

Application of GIS for Estimation of Brightness Temperature using Landsat Data in Kilite Awulalo, Tigray Ethiopia

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Abstract
Put into practice of on Plantation and Domestic/home gardens, as an important component of both rural and urban green infrastructure, could make significant contributions to rural and urban biodiversity and which results to minimizing global warming in general and surface temperature in particular. There for this study investigates surface temperature estimation using Landsat Data in Kilite Awulalo, Tigray Ethiopia. The reason for selecting this area is due to the fact that, in the area there was afforestation and reforestation program have be done from 1980s. This initiates to assessing the works of the area especially on plantation programs for regulation of surface temperature. To do this, the specific objective of the study is to examine the application of GIS for Estimating surface Temperature using landsat data. The land surface temperature (LST) was retrieved from thermal infrared band of each LANDSAT images covering over a period 1984 (Landsat-5 TM band 6); 2000 (Landsat-7 ETM+ band 6) and 2014 (Landsat-8 OLI_TIRS band 11) was used and analyzed using Arc GIS 10.1. The surface temperature is then extracted from the surface radiance. Based on Landsat image, mean temperature of the 1984 TM of the area is 28.12°C, minimum temperature as 12.78°C and the maximum temperature is 36.72^{o}C; mean temperature of the 2000 ETM+ of the area is 30.39°C, minimum temperature as 13.4°C and the maximum temperature is 41.92^{o}C; and mean temperature of the 2014 OLI_TIRS of the area is 35.77°C, minimum temperature as 31.9°C and the maximum temperature is 43.26^{o}C. From this we can understand that there is a significant change and increasing of brightness temperature between from year 1984, year 2000 and year 2014.
Keywords: Landsat Data, RS, GIS, Brightness Temperature

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). However, the country faces different problems in relation to natural resource management. From this, soil erosion is one of the most serious environmental problems (Million and Kassa, 2004; Gete, 2010). The major causes of soil erosion are associated with various factors. Some of these factors are: low adoption of introduced SWC technologies due to the benefits are too long term, the increasing of population, institutions and policy issues (Gizachew, 1994; Gete *et al*., 2006; Gizaw *et al*., 2009). The causes of soil erosion is also related to surface run-off draining to neighboring countries by transboundary rivers (EPA, 1998) in this Ethiopia is 'the country largest export' to Egypt (Woldeamlak, 2003), land cover change (Woldeamlak, 2002; Eric *et al.,* 2003; Haile and Assefa, 2012), civilization expansion into new areas for better soil (Hurni, 1988), Land degradation was largely neglected by policymakers until the 1970s (Genanew and Alemu, 2010) and by the components of climate (such as rainfall and wind) (Bezuayehu *et al*., 2002).

In the 21st century, global environmental changes are increasingly on top of the international scientific and political agenda (Efrem, 2010). This changes a far amount impacts on Earth system of the atmosphere and oceans and hence are experienced globally, and those that occur in distinct sites but are so widespread as to constitute a global change. 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 land use land cover (Gete, 2010).

Land use land cover changes alters the sensible and latent heat fluxes that exist within and between the earth's surface and boundary layers thus influencing and affects land surface properties where LST is one of the properties and is assessable continuously using satellite imagery (Mumina and Mundia 2014). Satellite data are very useful in various applications like, astronomy, atmospheric studies, earth observation, communications and navigation. Land surface temperature is an important parameter in the field of atmospheric in relation to surface temperature controls the surface heat and water exchange with the atmosphere which effecting climatic change in the region (Prasad et *al*,. 2013).

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 estimation of brightness temperature 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 for Estimation of Brightness temperature using Landsat Data in Kilite Awulalo Woreda, Eastern Tigray Zone between 1984 and 2014.

The specific objective of this study is to: Estimation of Land Surface Temperature from Llandsat TM, RTM+ and OLI_TIRS.

2. Site Description (Location)

The study area is located in Tigray state; 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.

