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Research Article

Geospatial Technologies Based Land Use and Land Cover Dynamics Characterization in the Central Rift Valley, Ethiopia

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ABSTRACT

Land use land cover change is a major issue in the global environmental change, particularly in developing countries. Ethiopia is one of the Sub-Saharan African countries where such practices have been very common compromising the environmental health. Particularly, in the Central Rift Valley of Ethiopia, in the last decades there has been unprecedented change in land use land cover. The study aimed at analyzing the land use and land cover dynamics, in the Central Rift Valley, Zeway Dugda and Dodota districts, Ethiopia. The analysis covered three-decade (1984- 2013) datasets of Multispectral Scanner System (MSS), Thematic Mapper (TM), and Enhanced Thematic mapper (ETM+) for the year, 1984, 1995, and 2013 respectively. The databases were obtained from United States Geological Survey (USGS), Center for Earth Observation Resources Science (EROS) available free of charge from http://glovis.usgs.gov/ and the Ethiopian Geospatial Information Institute. Geographical Information System (GIS) and Remote Sensing (RS) technologies were used to classify the images analyze the magnitude, and trend of land use land cover (LULC) dynamics over the study period. An object-oriented supervised classification method and a post-classification change detection technique were applied for categorizing the changes into a definite land use land cover class. The analysis revealed six LULC types, where farmlands and built-up areas have shown continuous progressive expansion at the expenses of barelands and forestlands. Farmlands and built-up areas in 1984 expanded from 33.3%and 2.6% to 40.6% and 8.2% in 2013, while forestlands and barelands coverage in 1984 dwindled from 11.7%, 17.7%, to 4.2% and 10.1% in the year 2013 respectively. Comparatively, shrublands and waterbodies were also slightly augmented by 1.9% and 0.2% from 1984 to 2013. In a nutshell, the study realized that there has been a considerable land use land cover change occurred in the course of the study period in the study area.

Keywords: Land use and land cover, Change detection, Geographical Information System, Remote Sensing, Landsat images.

INTRODUCTION

Land use land cover (LULC) change has become a concern of the twenty first century due to its dramatic implication for human survival, driving force for global environmental change and impacting peoples livelihoods (Codjoe, 2007; Elias et al., 2019; Fan et al., 2007; Foley et al., 2010; Mustard et al., 2004; Olson et al., 2008; Verburg et al., 2015). Conceptually, land cover refers to the observed biophysical cover of the earth's surface, while land use reflects man's activities on the land with their intentions (FAO, 2016; Lambin & Geist, 2006; Prakasam, 2010). The modification of Earth's terrestrial surface by human activities is commonly known as LULC change (Ellis, 2007; Hassan et al., 2016; Meyer and Turner, 1992).

Changes in land use have occurred at all times in the past, present, and are likely to continue in the future (Lambin et al., 2003; Reid et al., 2000). Over the last decades, the view of land

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use land cover change in Africa has been reappraised. For much of the last century, environmental degradation linearly increased with population density (Bassett and Zuéli, 2010). Consequently, concerns about LULC change emerged in the research agenda on global environmental change (Lambin et al., 2003). Recently, LULC changes have attracted the interest of a wide variety of researchers dealing with modeling the spatial and temporal patterns of land conversion and understanding the causes and effects of these changes (Bürgi et al., 2004; Irwin and Geoghegan, 2001).

LULC change resulted in environmental repercussion both at micro and macro levels. It is the greatest environmental concern for human beings to date (Bewket & Abebe, 2013; Minale, 2013). The change affects: biodiversity, climate, soil, and air in particular, and the ecosystem in general (Hailemariam et al., 2016; Long et al., 2007; Schmidt et al., 2001; Tsegaye et al., 2010) and it is regarded as a primary source of global environmental change such as emission of greenhouse gases, global climate change, loss of biodiversity, and loss of soil resources (Li et al., 2016).

