Impact of Deforestation on Land Surface Temperature in Northern Part of Bauchi State, Nigeria

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Abstract

This study analyses the change in vegetation and land surface temperature as a result of deforestation in northern part of Bauchi State, Nigeria using Landsat 8 OLI. The study employed both remote sensing and Geographic Information System (GIS) techniques to analyze the trend over a period of 33 years in northern part of Bauchi State, where a typical cycle of forest destruction is evident. Linear regression was used to determine the linear relationship between the vegetation abundance with Land Surface Temperature. From the NDVI and temperature change map for 1986 to 2002, the study area shows changes with reflectance 0.53 high and -0.66 low for NDVI while 12.75 high and -21.43 low for temperature. Similarly, the NDVI and Temperature change map for 2002-2018, the study area witnessed significant increase in the changed area with 0.68 and -0.52 high and low reflectance values of 17.82 high and -14.97 low temperature changes respectively. The results revealed that, decrease in vegetation abundance in the study area resulted to a relative increase in land surface temperature. It is therefore recommended that, further research should be conducted to cover the entire Bauchi State in order to have a holistic view, hence policy and decision for combating desertification.

Keywords: Deforestation**,** GIS, Remote Sensing, NDVI, LST, Landsat 8 OLI/TIRS

INTRODUCTION

Deforestation is the permanent removal of standing forests, as the U.S. Environmental Protection Agency defines it (USEPA, 2011). The impact of deforestation on land generally, implies temporary and permanent recession from higher to a lower status of productivity through deterioration of physical, chemical and biological aspects (Tagore, *et al*. 2012). Deforestation, arising from haphazard cutting or over-harvesting of trees to clear the land for agriculture, construction, ranching or any other human activities has been a major concern worldwide (Mortan *et al*. 2006 and Boucher, *et al*. 2011). It has been shown that in African countries rates of deforestation continue to worsen as forest are tightly linked to the livelihoods of poor rural African households. According to FAO, (2001) and WWF (2019) for thousands of years the action of man has been gradually diminishing the world's forest resources by clearing and felling of trees for fuel, bush burning or making way for agriculture, settlement and industry. This was a relatively slow process in many areas in the past, but it has now been speeded up by population explosion as well as economic activities especially in the provision of fuel wood and development (Mohammed, 2014).

Forests are known to reflect less sunlight and have higher evapotranspiration than open vegetation, meaning that deforestation and forestation could affect local land surface temperature.

Deforestation and forestation generally have opposite effects of similar magnitude on local and surface temperature (Yan Li, *et al*. 2016; Jayme, *et al*. 2019).

Different methods were used in the determination of deforestation and land surface temperature and their relationships. Youneszadeh *et al* (2015) had carried out an investigation into the application of remote sensing and GIS in connection with statistical methods to provide quantitative information on the effect of land use changes on land surface temperature (LST) by applying the MODIS Terra (MOD11A2) Satellite imagery product. Shakirudeen and Gbolahan (2015) also assessed the change in some environmental parameters in the Plateau region of Central Nigeria (Barkinladi, Jos and Kafanchan) using the nexus of land cover change, land surface temperature surface albedo and topography. The study employs both remote sensing and statistical techniques to analyse the dynamics between and within these environmental variables. The result of the study shows an increase in LST and albedo and a decrease in vegetation in the area.

Similarly, in their study, Koppa and Malin (2018), employ the potentials of Landsat8 and Landsat 4-5 data to estimate land surface temperature in parts of KumtaTalu of Uttara Kannada District region. The result show that surface temperature was high in barren and settlement regions whereas was low in the thick vegetation cover. A geospatial and survey techniques was used by Balogun and Samakinwa (2015) to identify various transformations in land use land cover types and their corresponding land surface temperature (LST) between a twenty year time intervals in Akure, Nigeria. A very strong negative correlation between the LST and the NDVI was established.

Since it was established that research and policy development on deforestation must be location based (Adams, 2009), this research would assess the impact of deforestation on land surface temperature in northern part of Bauchi State using Landsat imagery. This would be achieved by determining the different vegetation cover and land surface temperature of the study area. The relationship between these variables (vegetation abundance and land surface temperature) would also be determined.