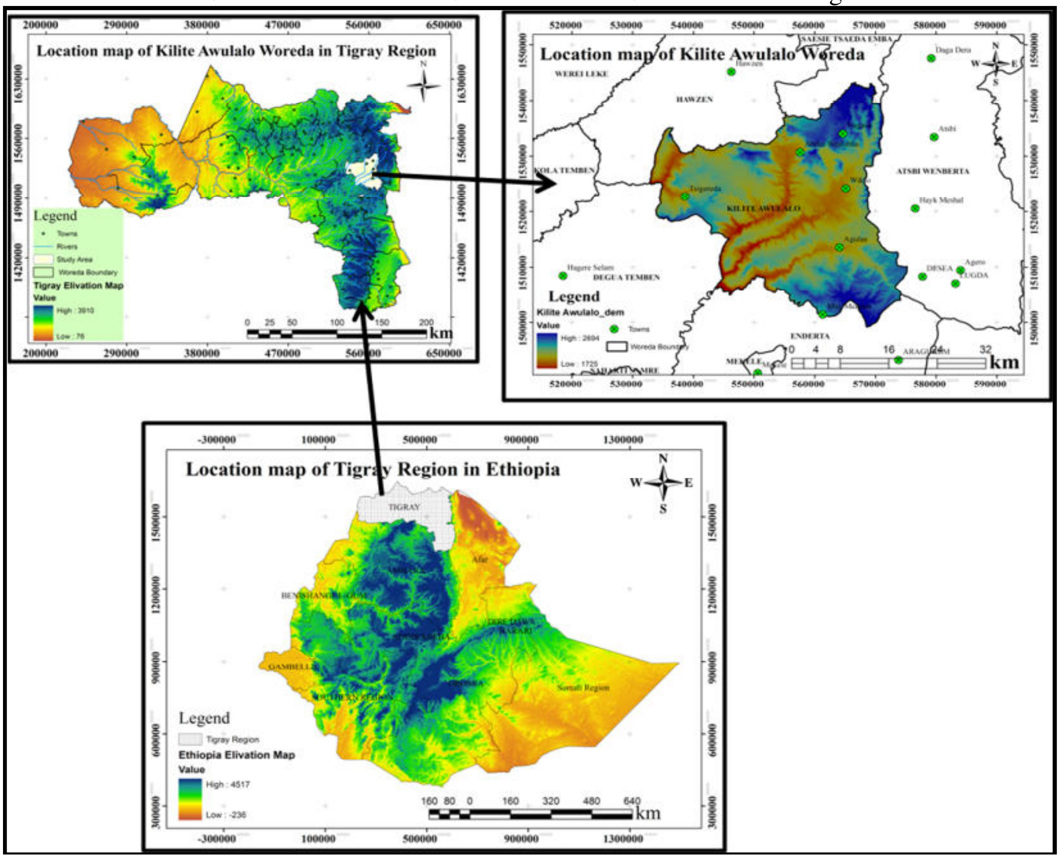

Figure 1: Location map of Kilite Awulalo Woreda

Topography

The digital elevation model (DEM) of area varies from 1725m 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.

