Advances in Physics Theories and Applications
ISSN 2224-719X (Paper) ISSN 2225-0638 (Online)
Vol.83, 2020

Estimation of land surface Temperature of Maiduguri Metropolitan Area: A Case Study of Jere & some part of Mafa using Landsat 8 Operational Land Image (OLI)

*[1]Mohammed K. Salihu, [2]Abubakar Aliyu, [3]Abdul-azeez Hayatu [4]R. O. Amusat [5]Samaila Hassan

[1,2,4,5] Department of Physics, University of Maiduguri, Borno State of Nigeria

[3]Department of physics, Adamawa State College of Education Hong, Nigeria

*mohamedks122@gmail.com

Abstract

Estimation of land surface Temperature of Maiduguri Metropolitan Area: A Case Study of Jere & some part of Mafa using Landsat 8 Operational Land Image (OLI) the research revealedmean solar radiance as 10.54 W/m^2/str/μm the calculated minimum and maximum NDVI values are respectively -0.01674 and 0.5489, used to obtain proportion to vegetation which is then used to determine the emmissivity of the area having minimum emmissivity of 0.986 and maximum of 0.99, the minimum and maximum land surface temperature of Maiduguri Metropolitan areas are respectively 41.16 ^{o}C and 26.11 ^{o}C.

KEY WORDS:- Landsat 8 satellite images, Temperature, Solar Radiance and Emmissivity

DOI: 10.7176/APTA/83-06
Publication date: March 31st, 2020

1. INTRODUCTION

Temperature is simply the average translational kinetic energy of a particular body of day to day basis. The weather aspect of temperature can be varied throughout the day. Cold and hot waves are factors that affect the temperatures of particular climates. Satellite Thermal Infrared sensors measure top atmosphere irradiances, from which temperatures can be determined using Plank's law (Ifatimehin, 2007).

Land surface temperature would provide vital information about climate changes which plays a role in many environmental processes (Dousset and Gourmelon, 2003). Temperature, controlled by atmospheric, thermal properties of the surface and subsurface media, is an important factor controlling most physical, chemical, and biological aspect of the Earth (Becker *et al*, 1990).

Surface temperature could be emphased as the temperature of any object recorded and is determined by the varying patterns of spectral responses of each object. Considering the resolution of satellite data, the surface temperature can be defined as the average surface temperature of the ground under the pixel scale mixed with different fractions of surface types.

Numerous factors need to be measured in order to estimate the surface temperature from satellite thermal data. Digital number from Landsat 8 Operational Land Image (OLI) with wavelength range of 10·4–12·5 μm was applied in order to calculate surface temperatures using equation 6, which state the radiance emitted from an object at a certain wavelength and its temperature (Shindell *et al* 2001). In the estimation of surface temperature from

satellite thermal data, the Digital Number (DN) of image pixels first needs to be converted into spectral radiance using the sensor calibration data (Markham and Barker, 1986).

However, the radiance converted from digital number does not represent a true surface temperature but a mixed signal or the sum of different fractions of energy. These fractions include the energy emitted from the ground, up welling radiance from the atmosphere, as well as the down welling radiance from the sky integrated over the hemisphere above the surface. Therefore, the effects of both surfaces emissivity and atmosphere must be corrected in the accurate estimation of Surface Temperature (Qin *et al*, 2001).

At infrared wavelengths the concept of surface temperature is useful for remote temperature measurements. At terrestrial IR wavelengths most land and water surfaces as well as dense cloud layers have a nearly constant emissivity $\varepsilon > 0.95$. Therefore, in case of a transparent atmosphere, the brightness temperature of the surface is very close to its thermodynamic temperature (Petty, 2004). Land surface emissivity is a key parameter for determination of Surface Temperature as well as in the environmental studies. Most natural surfaces are able to emit only part of their potential radiant energy (Caselles *et al*, 1997).

The aim of this research is to estimate the land surface temperature of Maiduguri Metropolitan area: a case study of Jere & some part of Mafa using Landsat 8 Operational Land Image.