Bauchi State is a state where deforestation is worst hit especially in the northern part of the state. The nature of deforestation is characterized by cutting down of trees for infrastructures that includes roads, buildings, non-availability of energy option such as kerosene and cooking gas has made people in the area to resort to fuel wood by cutting trees for their daily cooking and as source of income. The fuel wood is done by both commercial fuel merchants who use trucks to evacuate large quantity of woods to the capital city of Bauchi and other neighboring urban centers. These problems have far reaching adverse impact on human health, natural resources, environment and its effect on climate changes.

The study is designed to assess the impact of deforestation on land surface temperature in northern part of Bauchi State of Nigeria. The scope of the study therefore is limited to assessment of vegetation cover, computing land surface temperature, analysis and determination of changes in vegetation and land surface temperature for a period of 33yrs.

The study area

The study area is in Bauchi State situated in the north-eastern Nigeria. The state was formed in 1976 when the former north-eastern state was split. Bauchi State covers an area of 49,119km^2

representing 5.3% of Nigeria's total land mass and geographically located between latitudes 9° 3′ and 12° 3′ north and longitudes 8° 50′ and 11° 00′ east. The state has two distinctive vegetation zones, namely the Sudan savannah and the Sahel savannah with Rainfall between 1300mm per annum in the south and only 700mm per annum in the extreme north.

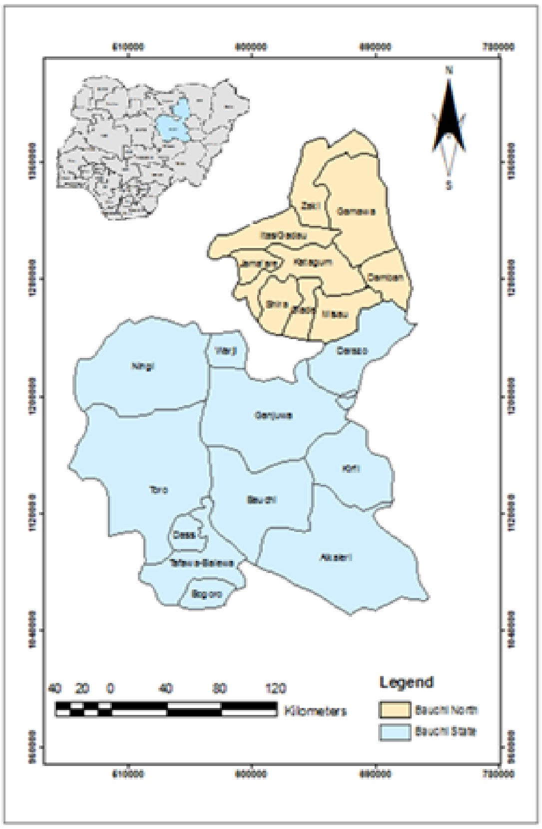

Table 1: Data set for Analysis

Data type	Resolution	Date	Source
Landsat 5,	30m	1986	USGS
Landsat 7	30m	2002	USGS
Landsat 8	30m	2018	USGS

Figure 1: Left, Study area, North of Bauchi State. Inset, map of Nigeria showing Bauchi State

METHODOLOGY

The procedure of data analysis includes computation of normalized difference vegetation index (NDVI), measurement of land surface temperature and producing change map from Normalized Difference Vegetation Index and Land surface temperature results of the year 1986-2018 using image differencing.

Data Processing and Analysis

Image processing and enhancement

The area of interest was extracted from Landsat 8 OLI/TIRS using image extraction by mask in the ArcGIS's ArcToolbox. The existing shapefile for the study area was used in extracting the boundary of the area of interest. Solar radiation reflected by the Earth's surface to satellite sensors is modified by its interaction with the atmosphere. The objective of applying an atmospheric correction is to determine true surface reflectance values and to retrieve physical parameters of the Earth's surface, including surface reflectance, by removing atmospheric effects from satellite images. Atmospheric correction is arguably the most important part of the pre-processing of satellite remotely sensed data. Such a correction is especially important in cases where multitemporal images are to be compared and analyzed. The parameter used for atmospheric correction were extracted from the metadata provided by the USGS for Landsat TM, ETM+ and OLI for 1986, 2002 and 2018 respectively. The digital numbers (DN) were converted to reflectance number which was in turn used for the atmospheric correction of the bands. The relationship below was used for atmospheric correction with the help of raster calculator.