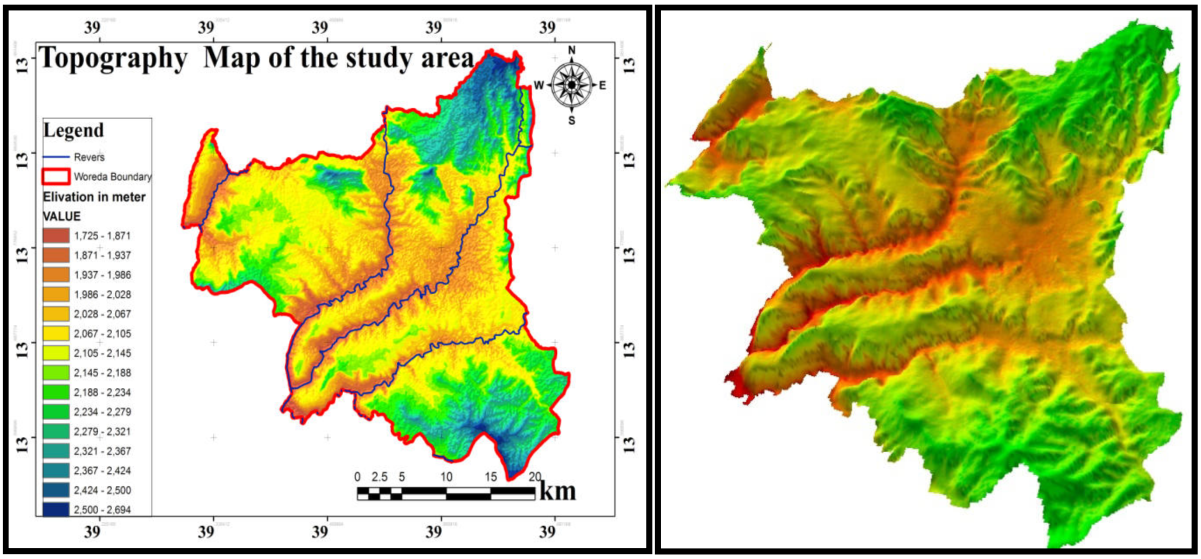

Figure 2: Elevation map of Kilite Awulalo Woreda

3. Materials and Methods

3.1. Data Used

Three Satellite imagery covering the period 1984 (Landsat-5 TM); 2000 (Landsat-7 ETM+) and 2014 (Landsat-8 OLI_TIRS) were used. The detail of the satellite images is given below.

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

Landsat-5 TM, Landsat-7 ETM+ and Landsat-8 OLI_TIRS thermal data have been used in this study. Procedure to estimate the temperature and the methodology in this study has been divided into four phases: (1) Data Preparation, (2) Conversion from Digital Numbers to Spectral Radiance, (3) Conversion from Spectral Radiance to Temperature, (4) Surface Temperature Map preparation has been shown in the flow chart [Figure 3].

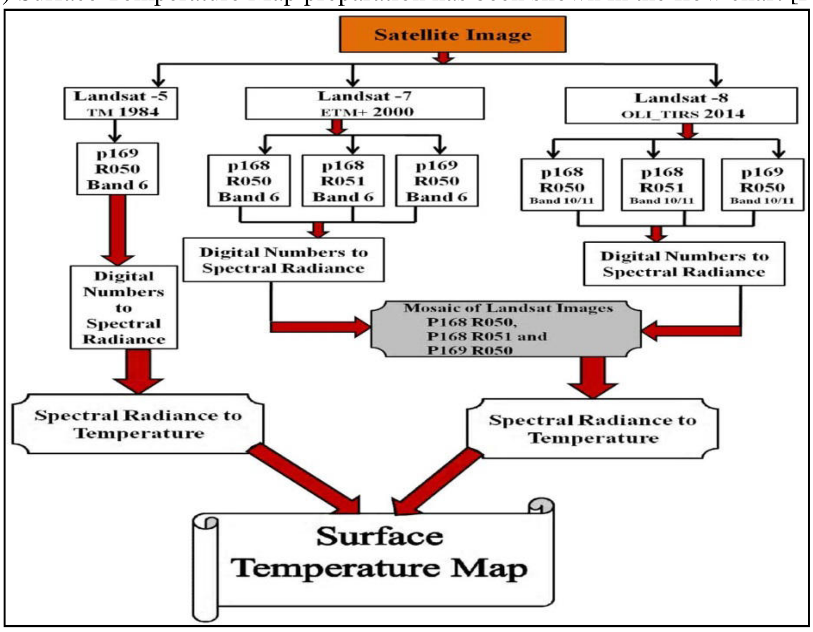

Figure 3: procedures for generating of Brightness temperature map from Satellite images

3.2. Methods

3.2.1. Derivation of brightness temperature

The retrieval methods of surface temperature from the TM, ETM+ and OLI_TIRS images are different, which are discussed as follows.

