WEST AFRICAN JOURNAL ON SUSTAINABLE DEVELOPMENT

Spatiotemporal Estimation Of Tree Cover Loss In Comparison With Land Surface Temperatures Using Remote Sensing Approach In Nnamdi Azikiwe University, Nigeria

J. A. Ogbodo[1], L. A. Chukwufulike[1], C. L. Umeh[1] and P. O. Odey[1]
[1]Department of Forestry and Wildlife, Nnamdi Azikiwe University, Awka

Corresponding author's email: ja.ogbodo@unizik.edu.ng

ABSTRACT

Human pressures have a unique impact on the carbon cycle and forest ecosystem resilience The loss of tree cover (TC). The increase in urban areas contributes significantly to the loss of vegetation cover (VC), which accelerates carbon emissions, increasing land surface temperature (LST) and global warming. This study used remote sensing and GIS techniques to estimate the Land Use/Land Cover (LU/LC) changes by focusing on VC loss and its impact on LST and carbon emissions in Nnamdi Azikiwe University during 2001-2021. The study's findings confirmed an reduction of VC of about -39% from 2001- 2011 with around 27.2% increase of vegetation cover loss, and corresponding LST rise from 22˚C to 35˚C. The trends were continuous, with a decrease in VC loss by -30% during 2011–2021, contributing 26˚C– 42˚C LST rise in the study area. Results indicate that the massive amount of carbon attracted the sun's rays due to the TC loss and raising the surface temperature by 20˚C since 2001, which directly contributing to global warming. Thus, to mitigate climate hazards, efforts to slow urbanization to reduce pollution gateways and increase carbon sinks through afforestation will significantly contribute to protecting humanity from global warming.

INTRODUCTION

One of the most significant environmental issues facing humanity today is global warming. The study of the connection between land surface temperature (LST) and forest resources has opened up a lot of new avenues recently. According to Chen et al. (2022), as a result of rapid urbanization, patterns and processes in the urban landscape have evolved, changing the types of surface cover and, ultimately, the thermodynamic properties of urban surfaces, giving rise to the urban heat island (UHI) effect and other ecological ramifications.

According to Ogbodo et al., (2020)'s three-decade campus-level research reveals that, unplanned urban expansion is a major factor contributing to tree cover change within the Awka Campus of Nnamdi Azikiwe University (NAU). Since its founding in 1992, NAU has experienced extraordinary growth, development, and developmental activities such as building, road construction, and many other human activities. Accordingly, such scenario directly contributes to increasing the land surface temperature (LST) of the Nnamdi Azikiwe University Campus.

Therefore, the primary goal of this study was to map the land surface temperature using multi-temporal satellite remote sensing images based on the different land cover types accessible inside the University in order to evaluate the influence of urban heat island within the Nnamdi Azikiwe University campus in Awka. Land surface temperatures (LST) within an ecological environment can be reliably modeled using remote sensing techniques (Hart and Sailor, 2009). It is simpler to assess, track, and simulate LULC and LST fluctuations when RS and GIS technologies are combined (Niyogi, 2019). Furthermore, the spatiotemporal evaluation of LULC and LST dynamics, which are applied to remotely sensed data, has produced important and clever answers to the temperature raising difficulties caused by haphazard land cover change (Celik, 2019).

Thermal remote sensing technology is to measure the urban heat island (UHI) which is considered as an effective approach to evaluate the inauspicious impacts of human activities on local climate over the last couple of decades (Naim and Kafy, 2021). In the light of the above, the goal of this study is to investigate a two-decade loss of forest cover and its impacts on LST (2001 to 2021) using Landsat satellite remote sensing approach in Nnamdi Azikiwe University Awka towards contributing to attaining sustainable university campus in line with the Paris Climate Agreement in Nigeria.

METHODOLOGY

Study Area: This study was conducted at Nnamdi Azikiwe University (NAU) in Awka, Anambra state. NAU is situated on the geographic coordinates of 6°14’38.4”N and 7°07’18.7”E. The temperature in Awka is generally 27–30oC between May and January but rises to 32–34^{o}C between February and April, with the last few months of the dry season marked by intense heat (Ogbodo et al., 2020).

Remote sensing data used in this study: Two multi-sensor Landsat imagery (i.e. Landsat 7 ETM and Landsat8 OLI) were downloaded from https://earthexplorer.usgs.gov and analyzed in this study. The above-mentioned data each has 30m spatial resolution. The Landsat satellite imageries were taken during the dry seasons of Years: 2001, 2011, and 2021.

