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## Geospatial assessment of land surface temperature in Owo Forest Reserve Area, Ondo State Nigeria

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### ABSTRACT

Nigeria's forest reserves no matter where they are located act as the last succour for the entire citizenry by rendering ubiquitous services that significantly contribute to her economy. This study was intended at assessing the Land Surface Temperature (LST) in Owo Forest Reserve Area (FRA) with a view to sustainable forest management.

### Goal and Objectives:

The essential objectives set for the research include: (i.) assessing the vegetation changes in Owo Forest Reserve Area (ii.) evaluating the LST in Owo forest reserve and (iii.) relating changes in vegetation cover to LST in other to ascertain whether the observed difference in vegetation cover has significant effect and contribution either positively or otherwise to LST values obtained in Owo forest reserve.

### Methodology:

Recorded spatial coordinates of some selected points constitute the primary data while the secondary data were the satellite dataset, which includes: the Operational Landsat Imager, Enhanced Thematic Mapper, and Thematic Mapper of different years (1991, 2002, 2014, and 2020) used for mapping the vegetation change in the forest reserves. Specifically, thermal bands of the Landsat image in conjunction with the Normalized Difference Vegetation Index (NDVI) were utilized for mapping the LST which is the hallmark of the research. Various data acquired were processed according to the best practices.

### Results:

The results obtained showed that moderate vegetation (shrubs and scattered trees) has been increasing, which signifies that these categories of vegetation in Owo forest reserve area is not depleting for the whole period of study. It was also discovered from the results garnered from 1991 to 2020 that areas with vegetation (Dense, moderate, and sparse) had the least LST values while the forecast probable future LST values for the year 2030 are in the purview of 24.22°C (minimum) and 53.98°C (maximum) which may have negative implications on the forest reserve. The research recommends a significant increase in the rate of tree planting and preserving green areas (vegetation) in order to mitigate the upsurge of LST while laws guiding illegal logging should be upheld with the utmost tenacity.

### Keywords:

Land Surface Temperature, Normalized Difference Vegetation Index, Spatial, Landsat Imagery, Single Window (SW) algorithm

## 1.0 Introduction

Currently in the World today, LST is one of the hot issues because of its effects on climate and environmental change at the 'three-tier level' of evaluation namely: neighborhood, locality, and international levels. A resultant effect of LST originated from the unimaginable rate of citified and its corresponding excessive land conversion (Balew & Korme, 2020). LST is the hotness of the earth's surface as determined by a radiative detector. Without the knowledge about LST, scientific investigations about the effect of climate change on the environment, geo-/biophysical, surface energy equilibrium, and international agricultural practices would have been impossible.

However, in accordance with Crago & Qualls (2014), the function LST is significant in many areas of geosciences such as earth net radiation allocation, robust information about greenhouse effects, and maintaining equilibrium between crops and vegetation. The rate and timing of plant growth according to the European Space Agency (2021) are influenced by LST as mechanized farmers use World's weathercast maps to evaluate water requirements for their crops during the summer in line with National Aeronautical Space Agency (2008) and also helps in controlling the pests and other crop diseases to spread over the field. Furthermore, attitudes towards land use and land cover (LULC) will either create an eco-friendly environment or otherwise. This was why Fahad *et al.* (2023) opined that LST was the most important environmental parameter that can assist to determine the equilibrium of energy and matter exchange in the space separating the earth's surface and the atmosphere.

Some of the identified challenges in the FRA include (i) the status of the vegetation cover in the forest reserve has not been determined over the years, (ii) the effect of exploitation of economic trees by wood loggers were not known, (iii) the perceived encroachment into the forest reserve by inhabitants of the camps surrounding the forest reserves area is alarming, (iv) uneconomical utilization of forest reserves by constituted Authorities (v) the forest reserves was characterized by slow growing trees of various speeches (vi) lack of gregarious stands since most of the forest trees are lost to plant diseases and insects, (vii) there is absent of recent information on the forest reserve with respect to vegetation change over time in the study area, and (viii.) unconfirmed forest reserve depletion and the assumption that the exposed portions may likely lead to high LST values which was the major essence for this research.

The aim of this research is to assess LST in response to vegetation cover change in Owo FRA with a view to improving afforestation and also creating sustainable forest management. The following research questions provide the impetus that enables the research aims to be achieved: (i) what are the vegetation changes in Owo Forest Reserve Area? (ii) what is the status of LST in Owo forest reserves area? and (iii) how do changes in the vegetation affect LST in Owo forest reserves area? Determining the vegetation change over the years using supervised classification, deriving the Normalized Difference Vegetation Index (NDVI), and generating the thermal band from satellite imageries of different years yielded the desired LST.

