# "Estimation of Land Surface Temperature of Al-Jfara District, Libya using Landsat 8 TIRS & OLI data"

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## Abstract

Land surface temperature (LST) is an important parameter in the studies of climate change, urban land use/land cover, heat balance and a key input for climate models. The present study focuses on the estimation of LST with normalized difference vegetation index (NDVI) over Al Jafara district in Libya, using remote sensing and GIS techniques (Raster functions and Raster calculation). The study also emphases using LANDSAT 8 satellite data to compute LST and the associated land cover parameters viz; land surface emissivity (LSE), Brightness Temperature (BT), and normalized difference vegetation index (NDVI). Thermal infrared (TIR) data Landsat 8 band 10 (thermal band) and the Red and Near Infrared bands 4 & 5 during 6 April 2018, 16 Nov 2018 were processed for LST and NDVI analysis. The Land Surface Emissivity (LSE) and Brightness Temperature (TB) were retrieved directly from NDVI and thermal infrared band. The study has proven that the results are feasible to calculate NDVI, LSE, TB and LST with appropriate accuracy of the study area.

**Keywords:** *Remote sensing, GIS, Land Surface Temperature (LST), Land Surface Emissivity (LSE), Normalized Difference Vegetation Index (NDVI).*

## 1. INTRODUCTION

Remote sensing technique has the advantages of being macroscopic, dynamic, and fast, as well as provides a unique method for obtaining Land surface temperature (LST), land surface emissivity (LSE) and normalized difference vegetation index (NDVI) information at global and regional scales (Liang, 2004). LST is the temperature of earth crust through the process of absorption, reflection and refraction of the radiation from the sun. Past studies (Barton, 1992, Lagouarde et al. 1995, Qin and Karnieli, 1999, Dash et al. 2002, Schmugge et al. 2002, Khalil et al. 2015, Babu et al. 2018) discovered that LST is very important in a wide variety of scientific studies, such as environment and global change. The significance of LST is become increasingly recognized, because many changes on the Earth's surface affected by changes in temperature (Khalil et al. 2015). LST is a key parameter for calculating highest and lowest temperature of a specific location. Medium spatial resolution data, such as that from the LANDSAT and SPOT are suitable for land cover or vegetation mapping at regional local scale. Landsat 8 Thermal Infrared Sensor (TIRS) created by the US Geological Survey as geographically tagged image file format (GeoTIFF). LANDSAT 8 data was successfully launched on 6 April 2018, 16 Nov 2018 and organized into orbit with two sensors; (1) the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI collects data at a 30m spatial resolution with nine spectral bands located in the visible (VIS), near infrared (NIR), and the shortwave infrared (SWIR) spectral regions. (2) TIRS senses the TIR radiance at a spatial resolution of 100m with two spectrally adjacent thermal bands (band 10 and band 11) with thermal characteristics (Knight & Kvaran 2014). Various algorithms have been improved to extract LST from Landsat 8 data. Some of the frequently used algorithms are single-channel methods, split window methods, and because of the larger calibration uncertainty related with band 11, the study used band 10 data for single-channel algorithm to retrieve LST from satellite TIRS data. More information about Landsat program can be found on the web of http://landsat.gsfc.nasa.gov/.

## 2. STUDY AREA

Al Jfara is one of the districts of Libya. Its capital and largest city is Al-Aziziya. Al Jfara is geographically located about 40 km South-West Tripoli, Jabal al Gharbi in the south and Zawiya in the west. It lies between $12^0$ 40′ 41″ , $13^0$ 06′ 58″ E longitude and $32^0$ 14′ 44″, $32^0$ 45′ 58″ N latitude, covering a total area of approximately 1197 $km^2$. It is situated at an altitude of 328 m above mean sea level (MSL). According to 2012 census, the population of Al Jfara district is roughly estimated at 150,353. (Figure 1 shows the study area)

