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Monitoring the effects of vegetation cover change on land surface temperature in Nimbia Forest Reserve, Nigeria

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ABSTRACT

Vegetation cover regulates the surface temperature through shading and evapotranspiration. The loss of vegetation cover is a major factor causing higher Land Surface Temperature (LST). This study analyses the effect of forest cover change on LST in Nimbia forest reserve, Nigeria using Landsat data. Maximum-likelihood algorithm was used to classify the area into vegetation and non-vegetation areas. Single-channel algorithm and Normalised Difference vegetation Index (NDVI) were used to extract LST and vegetation density respectively. The relationship between vegetation cover and LST was quantified by correlation analysis. The results revealed that from 2013 to 2020, the forest area decreased from 11.50km^2 (81.28%) to 10.14 km^2 (71.68%). The average NDVI also declined from 0.63 to 0.42 which led to the increase in the mean LST from 30°C to 34.5°C. There is a need for monitoring the forest reserve for proper conservation.

Introduction

Vegetation cover provides a vital role in the mitigation of climate change through the cooling effects of shading, high albedo and evapotranspiration [1]. Decrease in vegetation cover as a result of urban expansion and other anthropogenic activities contribute to an increase in surface temperature [2-4]. Land Surface temperature is the radiative temperature of the surface that is derived from solar radiation [5-6].

Remote sensing is one of the effective tools used for studying LST because of its ability to record emitted energy from the surface [4]. Moreover, vegetation cover can be studied from the remotely sensed data using an index [7]. Nimbia Forest reserve located in Kaduna, Nigeria experiences a decline as a result of anthropogenic activities [8]. The degradation of the forest affects both the surface and air temperature. This study analyses the effect of the forest change on LST.

Materials and Methods

Study area

Nimbia forest reserve located in Jema'a Local Government Area of Kaduna State, Nigeria lies between longitudes 8°30' and 8˚35' E and latitudes 9˚29' and 9˚31' N (Figure 1). It is located in the Guinea Savanna vegetation zone with an approximate area of 2, 282.4 hectares. The natural vegetation was cleared in 1976 and replaced with much teak (*Tectona grandis*) and a few *gmelina arbirea* stands. The minimum temperature ranges between 11˚C and 12.9˚C, while a maximum temperature of 25˚C is recorded in March [8]. July and August are the months with the highest relative humidity because of the high rainfall [8-9].

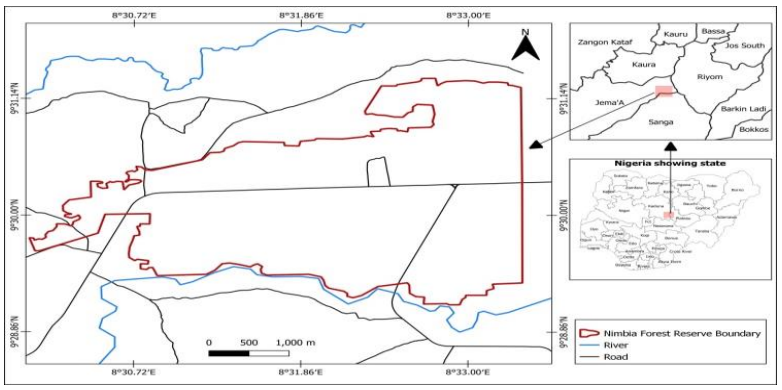

Figure 1. Location of the study area

Data

In this study, satellite data acquired by Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensors (TIRS) were obtained from the United States Geological Survey Earth Explorer data portal. Imageries dated 11 November, 2013 and 30 November, 2020 were used for the extraction of LST and vegetation cover.

Methods

The study area was classified into vegetation and non-vegetation using a maximum likelihood supervised classification. Normalised Difference Vegetation Index (NDVI) was employed to extract the vegetation density, Single channel algorithm was used to retrieve the LST and finally, the relationship between LST and vegetation cover was quantified using correlation analysis. The satellite imageries were processed using Semi-Automatic Classification Plugin (SCP) for QGIS.

Results

The results revealed that in 2013, the area was dominated by vegetation that covered 11.50km^2 (81.28%), while the non-vegetation area accounted for 2.65km^2 (18.72%). In 2020, the forest decreased to 10.14 km^2 (71.68%) as a result of the expansion of the non-vegetation area that increased to 4.01 km^2 (28.32%). Generally, from 2013 to 2020, the forest reserve decreased by 1.36 km^2 (13.45%) while the non-forest area expanded by 1.36 km^2 (33.87%). The density of the vegetation indicated by the NDVI values shows a spatial and temporal variation (Figure 2). In 2013, the lowest value was 0.43, while the highest was 0.83. There was a decline in 2020 with 0.19 and 0.65 as the lowest and highest values respectively.