## 2.0 Literature Review

The review of the past journals for the present studies show that LST analysis has been done severally in the United State of America, Europe, Asia, Africa, and Nigeria but none has been carried out in Owo

FRA. For example, Weng *et al* (2003) researched an urban heat island at Indianapolis City, USA while Tang *et al* (2018), Hasnat (2021) and Jeevalakshmi *et al* (2017) examined the effects of forests on temperatures in Europe and India respectively. Also, Mohd-Jaafar *et al* (2020) examined the influence of deforestation on LST in Malaysia while Zhi *et al* (2020), Mohamadi *et al* (2019), and Shatnawi & Qdais (2019) conducted studies on LST monitoring in Xigang District of Dalian City China, Southern China and Jordan sequentially. Furthermore, the work of El Garouani, *et al* (2021), Aik *et al.* (2021) and Ngie *et al* (2016) are example of LST researches that was carried out in Saïss Plain Morocco, Cameron Highland and Durban, South Africa consecutively. Similarly, James *et al* (2020) and Agbor & Makinde (2018) are researchers on LST that were explicitly domiciled in Bauchi and Ondo States, Nigeria. Hence, the reviewed literature confirmed that remote sensing methods and geoinformatics can be used for mapping LST with respect to the environment. However, the gap which this research seeks to fill is the use of geoinformatics techniques, remote sensing method coupled with forest map and Global Positioning System(GPS) to map LST, and to also investigate the change in the vegetation over time in Owo FRA which has never been evaluated before now.

## Materials & Methods

### 3.1 Study Area

Owo Reserve Area (FRA) has an area of 241 square kilometers and approximately lies within 7°05'N, 5°29'E; 7°03'N, 5°37'E; 6°55'N, 5°35'E; and 6°54'N, 5°32'E uniquely (Figure 1). It is located within Owo Local Government Area (LGA) of Ondo State and extends to Ose and Idanre Local Government Areas. The climate in the FRA is both wet and dry seasons while the temperature varies from 18°C to 32°C and is rarely less than 15°C or higher than 34°C in accordance to Weatherspark (2021). The average annual rainfall was 1569 mm, with an average elevation of 348mMSL (Meteobox, 2021). The people of Owo are farmers, artisans, and lumbermen. The economy of the Owo LGA contributed significantly to the annual GDP of Ondo State.

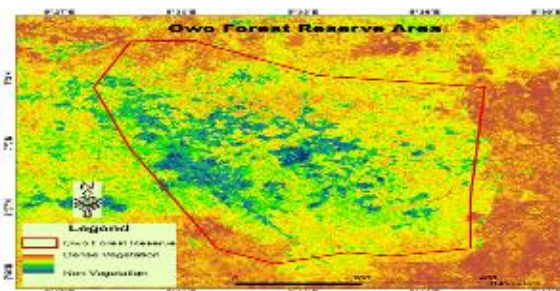


Figure 1: Study Area Map

### 3.2 Data Collection and Processing

Data and materials adopted for this research were classified into two categorical classes viz: primary and secondary. The former involves GPS coordinates obtained during the field survey exercise while the latter were derived from 30m resolution Landsat imageries of various years (1991, 2002, 2014, and 2020) used in the research. The information of Landsat data used was in accordance with USGS (2014). Other secondary data include Worldview 3 image (2022), the Administrative map of Ondo State, and the forest reserve boundary map sourced from Ondo State Ministry of Agriculture and Natural Resources, Akure.

The pre-processing stage involves the extraction of Near Infrared (NIR) and red bands from the zipped Landsat image. Specifically, the equation provided by Othman *et al* (2018) was inputted into the raster calculator of the ArcGIS software to produce a raster surface showing NDVI for individual measurements while the derived NDVI images were then interpreted in line with Hashim *et al*. (2019). In addition, the boundary shape file (.shp) of the study area was used to clip the derived NDVI image while LST was estimated using the thermal infrared bands in the selected Landsat images based on Single Window (SW) algorithm (Advan & Jovanovska, 2016; Lamidi & Ijaware, 2022).

#### 4.0 Results and Discussion

The analysis of the result is categorized into four sections viz: the vegetation extent, the trend of vegetation categories, land surface temperature and future greenness levels, and LST.

##### 4.1 Vegetation Extent

The vegetation level of Owo Forest Reserve Area (FRA) was assessed from 1991 to 2020. The vegetation levels in 1991 were classified as non-vegetation, sparse vegetation (grassland), moderate vegetation (shrub and grassland), and dense vegetation. These vegetation levels were classified based on the maximum likelihood algorithm. It was observed that in the year 1991, moderate vegetation and sparse vegetation were the dominant vegetation classes while non-vegetation and Dense vegetation were barely noticeable (Table 1). The proportion of vegetation according to Figure 2a indicated that the dominant vegetation was found majorly toward the edges and central part of the forest reserve Area.