Ground-Truthing Data for Validation: To validate the classified maps, ground-truth (reference) data together with their Global Positioning System (GPS) coordinates were obtained from Google Earth in ascertaining how many ground truth pixels are correctly classified. Therefore, fifty (50) regions of interest (AOI) were purposefully sampled per land cover class in the study area.

Estimation of Normalized Differential Vegetation Index (NDVI): For this study, NDVI values are grouped/ stratified into five classes using the raster calculator. The resolutions of the NDVI values were compared with standard NDVI values to determine the loss of VC over the study area for the years 2001, 2011 and 2021. The class of NDVI was estimated to identify the concentration of LST rise in different categories of VC classes. NDVI values were calculated using Equation 1 (Pettorelli, 2013):

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

Estimation of Land Surface Temperature (LST): Land Surface Temperature which measures the thermal radiance from the land surface where the incoming solar energy interacts with and heats the ground was estimated using Landsat thermal band images from 2001, 2011, and 2021 which are band 6 (2001 and 2011) and band 10 (2021). The LST for this study was calculated using the raster calculator in Arc GIS 10.3. Landsat sensors accumulate thermal data and Digital Numbers (DN and these DN were converted to LST with four steps process illustrated below (Kafy et al., 2021; Celik et al., 2019).

Estimation of Land Cover: Satellite images were classified into five land cover classes, namely built-up area, forest, farm land, pave land and bare surfaces in the study area. The aforementioned land cover classes were made based on spectral characteristics of the at image analysis (Phiri and Morgenroth, 2017). Next, supervised classification was done by following three stages that included training data sets, classification and output. Training samples were taken for each land cover type that was identified on the supervised classification output. The classification was done by using maximum likelihood classifier (Shivakumar and Rajashekararadhya, (2018). The

Supervised classification scheme which was used and identified on the image is five land cover classes: Built-up Area, Bare Ground, Forest, Farmlands and Pave land. The Raster processing tools on ArcGIS were used for data processing and training samples from the different images were collected using image classification tools on ArcMap and the accuracy was evaluated. After the collection of training samples, the images are classified based on the algorithm specified.

RESULTS

i. **Results of Land Cover Classification Analysis**

In the supervised classification, false color composite of the image was created for the classification to be done, bands 7, 4, 2 for Landsat 7 images and 7, 5, 3 for Landsat 8 images. The data below in table 2 shows the percentages of change detected in 2001 over 2021, which are; built-up areas (67.39%), farm lands (62.77%) and reduction in forest (-55.50%), bare lands (-52.94%) as a result urbanization, agriculture, industrialization etc.

ii. **Analyzing the intensity of vegetation coverage from 2001 - 2021**

The health status of Vegetation Cover in the study area for different time intervals is estimated using NDVI distribution analysis illustrated in figure 6 where the green areas indicates vegetation and the yellow and red areas indicates non- vegetation In the supervised classification, false color composite of the image was created for the classification to be done, bands 7, 4, 2 for Landsat 7 images and 7, 5, 3 for Landsat 8 images. The data below in table 2 shows the percentages of change detected in 2001 over

2021, which are; built-up areas (67.39%), farm lands (62.77%) and reduction in forest (-55.50%), bare lands (-52.94%) as a result urbanization, agriculture, industrialization etc. Figure 2 shows the land cover map for the period under investigation while Figure 1 shows the graphical representation of the land covers distribution of the study years.