2. METHODS

2.1 Data Used

Landsat 8 satellite images data of Borno state, primarily downloaded from United States Geological Survey (USGS) was used for this research. The Thermal Infrared (TIR) band 10 was used to estimate brightness temperature of the study area. Landsat 8 provides metadata of the band such as thermal constant, rescaling factor value etc., which can be used to calculate the LST. Band Wavelength of (10.60 µm -11.20 µm) and Resolution of 30 m of Landsat8 are given in Metadata (MTD) file and the following values were used.

- ✓ Radiance Add Band 10=R_{add_B} = 0.10000
- ✓ Radiance Mult Band_10=R_{mal_B} = 0.0003342
- ✓ K_1 Constant band 10 = 774.8853
- ✓ K_2 Constant Band 10 = 1321.0789

2.2 Data processing

2.2.1 Solar Radiance

Using the rescaling factor from MTD file, (TIR) Digital Numbers can be converted to solar radiance.

$$L_\lambda = R_{ML}(Q_{cal}) + R_{AL} \quad (1)$$

Where:

L_λ = Solar radiance (W/m^2/ster/µm);

R_{ML} = Band Specific multiplicative rescaling factor from the MTD file

R_{AL} = Band specific additive rescaling factor from the MTDfile

Q_{cal} = Quantized and calibrated standard product digital numbers (DN);

2.2.2 Brightness Temperature:

Solar radiance would be converted to brightness temperature using the thermal constant Values in MTD file (Qin, *et-al* (2001)):

$$BT = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda}+1\right)} - 273.15 \quad (2)$$

Where:

BT = Brightness temperature (°C)

2.2.3 Normalized Differential Vegetation Index (NDVI):

To determine NDVI standardized vegetation index which will be calculated using Near Infra-red (Band5) and Red (Band4).

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)} \text{ or } \frac{(BAND5-BAND4)}{(BAND5+BAND4)} \quad (3)$$

Where:

RED= DN values from the RED band4

NIR= DN values from Near-Infrared band5

2.2.4 Land Surface Emissivity (LSE):

Land surface emissivity (LSE) is the mean emissivity of the surface of the Earth, it can be calculated from NDVI values but we are to first calculate proportion of vegetation (PV) value from NDVI.

$$Pv = \left(\frac{NDVI-NDVI_{min}}{NDVI_{max}+NDVI_{min}}\right)^2 \quad (4)$$

Where:

PV = Proportion of Vegetation

NDVI = DN values from NDVI Image

NDVI min = Minimum DN values from NDVI Image

NDVI max = Maximum DN values from NDVI Image

After calculating Proportion of vegetation, land surface emissivity was then calculated using equation 5 below

$$e = 0.004\ xPvx\ 0.986 \quad (5)$$

Where:

e = Land Surface Emissivity

2.2.5 Land Surface Temperature (LST):

Finally, the LST was calculated using brightness temperature, solar radiance and Land Surface Emissivity (Qin, *et-al* (2001)):

$$LST = \frac{BT}{\left(\frac{L_\lambda * BT}{14380}+1\right)lne} \quad (6)$$

3 Resuls:

3.1 Solar Radiance

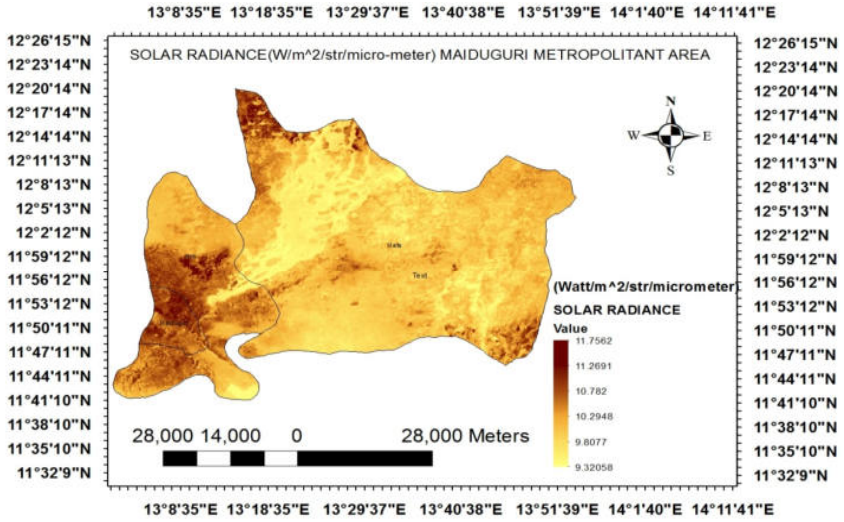

Fig.1 Solar Radiance Map of Maiduguri Metrapolitan Area

The calculated solar radiance of Maiduguri metropolitan shows a maximum values of abaut 11.76 W/(m^2str µm), minimum values of 09.32 W/(m^2 str µm) and mean values of 10.54 W/(m^2str µm)