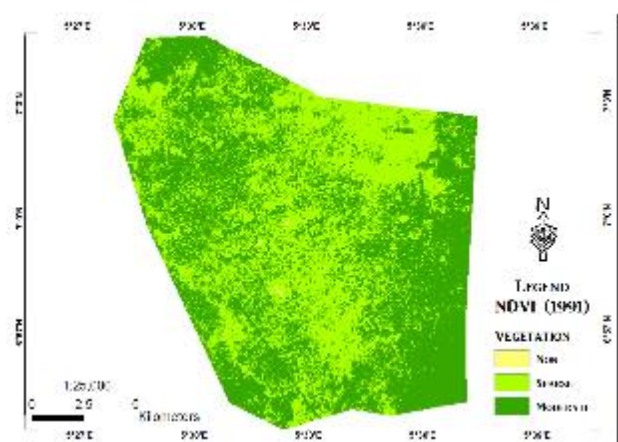


Figure 2a: Map of vegetation level of Owo FRA in the year 1991

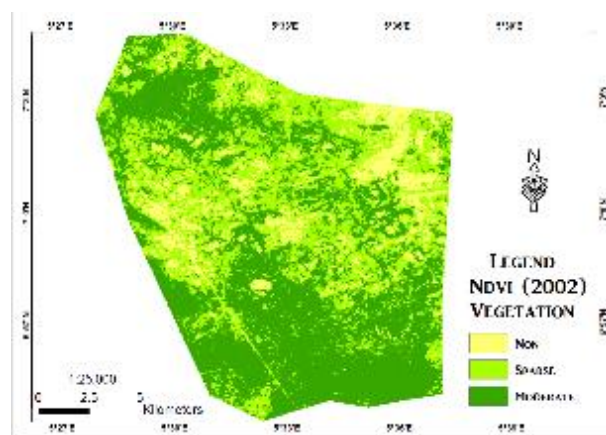


Fig.2b: Map of vegetation level of Owo FRA in the year 2002

However, in the year 2002 (Figure 2b), part of sparse vegetation, which were majorly grasslands, located in the North-eastern part, and also towards the central part of Owo FRA changed to non-vegetation (majorly bare land), while moderate vegetation (Shrub) became the most notable categories of vegetation both in the west and Northwest of Owo FRA

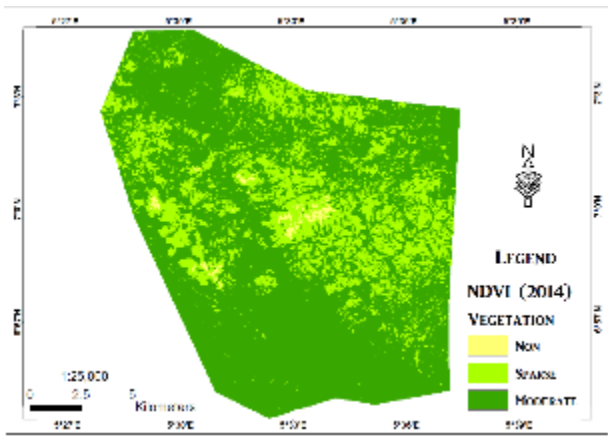


Figure 3a: Map of vegetation level of Owo FRA in the year 2014

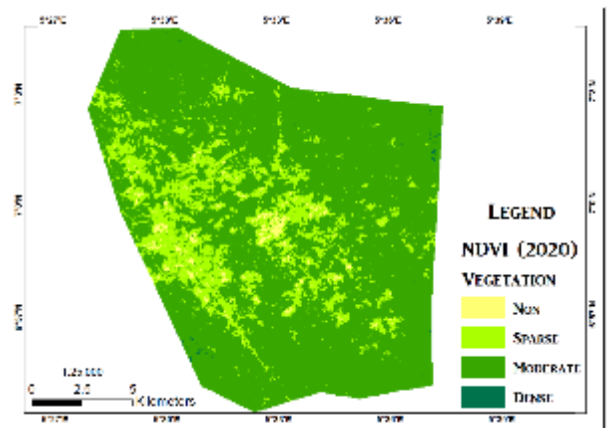


Fig. 3b: Map of vegetation level of Owo FRA in the year 2020

Similarly, in the year 2014, moderate vegetation occupied the western and partially northern parts of the forest reserve, while sparse vegetation was majorly found in the middle part of the FRA. Correspondingly, non-vegetation covered a small area in the center of Owo FRA. Also, the most important vegetation in the year 2020 was moderate vegetation which was found in large concentrations in the entire forest reserve as sparse and non-vegetation were slightly noticed, although dense vegetation, which is few, occurred in the southwest section of the FRA.

Table 1: Extent of vegetation level in Owo FRA from 1991 to 2020

NAME	1991km <sup>2</sup>	2002 km <sup>2</sup>	2014 km <sup>2</sup>	2020 km <sup>2</sup>
Non-Vegetation	0.22	16.59	1.94	4.08
Sparse Vegetation	108.35	88.31	60.37	42.92
Moderate Vegetation	132.46	136.13	178.71	193.78
Dense Vegetation	0.00	0.00	0.00	0.25
<b>TOTAL</b>	<b>241.02</b>	<b>241.02</b>	<b>241.02</b>	<b>241.02</b>

Significantly, throughout the year of study, sparse vegetation was decreasing at the same time, and moderate and dense vegetation was on the increase. The increase in dense vegetation can be attributed to the outbreak of the Coronavirus pandemic in 2020 which incapacitated anthropogenic activities for about a year.

#### 4.2 Trend of Vegetation Category

The trend of each vegetation level when assessed over the study years as presented in Figure 3a revealed that the non-vegetation level increased from 0.22 km<sup>2</sup> to 16.59 km<sup>2</sup> between the year 1991 and 2002 before declining to 1.94 km<sup>2</sup> in the year 2014, and it later increased in extent to 4.08 km<sup>2</sup> in year 2020.