3.2.1.1. Retrieval of surface temperature from TM and ETM images

Chander *et al.* (2009) proposed a method of deriving surface temperature in two steps:
First, the digital numbers (DNs) of band 6 are converted to Radiance (R_{TM6}, [W/(m^2/ µm)]) by the following formula:

A. Calculation of radiance

$$L_\lambda = G_{rescale} \times Q_{cal} + B_{rescale} \qquad \text{.......... 1}$$

Where

L_λ = Spectral radiance at the sensor's aperture [W/(m2 sr µm)]

$G_{rescale}$ = Band-specific rescaling gain factor [(W/ (m2 sr µm))/DN]: Which is also called BAND_GAIN and taking from the MET files from the image.

$B_{rescale}$ = Band-specific rescaling bias factor [W/(m2 sr µm)]: Which is also called BAND_BIAS and taking from the MET files from the image.

Q_{cal} = Quantized calibrated pixel value [DN]: Pixel value of the Image and we take [value].

B. Calculation of Temperature

According to **Chander *et al.*** (2009), the thermal band data (Band 6 on TM and ETM+) can be converted from at-sensor spectral radiance to effective at-sensor brightness temperature. The sensor brightness temperature assumes that the Earth's surface is a black body (i.e., spectral emissivity is 1), and includes atmospheric effects (absorption and emissions along path). The at-sensor temperature uses the prelaunch calibration constants given in Table 1. The conversion formula from the at-sensor's spectral radiance to at-sensor brightness temperature is:

$$T = \frac{K2}{In(\frac{K1}{L_\lambda}+1)} \qquad \text{.......... 2}$$

Where:

T = Effective at-sensor brightness temperature [Kelvin]

K2 = Calibration constant 2 [Kelvin]

K1= Calibration constant 1 [W/(m2 sr µm)]

$L\lambda$ = Spectral radiance at the sensor's aperture [W/(m2 sr µm)]

In = Natural logarithm

Table 2: TM and ETM+ thermal band calibration constants

Constant	**Constant K1**	**Constant K2**
Units	**W/(m2 sr µm)]**	**Kelvin**
L5 TM	607.76	1260.56
L7 ETM+	666.09	1282.71

Source: Chander *et al.* (2009

3.2.1.2. Retrieval of surface temperature from Landsat 8 OLI_TIRS images

A. Calculation of radiance

$$L_\lambda = ((M_L \times Q_{cal}) + A_L)/ \qquad \text{.......... 3}$$

Where

L_λ = TOA Spectral radiance at the sensor's aperture [W/(m^2 sr µm)]

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN): Pixel value of the Image and we take [value].

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number).

B. Conversion to At-Satellite Brightness Temperature

Thermal Infrared Sensor (TIRS) band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file:

$$T = \frac{K2}{In(\frac{K1}{L_\lambda}+1)} \qquad \text{.......... 4}$$

Where:

T = At-satellite brightness temperature [Kelvin]

K2 = Calibration constant 2 [Kelvin]: Band-specific thermal conversion constant from the metadata

(K2_CONSTANT_BAND_x, where x is the band number, 10 or 11).
K1= Calibration constant 1 [W/(m2 sr µm)]: Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the band number, 10 or 11).
Lλ = **Spectral radiance** at the sensor's aperture [W/(m2 sr µm)]
ln = Natural logarithm
The temperatures are estimated in degrees Kelvin, and are then converted to degree Celsius by T $\mathbf{T_C = T_k - 273.15}$**……………………………………………...………………5**
Where T_c is the temperature in Celsius (°C), T_k is the temperature in Kelvin (K).

4. Results and Discussion

4.1. Analysis of Normalize Difference Vegetation Index (NDVI)

Generally, the value of NDVI is divided into non-vegetated 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.

