Journal of the Nigerian Association of Mathematical Physics
Volume 56(March – May *2020 Issue*), pp69 – 72

LAND SURFACE TEMPERATURE VARIATION WITH VEGETATION COVER IN ABIA STATE AND ENVIRONS USING REMOTELY SENSED DATA

Azunna D. E[1], Chukwu G. U., Nwokoma E. U.[2] and Anyadiegwu F. C.[2]

[1]Department of Physics, Faculty of Science, Clifford University, Owerrinta, Abia State, Nigeria.
[2]Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Abstract

Land surface temperature and the vegetation cover of the study area were investigated using landsat imagery which is a form of remote sensing. The study area covers Abia State and parts of Enugu, Ebonyi and Benue states. It has an area about 48,400 km^2 and lies between latitude 5^0 0'N to $7^0$0'N and $7^0$0'E to $8^0$0'E. The Enhanced Thematic Mapper Plus (ETM+) of the Landsat 8 was used. A scene size of 220km NS by 110km EW was obtained from the United States Geologic Survey database and was analyzed. Results show that the study area has two forms of vegetation cover. The rainforest and the Guinea Savannah were noticed in the South-Eastern and North-Eastern parts respectively. Bende, Arochukwu and Uturu are observed to have thick vegetation cover while Umuahia, Aba, Enugu, Owerri and Ohafia all have sparse vegetation and open lands. The LST on ther hand ranges from 20 – 34 ^{0}C with the North-Eastern relatively warmer than South-Eastern sides. Built up areas like Umuahia, Aba, Owerri, Enugu and Ohafia are relatively warmer with temperature of about 34 ^{0}C which is relatively higher than other parts of the study area. There is therefore a negative correlation between LST and vegetation cover because areas with high LST have sparse vegetation cover. The relative high temperature experienced in such areas is attributed to civilization, development, human activities, burning of fossil fuels, increase in population and deforestation. There is therefore a pertinent need to check these activities and embark on environmentally friendly activities in order to mitigate the potential of adverse climate change in such areas.

Keywords: Remote Sensing, Landsat, Land Surface Temperature, Vegetaion, Climate Change.

INTRODUCTION

Land Surface Temperature (LST) is the thermal emission from the landscape surface including soils and top of vegetated surfaces. It controls the surface heat and water exchanges with the atmosphere [1]. Earth's chemical, physical and biological processes are chiefly controlled by LST and as such, it has become fundamental information in studying environmental resources [2]. Numerous studies in climate modeling, heat balance and global change monitoring have been done using LST obtained from satellite borne sensors [3-5]. LST is also vital in modeling meteorological, agricultural, ecological and hydrological processes on the earth's surface [6-7].

Variations in LST is found to be spatially correlated with land use and land cover [8]. Land Use and Land Cover Changes (LUCC) though affected by climate change are the main drivers of environmental changes [9]. There is therefore a strong correlation between LST and land use types as confirmed by [10-12]. It has also been established in [13] and [14] that vegetation cover affects LST and the land-air exchange of energy and water.

The relationship between LST and different vegetation parameters like; Soil Adjusted Vegetation index (SAVI), Vegetation Indices (VIs), Ratio Vegetation Index (RVI) and Normalized Difference Vegetation Index (NDVI) have been widely studied. Some of them can be seen in the works of [15-19]. Lowest LST are mostly found in densely vegetated areas though it can vary with time, place and type of vegetation distribution [20]. Furthermore, LST increase is associated with decrease in vegetation and water-pervious surfaces as well as with increase in anthropogenic heat discharge due to energy consumption [7].