3.2 Normalized Differential Vegetation Index (NDVI)

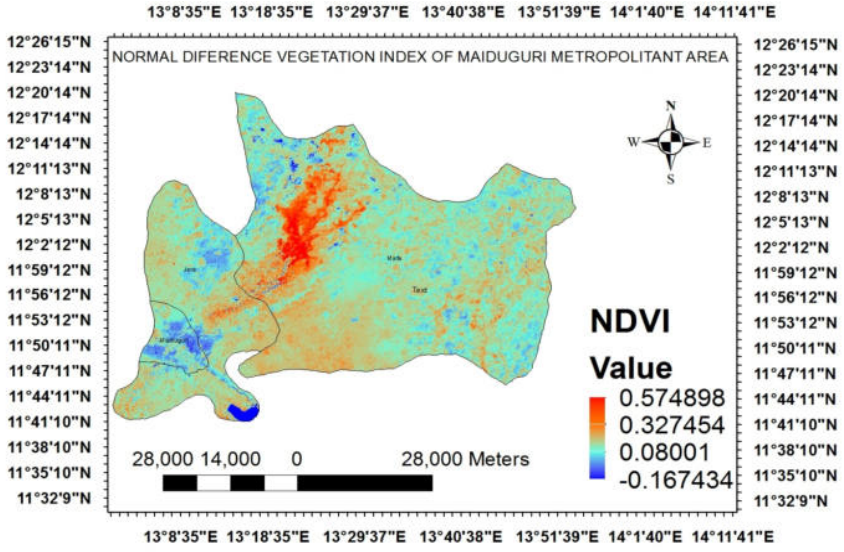

Fig. 2: Normalized Differential Vegetation Index (NDVI) Map of Maiduguri Metrapolitan Area

Normalised diffrernce visualised index of maiduguri metropolitan council have been determined given the lowest value of -0.167434 indicating water body or highly moisture area, highest values of 0.574898 are revealed in

housing and residential areas while vegetation regions have an intermediate values ranging between 0.08001 to 0.327454.

3.3 Land Surface Emmisivity

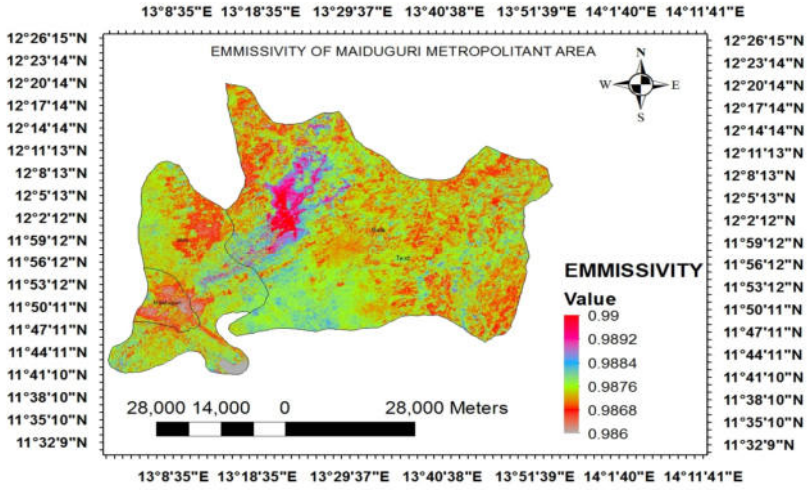

Fig. 3: Land Surface Emmissivity Maps of Maiduguri Metropolitan Area

The emmissivity were determined in order to calculate the accurate land surface temperature from the solar radiant and brightness temperature, while we have the minimum value of 0.986 and maximum value of 0.99.