Reflectance = Reflectance Multiband * DN Values + Reflectance ADD_Band/Sin (Sun Angle)

Where;
DN values are the respective bands for study period

Correction for sun angle = TOA reflectance /sin(sun elevation) 1

The above parameters were added in the equation above to obtain the atmospherically corrected images for the study period from 1986 to 2018, hence NDVI computation.

Assessing the vegetation cover

Normalized Difference Vegetation Index (NDVI) was used to assess the vegetation vigour. NDVI is therefore a measure of vegetation health and productivity, sensitive vegetation density and photosynthetic capacity. The equation below was used in creating the NDVI map.

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED} \qquad 2$$

Land surface temperature measurement

The land surface temperature was measured to determine the spatio-temporal variation in temperature, raster calculator of Arc map 10.1 was used. This was achieved using the following equations

Convert DN to radiance

$$L_{\lambda} = \left((LMAX_{\lambda} - LMIN_{\lambda})/(QCALMAX - QCALMIN)\right) \times (QCAL - QCALMIN)LMI \qquad 3$$

where:
Lλ= Spectral Radiance at the sensor's aperture in watts
QCAL= the quantized calibrated pixel value in DN
$LMIN_{\lambda}$= the spectral radiance that is scaled to QCALMIN in watts
$LMAX_{\lambda}$= the spectral radiance that is scaled to QCALMAX in watts
QCALMIN= the minimum quantized calibrated pixel value (corresponding to $LMIN_{\lambda}$)
QCALMAX= the maximum quantized calibrated pixel value (corresponding to $LMAX_{\lambda}$)

Convert temperature (in Kelvin)

The temperature of the area measured using the relation in equation 4 below:

$$T = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)} \qquad 4$$

Where:
T = Effective at-satellite temperature in Kelvin
K1 = Calibration constant 1 from Table 2.2

K2 = Calibration constant 2 from Table 2.2
L = Spectral radiance in watts

Convert from degree Kelvin to degree Celsius
The temperature was converted from Kelvin to degrees using equation 4 above.

$$C = K - 273.15 \quad 5$$

Table 2: Thermal Band Calibration Constants

Sensor	Constant 1-K1	Constant 2 –K2
Landsat 7	666.09	282.71
Landsat 5	607.76	1260.56

Relationship between Land Surface Temperature and Vegetation Abundance
Microsoft excel was used to explore the relationship between Land Surface Temperature and vegetation abundance. Scatter plot was used to show linear relationship between temperature and vegetation cover.

Change detection analysis
Change detection was done for both Normalized Difference Vegetation Index and Land Surface Temperature. Image difference was used in performing the change detection with the help of image difference tool in image analyst of ArcGIS 10.1 version.

RESULTS AND DISCUSSION

Results

Figure 2, 3 and 4 are the NDVI map of the year 1986, 2002 and 2018 of the area respectively. In 1986 (figure 2a), there is significant amount of vegetation especially towards the southern part of the area. But in 2002 and 2018 (figure2b, c), the maps shows a significant drop in the amount of vegetation around the southern part of the area compared to that of 1986. These indicate that the amount of vegetation continues to witness a decline in the area over this period.

The LST maps of the area in 1986, 2002 and 2018 are hereby presented below in figures 5, 6 and 7 respectively. In 1986 (figure 3a), the nortern part of the study aarea where vegetation seems to be very low shows a high amount of temperature in terms of reflectance. The temperature continue to increase significantly almost throughout the study area between 2002 and 2018 (figures 3b,c) respectively.

Microsft excell was used to calculate the relationship between the LST and the vegetation abundance. The relationship are presented on figure 4a,b,c. Figure 4a shows the relationship between NDVI and LST in 1986, Figure 4b is the relationship between NDVI and LST in 2002 while Figure 4c shows the relationship between NDVI and LST in 2018. All the results for 1986, 2002 and 2018 shows strong correlation between LST and NDVI.