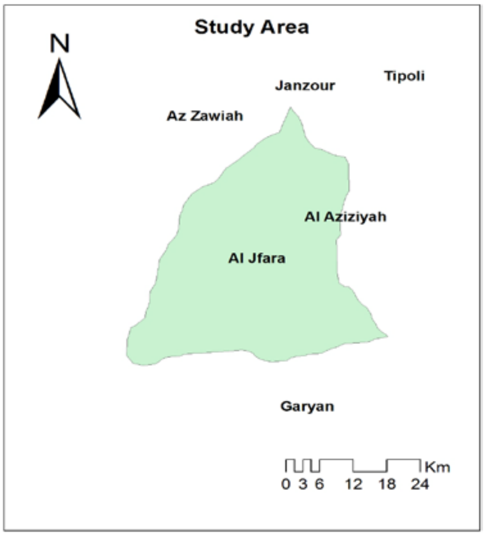


Fig-1

## 3. OBJECTIVES

The study aims to estimate land surface temperature with normalized difference vegetation index by the following steps;

1- To calculate Normalized Difference Vegetation Index

2- To convert TIRS band data to TOA spectral radiance

3- To calculate Atmosphere Brightness Temperature

4- To estimate Land Surface Temperature

5- To calculate the area for different temperature ranges.

## 4. MATERIALS AND METHODS

### 4.1 Data Used

Landsat 8 is one of the Landsat series of NASA (National Aeronautics and Space Administration). The data of Landsat 8 is available in USGS (United States Geological Survey) Earth Explorer website at free of cost. Satellite data over Al Jfara region of April and November of 2018 have been acquired in this study. Several algorithms have been developed to extract LST from Landsat 8 data. The study was used single-channel method to retrieve LST from satellite TIRS data.

TIRS band 10 was used to estimate brightness temperature and bands 4 and 5 were used to create Emissivity and NDVI of the study area. Landsat 8 runs metadata of the bands (thermal constant, rescaling factor value etc.), which can be used for computing such as LST. Bands, Wavelength and Resolution of Landsat8 are as shown in Table-1

*Table 1: Band properties of Landsat 8*

| Bands | Wavelength (micrometers) | Resolution (meters) |
|---|---|---|
| Band 1 – Ultra Blue (coastal/aerosol) | 0.435 – 0.451 | 30 |
| Band 2 - Blue | 0.452 – 0.512 | 30 |
| Band 3 - Green | 0.533 – 0.590 | 30 |
| Band 4 - Red | 0.636 – 0.673 | 30 |
| Band 5 - Near Infrared (NIR) | 0.851 - 0.879 | 30 |
| Band 6 - Shortwave Infrared (SWIR) 1 | 1.566 - 1.651 | 30 |
| Band 7 - Shortwave Infrared (SWIR) 2 | 2.107 - 2.294 | 30 |
| Band 8 - Panchromatic | 0.503 - 0.676 | 15 |
| Band 9 - Cirrus | 1.363 - 1.384 | 30 |
| Band 10 - Thermal Infrared (TIRS) 1 | 10.60 - 11.19 | 30 |
| Band 11 - Thermal Infrared (TIRS) 2 | 11.50 - 12.51 | 30 |

The USGS provides data in the GeoTIFF with Metadata format. Following file that ends with "**_MTL.TXT**" were used for calculation;

 Radiance Add Band 10 = 0.10000

- Radiance Mult Band_10 = 0.0003342
- K1 Constant band 10 = 774.8853
- K2 Constant Band 10 = 1321.0789

