Application of GIS for Calculate Normalize Difference Vegetation Index (NDVI) using LANDSAT MSS, TM, ETM+ and OLI_TIRS in Kilite Awulalo, Tigray State, Ethiopia

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Abstract
The Normalized Difference Vegetation Index (NDVI), estimating and measures the amount of vegetation cover and changing green vegetation. NDVI, a ratio (reflectance difference) of the near infrared (NIR) wavelength band and the visible red band, identifies the "greenness" of vegetation, making it a useful tool to highlight vegetation cover density. To do this, the aims of the study are to examine the application of GIS for the amount of vegetation cover and changing green vegetation. For this study, three LANDSAT images covering over a period 1984 (Landsat-5 TM); 2000 (Landsat-7 ETM+) and 2014 (Landsat-8 OLI_TIRS) was used and analyzed using Arc GIS 10.1. Preprocessing stages including radiance and radiometric corrections were conducted, and NDVI of those images were derived. The result shows that the value of NDVI for image 1984 (TM), the NDVI value fluctuated from –0.508629 to +0.756483, for image 2000 (ETM+) the derived values varies from -0.972671 to + 0.999338 and for image 2014 (OLI_TIRS) values varies from -0.381363 to + 0.886275. From this we can understand that there is a significant change between vegetated and non-vegetated land from year 1984, year 2000 and year 2014.
Keywords: Landsat, Remote Sensing, Vegetation Index, NDVI.

1. INTRODUCTION

Ethiopia is one of the most well endowed countries in Sub-Saharan Africa in terms of natural resources including fauna and flora (Gete et al., 2006). About 50 percent of Ethiopia can be defined as mountainous, be it because of altitude above about 1500m, or because of steep slopes. The country's highland areas comprise about 90% of its arable lands and are occupied by 90 percent of the human population and 60 percent of all livestock. The mountains of Ethiopia offer excellent conditions for natural diversity and human development. Since then population has expanded all over the highland parts of Ethiopia as they are very suitable places for living and agriculture than the malaria - infected harsh lowland areas surrounding the highlands (Gete, 2010).

However, the country faces different problems in relation to natural resource management. From this, land cover change is one of the most serious environmental problems. According to Eric et al. (2003), summarizing a large number of case studies, and find that land-use change is driven by a combination of resource scarcity; changing opportunities created by markets; outside policy intervention; loss of adaptive capacity and increased vulnerability; and finally changes in social organization, in resource access, and in attitudes.

In the Ethiopian case, serious environmental problems are associated with the overwhelming proportion of the Ethiopian population lives in rural areas (85%) and about 90% lives in the Ethiopian highlands and directly depends on subsistence agriculture which is entirely dependent on natural resources (Gete, 2010). Therefore, in the country Land use and cover changes have been particularly dynamic in the 20th Century. This is due to increasing population, expansion of the agricultural sector and climatic change (Haile and Assefa, 2012). On the other hand Amare (2013)**,** explain as rapid population growth and the low economic standard of living in Ethiopia have brought in their awake numerous consequences to land cover and use changes; change in climate and hydrological status in the country. In addition to this land tenure policy changes since 1975 are also contributed for the dynamic change of LULC (Gete, 2010).

GIS is a computer based system that deals with spatial data collection, storage, management, retrieval, conversion/changing, analysis, modelling, and it provided the potential for mapping and monitoring the spatial extent of the built environment and the associated land use/ land cover change.

The acquisition, processing, integration, visualization and utilisation of various kinds of airborne or satellite derived data constitute several important problems, in the context of time limitations with respect to accessibility of sensors, the atmosphere influence (clouds presence, need for atmospheric corrections of measured radiance), insufficient spatial resolution, imperfection of models for the desired parameters derivation, etc (Dash, 2005). Therefore, an attempt was made in the study to examine the application of GIS for Calculate Normalize Difference Vegetation Index (NDVI) using Landsat that is taken place connecting from the year 1984 to 2014.

OBJECTIVES OF THE STUDY

Main (General) objective of the study

The main objective of this study is to examine the application of GIS and Remote Sensing for Calculate Normalize Difference Vegetation Index (NDVI) in Kilite Awulalo Woreda, Eastern Tigray Zone for the year of 1984, 2000 and 2014. The specific objectives of this study are to: Calculating and mapping of Normalize Difference Vegetation Index using satellite image; and analyze the NDVI changes between 1984 and 2000 and 2000 and 2014

2. SITE DESCRIPTION (LOCATION)

The study area is located in Tigray region; north part of Ethiopia within the geographical grid coordinates of 13°33'37.618"N to 13°57'29.447"N latitude and 39°18'8.606"E - 39°41'44.647"E longitude.