Table 1: NDVI values showing tree loss in the study period

Study Year	2001	2011	2021
NDVI Values	0.56	0.52	0.34

NDVI values for 2001, 2011 and 2021

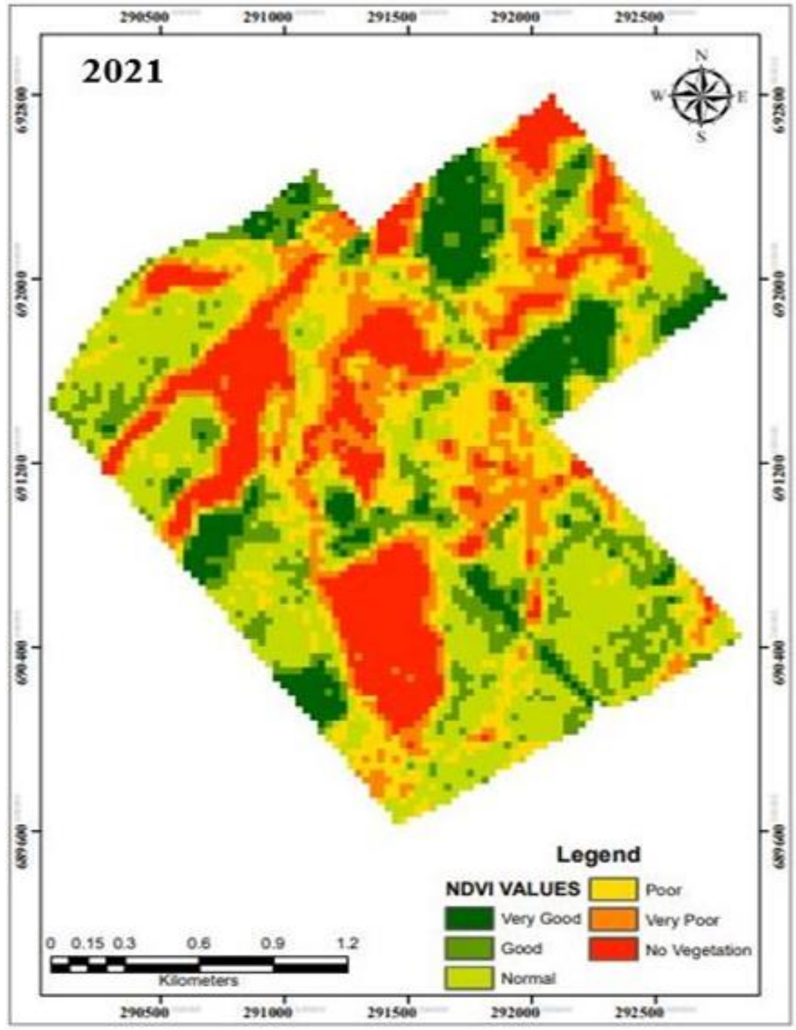

Figure 1: Map of the landcover types showing tree cover density (green colour) in 2021

iii. **Variations of LST – 2001, 2011 and 2021**

Spatial distribution map in Figure 1 indicates the lowest and the highest LST values range that vary across the three selected periods which are; 22˚C - 33˚C for the year 2001, which increased to 26˚C to 35˚C in 2011 and further increased to 28˚C to 42˚C in the year 2021.

DISCUSSION

Ogbodo et al. (2017) express that expansion of infrastructures is one of the factors that drive deforestation in public universities that are majorly situated within the natural forest part of Southern Nigeria. The results of this study is in agreement to Ogbodo et al. (2017) as forest land cover was the major land cover in 2001, but gradually reduced as a result of human induced factors, while built ups continued to increase and gradually became the major land cover in 2021 such as lecture theatres, administrative blocks, student hotels, without corresponding reforestation or afforestation. Furthermore, Igu *et al.*, (2021) expressed that, forest cover is reducing at astronomical scales as a result of a host of anthropogenic activities. Its greatest toll and impact are however seen in tropical landscapes where land use changes arising from agriculture and urbanization (built up areas) are growing in scale. Clearly, forest land cover suffers in the face of industrialization, urbanization, human population increase and infrastructural development; due to the fact that Governments and some individuals are more interested in the immediate economic growth, hence pay little attention to the environmental services that forest vegetation provide. Fiasal *et al.*, (2021), identified that deduction of healthy vegetation cover by impervious surfaces such as buildings and roads accelerates less sensible heat fluxes by replacing robust latent heat fluxes released by Vegetation Cover through evapotranspiration. Pettorelli, (2013) stated that, the health of a forest is mostly determined by how well its vegetation absorbs most of the visible light that hits it, while reflecting a large portion of the near – infrared light. Unhealthy or sparse vegetation reflects more visible light and less near – infrared light. While in 2021, it was observed that the forest cover reduced to 18.5%, likewise it's NDVI value to 0.34 and it's LST increased to 28◦C. This is an indication of a loss in the protective function of the forests in the study area, as more solar radiation directly hits the land surface. Such anomalies are expected and inevitable in an area with increasing population and attendant pressures such as the Niger Delta region and much of tropical landscapes (Igu, 2017). The declination of vegetation cover and the increase of non-vegetated areas have intensified this huge increase of LST. This period was characterized by intense deforestation and clearing of land for various developmental projects and agriculture which is made evident by the level of increase in observed bare land and built-up areas which are characterized by vegetal removal and the concomitant decrease in total vegetal cover. This rapid depletion of vegetation cover has a wide range of impacts such as in the reduction of the natural cooling effects of shading and evapotranspiration of plants and shrubs. However, rapid urbanization and reduction in Vegetation Cover are mainly responsible for temperature increase and Urban Heat Island effect.