**4.2 Software's Used:** Arc GIS Version 10.3

## 4.3 Methodology

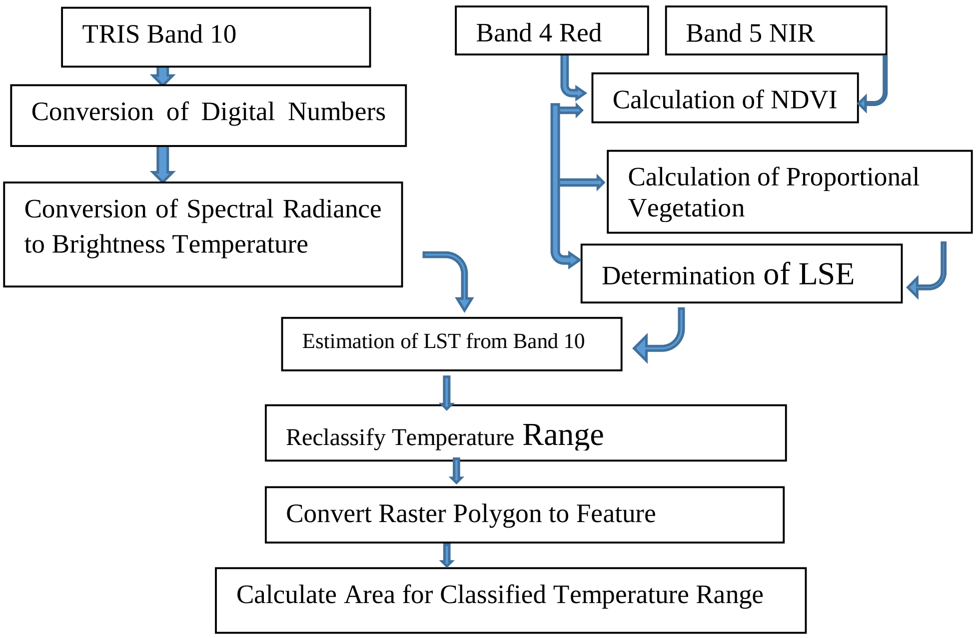


*Fig – 2: Flowchart*

### 4.3.1 PROSSES

**i.** Top of Atmosphere (TOA) Radiance: The first step is to convert the DNs to radiance using rescaling factors (Tania et al. 2017).

$$L\lambda = ML * Qcal + AL \tag{1}$$

Where $L\lambda$ is the TOA spectral radiance (Watts/ (m2 * sr * µm)), ML is the Radiance multiplicative Band (No.), Qcal is the Quantized and calibrated standard product pixel values (DN), and AL is the Radiance Add Band (No.)

**ii.** Top of Atmosphere (TOA) Brightness Temperature: Using the thermal constant values in Meta data file, spectral radiance can be converted to TOA brightness temperature (Oguz, 2016).

$$BT = K2 / \ln (k1 / L\lambda + 1) - 272.15 \quad (2)$$

Where BT is the Top of atmosphere brightness temperature (°C), $L\lambda$ is the TOA spectral radiance (Watts / (m2 * sr * µm)), K1 is the K1 Constant Band, and K2 is the K2 Constant Band.

**Iii:** Normalized Differential Vegetation Index (NDVI). NDVI is calculated with the following expression:

$$NDVI = (NIR-Red) / (NIR+Red) \quad (3)$$

Where RED is the DN values from the RED band, NIR is the DN values from Near-Infrared band (Baldi. 2008)

**iv:** Land Surface Emissivity (LSE): LSE is the average emissivity of an element of the surface of the Earth calculated from NDVI values (Dash. 2005).

$$PV = [(NDVI – NDVI\ min) / (NDVI\ max + NDVI\ min)]^{\wedge}2 \quad (4)$$

Where PV is the proportion of vegetation, NDVI is the DN values from NDVI Image, NDVI min is the minimum DN values from NDVI Image, and NDVI max is the maximum DN values from NDVI Image.

$$E = 0.004 * PV + 0.986 \quad (5)$$

Where E is the Land Surface Emissivity, and PV is the proportion of vegetation

**v:** Land Surface Temperature (LST): LST is the radioactive temperature, which calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance and LSE (Hakan, 2017).

$$LST = (BT / 1) + W * (BT / 14380) * \ln (E) \quad (6)$$

Where BT is the Top of atmosphere brightness temperature (°C), W is the Wavelength of emitted radiance, and E is the Land Surface Emissivity

## 5. RESULT AND DISCUSSIONS

The NDVI map for the months of April and November illustrate that the NDVI value ranged between -0.01 to 0.52. The resulting map shows NDVI values were lower in the mid dry season (April) as well as in the wet season (November). (Figure 3, 4).