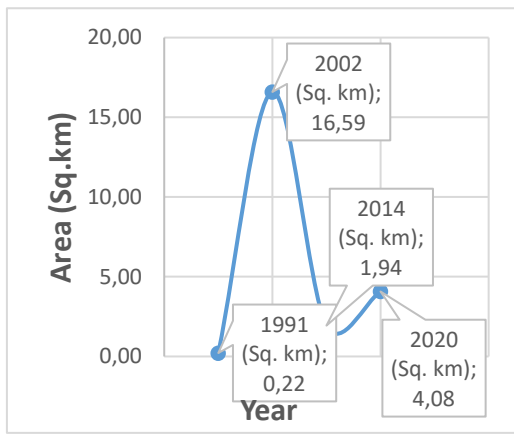


Figure 3a: Trend of non-vegetation from 1991 to 2020

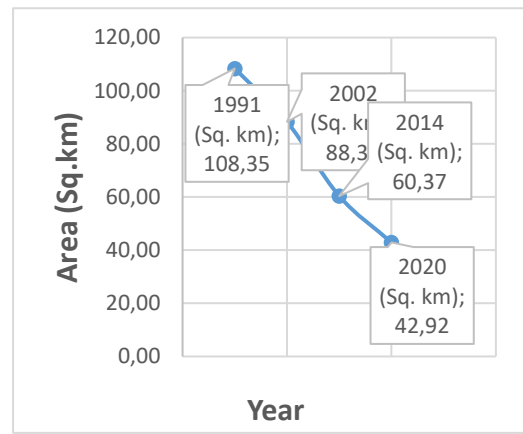


Figure 3b: Trend of sparse vegetation from 1991 to 2020

Continuous declination was experienced on sparse vegetation as the extent decreased from 108.35 km<sup>2</sup> in 1991 to 88.31 km<sup>2</sup> in 2002, and it declined further to 60.37 km<sup>2</sup> and 42.92 km<sup>2</sup> in the year 2014 and 2020 apiece as shown in Figure 3b. However, moderate vegetation experienced continuous inclination as the extent increased in 1991 from 132.46 km<sup>2</sup> to 193.78 km<sup>2</sup> in the year 2020, as shown in figure 4a.

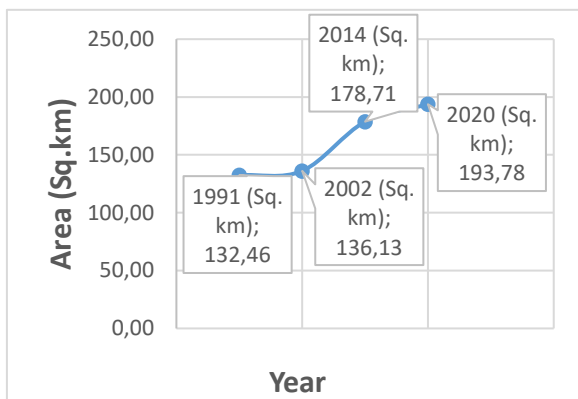


Figure 4a: Trend of moderate vegetation from 1991 to 2020

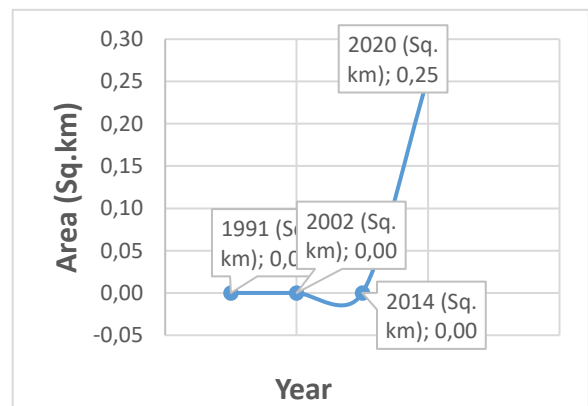


Figure 4b: Trend of dense vegetation from 1991 to 2020 (Right)

From the NDVI vegetation level maps and also from Table 1, it was shown that Dense vegetation was not recorded in Owo FRA between 1991 and 2014, but was recorded in the year 2020, which covered 0.25 km<sup>2</sup> as displayed in Figure 4b. Generally, the overall analysis showed that moderate vegetation, which comprises shrub majorly and scattered trees have been increasing from the beginning to the end of the research period, which signifies that the vegetation in Owo forest reserve area has not been depleting over the years. This was however, due to government legislation that compelled stakeholders in the forest product merchandise to strict compliance and the continuous policing of the forest reserve area against Herdsmen by Amotekun corps organized and chaired by the Ondo State Governor.

### 4.3 Land Surface Temperature (LST)

Mapping of LST at Owo forest reserve area for the study years (1991, 2002, 2014 and 2020) yielded figures 5a to 6b.