Studies have shown that significant land use land cover change (LULCC) have occurred in Ethiopia (e.g. Tsegaye, 2010; Shiferaw, 2011; Meshesha, 2016; Hailemariam et al., 2016; Tolosa, 2018; Gashu and Gebre-Egziabher, 2018). The rate of change irrespective of the efforts made by different stakeholders on conservation actions has been accelerated in the last three four decades (Hailemariam et al., 2016). In Ethiopia, over the last decades, land use land cover change has been taking place at unprecedented rate. As a result, many land forms have been transformed. Absence of a proper land use plan in the country in general and in the study area in particular contributed to the escalation of the problem. In connection to this, (Morton, 2007; Thornton et al., 2006) noted that many of the localities that are found in the Ethiopian Central Rift Valley are highly susceptible for climate variability induced droughts and irregularities in distribution of precipitation. Supporting this, Jansen et al., (2007) indicated that the Ethiopian Central Rift Valley is among the environmentally vulnerable area which resulted from degradation of natural resources. This indicated that erratic nature of precipitation and frequent drought in the area contributed for the accelerated rate of land use land cover change.

The Ethiopian Central Rift Valley (CRV), which is part of the Great East Africa Rift Valley System, is an important region in terms of its extensive ecosystem services and rich biodiversity. However, as researches revealed that in the last series of years, it has been increasingly highly prone for rapid land use land cover change. Not only that, it is also under terrific pressure from fast population growth, unsustainable developmental activities, unplanned urbanization, aggressive agricultural expansion, climate change, vulnerability to drought and the associated changes in land use and land cover (Elias et al., 2019). Therefore, understanding the temporal and spatial dynamics of LULC change at local and regional levels is vital to synthesize knowledge on the relationship between humans and their environment (Lambin et al., 2003; Verburg et al., 2015). In addition, it also helps to develop a sustainable land management system, analyze land-use related policies, and understand the earth as a system (Mottet et al., 2006; Nagarajan & Poongothai, 2011).

Even though detail and extensive land use land cover change study is essential for all Ethiopian Central Rift Valley areas. As far as my knowledge is concerned limited in-depth researches have been conducted. Hence, it is pertinent to carry out this study because it would be beneficial to show explicitly to the scientific community and policy makers the trend of change both in space and time, and most importantly it would give a clear picture to the local officials and concerned authorities over the existing LULC change. To this end, this research was initiated to analyze and quantify the land use land cover change, in the Central Rift Valley, Zeway Dudga and Dodota districts, Ethiopia.

MATERIALS AND METHODS

Description of the study area

The Ethiopia Rift Valley is part of the Great East African Rift Valley System, consists of three main parts: the northern, southern, and central (Abera et al., 2019). This study was conducted in the Central Rift Valley system which encompasses two districts: Zeway Dugda and Dodota, found in Oromia region, Ethiopia. Geographically, the study area is located between 7°27'00"N-8°00'34"N Latitude and 38°45'00"E-39°03'13"E Longitude covering a total area of 1247 km2 (Fig. 1)

Figure 1: Study area map.

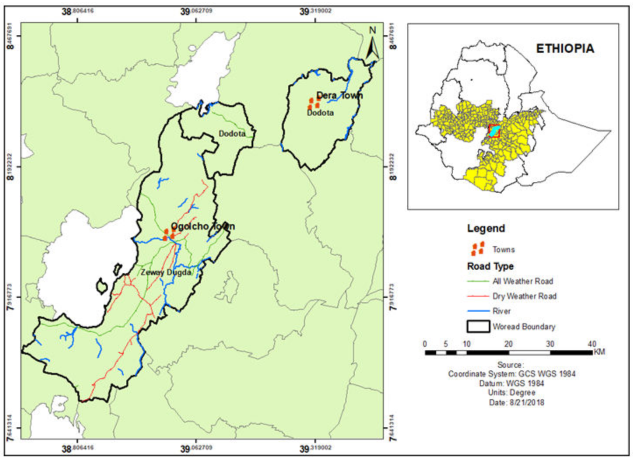


Image Acquisition and pre-classification processes

To ensure maximum detection, relatively cloud-free dry months i.e. December and January imageries were used. This helps to minimize classification discrepancies among the land use classes which would be caused by difference in season (Kindu et al., 2013). Once all the required images were downloaded, they passed through various image preprocessing stages. The images were stacked, mosaicked, and various image enhancement techniques (spatial, spectral and radiometric) were applied using both ArcGIS 10.5 and ERDAS imagine 14. This was done to increase the clarity and visual interpretability of the images, to remove haze, and reduce noise.