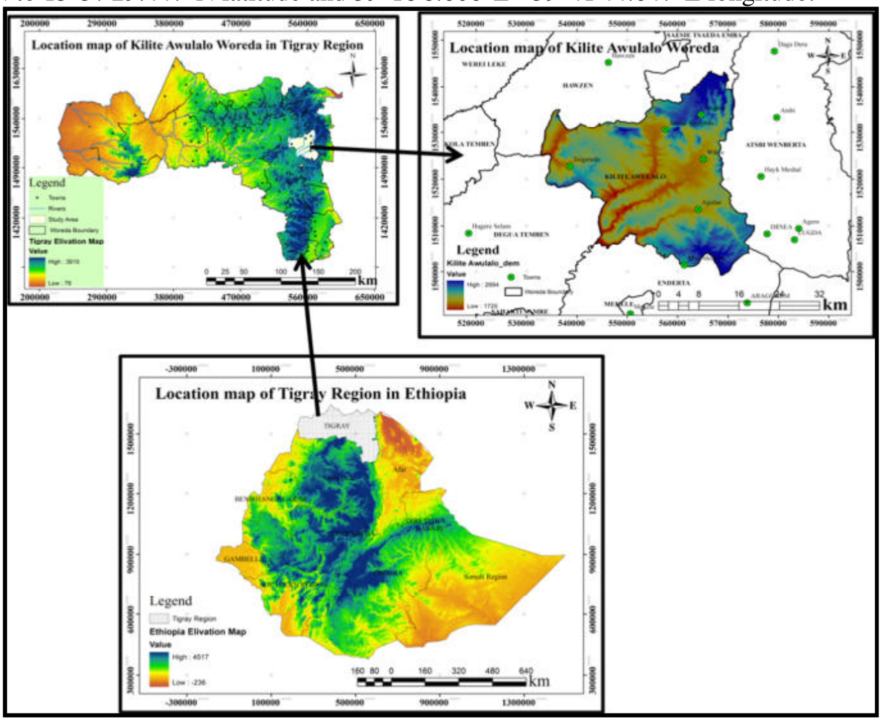

Figure 1: Location map of Kilite Awulalo Woreda

Topography

The digital elevation model (DEM) of area varies from 1750m a.s.l at the western and central part and to 2694m a.s.l at north eastern and south eastern part of the area.

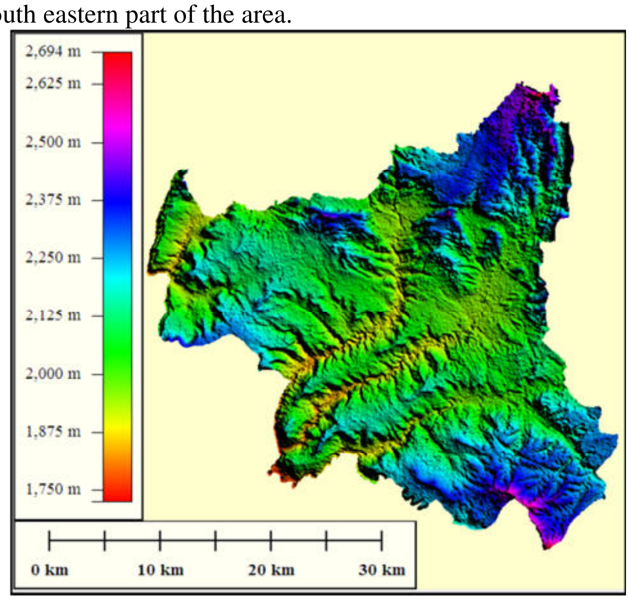

Figure 2: Elevation map of Kilite Awulalo Woreda

3. MATERIALS AND METHODS

Table 1: Source and Satellite Images data collection processing

Satellite/ Spacecraft_ID	Sensor ID	Path/row	Date of acquisition	Spatial resolution/ Grid Cell Size (m)	Sun Elevation	Cloud Cover
Landsat-5	TM	169/050	1984-11-22	30m	46.140000	-1
Landsat-7	ETM+	168/050	2000-02-05	30m	47.3496421	0
		168/051	2000-02-05	30m	48.1988543	0
		169/050	2000-01-27	30m	45.8008678	0
Landsat-8	OLI_TIRS	168/50	2014-03-07	30m	56.46464264	0.60
		168/51	2014-03-23	30m	61.10639256	3.90
		169/50	2014-03-30	30m	62.39484780	0.48

Software Used

Certain parameters/algorithms of the following software would be used for the processing and/or analysis of data/images.