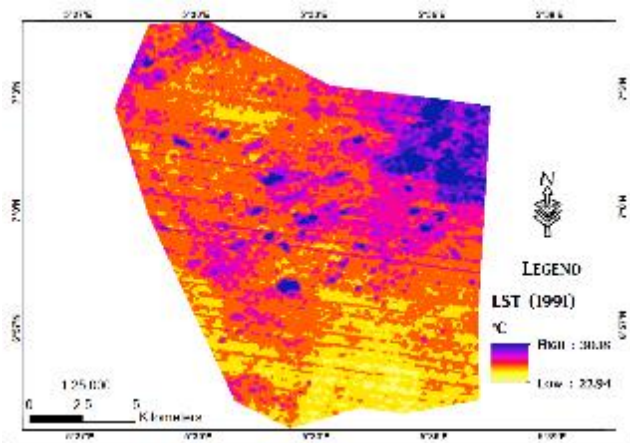


Fig. 5a: Land Surface temperature distribution in the year 1991

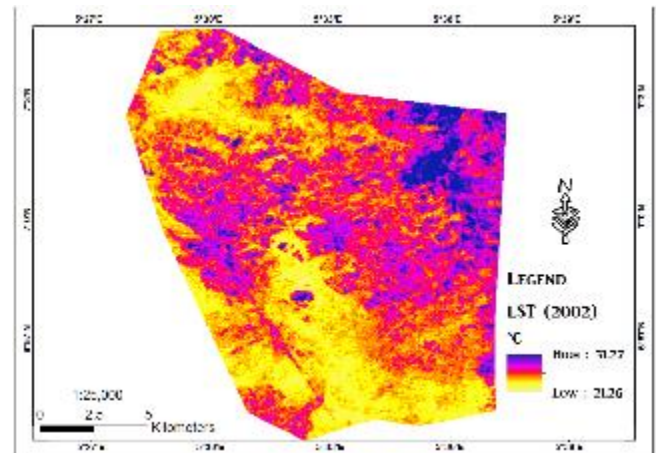


Fig.5b: Land Surface temperature distribution in the year 2002

Significantly, figure 5a showed that the temperature ranged from 22.94°C to 30.18°C at Owo FRA in the year 1991 and it was observed that high temperatures existed in North Eastern section while the least range temperature was observed in the southern part of the forest reserve. Similarly, LST values ranged between 21.6°C to 32.7°C in 2002 such that, the coolest area was found in the southern part which extended to the Northcentral, and Northwestern part of the forest reserve while the hottest area advanced towards the Northeastern part of the forest reserve area (Figure 5b).

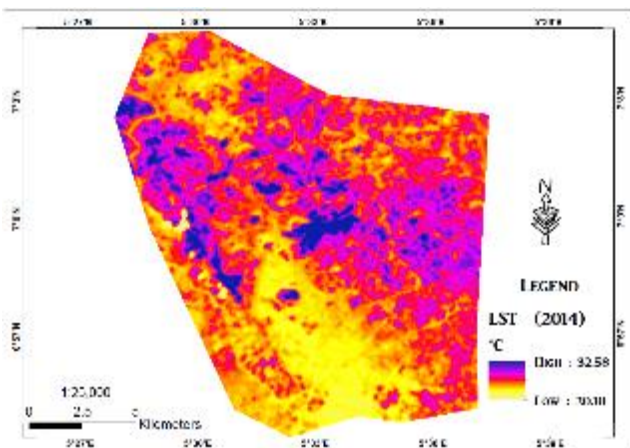


Fig. 6a: Land Surface temperature distribution in the year 2014

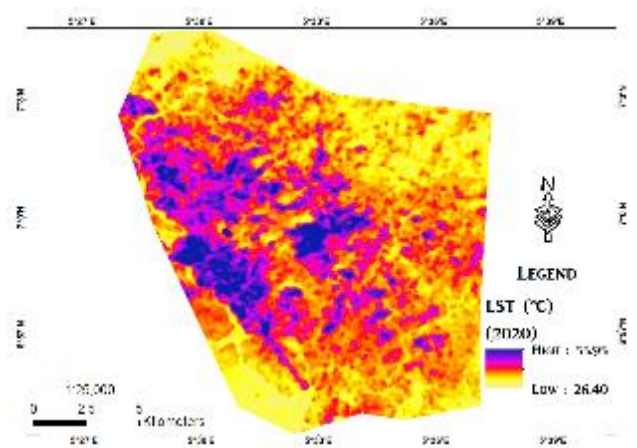


Fig. 6b: Land Surface temperature distribution in the year 2020

Furthermore, in 2014, the LST values ranged from 20.1°C to 32.58°C (Figure 6a) and the LST distribution showed that the least temperature was concentrated in the south, extending to the North-central, while the hottest part (Places with the highest LST value) domicile uniquely at the middle of the forest reserve. Also, the year 2020 recorded the highest range of LST values, which was from 26.4°C to 55.95°C (Figure 6b) in such a way that the southwestern and the Northeastern parts of the study area were the coolest part (Places with the least LST values), while the central part of

the study area was the hottest, as they had the highest LST values. The increase in LST values was as a result of global warming that does not have a boundary. The minimal, mean, and maximal values of LST were calculated to showcase the LST trend for the study periods (Table 2).

Table 2: Min, Mean and Max. LST values from 1991 to 2020

categories	Years			
LST °C	1991	2002	2014	2020
Minimum	22.94	21.26	20.1	26.4
Mean	24.42	24.15	25.75	31.36
Maximum	30.18	31.27	32.58	55.95

From Table 2, LST values vary from one year to the other. Specifically, the minimum LST at Owo Forest Reserve (FRA) was 22.94°C in 1991, which decreased to 21.26°C in 2002, and further dropped to 20.1°C in 2014, then, it escalated to 26.4°C, in 2020, which was the highest of all (Figure 7a).