Corresponding Author**:** Azunna D.E., Email: azunnad@cliffordúni.edu,ng, Tel: +2347034477131

Remote sensing (RS) which is also called earth observation refers to the process of obtaining information about objects or areas at the Earth's surface without being in direct contact with the object or area. It allows images of the earth surface to be taken in various wavelength regions of the electromagnetic spectrum (EMS) [21]. It also involves the use of a remote sensor to acquire thermal signal at the Top of Atmosphere (TOA) [7]. Though point estimates of LST can be estimated from land based observation stations, remote sensing method produces actual values. There is also reliable, high resolution, repetitive coverage and proficiency of measurements of the conditions of the earth surface in remotely sensed data [22].
Analysis of Spatio-temporal dynamics of the earth's surface which helps in managing natural resources like forests and water bodies as well as the assessment of environmental changes can be achieved by space borne remotely sensed data together with Geographic Information System (GIS) [23].
Surface temperature and land surface emissivity reflecting energy in the red and near infrared portions of the EM spectrum are recorded by the sensor and are used to examine various changes in the conditions of vegetation [15]. Earth's surface thermal emissions give rise to the energy in thermal infrared band with a wavelength range of 3 -14µm and the thermal emission of the earth's surface at 300K has a peak wavelength of 10µm [24].

THE STUDY AREA

The study area covers Abia State, Southeastern Nigeria and parts of its surrounding states; Imo, Enugu, Ebonyi and Benue states. It lies between latitude 5^0 0'N to $7^0$0'N and $7^0$0'E to $8^0$0'E and has an area of about 48,400 km^2. The topography is undulating with an elevation range of 100m to 600m above the sea level. There is however a relatively even topography in the Southern parts. Geologically, the study area forms part of the Southern Benue Trough as discussed by [25] and [26]. Figure 1 shows the location map of the study area.

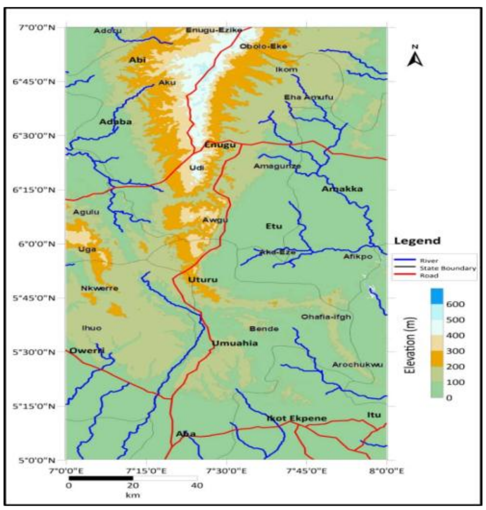

Figure 1.: The Location Map of the Study Area Showing the Elevation [26].

MATERIALS AND METHOD

In order to determine the LST and vegetation cover of the study area, the landsat imagery for the study area was obtained from the United States Geological Survey (USGS) database. Though there are other remote sensing data sources used in studying the earth's surface, landsat has a relatively high spatial resolution and more detailed land surface temperature pattern can be obtained easily [27]. It affords more possibility to study the relationship between land surface temperature and different land use types. It also enables the detection of single sources of the highest heat emission, subtle variation in soil moisture, soil type, mineral and vegetation distribution [28].
Data source was from the Enhanced Thematic Mapper plus (ETM+) of Landsat 8 which orbits the earth at an altitude of 705 km in a 185 km swath in a North-South direction over the sunlit side of the earth. It makes a complete orbit every 98.8 minute [29]. The data was collected at a resolution of 100m with an approximate scene size of 220 km North-South by 110 km East-West and the wavelength of the spectral band 10 ranges from 10.6 – 11.19µm.
The data was thereafter digitized and was subjected to various image enhancements to obtain the vegetation and analytical processes were undertaken to obtain the land surface temperature. The LST was obtained by converting the digital number (DN) of image pixels into spectral radiance (L_λ) using the sensor calibrated data as explained by [30].
The spectral radiance was thereafter converted to surface temperature in Celsius using equation 1 as defined by [30] and thereafter mapped.

$$T = \frac{K_2}{In(\frac{K_1}{L_\lambda} + 1)} - 273.15 \qquad (1)$$

where T = At-Satellite Brightness Temperature
L_λ = Top of Atmosphere (TOA) spectral radiance
K_2 = Caliberation constant 2 (Kelvin)
K_1 = Caliberation constant 1 ($Wm^{-2}sr^{-1}\mu m^{-1}$)

K_1 and K_2 are coefficients which are determined by the effective wavelength of a satellite sensor. For landsat 8, thermal band 10, $K_1 = 774.89\ Wm^{-2}sr^{-1}\mu m^{-1}$, $K_2 = 1321.08K$..
The spectral radiance (L_λ) is defined in equation 2.

$$L_\lambda = M_L Q_{cal} + A_L \qquad (2)$$

where M_L = Band-specific multiplicative rescaling factor from metadata
Q_{cal} = Quantised and calibrated standard product pixel value DN
A_L = Band specific addictive rescaling factor from metadata

For spectral band 10, M_L and A_L have identical values of $3.34x10^{-4}$.