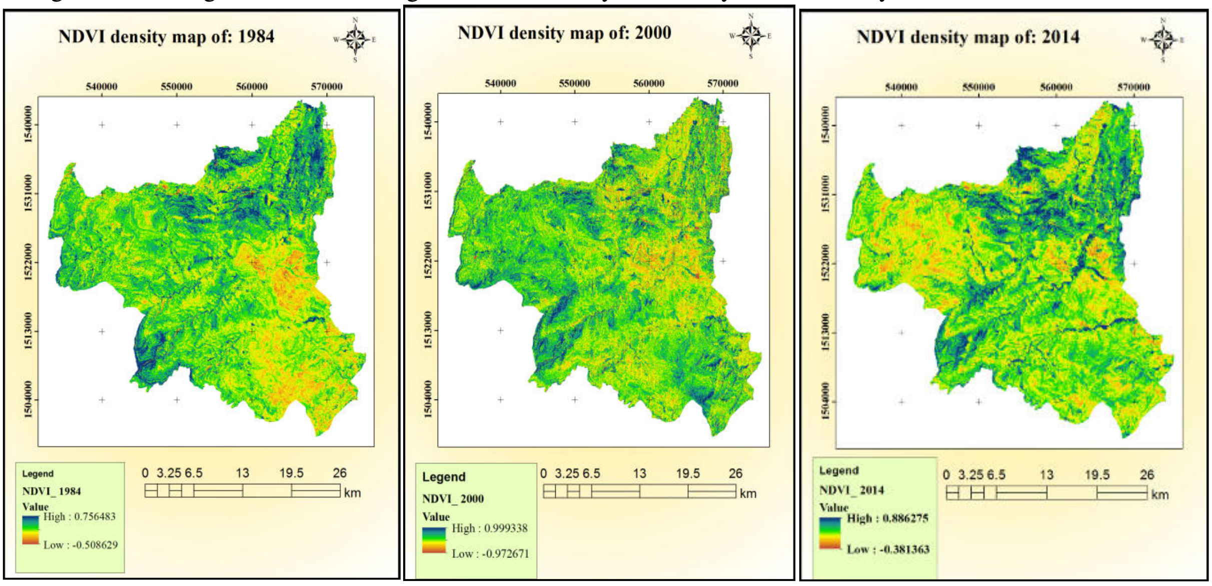

Figure 4: The continuous maps of NDVI values of Kilite Awulalo in year 1984, 2000 and 2014

Based on the Figure 4, 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 3).