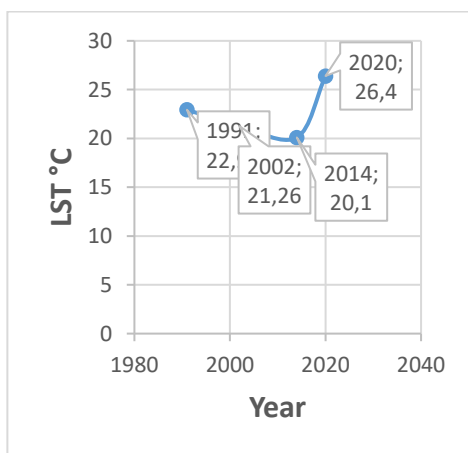


Fig. 7a: Trend of Minimum values of LST from 1991 to 2020

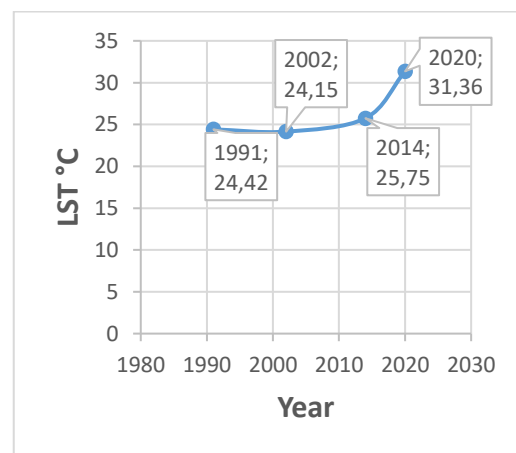


Fig. 7b: Trend of Mean values of LST from 1991 to 2020

Also, the trend analysis of the mean LST values from 1991 to 2020 (Figure 7b) indicated that the mean LST value for the year 1991 was 24.2°C, which slightly decreased to 24.15°C in 2002, but slightly increased in 2014 to 25.75°C with an upsurge to 31.36°C in 2020. Likewise, figure 7c showed that the maximum values of LST increased continuously from 1991 to 2020 that is, years 1991, 2002, 2014 and 2020, and the corresponding LST values were 30.18°C, 31.27°C, 32.58°C and 55.95°C respectively. The astronomical LST values recorded in 2020 may be as a result of climate change caused by global warming and this was in line with climate signals (2023)

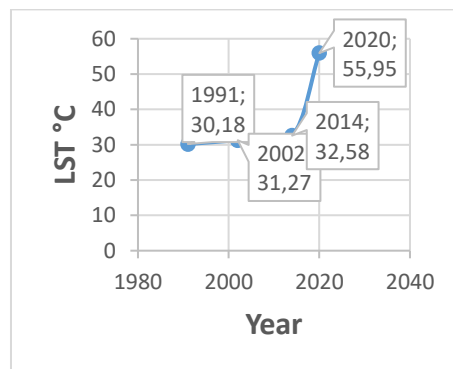


Figure 7c: Trend of Maximum values of LST from 1991 to 2020.

#### 4.4 Future greenness levels and LST

The probable future state of both variables (vegetation levels and LST) based on the previous results was carried out for the next ten years using the linear trend forecast tool in Microsoft Excel. The result of the prediction revealed that out of all the vegetation categories found in Owo forest reserve, it was only moderate vegetation that will have a significant increase in the year 2030 (Figure 8)

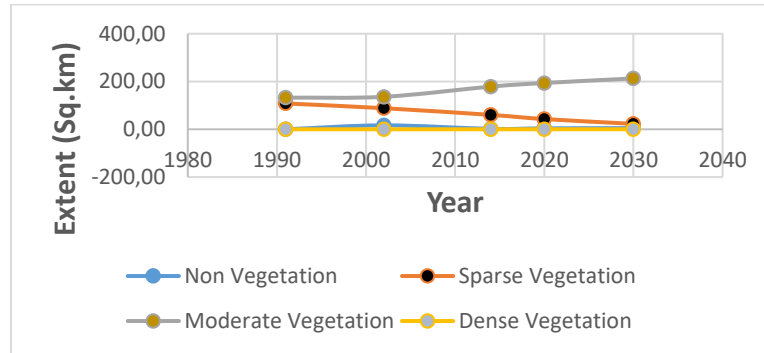


Figure 8: Forecast for the probable future vegetation levels in Owo FRA in the year 2030

Also, the outcome of the forecast for probable future LST values as rendered in Figure 9 shows that minimal, mean, and maximal LST will drop to 24.22°C, 31.22°C, and 53.98°C respectively in 2030.