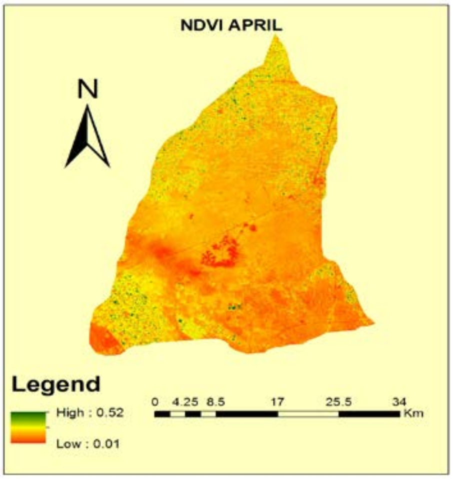


*Fig-5*

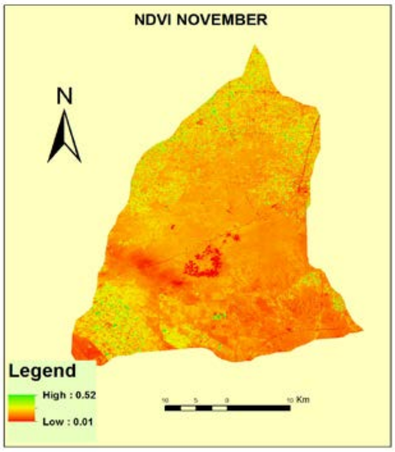


*Fig- 6*

The Brightness Temperature map for the month of April shows that the temperature value ranges between 22.74 to 37.89 **°C** (Fig-7). On the other hand, the Brightness Temperature resulting for the month of November shows that the temperature value ranges between 16.90 to 26.49 °C (Fig-8).

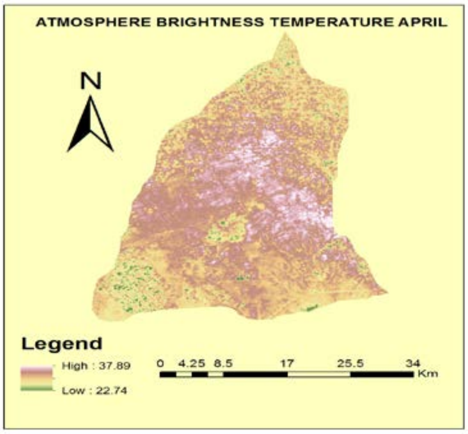


*Fig – 7*

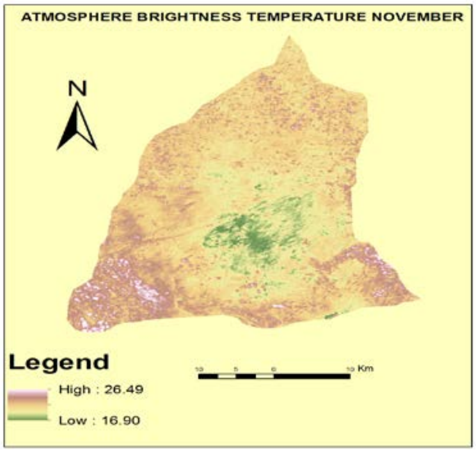


*Fig-8*

Land surface map (Fig-9) has been derived using brightness temperature and LSE. LST temperature ranges and areas for the month of April are shown in table-2.

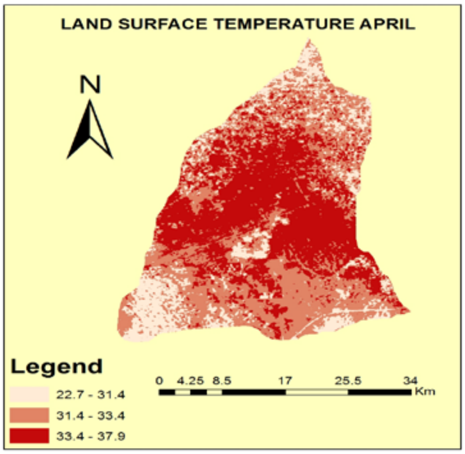


*Fig-9*

*Table-2*

| S. No | Temperature (°C) | Area (Sq.km) | Percentage (%) |
|---|---|---|---|
| 1 | 22.7 – 31.4 | 208 | 17.3 |
| 2 | 31.4 – 33.4 | 504 | 42.1 |
| 3 | 33.4 – 37.9 | 485 | 40.5 |