- **a)** Arc GIS 10.1: NDVI classification (-1 to +1)
- **b)** Quantum GIS 2.6 for changing DN values to reflectance

Satellite Images data collection Processing

In order to study NDVI of the study area, three LANDSAT satellite imagery covering the period 1984, 2000 and 2014 images were used.

Formula to be used for Vegetation index

Vegetation cover can be estimated using vegetation indices derived from satellite images. Vegetation indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The Normalized Difference Vegetation Index (NDVI), one of the vegetation indices, estimating and measures the amount of changing green vegetation.

The NDVI values vary according to the radiation absorption by the chlorophyll in the red spectral area and its reflectance in the near infra red spectrum. These values are between -1 and +1, corresponding to the consistency of the green vegetation. The ones close to +1 represent a higher consistency of the vegetation and are specific to the dense broadleaf forest. The ones close to -1 represent the land with lack of vegetation, having visible soil or rock surface. The 0 value (intermediate color) is associated with grass lands. It is useful in mapping of vegetation areas, vegetation types, vegetation health status, the land use etc.

The formula for calculating this index is:

NDVI, a ratio (reflectance difference) of the near infrared (NIR) wavelength band and the visible red band, identifies the "greenness" of vegetation, making it a useful tool to highlight vegetation cover density.

$$\mathbf{NDVI} = \frac{(\boldsymbol{NIR}-\boldsymbol{R})}{(\boldsymbol{NIR}+\boldsymbol{R})} \quad \textbf{1}$$

Where

- ⊕ NIR: A reflectance in the **near infrared band** ***($4^{th}/5^{th}$ band image)***
- ⊕ R: A reflectance in **red band** ***($3^{rd}/4^{th}$ band image)***

Therefore, ***for landsat sensor TM*** and ***ETM+*** the formula can be writing as follows

$$\mathbf{NDVI} = \frac{\mathbf{Band4\ (NIR)}-\mathbf{Band3(R)}}{\mathbf{Band4\ (NIR)}+\mathbf{Band3(R)}} \quad \textbf{2}$$

Whereas ***for landsat sensor OLI_TIRS (Landsat – 8)*** the formula can be writing as follows

$$\mathbf{NDVI} = \frac{\mathbf{Band5\ (NIR)}-\mathbf{Band4(R)}}{\mathbf{Band5\ (NIR)}+\mathbf{Band4(R)}} \quad \textbf{3}$$

4. RESULTS AND DISCUSSION

4.1. Land Use Land Cover Classification

The LULC classification for 1984 from TM satellite image (fig. 3 on graph) showed that the greatest share of LULC from all classes is bush land - 47900.79 ha (47.26 %). Forest land and agriculture land cover an aerial size of 21706.65 ha (21.42 %) and 20856.78 ha (20.58%) respectively. The LULC classification for 2000 from ETM+ satellite image (fig. 3 on graph) showed that even though bush land is declined from 1972 to 1984 to 2000, the greatest share of LULC from all classes is still bush land, which covers an area of 45000.10ha (44.402371%). Forest land and agriculture land cover an aerial size of 12065.70 ha (11.905414%) and 23000.09

ha (22.694594%). The LULC classification for 2014 from OLI_IRS satellite image (fig. 3 on graph) showed that majority of the study area was still covered by bush land 40573.53 hectares (ha), contributes 40.03% of the total area. Forest land and agriculture land cover an aerial size of 11916.4 ha (11.76 %) and 30402.27 ha (30 %) respectively.