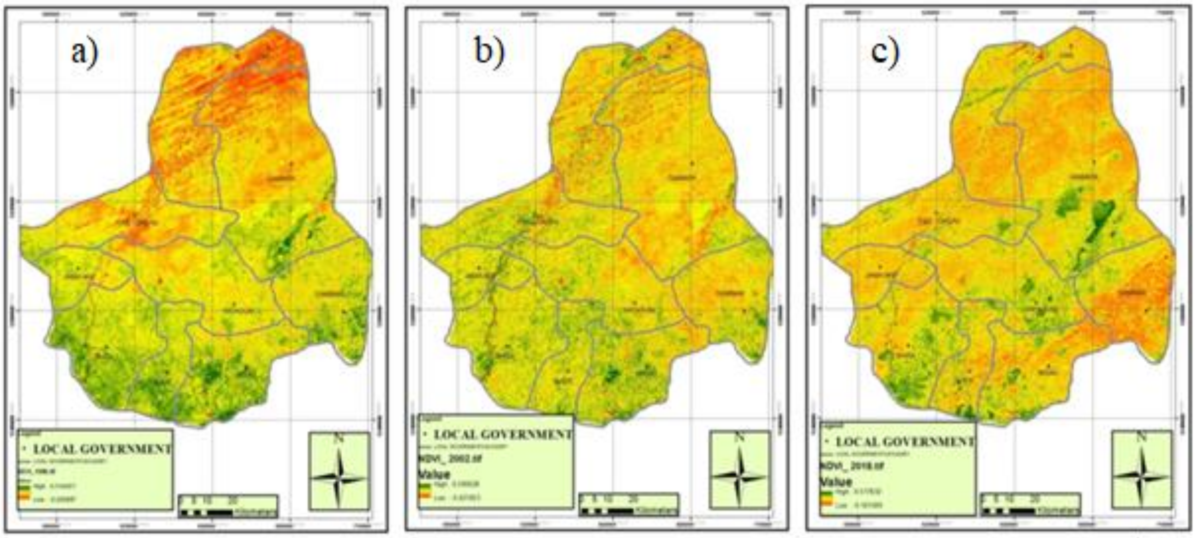

Figure 2: NDVI maps of: a) 1986, b) 2002 and c) 2018

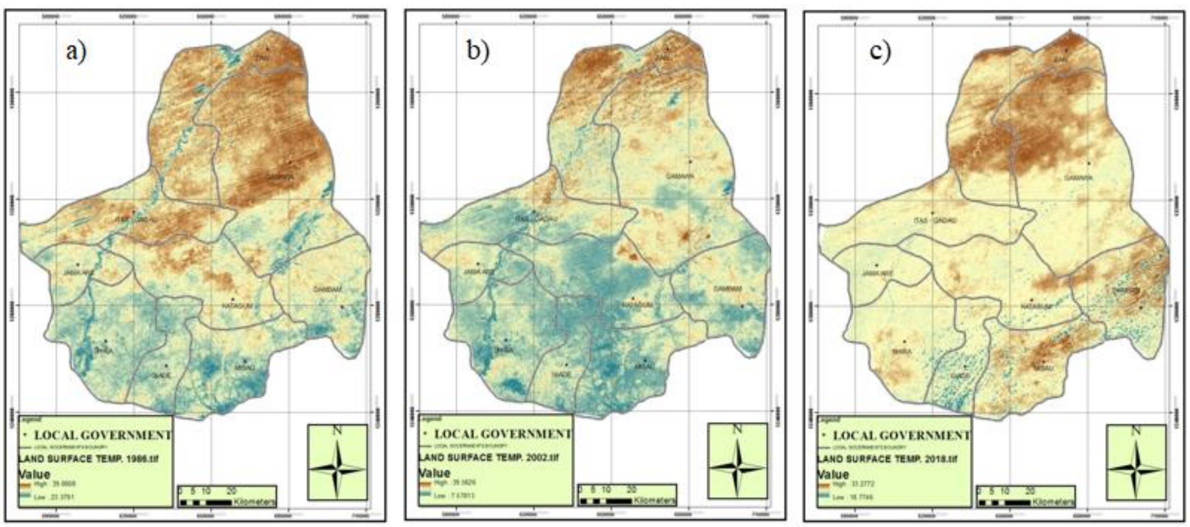

Figure 3: LST maps of: a) 1986, b) 2002 and c) 2018

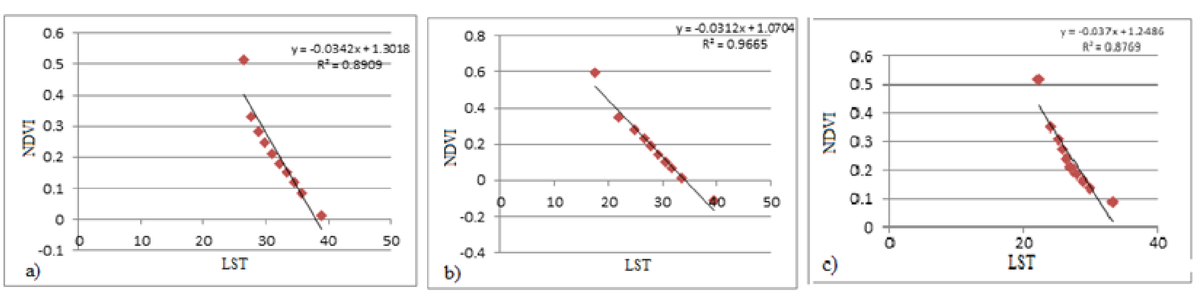

Figure 4: NDVI vs LST maps of: a) 1986, b) 2002 and c) 2018

Image differencing was used to determine changes in the NDVI during the period under study. In figure 5a, NDVI change map shows high changes around the northern and central part of the study area with little changes witnessed in the southern part. These changes could be as a result of decrease in vegetation cover. 2002 to 2018 also shows significant increase in changes as seen in figure 5b. This has mainly affected areas around Zaki, Gamawa, Dambam and Katagum. Similarly changes in LST from 1986 to 2018 is high and it is withnessed in Shira, Jama'are, Giade, Misau, Dambam and Zaki areas, this is seen in figures 6a and 6b.