Data Analysis

After pre-processing, each satellite image has been classified accurately into the desired land use land cover classes and a change detection technique was applied to show the change between the different sets of images. Object-based supervised classification with the Maximum Likelihood Classifier (MLC) was employed to classify the image into six land use classes (Chen et al., 2012; Hussain et al., 2013). This was done using post classification image comparison algorithm to determine the changes in land cover in different intervals, in this case ten years intervals was employed (Abera et al., 2019; Gebreslassie, 2014; Lillesand et al., 2015; Yuan et al., 2005). The classified images were compared in three periods, i.e., 1984-1995, 1995-2013, and 1984-2013 and detailed change detection statistics were computed by comparing the analysis output of each image values of one dataset with the corresponding value of the second data set of each period.

The rate of change within the same LULC class and between two time points were calculated and presented in hectares (ha) and percentages (%) using the following equation (Eq.1):

$$\text{Change \%} = \frac{A_{rt} - A_{pt}}{A_{pt}} * 100 \qquad (1)$$

Where: Change (%): percent change in the area of specific land use land cover class between times i_n and i_{n-1} A_{rt}: is a recent year of LULC at time t and A_{pt}: is the previous area of LULC at earlier time t.

ERDAS imagine version 14 and ArcGIS 10.5 software were used to perform the land use land cover classification, to calculate the statistical analysis, and mapping the land use land cover changes. In relation to this, as noted by (Herold et al., 2003) both Remote Sensing (RS) and Geographic Information Systems (GIS) have been widely applied and recognized as powerful and effective tools in detecting the spatio-temporal dynamics of land use and land cover (LULC). In the same vein, RS can provide researchers with valuable multi-temporal data for monitoring land-use patterns and processes (Lambin et al., 2001), whereas GIS techniques make possible the analysis and mapping of these patterns (Zhang et al., 2019). Therefore, as shown in figure 2 below, different procedure and stapes were used in this analysis.