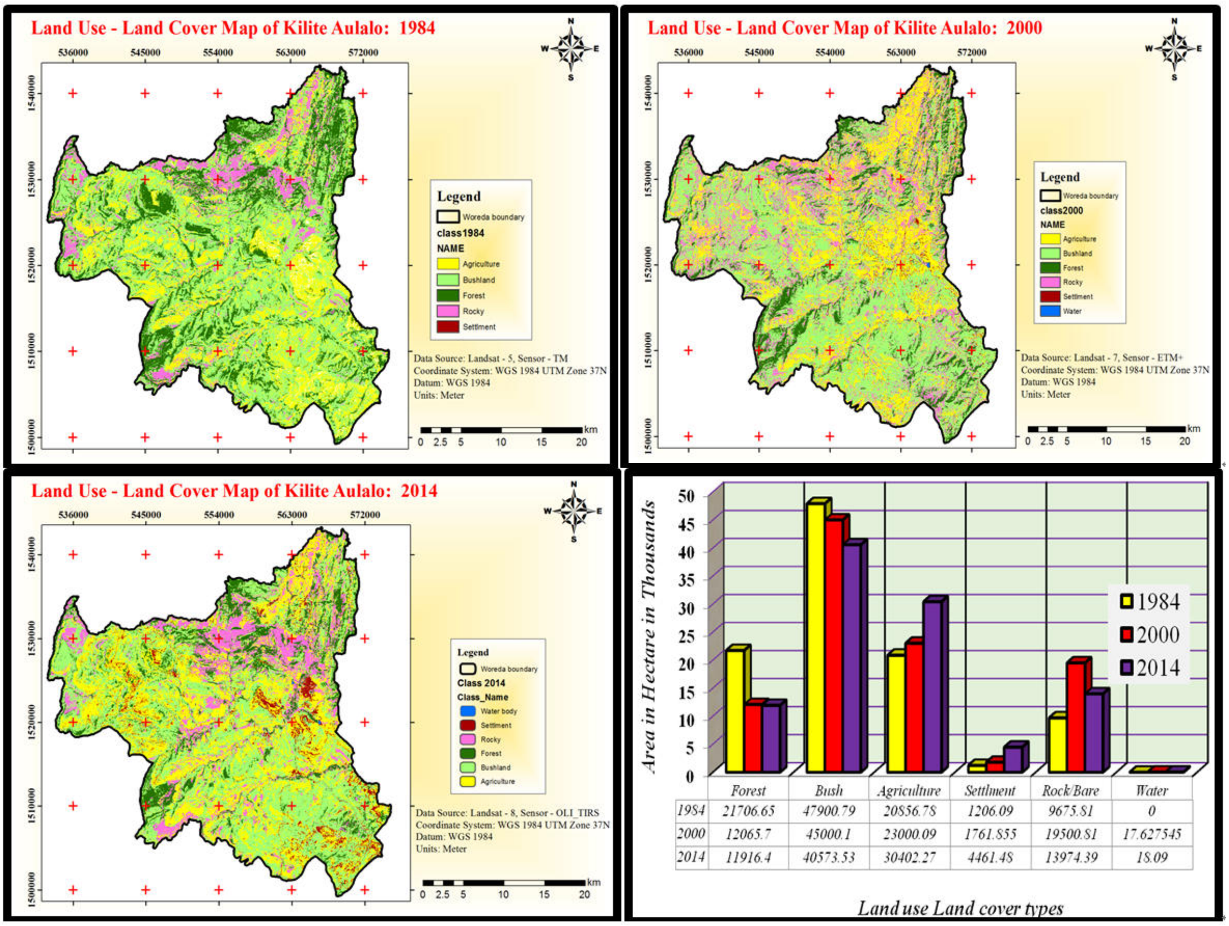

Figure 3: Land use and land cover map of the Kilite Awulalo in 1984, 2000 and 2014

4.2. Normalize Difference Vegetation Index (NDVI) Analysis

Generally, the value of NDVI is divided into non-vegetated land and vegetated land. As mentioned before about the value of NDVI, the negative values and zero value represent non-vegetated land while positive values represent vegetated land. Figure 3 illustrates the continuous images of NDVI results to display the distribution of NDVI values, and from their legends, the distribution of vegetated land and non-vegetated land are also shown. As indicating in figure 4 for image 1984 (TM) shows that, the NDVI value fluctuated from –0.508629 to +0.756483, for image 2000 (ETM+) the derived values varies from -0.972671 to + 0.999338 and for image 2014 (OLI_TIRS) values varies from -0.381363 to + 0.886275. From this we can understand that there is a significant change between vegetated and non-vegetated land from year 1984, year 2000 and year 2014.