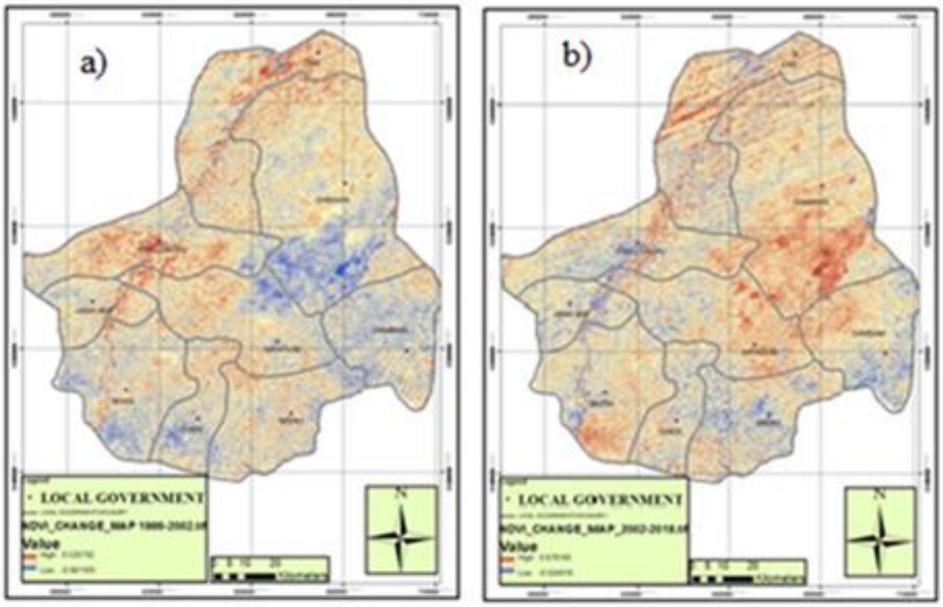

Figure 5: NDVI change map for a) 1986-2002, b) 2002-2018

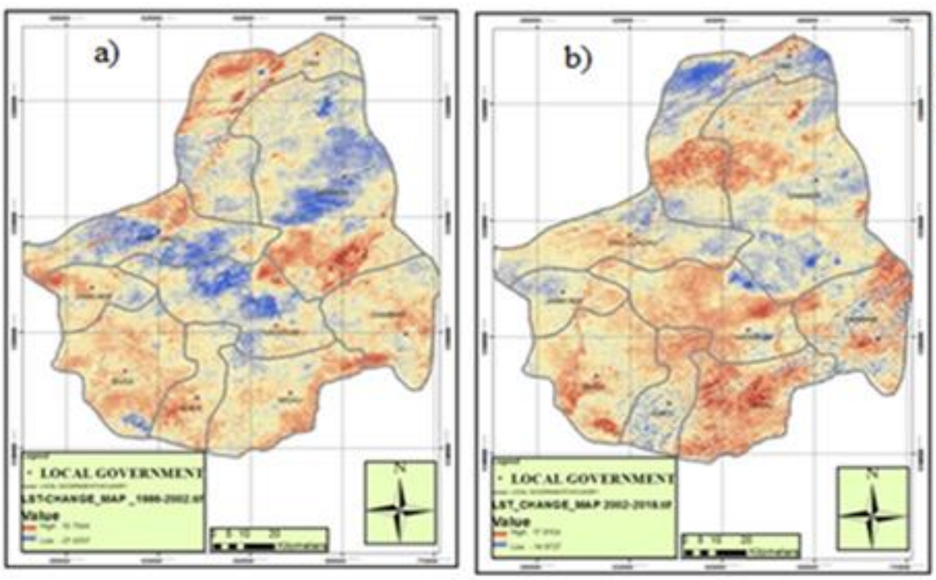

Figure 6: LST change map for a) 1986-2002, b) 2002-2018

Discussion

The NDVI map of northern part of Bauchi, Nigeria in 1986 shows a significant amount of vegetation base on spatial location especially in the southern part of the area. In 2002, the NDVI map shows a significant drop in the amount of vegetation in the study area. A similar trend was noticed in the year 2018 where the amount of vegetation continues to witness a decline. In a similar study carried out by Nurhussen (2016), the highest level of vegetation in the northern Ethiopian island was noticed in 1986 and the vegetation keeps declining to 2003. In a different study, Ozyayuz *et al* (2015) in the Mediterranean region applied the NDVI classification of Landsat satellite image for the year 1987, 2002 and 2012. The highest NDVI values were noticed in the year 2002 as compared to 1987 and 2012. The research by Ozyavuz (2015) portrayed a different scenario in this case where the NDVI tend to increase from 1986 to 2002 and decreases from 2002 to 2012. This is contrary to this study where the decrease continued from 1986 through 2002 to 2018.

The NDVI change map for 1986 to 2002 indicates vegetation loss around Gamawa, Giade northern part of Katagum and toward the southern part of Shira Local Government Areas of Bauchi State. However in 2002 to 2018 NDVI change map shows a mild changes around Dambam, Misau and southern eastern part of the study area. The Land Surface Temperature map also shows that Gamawa, Itas Gadau and Katagum are worst hit with changes in Land Surface Temperature. The same Local Government Areas