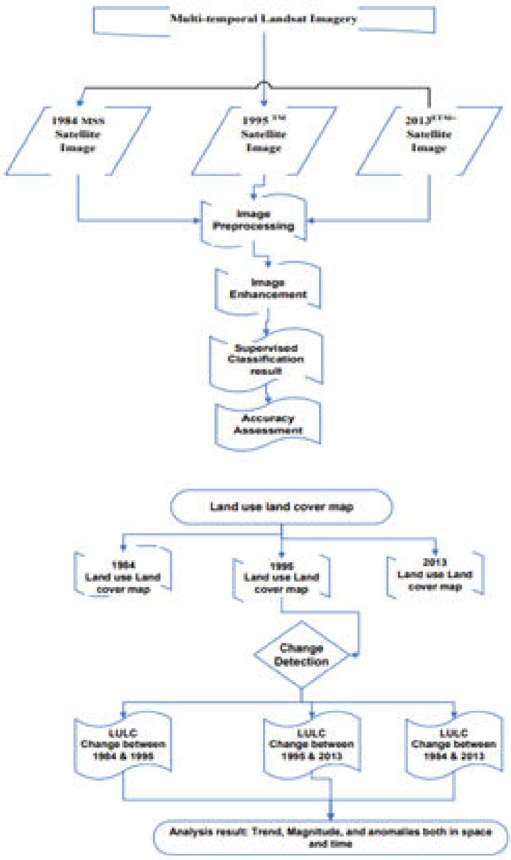


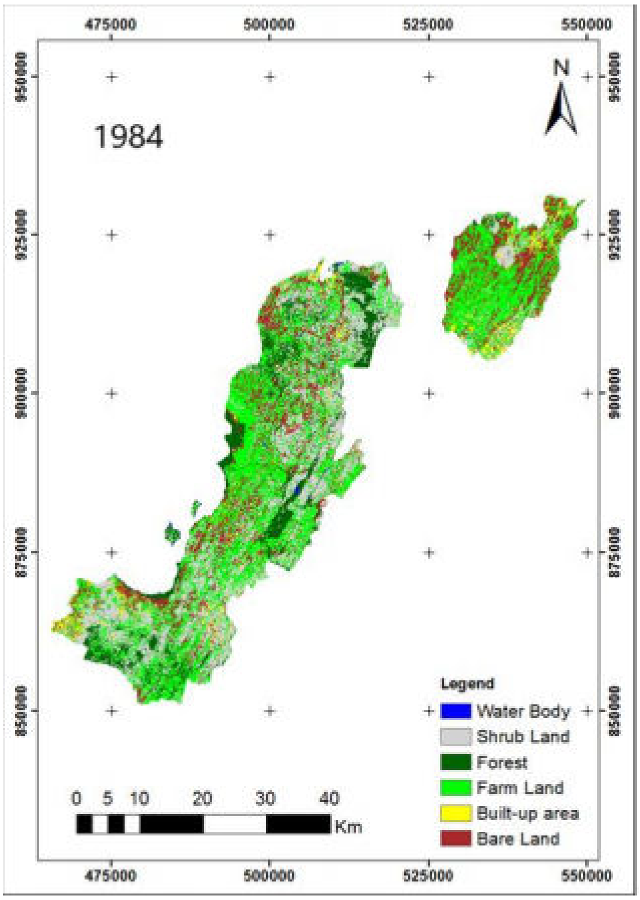
Figure 2: Analytical framework to understand the land use land cover change classification.

RESULT AND DISCUSSION

Land Use Land Cover classification of 1984

The satellite image of the year 1984 was classified into six land use land cover classes, namely: barelands, built-up areas, farmlands, forests, shrublands, and waterbody. As shown in table 1 and figure 2, the dominant LULC were: shrublands, farmlands, and barelands which accounts for 56170.9ha, 54485.8ha and 28970.0ha respectively. On the other hand, built-up areas 4205.6ha, forestlands 19123.9ha, and waterbodies 434.8ha consecutively occupied the remaining.

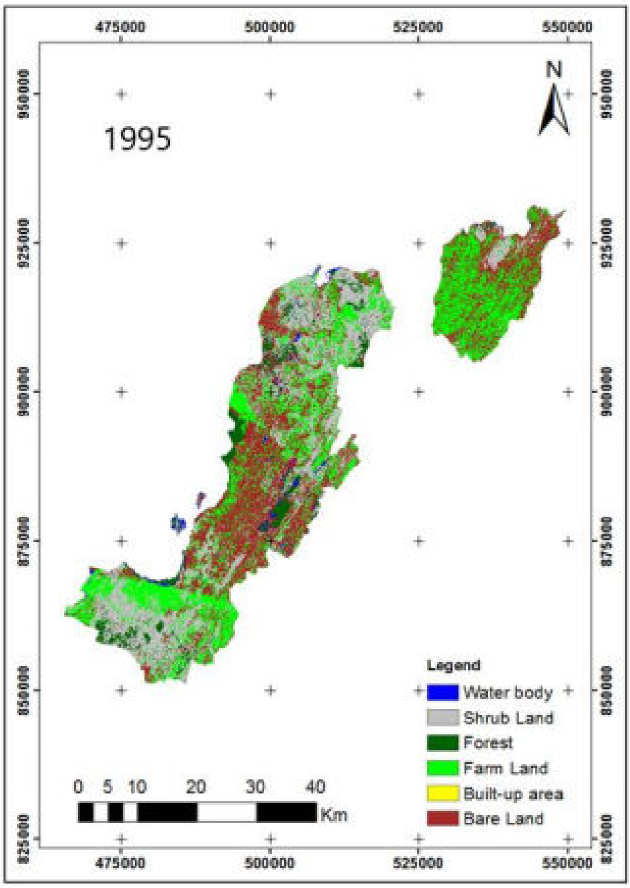
Figure 3: Land use land cover classification map for 1984.