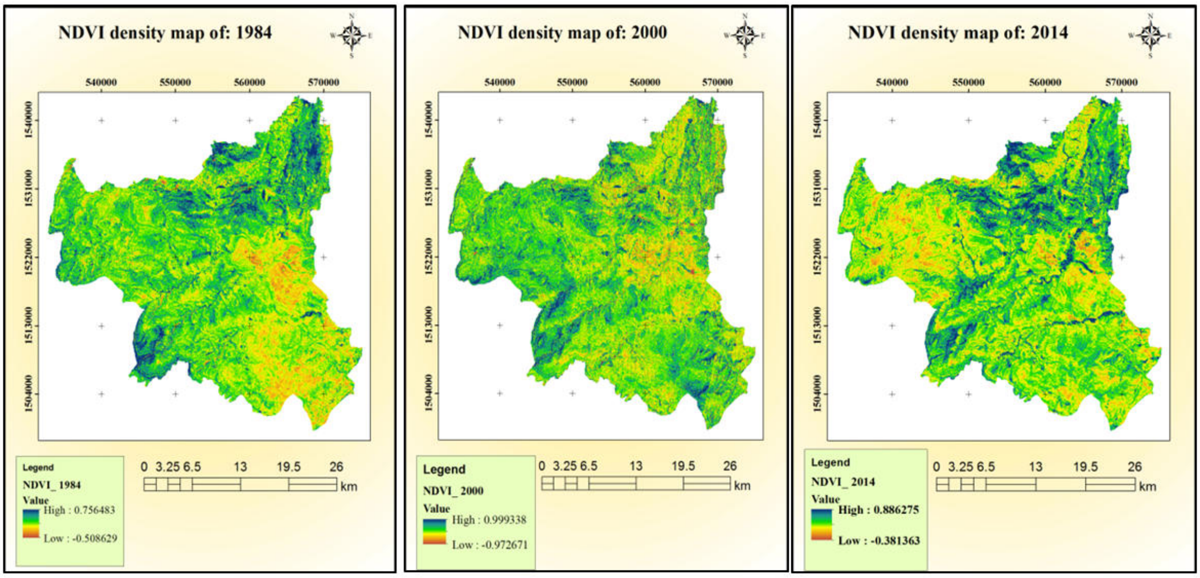

Figure 4: The continuous maps of NDVI values of Kilite Awulalo in year 1984, 2000 and 2014

Based on the Figure 3, it can be seen that in year 1984, 2000 and 2014 the area coverage of vegetated land with positive value was far larger than area coverage of non-vegetated land with negative value and zero value. In generally the value of NDVI is divided into non-vegetated land and vegetated land is classified as No vegetation (Less than 0.1), Very small vegetation (between 0.1 to 0.2), Small vegetation (between 0.2 to 0.3), Medium vegetation (between 0.3 to 0.4) and High vegetation (greater than 0.4) (Table 2).

Table 2: The NDVI density classes between of 1984, 2000 and 2014

	1984		2000		2014	
NDVI density classes	**Area in Hectare**	**Percentage**	**Area in Hectare**	**Percentage**	**Area in Hectare**	**Percentage**
Less than 0.1	568.62	0.561	1808.873	1.785	35.1	0.035
between 0.1 to 0.2	86047.4	84.904	16666.260	16.445	6872.4	6.781
between 0.2 to 0.3	13938.2	13.753	52531.342	51.833	70469.9	69.534
between 0.3 to 0.4	625.86	0.618	23938.961	23.62	19808.0	19.545
Greater than 0.4	166.05	0.164	6400.704	6.316	4160.7	4.105
Total	101346.12	100	101346.14	100	101346.12	100