were affected with Land surface Temperature change in the year 2002 to 2018. This trend clearly demonstrated the fact that changes in vegetation cover normally bring about corresponding changes in the land surface temperature indicating a strong correlation between the two (LST and NDVI). In exploring the relationship between LST and NDVI, the R^2 gave a linear relationship with 0.89 (89%), 0.97 (97%) and 0.88 (88%) were noticed for 1986, 2002 and 2018 respectively.

In his research Melkamu (2016) assert that, the Land Surface Temperature of the Andassa watershed has increased during the study periods from 1986 to 2016. Overall, average LST has been rising with an increasing rate of 0.081^{o}C per year. Other results of this study also showed that there has been a dynamic change in vegetation cover of the watershed in all seasons. There was also a negative correlation between LST and NDVI in all the studied years. From this study we can understand that there has been degradation of vegetation and intensification of LST from 1986 to 2016 as it is the case in this study from 1986 to 2018.

Similarly, Koppad and Malin (2018) shows that surface temperature is always high in the barren and settlement regions whereas it was low in the thick vegetation cover region. Balogun and Samakinwa (2015) also confirm the same trend in a study of 20-year time intervals in Akure, Nigeria. The study equally reveals that the vegetation cover has reduced from 47.23% to 37.79% with an increase of 2.79°C in temperature. A very strong correlation between the LST and the NDVI has also been established suggesting that the result in this study is in agreement with most of the previous studies carried out by other authors as shown above.