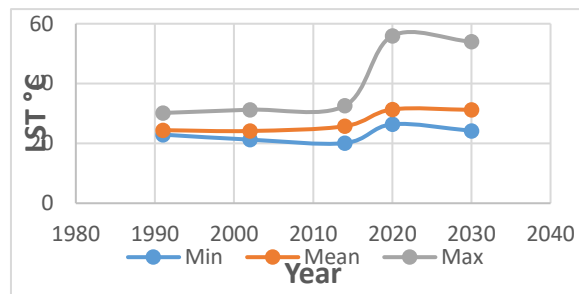


Figure 9: Forecast for the probable future LST values in Owo FRA in the year 2030

Generally, the results of forecast of both vegetation level and LST values at Owo FRA for the year 2030 based on the previous results showed that non-vegetation and moderate vegetation will increase, while sparse and dense vegetation will decrease in the year 2030, which implies that moderate vegetation (Shrub and scattered trees) will continue to increase, which is a major vegetation cover. Similarly, the minimal, mean, and maximal LST will decline in the year 2030, which is suspected to be as a result of the anticipated increase in non-vegetation and moderate vegetation levels in the year 2030.

#### 5.0 CONCLUSION

In this study, the results obtained unveiled that: moderate vegetation, has been increasing over the years, which implies that, the vegetation in Owo forest reserve area has not depleted significantly for about three decades; also, the results from 1991 to 2020 showed that areas with vegetation (Dense, moderate and sparse) had the least Land Surface Temperature (LST) value, which means that vegetation reduces LST values; similarly, the forecast for the year 2030 showed that non-vegetation will increase, while sparse vegetation and dense vegetation will decrease but moderate vegetation (Shrub and scattered trees) will continue to increase significantly, and may dominate the study area; in addition, the forecast for the year 2030 encapsulates that entire LST in Owo forest reserve will

decline, and the probable decrease in the year 2030 may be as a result of the projected extent of moderate vegetation level in the year 2030; furthermore, the results of the minimum, mean and maximum LST values in Owo FRA from 1991 to 2020 showed that the LST varies from one year to the other such that dense vegetation had the least LST values, which signified presence of vegetation cover, while areas covered by non-vegetation had the highest LST values over the study years and this was in agreement with the research of Ibrahim *et al* (2016). Therefore, from the results obtained, the research outcome established that vegetation reduces the LST values of an area as the least LST values are situated in areas dominated by vegetation in line with Odunuga and Badru (2015). From the above findings, it is hereby concluded that change in vegetation in Owo Forest Reserve Area has an effect on the values of Land Surface Temperature.

## 6.0 Recommendation

The Ministries of Agriculture and Natural Resources Ondo State should:

- i. Use this research as a guide as it is an easier and cost-effective method to map and monitor the vegetation level of Owo forest reserves area, and
- ii. Increase the rate of tree planting and green areas preservation (vegetation) in order to mitigate the increase of Land Surface Temperature (LST).

## 7.0 Acknowledgment

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## 8.0 References

1. Agbor, C.F. and Makinde, E.O. (2018). Land Surface Temperature Mapping Using Geoinformation Techniques. *Geoinformatics FCE CTU*. doi:10.14311/gi.17.1.2.
2. Aik, D. H. J., Ismail, M. H. Muharam, F. M. and Alias, M. A. (2021). Evaluating the impacts of land use land cover changes across topography against land surface temperature in Cameron Highlands. Available at <https://www.researchgate.net/publication/350040633...> Visited on 17 June 2023
3. Avdan, U. and Jovanovska, J. (2016). Algorithm for Automated Mapping of Land Surface Temperature Using LANDSAT 8 Satellite Data. Hindawi Publishing Corporation, *Journal of Sensors*. Article ID 1480307. doi.org/10.1155/2016/1480307.
4. Balew, A. and Korme, T. (2020). Monitoring land surface temperature in Bahir Dar city and its surrounding using Landsat images. *The Egyptian Journal of Remote Sensing and Space Sciences*. doi.org/10.1016/j.ejrs.2020.02.001.
5. Climate signals(2023). *Global land surface temperature trends and climate change*. Available at <https://www.climatesignals.org/climate-signals/land-surface-temperature-increase>. Visited on 14/6/23