Land Use Land Cover Classification of 1995

Classification of year 1995 satellite image resulted in six land use and land cover classes. As shown in table 2 and figure 3, farmland 51262.8ha, shrub-land 47039.2ha, and built-up area 25168.7ha are dominant LULC classes. Similar to the previous year, the smallest LULC class was waterbody which constituted 2102.6ha.

Figure 4: Land use land cover classification map of 1995.



Comparison between 1984 and 1995 Land Use Land Cover Classes

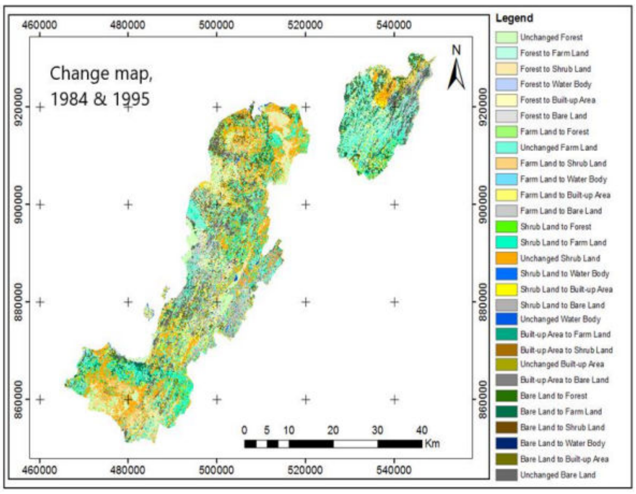
The land use conversion matrix in table 3, indicated that the land use/cover change of the study period between 1984 and 1995. The highlighted diagonal values are the unchanged values of each land use class. The change detection matrix result on table 3 and figure 4 stipulated that, compared to 1984, the proportion of forest and shrubland were reduced considerably in 1995. Of the total land use, forest 6992.1ha and shrubland 16002ha were transformed into shrubland and farmland respectively. This implied that both land use classes undergone a series of changes in ten years' period. The size of forest coverage has reduced by 9059.8ha and at the same time shrubland dropped by 9145.6ha. Conversely, the built-up land use class significantly increased from 4205.6ha in 1984 to 20941.5ha in 1995, of which 1364.6ha forest, 10052ha farmland, 6681.9ha shrublands, and 6303.7ha barelands were transformed to built-up areas. Water bodies were also increased at 1628.0ha. In connection to this, (Hassan et al., 2016) in its report indicated that the intensity and rate of LULC change far greater now than were in the past.

In the initial year, the waterbody coverage was 434.8ha, however, in the course of time, it was ramped up to 2062.8ha with an increase of 1628ha. Land cover/use that were changed into the waterbody were 891.8ha of forest, 265.6ha farmland and 383.9ha of shrubland. On the other hand, other land use types such as bareland declined by 1113.7ha and farmland also attenuated by 3250.6ha.

Table 4: Change Detection Matrix for 1984 and 1995 land use classes.