3.4 Land Surface Temperature

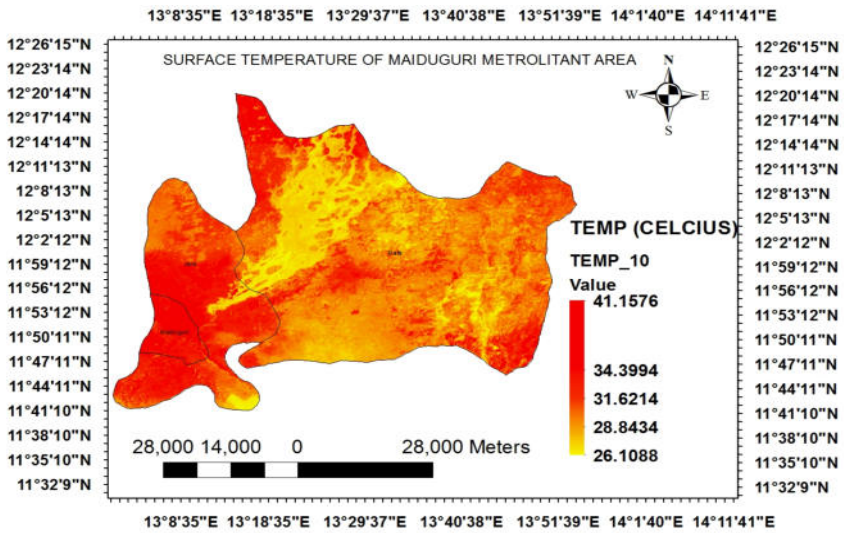

Fig. 4: Land Surface Temperature of Maiduguri Metropolitan Area

The land surface temperature of maiduguri metropolitan council was determined and the result show maximum temperature of 41.16ºC and minimum land surface temperature of 26.11ºC.

4. Conclusion

This research successfully determined Land Surface Temperature of Maiduguri Metropolitan having Minimum and Maximum values of 26.11 ºC and 41.16 ºC respectively. This was accompanished by values obtained from the following tools; solar radiance value of 10.54 W/m^2/str/µm, minimum and maximum values of NDVI as -0.01674 and 0.5489 respectively why land surface emissivity minimum value of 0.986 and maximum value of 0.99. It is obvious that water and vegetation are very good shielding factors for radiation and temperature.

Reference

Arvidson, T. (2002). Personal Correspondence, Landsat 7 Senior Systems Engineer, Landsat Project Science Office, Goddard Space Flight Center, Washington, DC.

Becker, F., & Li, Z. -L. (1990). Temperature-independent spectral indices in TIR bands. Remote Sensing of Environment, 32, 17– 33.

Dousset, B. & Gourmelon, F., (2003). Satellite multi-sensor data analysis of urban surface temperatures and landcover, ISPRS Journal of Photogrammetry and Remote Sensing. 58: (1-2), 43-54

Dammo, M. N., Yadima S.G and Sangodoyin, A.Y. (2016) Modeling Trends of Temperature Effects on Water Level of Rivers in N/E Nigeria. Civil and Environmental Research Vol.8, No.4, 13-17.

Ifatimehin, O.O. (2007) Estimating the Surface temperature of a rapidly developing Urban centre in Nigeria using Geo-informatics Technology, International Journal of Ecology and Environmental Dynamics, 4:1-10

Oesch, E. D. (2006): Validation of satellite observed thermal emission with in-situ measurements over an urban surface. Remote Sensing of Environment 104:201-210.

Markham, B. L. & J. L Barker (1986). Landsat MSS and TM post-calibration dynamic rangers, exoatmospheric reflectance and at-satellite temperatures. EOSAT Landsat Tech. Notes (Aug.): 3-8.

Petty, G. W. (2004) A first course in atmospheric radiation. Sundog Publishing, Madison, Wisconsin

Qin Z, Karniel A, & Berliner, P. (2001): A mono-window algorithm for retrieving land surface temperature from Landsat TM data and its application to the Israel-Egypt border region. Int J Remote Sensing, 22:3719-3746.

Shindell, D.T., Schmidt, G.A., Mann, M.E., Rind, D. & Waple, A., (2001), “Solar Forcing of Regional Climate Change During the Maunder Minimum”, Science, 294, 2149–2152.