6. Crago, R. D. and Qualls, R.J. (2014). Use of land surface temperature to estimate surface energy fluxes: Contributions of Wilfried Brutsaert and collaborators, *Water Resour. Res.*, 50, 3396–3408. doi:10.1002/2013WR015223.
7. El Garouani, M., Amyay, M., Lahrach, A., Oulidi, H. (2021). Land Surface Temperature in Response to Land Use/Cover Change Based on Remote Sensing Data and GIS Techniques: Application to Saïss Plain, Morocco. *Journal of Ecological Engineering*. ISSN 2299–8993. doi.org/10.12911/22998993/139065.
8. European Space Agency (2021). *Land Surface Temperature*. Available at <https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-3slstr/overview/geophysical-measurements/land-surface-temperature> visited on 2nd May, 2023
9. Fahad, A., Bassam, A. A., & Hazem, T. A. (2023). Impact of land use dynamics on land surface temperature using optical remote sensing data integrated with statistical analysis in Riyadh, Saudi Arabia. *Advances in Space Research*. Science Direct <https://doi.org/10.1016/j.asr.2023.04.051>
10. Hashim, H., Abd Latif, Z., and Adnan, N.A (2019). Urban Vegetation Classification with NDVI Threshold Value Method with Very High Resolution (VHR) Pleiades Imagery. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XLII-4/W16. 6th International Conference on Geomatics and Geospatial Technology (GGT 2019), 1–3 October 2019, Kuala Lumpur, Malaysia. <https://doi.org/10.5194/isprs-archives-XLII-4-W16-237-2019>.
11. Hasnat G.N.T (2021) A Time Series Analysis of Forest Cover and Land Surface Temperature Change Over Dudpukuria-Dhopachari Wildlife Sanctuary Using Landsat Imagery. *Frontier Forest Global Change* 4:687988. doi: 10.3389/ffgc.2021.68798
12. Ibrahim, I., Abu samah, A., Fauzi, R., and Noor, N. (2016). The land surface temperature impact to land cover types. ISPRS - *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. XLI-B3. 871-876. DOI:10.5194/isprs-archives-XLI-B3-871-2016.
13. James, J.M., Abubakar, T. and Gundiri, L.R. (2020). Impact of Deforestation on Land Surface Temperature in Northern Part of Bauchi State, Nigeria. *FUTY Journal of the Environment. Photogrammetry, Remote Sensing and spatial Information Science*. Vol XL-1/W5. <http://creativecommons.org/licenses/by/4.0/>.
14. Jeevalakshmi, D., Narayana, S., and Manikiam, B. (2017). Land Surface Temperature Retrieval from LANDSAT data using Emissivity Estimation. *International Journal of Applied Engineering Research*. ISSN 0973-4562
15. Lamidi, A. J. and **Ijaware, V. A (2022)**. Land Suitability for None-Rice Cultivation Areas in Ekiti State Using a GIS- Based Analytic Hierarchy Process Approach. In *European Journal of Environment. and Earth Science.(EJ-GEO)* vol. 3, issue 5. ISSN:2684-446X(online). United Kingdom [www.sciencepublishinggroup.com/j/ijaas](http://www.sciencepublishinggroup.com/j/ijaas)
14. Meteobox (2021). Owo, Ondo. <https://meteobox.com/nigeria/owo/>. Visited on 5<sup>th</sup> June 2021

15. Mohamadi, B., Chen, S., Balz, T., Gulshad, K. and McClure, S.C. (2019). Normalized Method for Land Surface Temperature Monitoring on Coastal Reclaimed Areas. *MPDI. Sensors*. doi:10.3390/s19224836.
15. Mohd Jaafar, W., Abdul Maulud, K.N., Kamarulzaman, A.M., Raihan, A., Sah, S.M., Ahmad, A., Saad, S.N., Mohd Azmi, A.T., Syukri, N.K., Khan, W.R. (2020) The Influence of Deforestation on Land Surface Temperature—A Case Study of Perak and Kedah, Malaysia. *Forests. MPDI*. doi:10.3390/f11060670
15. National Aeronautical Space Agency (2008, October). *Land Surface Temperature Product*. [https://modis.gsfc.nasa.gov/gallery/individual.php?db\\_date=2008-10-27](https://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2008-10-27). Visited on 6/5/2021
16. Ngie, A., Abutaleb, K., Ahmed, F., Taiwo, A., Darwish, A.A., and Ahmed, A. (2016). An Estimation of Land Surface Temperatures from Landsat ETM+ images for Durban, South Africa. *Rwanda Journal Life and Natural Sciences: Special issue II*. doi.org/10.4314/rj.v1i1S.2D.
16. Odunuga, S. and Badru, G. (2015). Landcover Change, Land Surface Temperature, Surface Albedo and Topography in the Plateau Region of North-Central Nigeria. *Land*. ISSN 2073-445X
17. Othman, M.A. Ash'aari & Ranli, M. (2018). Tropical deforestation monitoring using NDVI from MODIS satellite: a case study in Pahang, Malaysia. *Environmental Science, Mathematics IOP Conference Series: Earth and Environmental Science* DOI:[10.1088/1755-1315/169/1/012047](https://doi.org/10.1088/1755-1315/169/1/012047) Corpus ID: 134751947
18. Tang, B., Zhao, X., and Zhao, W. (2018). Local Effects of Forests on Temperatures across Europe. *MPDI. Remote sensing*. doi:10.3390/rs10040529.
19. Shatnawi, N. and Abu Qdais, H. (2019). Mapping urban land surface temperature using remote sensing techniques and artificial neural network modelling. *International Journal of Remote Sensing*. doi: 10.1080/01431161.2018.1557792.  
Weatherspark (2021). *Average weather in Owo, Nigeria*. <https://weatherspark.com/y/51416/Average-weather-in-Owo-Nigeria-Year-Round>
- Weng, Q., Lu, D., and Schubring, J. (2003). Estimation of land surface temperature vegetation abundance relationship for urban heat island studies. Elsevier. *Remote Sensing of Environment* – Elsevier. doi:10.1016/j.rse.2003.11.005.
23. WorldView-3 Overview(2022) - *Earth Online*. Available at <https://earth.esa.int/eogateway/missions/worldview-3/description?text=2022>. Visited on 6/9/2022
23. Zhi, Y., Shan, L., Ke, L., and Yang, R. (2020). Analysis of Land Surface Temperature Driving Factors and Spatial Heterogeneity Research Based on Geographically Weighted Regression Model. *Hindawi*. Volume 2020, Article ID 2862917. <https://doi.org/10.1155/2020/2862917>.