.24**	**94.12**	**75**		
	Overall Accu. %	**86.67%**					
	Kappacoefficient	0.82					

Table 6: Confusion Matrix for the LULC Map of 2002

Reference Data

	LULC Class	Forest	Bush land	Agriculture	Grass land	Row Total	Users Accu. %
Classified Data	Forest	**12**	0	0	2	14	85.71%
	Bush land	1	**6**	1	0	8	75.00%
	Agriculture	0	0	**13**	1	14	92.86%
	Grass land	1	0	0	**13**	14	92.86%
	Column Total	14	6	14	16	50	
	Producers Accu.%	85.71%	100.00%	92.86%	81.25%		
	Overall Accu. %	88.00%					
	Kappacoefficient	0.83					

Table 7: Confusion Matrix for the LULC Map of 2019

Classified Data	Forest Lan	Settlement	Buha Land	Grass Land	Agricultur	Row Total	Users Accu %
Forest Land	**19**	0	1	0	0	20	95.00%
Settlement	0	**9**	0	1	0	10	90.00%
Buha Land	1	1	**19**	1	0	22	86.36%
Grass Land	0	0	0	**20**	1	21	95.24%
Agriculture Lan	1	3	0	1	**19**	24	79.17%
Column Total	21	13	20	23	20	97	
Producers Accu.%	90.48%	69.23%	95.00%	86.96%	95.00%		
Overall Accu. %				88.66%			
Kappa coefficient			0.86				

4.3 Land Use/Land Cover Change: Trend, Rate and Magnitude

An important aspect of change detection is to determine what is actually changing to what i.e. which land use class is changing to which other classes. This information reveals both the changes (additions and reductions) and classes that are relatively stable overtime. This information will also serve as a vital tool in management decisions.

Table 8: Post-classification Matrix of Study Area between 1986 and 2002

2002		Forest	Bush land	Agriculture	Grass land	Grand Total
1986	Grass Land	9.24	5.76	57.87	122.16	195.03
	Agriculture	19.87	5.83	1160.88	102.01	1288.59
	Bush Land	14.46	16.34	30.82	58.69	120.31
	Forest	82.05	12.52	36.32	24.3	155.19
	Grand Total	125.62	40.45	1285.89	307.16	1759.12

Table 9: Post-classification Matrix of Study Area between 2002 and 2019

	2019						
		Forest Land	Bush Land	Agriculture Land	Grass Land	Settlement	Grand Total
2002	Forest	27.24	48.67	23.89	22.98	1.08	123.86
	Bush land	12.72	14.33	6.55	6.39	0.28	40.27
	Agriculture	85.22	308.13	673.99	190.29	20.04	1277.67
	Grass land	23.32	77.9	87.71	112.71	4.16	305.8
	Grand Total	148.5	449.03	792.14	332.37	25.56	1747.6

5. Conclusion and Recommendation

5.1 Conclusion

- From the remote sensing of image classification result, the watershed showed significant change in the LULC over the last three decades. The changes were largely caused by increased deforestation, free grazing, Rehabilitation or plantation.
- From the observed changes expansion of forest and Bush landcoveragecan be taken as something positive.
- In the first study period the study area was covered by four LULC categories namely Agricultural land, Grassland, Bush land and forest land.
- During the second study period the number of LULC typeshas increased to five categories namelyAgricultural land, Grass land, Bush land, Forest land and Settlement (new LULC class).
- From the observed changes Bush land are the most converted land use type during the entire study period andforest land increased by 8.48 % (149.12 ha)due to protecting free grazing and expansion of plantation through Rehabilitation of degraded areas practices.

5.2 Recommendations

Based on the findings of this study, the following recommendations are forwarded for policy implications and future research directions:

- The use of high-resolution imageries such as IKONOS and Quick Bird are important ingenerating good quality of LULC maps. Because it is difficult to map small parcels of LULC like Settlement areas in 1986 and 2002 study periods and high-resolution imagery provide better information by mapping these areas. Therefore, for future studies it is better to use high resolution images to fill such kind of gaps.
- Although rehabilitation of degraded areas has being practiced, free grazing and deforestation were the major factors for LULC changes during the first period, therefore, different mitigation measures should be implemented to use the resources of the area sustainably.

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