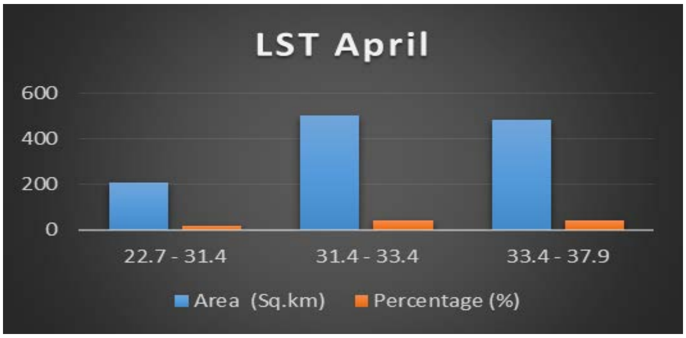


*Fig-10*

LST map (Fig-11) has been determined using brightness temperature and LSE. LST ranges and areas for the month of November are shown in (table-3).

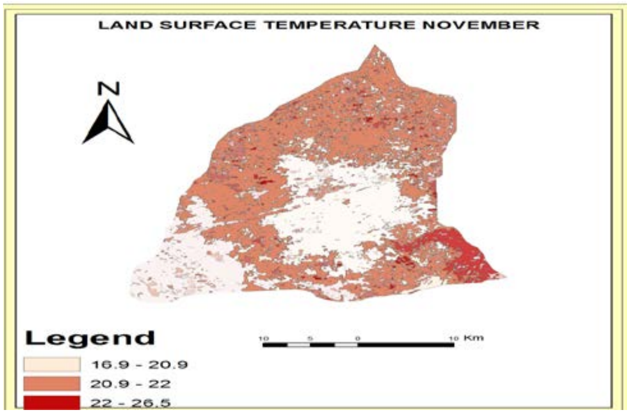


*Fig-11*

*Table-3*

| S. No | Temperature (°C) | Area (Sq.km) | Percentage (%) |
|---|---|---|---|
| 1 | 16.9 - 20.9 | 305 | 25.5 |
| 2 | 20.9 - 22 | 619 | 51,7 |
| 3 | 22 - 26.5 | 273 | 22.8 |

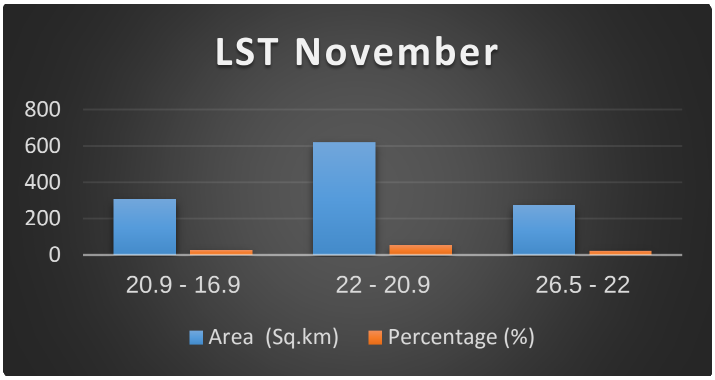


*Fig-12*

## 6. CONCLUSION

NDVI, brightness temperature, LSE, and LST of an area were derived using Arc GIS software. NDVI Maps illustrate that vegetation is low in the month of April as well as in the November. Estimated LST values explain that in the month of

April 42.1% of the total area, surface temperature lies in the range of 31 -33°C and in the month of November 51.7 % of the total area, surface temperature lies in the range 20.9 – 22 °C. Thus, LST can be estimated using Landsat 8 data with single-channel algorithm from satellite TIRS data.

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