Table 3: 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

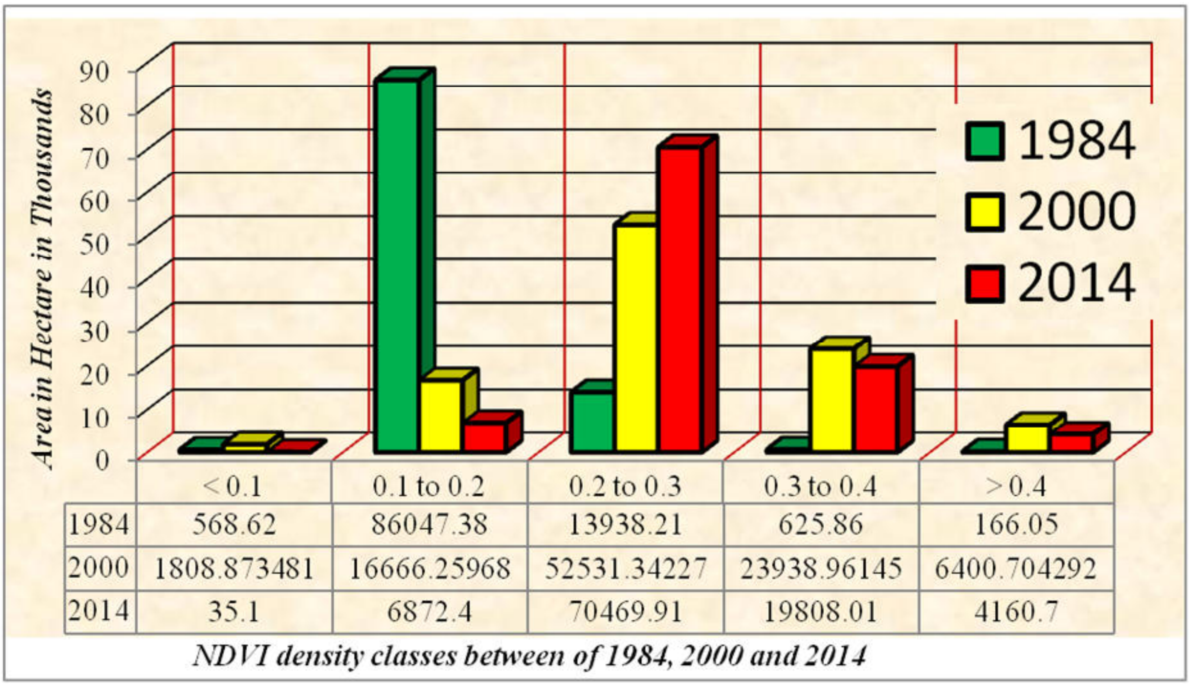

Figure 5: The NDVI density classes and trends of 1984, 2000 and 2014

4.2. Estimation of Brightness temperature

A. Brightness temperature of 1984: Based on Landsat image, mean temperature of the 1984 TM of the area is 28.12°C, minimum temperature as 12.78°C and the maximum temperature is 36.72°C.The majority of the area characterized by it brightness temperature between 24.75 °C to 31.93 °C (Figure 6).

B. Brightness temperature of 2000: Based on Landsat image, mean temperature of the 2000 ETM+ of the area is 30.39°C, minimum temperature as 13.4°C and the maximum temperature is 41.92°C. From the year 1984 to 2000, brightness temperature is increasing.The majority of the area characterized by it brightness temperature between 24.75 °C to 35.54 °C (Figure 7).