RESULTS AND DISCUSSION

The LST map and the vegetation map of the study area are shown in Figures 2 and 3. From the land surface temperature obtained, the study area has temperature range of 20 – 34 ^{0}C with the south-Eastern areas predominantly cooler than the North-Eastern sides. Umuahia, Aba, Ohafia, Enugu and Owerri have a temperature of about 34 ^{0}C while Arochukwu, Bende, Itu and Ikot-Ekpene are relatively cooler with a surface temperature of about 20 ^{0}C.

Similarly, the vegetation map reveals two forms of vegetation which is the Rainforest and Guinea Savannah. The rainforest vegetation forms a dense canopy cover while the Guinea Savannah is covered mostly by grasses in flat and open areas [31]. The South-Eastern parts of the study area are mainly covered by thick canopy unlike the North-Eastern parts which predominantly have open lands and grasslands. Areas like Bende, Arochukwu and Uturu are good examples of the areas with the rainforest type of vegetation. They have tall trees like iroko, oil palm, mahogany, rubber, cashew and walnut. Conversely, Umuahia, Owerri, Enugu, Aba, Aka-Eze, Afikpo, Ikot-Ekpene and Nkwere all have open and grass lands filled with natural grasses and sparse trees. However, the built up areas have insignificant vegetation cover due to civilization and human activities.

Furthermore, we discovered from a closer observation at the two maps that they have an identical trend with negative correlation because areas with high temperature have sparse vegetation while cooler areas have thick vegetation cover. This agrees with the findings in [7-13, 20]. The urban areas and state capitals are relatively warmer due to dense population, deforestation, construction activities where concrete and asphalt which do not allow water to absorb large amount of heat leading to Urban Heat Island (UHI) [32]. Since Vegetation absorbs carbon dioxide and releases oxygen. Vegetation degradation therefore leads to greenhouse effect and subsequently increases atmospheric and Land Surface Temperatures [33].This undoubtedly poses a potential danger of climatic, environmental and health challenges to inhabitants of such areas.

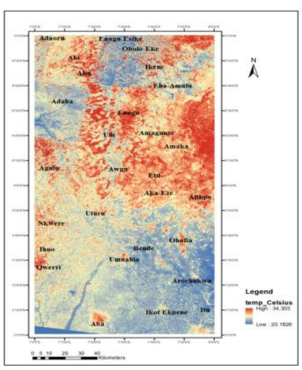

Figure 2: Land Surface Temperature of the study area

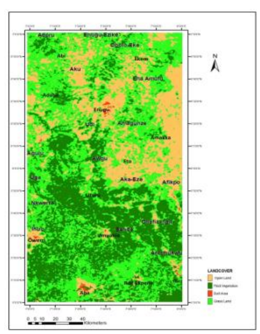

Figure. 3: Vegetation of the Study Area

CONCLUSION

Remote sensing is an invaluable tool in geospatial and geological studies. Satellite imagery data over the study area was acquired from Landsat 8. The study area has an area of 48,400km^2. The LST temperature varies from 20 – 34 ^{0}C with the urban areas having higher temperature values. The vegetation is of two types; the rainforest type and the Guinea Savannah. The rainforest type has thick canopy covers due to the presence of tall trees while the Guinea Savannah has grasses and sparsely distributed tree.

It is also established that there is a negative correlation between LST and the vegetation of the study area. Areas with high surface temperature have sparse vegetation whereas areas with low temperature values have high vegetation cover. The urban areas and State Capitals like Umuahia, Enugu, Aba, Ohafia and Owerri have high average LST of 34 ^{0}C resulting to UHI whereas areas like Arochukwu, Bende and Uturu are relatively cooler due to thick vegetation cover.