Change Detection Matrix result of 1984 and 1995															
Year	Land Use Land Cover class for 1995														
Land Use Land Cover class for 1984	LU/LC Type	Forest		Farm Land		Shrub Land		Water Body		Built-up area		Bare Land		Class Total	
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	**Area (ha)**	%
	Forest	9235.7	5.7	166.9	0.1	6992.1	4.3	891.8	0.5	1364.6	0.8	472.8	0.3	19123.9	11.7
	Farm Land	339.6	0.2	24195.0	14.8	10262.7	6.3	265.6	0.2	10052.0	6.2	9370.9	5.7	54485.8	33.3
	Shrub Land	321.7	0.2	16002.0	9.8	25710.3	15.7	383.9	0.2	6681.9	4.1	7071.0	4.3	56170.9	34.4
	Water Body	31.4	0.0	6.1	0.0	44.5	0.0	301.0	0.2	28.4	0.0	23.5	0.0	434.8	0.3
	Built-up area	0.5	0.0	1992.5	1.2	561.2	0.3	19.6	0.0	716.6	0.4	915.2	0.6	4205.6	2.6
	Bare Land	135.2	0.1	8872.7	5.4	3454.6	2.1	201.1	0.1	6303.7	3.9	10002.9	6.1	28970.0	17.7
	Class Total	10064.1	6.2	51235.2	31.4	47025.3	28.8	2062.8	1.3	25147.1	15.4	27856.3	17.0	163391	100
	Image Difference	-9059.8	-5.5	-3250.6	-2.0	-9145.6	5.6	1628.0	1.0	20941.5	12.8	-1113.7	-0.7		

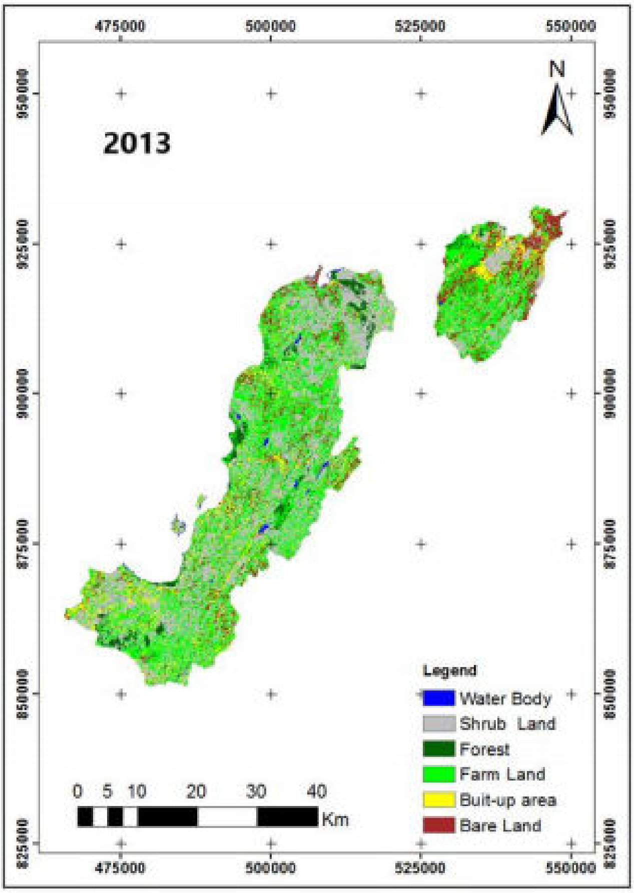
Figure 5: Change Map of the study area b/n 1984 and 1995.



Land Use Land Cover of 2013

Satellite image of the year 2013 was also classified into six land use and land cover classes. In this classification, the result demonstrated that water body was the least coverage, which was 890.9ha, while farmland and shrub land constituted the largest proportion, 66247.4ha and 59264.2ha respectively. Nevertheless, significant negative change was observed in the built-up land use class which was reduced by half.

Figure 6: Land use land cover classification for 2013.