CONCLUSION AND RECOMMENDATION

This paper reports a significant change in tree cover density of the study area basically due to expansion in the built-up areas. The NDVI values further indicates that, tree cover areal has reduced during the period of 2001 – 2021. Over the course of the study years, there is a corresponding increase in the LST values in the University. Specifically, LST values are higher where NDVI values are -1 (red colours in Figure 1). In conclusion, Nnamdi Azikiwe University has continuously recorded a significant loss of tree cover density from 2001 to 2021. During the same period, high land surface temperature values were also reported. As a recommendation, there is need for massive tree planting activities to mitigate the impacts of tree cover loss in the study area.

REFRENCES

Celik, S. Kaya, U. Alganci, D.Z. Seker, (2019). Assessment of the relationship between land use/cover changes and land surface temperatures: a case study of thermal remote sensing, Feb-Fresenius Environmental Fresenius Environ. Bull. 3 (541).

Chen Han, Yizhao Wei, and Jinhui Jeanne Huang (2023). Altered landscape pattern dominates the declined urban evapotranspiration trend, Journal of Hydrology, Volume 627, Part B, 130296, https://doi.org/10.1016/j.jhydrol.2023.130296

Hart, M.A., Sailor, D.J., (2009). Quantifying the influence of land-use and surface characteristics on spatial variability in the urban heat island. Theor. Appl. Climatol. 95, 397–406.https://eos.com/blog/ndvi-faq-all-you-need-to-know-about-ndvi/

Igu, N. I., Ayogu, C, N. and Okolo, N. V. (2021). Soil carbon dynamics in a humid tropical zone in SE Nigeria: Environmental influences and conservation prioritization. Journal of Geography and Regional Planning, 14 (1): 19-31.

Ogbodo, John Agbo and Okeke, Francis Ifeanyi (2022). Spatial analysis of southeastern forest reserves in Nigeria using open geospatial data, African Geographical Review, DOI: 10.1080/19376812.2021.2019069.

Phiri, Darius, and Justin Morgenroth. (2017). "Developments in Landsat Land Cover Classification Methods: A Review" Remote Sensing 9, no. 9: 967. https://www.mdpi.com/2072-4292/9/9/967

Kafy A.A, Rahman M.S., Faisal A.A., Hasan M.M., Islam M., (2021). Modelling Future Land Use Land Cover Changes and Their Impacts on Land Surface Temperatures in Rajshahi, Bangladesh, Remote Sensing Applications: Society and Environment. LST-Land Surface Temperature (2021, August 04) Copernicus Global Land Service https://land.copernicus.eu/global/products/lst

Naim M.N.H., Kafy A.A., (2021). Assessment of Urban Thermal Field Variance Index and Defining the Relationship between Land Cover and Surface Temperature in Chattogram City: A Remote Sensing and Statistical Approach, Environmental Challenges,, p. 100107

Niyogi, D., (2019). Land Surface Processes, in: Current Trends in the Representation of Physical

Processes in Weather and Climate Models. Springer, pp. 349-370.

Ogbodo, John a., Obimdike Loretta M. and Benison Yason (2020). Remote Sensing For Urban Tree Canopy Change Detection With Landsat Satellite Data In Nnamdi Azikiwe University Awka – Nigeria

Ogbodo, J. A., Oke, D. O., & Dagba, B. I. (2015). The Potential of Synthetic Aperture Radar (SAR) Imagery in Automated Detection of Forest Degradation Features Using Visual and Semi-Automated Analyses. Land Use, Landuse Change and Forestry.

Ogbodo, J. A., Tembe, E. T., & Peter, J. G. (2017). Assessing the issues and prospects of sustainable forestry in Nigeria. *WFO Farmletter*, 9–12. Retrieved from https://www.researchgate.net/publication/314239587_Assessing_the_issues_and_prospects_of_sustainable_forestry_in_Nigeria

Pettorelli, N. (2013). The normalized difference vegetation index. Oxford University Press, UK. https://academic.oup.com/book/8114

Shivakumar, B. R. and Rajashekararadhya, S.V., (2018). Investigation on Land Cover Mapping Capability of Maximum Likelihood Classifier: A Case Study on North Canara, India, Procedia Computer Science, Volume 143, Pages 579-586. https://www.sciencedirect.com/science/article/pii/S187705091832132X