The spatiotemporal pattern of the LST varied over the forest reserve or the study period (Figure 2). A surface temperature ranges from 26^{o}C to 34^{o}C was recorded in 2013 with an increase in 2020 that range from 29^{o}C to 40^{o}C. There is a negative correlation between vegetation cover and LST with -0.79 and -0.81 for 2013 and 2020 respectively.

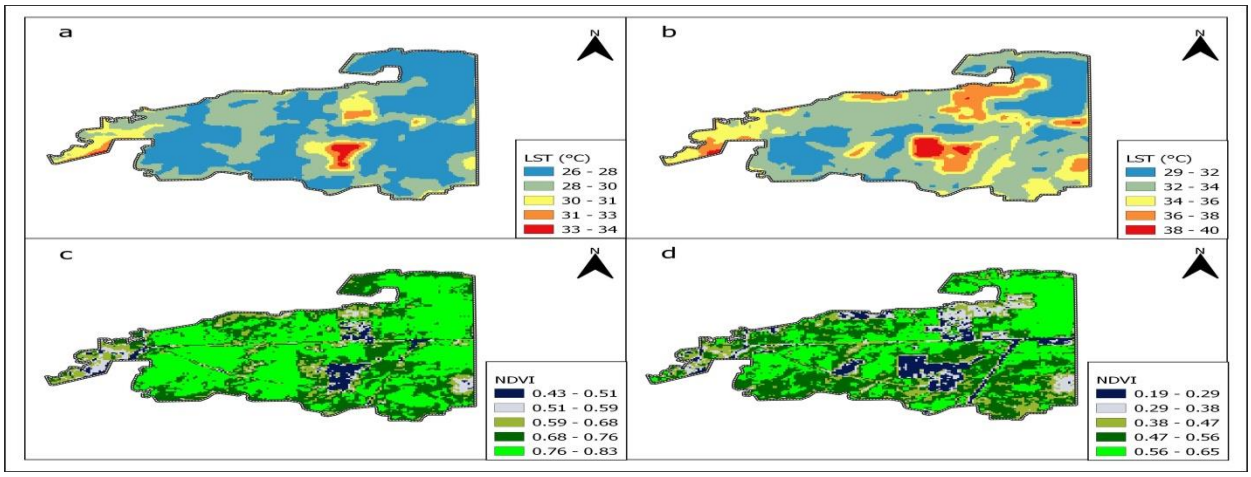

Figure 2. (a) LST map for 2013 (b) LST map for 2020 (c) NDVI map for 2013 (d) NDVI map for 2020

Discussion

The decrease in the forest reserve is a result of anthropogenic activities like clearance for agriculture and collection of wood from the forest. The decrease in the density of the forest indicated by the NDVI values can be attributed to such anthropogenic activities. A previous study by [8] also found a decline in the forest reserve as a result of the anthropogenic activities. An increase in the spatiotemporal pattern of the LST is connected with the decrease in vegetation as a result of decrease in shade, albedo, and evapotranspiration. Moreover, heat emission from the cleared part of the forest contributed to the increase in the surface temperature. The negative correlation between the vegetation cover and LST shows the effect of vegetation in mitigating the LST.

Conclusion

This study examines the effect of vegetation cover change on LST in Nimbia forest reserve, Nigeria. Landsat data were used to extract vegetation and LST single-channel algorithm and NDVI respectively. Maximum likelihood supervised classification was applied to classify the area into vegetation and non-vegetation areas. Correlation analysis was used to quantify the relationship between vegetation and LST. The result revealed a decrease in the area of the forest as a result of anthropogenic activities that led to a decline in its density. There was an increase in the spatiotemporal pattern of the LST caused by the decrease in the vegetation cover. A negative correlation indicated the effect of forest in mitigating LST. Remote sensing is a powerful tool for evaluating the influence of vegetation cover change on LST.

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Author contributions:

Bello Abubakar Abubakar: Conceptualization, Methodology, Writing-Original draft preparation, Writing-Reviewing and Editing. **Sani Abubakar Abubakar:** Data curation, Software, Validation**,** Visualization, Investigation.

Conflicts of interest: The authors declare no conflicts of interest.

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