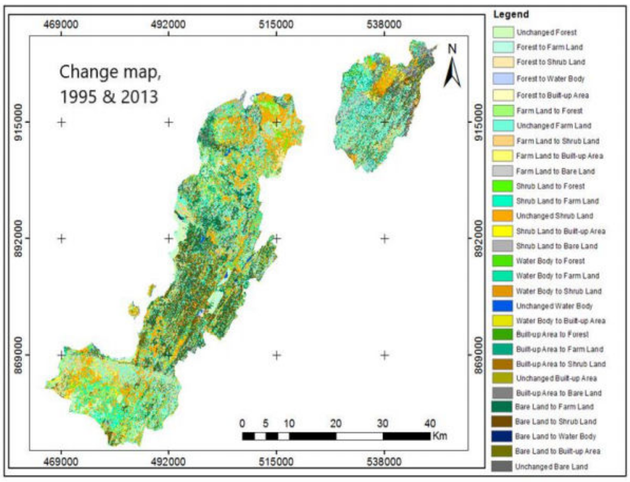


As the change detection matrix illustrated under table 4, Bareland, Built-up area, Forest, and Waterbody undergone through negative change. Shrubland and Farmland were significantly increased. The Bareland and Built-up area were reduced by 11286.7ha and 7680.2ha respectively between the year 1995 and 2013. At the same time, forest and waterbody also declined by 3878.4ha and 1240.8ha successively. A large portion of forest, 2868.7ha, 2408.2ha and 602.2ha were transformed to Farmland, Shrubland and Built-up area. Shrubland increased by 7125.5ha and farmland by 16960.5ha.

Table 6: Change Detection Matrix of 1995 and 2013.

Year	Change Detection Matrix, 1995 and 2013 in (Ha & %)Land Use Land Cover class for 2013														
Land Use Land Cover class for 1995	LULC Type	Forest		Farm Land		Shrub Land		Water Body		Built-up area		Bare Land		Class Total	
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (ha)	%
	Forest	3976.4	2.4	2868.7	1.7	2408.2	1.5	160.2	0.1	602.2	0.4	36.9	0	10052.5	6.1
	Farm Land	285.6	0.2	25600	15.6	12913.6	7.9	39.6	0	5479.3	3.3	6944.7	4.2	51262.8	31.3
	Shrub Land	1454.7	0.9	14741.9	9	23898.3	14.6	60.1	0	4896.7	3	1987.4	1.2	47039.2	28.7
	Water Body	119.1	0.1	711.1	0.4	574.3	0.4	437	0.3	218.4	0.1	42.6	0	2102.6	1.3
	Built-up area	262.2	0.2	11708	7.1	6851.4	4.2	75.1	0	3329.2	2	2942.8	1.8	25168.7	15.4
	Bare Land	76.1	0	12593.5	7.7	7519	4.6	89.7	0.1	2962.7	1.8	4609.8	2.8	27850.9	17
	Class Total	6174.1	3.8	68223.2	41.6	54164.8	33	861.8	0.5	17488.6	10.7	16564.2	10.1	163477	100
	Image Difference	-3878.4	-2.4	16960.5	10.3	7125.5	4.3	-1240.8	-0.8	-7680.2	-4.7	-11287	-6.9		

Figure 7: Change Map of the study area between 1995 and 2013.



Comparison between 1984 and 2013 Land Use Classes

This section tried to interpret the change detection matrix result obtained between the year 1984 and 2013 as shown in the change detection matrix under table 5.

Forest Coverage

The 1984 LULC classification result portrayed that the total forest coverage was 19140.4ha, however, this was reduced to 6882.1ha in the year 2013, i.e. the forest cover declined by 12258.4ha. The change detection matrix (Table 5) exhibited that most of the forest lands were converted to Shrublands 6791.3ha, farm-lands 5621.9ha, and Built-up areas 696.7ha. The findings of the study are consistent with the work of (Dessie & Kleman, 2007) which demonstrated that the natural forest cover in the Central Rift Valley area significantly declined from 16% in 1972 to 2.8% in 2000. The cause for the large devastation of forest in the area related to deforestation through cutting of acacia trees for charcoal production has also become a common phenomenon as it is an easy cash source for some farmers (Muzein, 2006) drawn in the work of (Elias et al., 2019).