The warm temperature in the built up areas is as a result of human activities like construction, burning of fuels and green house gas emission, deforestation and increase in population due to rural-urban migration. Since climate change and their adverse effects are connected to increase in surface and atmospheric temperature, there is need to check the activities in the urban areas in order to mitigate the effects of climate change while embarking on environmentally friendly activities.

REFERENCES

[1] Dickinson, R.E. (2010) Land Surface Skin Temperature Climatology: Benefitting from the Strengths of Satellite Observations. *Environmental Research Letters*, **5**, Article ID: 044004. http://dx.doi.org/10.1088/1748-9326/5/4/044004

[2] Pu R, Gong P, Michishita R, Sasagawa T (2006). Assessment of multiresolution and multi-sensor data for urban surface temperature retrieval. Remote Sens Environ, 104(2): 211–225

[3] Azunna, D. E., Chukwu, G. U., Igboekwe, M. U., & Anyadiegwu, F. C. (2020). Climate Change: Global Indicators, Socio-economic Implications and Mitigation. *International Journal of Environment and Climate Change, 10(2), 70-80.*

[4] Bhattacharya B K, Mallick K, Patel N K, Parihar J S (2010). Regional clear sky evapotranspiration over agricultural land using remote sensing data from Indian geostationary meteorological satellite. J Hydrol (Amst), 387(1–2): 65–80

[5] Fall S, Niyogi D, Gluhovsky A, Pielke R A Sr, Kalnay E, Rochon G (2010). Impacts of land use land cover on temperature trends over the continental United States: assessment using the North American Regional Reanalysis. Int J Climatol, 30(13): 1980–1993

[6] Li, Z.L.; Tang, B.H.; Wu, H.; Ren, H.; Yan, G.;Wan, Z.; Trigo, I.F.; Sobrino, J.A. (2013). Satellite-derived land surface temperature: Current status and perspectives. Remote Sens. Environ. 131, 14–37

[7] Zhou, J.; Chen, Y.H.; Wang, J.F.; Zhan, W.F (2011). Maximum night time Urban Heat Island (UHI) intensity simulation by integrating remotely sensed data and meteorological observations. IEEE J. Sel. Top. Appl. Earth Observ., 4, 138–146.

[8] Wang S, Ma Q, Ding H, Liang H (2016). Detection of urban expansion and land surface temperature change using multi-temporal Landsat images. Resour Conserv Recycling, doi: 10.1016/j.resconrec. rec. 2016.05.011

[9] Brunsell N A (2006). Characterization of land–surface precipitation feedback regimes with remote sensing. Remote Sens Environ, 100 (2): 200–211

[10] Yokohari M, Brown R D, Kato Y, Yamamoto S (2001). The cooling effect of paddy fields on summertime air temperature in residential Tokyo, Japan. Landsc Urban Plan, 53(1–4): 17–27.

[11] Chen X L, Zhao H M, Li P X, Yin Z Y (2006). Remote sensing image based analysis of the relationship between urban heat island and land use/cover changes. Remote Sens Environ, 104(2): 133–146

[12] Cheng K S, Su Y F, Kuo F T, Hung W C, Chiang J L (2008). Assessing the effect of landcover on air temperature using remote sensing images—A pilot study in northern Taiwan. Landsc Urban Plan, 85 (2): 85–96

[13] Kumar D, Shekhar S (2015). Statistical analysis of land surface temperature–vegetation indexes relationship through thermal remote sensing. Ecotoxicol Environ Saf, 121: 39–44

[14] Petropoulos G P, Griffiths H M, Kalivas D P (2014). Quantifying spatial and temporal vegetation recovery dynamics following a wildfire event in a Mediterranean landscape using EO data and GIS. Appl Geogr, 50(2): 120–131

[15] Yue W, Xu J, Tan W, Xu L (2007). The relationship between land surface temperature and NDVI with remote sensing: application to Shanghai Landsat 7 ETM+ data. Int J Remote Sens, 28(15): 3205– 3226