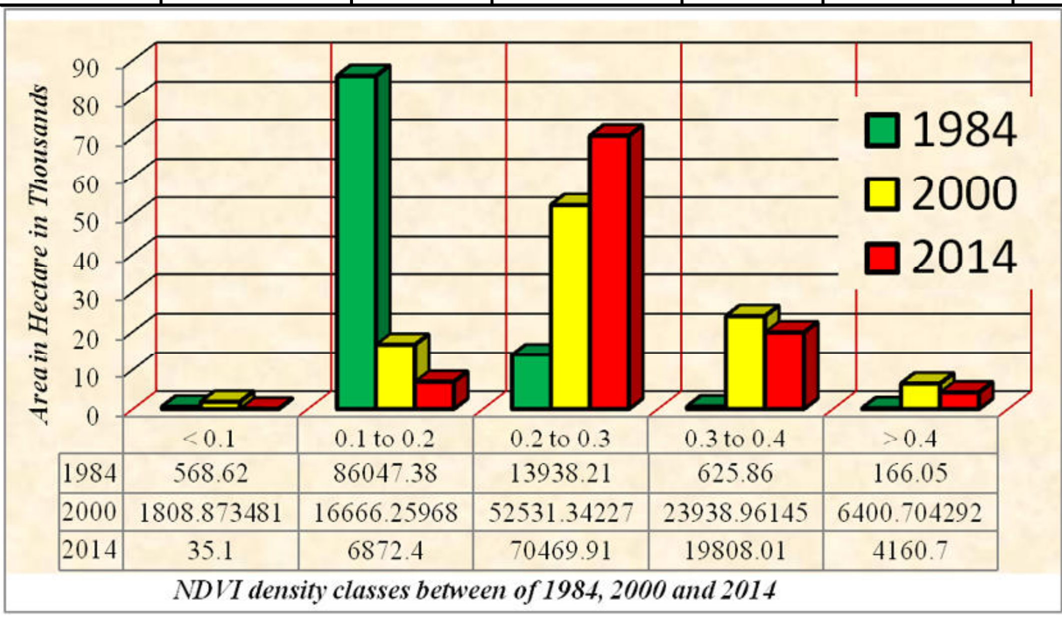

Figure 5: The NDVI density classes and trends of 1984, 2000 and 2014

4.2.2. NDVI density classes and trends in the area (1984 -2000)

As it can be observed from statistics, there was an increasing trend of Small vegetation (between 0.2 to 0.3), Medium vegetation (between 0.3 to 0.4) and High vegetation (greater than 0.4) from the year 1984 to 2000.

From this we can understand that 2000 year was high NDVI value than the year 1984 which means year 2000 high vegetation density than 1984 (Table 3).

Table 3: Change of the NDVI density classes between 1984 and 2000

NDVI density classes	1984		2000		Change between 2000 - 1984		Average rate of change/year	
	Area in Hectare	%	Area in Hectare	%	Area in Hectare	%	Area in Hectare	%
Less than 0.1	568.62	0.561	1808.873	1.785	1240.253	1.224	77.515	0.0765
between 0.1 to 0.2	86047.4	84.904	16666.26	16.445	-69381.14	-68.459	-4336.322	-4.278
between 0.2 to 0.3	13938.2	13.753	52531.342	51.833	38593.142	38.08	2412.0714	2.38
between 0.3 to 0.4	625.86	0.618	23938.961	23.62	23313.101	23.002	1457.069	1.437
Greater than 0.4	166.05	0.164	6400.704	6.316	6234.654	6.152	389.665	0.3845
Total	**101346.12**	**100**	**101346.14**	**100**				

4.2.3. NDVI density classes and trends in the area (2000 - 2014)

In the time period from 2000 to 2014 the change detection shows that there is an increase in area coverage/proportion of Agriculture, Settlement, and Water/artificial lake; and there is a decline of Forest, Bush land and Rocky/Bare land areal coverage (Figure 3). As it can be observed from table 4, there was an increasing trend of Small vegetation (between 0.2 to 0.3), decreasing of Medium vegetation (between 0.3 to 0.4) and High vegetation (greater than 0.4) from the year 2000 to 2014. From this we can understand that the NDVI value for the year 2000 and 2014 shows that there is a significant change on the value of NDVI (Table 4).

Table 4: Change of the NDVI density classes between 2000 and 2014

NDVI density classes	2000		2014		Change between 2014 - 2000		Average rate of change/year	
	Area in Hectare	%	Area in Hectare	%	Area in Hectare	%	Area in Hectare	%
Less than 0.1	1808.873	1.785	35.1	0.035	-1773.77	-1.7502	-126.698	-0.125
between 0.1 to 0.2	16666.26	16.445	6872.4	6.781	-9793.86	-9.6638	-699.561	-0.690
between 0.2 to 0.3	52531.342	51.833	70469.91	69.534	17938.57	17.7003	1281.326	1.264
between 0.3 to 0.4	23938.961	23.62	19808.01	19.545	-4130.95	-4.0761	-295.068	-0.291
Greater than 0.4	6400.704	6.316	4160.7	4.105	-2240.00	-2.2103	-160.000	-0.158
Total	**101346.14**	**100**	**101346.12**	**100.0**				