Farmland

The area of land that was occupied by farm-land in 1984 was 54430.2ha and it rose to 66247.4ha in 2013. In general, farmlands augmented by 11817.2ha, where it was gained from shrubland, 20341.6 ha, bareland, 13297.4ha, and forestland, 5621.9ha over the three decades.

Shrubland

On the first decade of the study period, this land use/cover category covered a total area of 56088.6ha, eventually increased to 59264.2ha, i.e., from 34.3% in 1984 to 36.3% in 2013. Shrub- land expanded in the expense of farmland, forest, and bareland where each attributed, 16970.3ha, 6791.3ha and 6515.8ha respectively.

Water Body

The change detection algorithm of the year 1984 image analysis revealed that in 1984 waterbody occupied 431.8ha and it slightly increased to 890.9ha in 2013. The magnitude of waterbody increased at 459.1ha in the last three decades. This is due to construction of water harvesting structures like ponds and micro dams in the study area.

Built-up Area

The classification output of built-up area was 4211.9ha in 1984 and it increased to 13419.3ha in 2013. The built-up LULC was augmented by 9207.4ha in the last three decades. Except the water body land use all other land use types contributed for the increase of built-up area. About 5357.3ha of farm-land, 3690.1ha of shrubland, 2768.2ha of bareland, and 696.7ha of forest have been converted to built-up area (see table 5).

Bare Land

The change detection matrix result has shown on table 5, the proportion of bareland was greatly reduced by 11286.7ha. In this respect, 13297.4ha, 6515.8ha and 2768.2ha of the bareland was altered to farmland, shrubland and built-up area respectively.

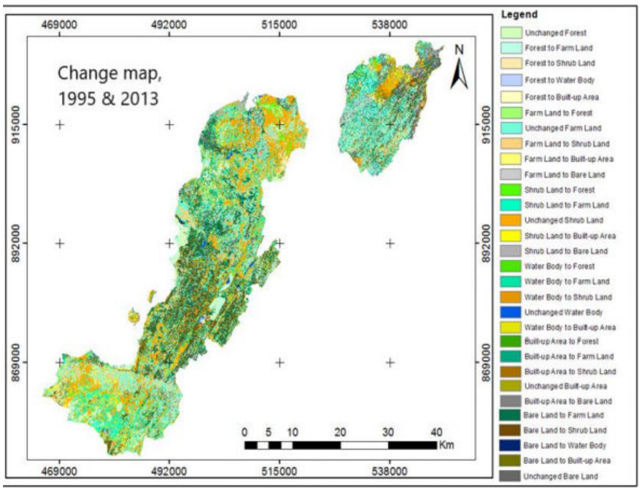
Table 7: Change Detection Matrix of 1984 and 2013.

	Change Detection Matrix, 1984 and 2013 in (Ha & %)
Year	Land Use Land Cover class for 2013
Land Use class of 1984	LULC Type

	[illegible]
Forest	[illegible]
Farm Land	[illegible]
Shrub Land	[illegible]
Water Body	[illegible]
Built-up area	[illegible]
Bare Land	[illegible]
Class Total	[illegible]

Image Difference

Figure 8: Change Map of the study area between 1984 and 2013.



CONCLUSION

The study has shown the prominence of GIS and Remote sensing technologies in obtaining, pre- processing, interpretation, and analyzing the dynamics of LULC change across time in the study area. The study signposted that a considerable LULC change has occurred over the last three decades (1984-2013) in the Central Rift Valley, Zeway Dugda and Dodota districts, Oromia Region, Ethiopia. Significant positive trends were observed in the Built-up and Farmland land use classes, while substantial reduction occurred in the Forest and Barelands. As the forest coverage demeaning, there was a high risk for land degradation that would in turn impart an adverse effect on the eco-services and micro-climate of the area. This eventually has an impact on the livelihood sources of the local community. Therefore, the study suggested that priority has to be given by concerned jurisdiction in taking ameliorative measures in changing the traditional practices through the rational utilization of environmental resources in eco-friendly manner.

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