[16] Wei M A, Zhou J (2011). Quantitative analysis of land surface temperature–vegetation indexes relationship based on remote sensing. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B6b. Beijing

[17] Lv Z Q, Zhou Q G (2011). Utility of Landsat image in the study of land cover and land surface temperature change. Procedia Environ Sci, 10 (1): 1287–1292

[18] Buyadi S N A, Mohd W M N W, Misni A (2013). Impact of land use changes on the surface temperature distribution of area surrounding the National Botanic Garden, Shah Alam. Procedia Soc Behav Sci, 101: 516–525

[19] Pal S, SkZiaul (2017). Detection of land use and land cover change and land surface temperature in English Bazar urban centre. Egypt J Remote Sens Space Sci, 20(1): 125–145

[20] Joshi, J.P.; Bhatt, B (2012). Estimating temporal land surface temperature using remote sensing: A study of Vadodara urban area, Gujarat. Int. J. Geol. Earth Environ. Sci., 2, 123–130.

[21] Sivakumar, M. V. K. P. S. Roy, K. Harmsen and S. K. Saha (2003). Satellite remote sensing and GIS applications in Agricultural metereology. World Meterological Organisation, Geneva. pp 23-39

[22] Zaharaddeen, Isa, Ibrahim I. Baba and Zachariah, Ayuba. (2016) Estimation of Land Surface Temperature of Kaduna Metropolis, Nigeria Using Landsat Images. *Science World Journal Vol 11 (No 3). 36-42*

[23] Bharath Setturu, Rajan KS and Ramachandra TV (2013). Land Surface Temperature Responses to Land Use Land Cover Dynamics. *Geoinformatics & Geostatistics: An Overview 1(4). 1-10.*

[24] Klaus, Tempfli, Norman, Kerle, Gerrit C. HUurneman and Lucas L.F. Jansseen (2009). Principles of remote sensing. The international institute for geo-information science and earth observation pp 56 – 105.

[25] Ofoegbu, C. O. A review of the geology of the Benue Trough, Nigeria. (1985) *J. Afr. Earth Sci.,* 3: 293-296

[26] Azunna, D. E., Chukwu G.U and Igboekwe, M. U (2020). Investigation of the Geomorphology, Mineral and Hydrocarbon Potential of Abia State and Environs, Southern Nigeria Using Landsat Imagery. *International Journal of Engineering and Scientific Inventions Vol 9(4). 32-44*

[27] Gastellu-Etchegorry. J. P. (1990). An assessment of SPOT X and Landsat MSS data for digital classification of near-urban land cover, International *Journal of Remote Sensing 11(2): 225-235.*

[28] Goward , S.N. & D.L Williams (1997). Landsat and Earth Systems Science: Development of terrestrial monitoring. *Photogrammetric Engineering and Remote Sensing,* 63 (7), Pp 887-900.

[29] United States Geological Survey (USGS). Landsat-A global Land-Imaging Mission. Fact Sheet of the U.S Geological Survey. 2013.

[30] Qin, Z., A. Karnieli, and P. Berliner (2001). A mono-window algorithm for retrieving land surface temperature from Landsat TM data and its application to the Israel-Egypt border region. *International Journal of Remote Sensing, 22, pp.3719-3746.*

[31] Geographical Alliance of Iowa (GAI) (2010). The human and physical characteristics of Nigeria. University of Northern Iowa.

[32] Gusso, A.; Cafruni, C.; Bordin, F.; Veronez, M.R.; Lenz, L (2014). Multitemporal Analysis of Thermal Distribution Characteristics for Urban Heat Island Management. In Proceedings of the 4thWorld Sustainability Forum, Basel, Switzerland, 1–30; pp. 1–17.

[33] Ma, W., Chen, Y. and Zhou J., (2008), "Vegetation Coverage and Land Surface Temperature Relationship for Quantitative Analyses of Urban Heat Island", State Laboratory of Earth Surface Processes and Resource Ecology, College of Resources Science and Technology, Beijing Normal University, Beijing, China 100875, pp 1-2.