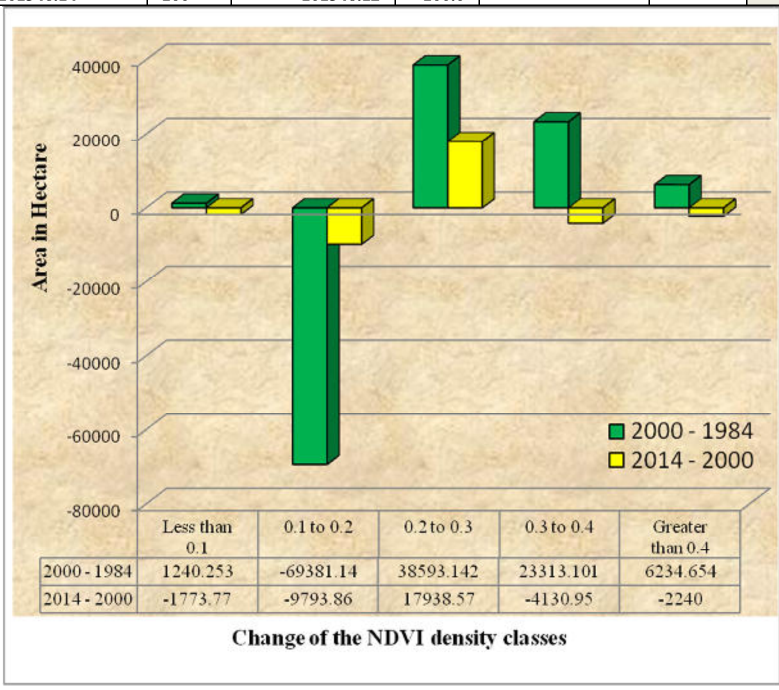

Figure 6: Change of the NDVI density classes between 2000 to 1984 and 2014 to 2000

5. Conclusions

The results of this study show that there is a change in NDVI from the year 1984 to 2014 in Kilte Awlalo Destrict of Tigray State. The change detection clearly depicts that higher NDVI increased the periods 1984 to 2000 and Decreasing the year 2000 to 2014. As a result they showed increasing trend for some times, however, the government had planned to protect the environment through research based soil water conservation strategies and conserving of biodiversity for increasing vegetation cover.

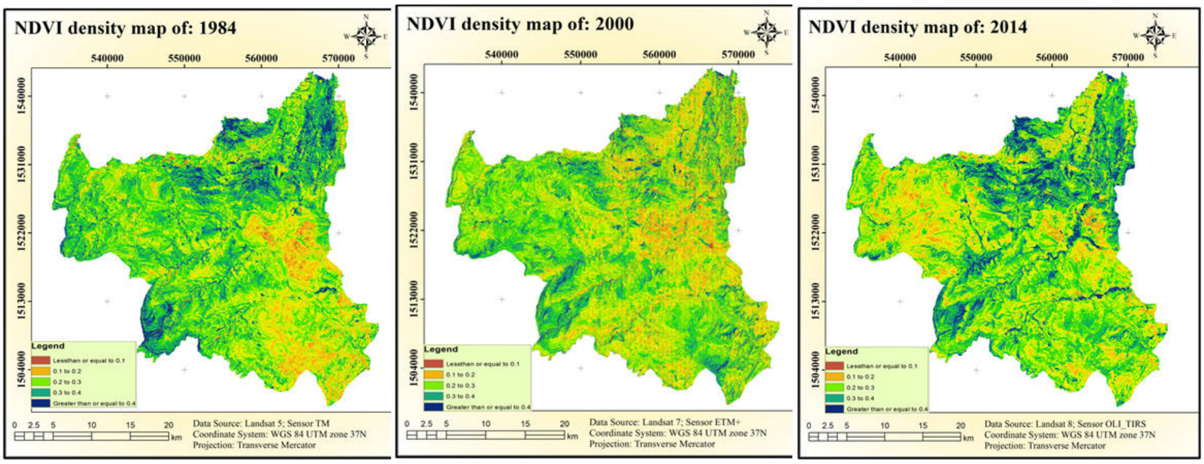

Figure 6: The NDVI density change between 1984, 2000 and 2014

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