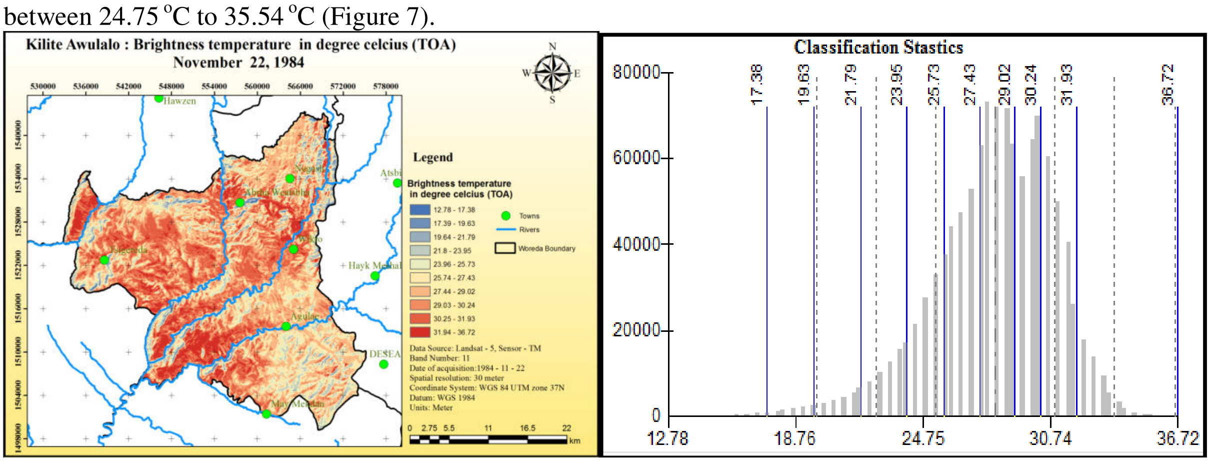

Figure 6: Brightness temperature for the year 1984

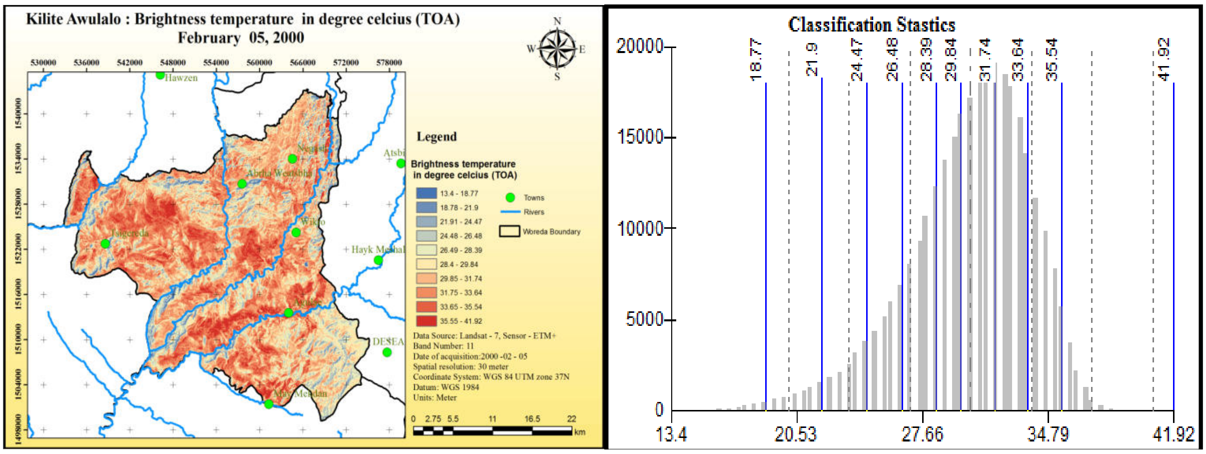

Figure 7: Brightness temperature for the year 2000

C. Brightness temperature of 2014: Based on Landsat image, mean temperature of the 2014 OLI_TIRS of the area is 35.77°C, min temperature as 31.9°C and the maximum temperature is 43.26°C. From the year 1984 to 2000 to 2014 brightness temperature is increasing.The majority of the area characterized by it brightness temperature between 30.35 °C to 39.24 °C.

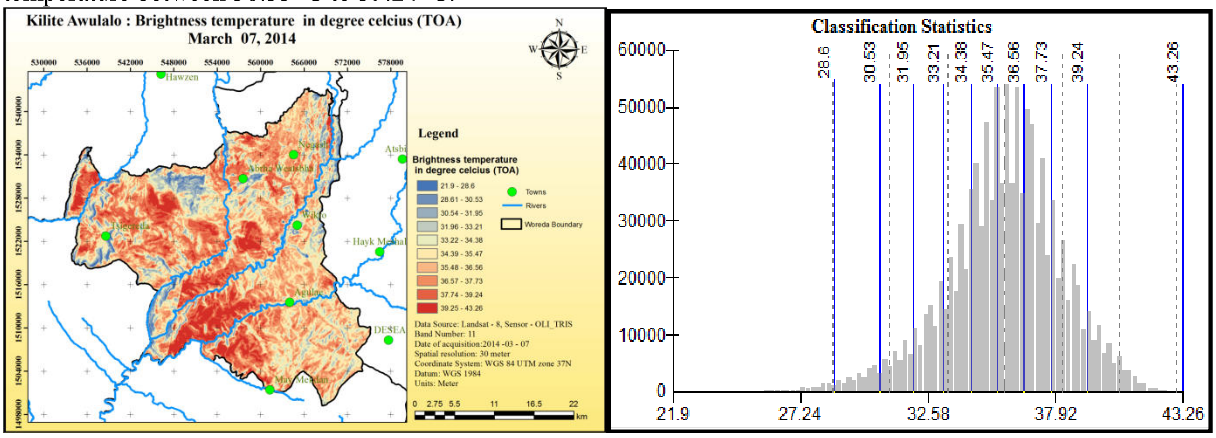

Figure 8: Brightness temperature for the year 2014

5. Conclusions

The results of this study show that there is an increasing of brightness temperature from the year 1984 to 2014 in Kilte Awlalo Destrict of Tigray State.

From this we can understand that there is a significant change and increasing of brightness temperature between from year 1984, year 2000 and year 2014.

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