CONCLUSION

The study has revealed the correlation between vegetation cover and land surface temperature, where a decrease in vegetation result to an increase in the land surface temperature of the area which is in agreement with other researchers in other places of the tropical region. The change in the vegetation cover and land surface temperature of the area has been brought to limelight. It is no doubt that deforestation has a lot of impact in increased land surface temperature over the years. It is therefore recommended that, similar research should be carried out to cover the rest of Bauchi State to have a holistic look at the trend of vegetation and temperature with a view to curtailing the continues decline in vegetation cover in the entire area through formulation of strategies and policies. Other research with different methods of determining impact of deforestation on land surface temperature should also be carried out to affirm the efficacy of the results shown here.

References

Adams, W. M. (2009) Green Development Environment and Sustainability in the Third World, 3rd ed.

Balogun, I. A. and Samakinwa, E. K. (2015) ICUC9 - 9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment. Bauchi State Govt. Publication.

Boucher, D., Elias, P., Lininger, K., May-Tobin, C., Roquemore, S. and Saxan, E. (2011).The Root of the Problem What's Driving Tropical Deforestation today.

FAO (2001) Global Forest Resource Assessment, FAO Forestry Paper 140. Food and Agriculture Organization of the United Nation, Rome.

Jayme, A., Prevedello, R. W., Marcelo, M., Weber, E., Nichols, B. S. (2019) Impacts of Forestation and Deforestation on local Temperature Across the Globe

Koppad, A. G. and Malin, P. J. (2018) Estimation of Land Surface Temperature of Kumta Taluk using Remote Sensing and GIS Techniques. *Journal f Environmental Science. http://wwwresearchgate.net*

Melkamu, M. A. (2016) Journal of Resources and Ecology Vol. 10 No.1 *National Academy of Sciences.*85 (1988): 156-159. Print. New York: Cambridge University Press, 2001. Print. New York: DK Books, 2009. Print.

Mohammed, U. H. (2014). The Impact of Economic Activities on Deforestation in Bauchi State. A Theoritical Perspective. *Journal f Humanities and Social Sciences Vol 19 (3) pp 14-18.*

Mortan, D.C., Deries, R. S. Shimabukuro, Y. E., Anderson, L.O. Aval, E., Del Bon Espirito-Santos, F. and Morisette, J. (2006) Cropland Expansion Changes Deforestation Dynamics in the Southern Brazilian Amazon. Proceedings of the National Academy of Science 103 (39), 14637-14641.

Nurhussen, A. (2016) Application of NDVI in Vegetation Monitoring using GIS and Remote Sensing in Northern Ethiopian Highlands. *Abyssinia Journal of Science and Technology wallo University. vol. 1 no. 1 p12-17.*

Ozyavuz, M., Bilgili, B. C.and Salici, A. (2015) Determination of Vegetation Changes with NDVI Method. *Journal of Environmental Protection and Ecology.* Vol.16 No.1 pp264-273

Shakirudeen, O. and Gbolahan, B. (2015). Land Cover Change, Land Surface Temperature, Surface Albedo and Topography in the Plateau Region of North-Central Nigeria. *http://creativecommons.org/licences/by/4.0/*

Tagore, B. S., Yerma, B. (2012).Sustainable World. Washington D.C.: National Academies Press, 2000. Print.Trade, Poverty and Land Use. London: Earth scan, 2000. We Can Do About It. New York: Rodale Books, 2006. Print.

United States Environmental Protection Agency (USEPA). 2011. Region 9. Perchlorate in the Pacific Southwest.

World Wildlife Fund (WWF, 2019) Deforestation and Forest Degradation, NW Washington DC 0037

Yau, Li., Maosheng, Z., David, J., Mildrexler, S. M., Qiaozhen. M., Eugenia, A., Fang, Z., Shuangchang, L. and Kalcun, W. (2016) Potential and Actual Impacts of Deforestation and Afforestation on Land Surface Temperature. *Journal of Geophysical Research; Atmosphere vol. 121 issue 24*

Youneszadeh , S. Amiri, N. A. and Pilesjo, P. (2015). The International Achieves of the

Photogrammetry, Remote Sensing and spatial Information Science. Vol XL-1/W5, International Conference on Sensor and Models in Kishilang, Iran.