A Geospatial Analysis of Environmental Impacts of Climate Change on Osogbo and Environs

Victor Ayodele Ijaware1,* and Tomisin Ayinla Olagboye2

ABSTRACT

Climate change is one of the alarming global environmental changes likely to have deleterious effects on natural, social, cultural, and human systems. The risks associated with it call for a broad spectrum of policy responses and strategies at local, regional, national, and global levels. This research aims to carry out a geospatial analysis of the environmental impact of climate change on Osogbo and its environs with a view to providing information towards mitigating the negative impact of climate change in the study area. This study uses Landsat 4, Landsat 7, and Landsat 8 satellite data from 1982, 2002, and 2022, respectively, to evaluate land cover and temperature variation as a climatic change in the study area over four decades. The land survey method was carried out to collect ground truth data for validation of the satellite imageries. The drought map was produced based on the Vegetation Condition Index (VCI) map computed from Normalized Difference Vegetation Index (NDVI) datasets and was further classified into three categories: moderate, mild, and no drought. Analysis of the Land Use Land Cover (LULC) of the study area shows that the vegetation decreased from 84% in 1982 to 59% in 2002 and 56% in 2022. The built-up/exposed surface increased from 15.28% in 1982 to 38% in 2002 and 41.28% in 2022. The water bodies also increased from 0.17% in 1982 to 15.31% in 2022. LST analysis reveals that the mean temperature of the study area increased by 10.73 °C during the past four decades (from 1982 to 2022), with the most accelerated warming (11.41 °C) occurring during the last two decades (from 2002 to 2022). The Vegetation Condition Index (VCI) based drought map shows that there was no extreme or severe drought in the study area. However, moderate and mild droughts were observed mostly in the developed part of the study area, which confirmed the presence of drought. It is hereby recommended to introduce sustainable water management strategies to mitigate water shortage in the study area.

Keywords: Climate change, Drought, Geographic information system, Land surface temperature.

1. Introduction

According to [1], Climate change is indeed a global phenomenon that is affecting the entire planet. It is driven by the increase in greenhouse gas emissions, primarily carbon dioxide, resulting from human activities such as burning fossil fuels, deforestation, and industrial processes. The impacts of climate change, however, vary across different regions and even within different areas of the same continent [2].

Indeed, Africa is considered one of the most vulnerable continents to climate change [3]. Consistent rising temperatures and climate change have been linked to more prevalent drought, increased water scarcity, low harvests, and more extreme weather events [4].

In Nigeria, droughts can indeed be attributed to climate change and changing weather patterns. Several factors contribute to the occurrence of droughts in the country, including Excessive Buildup of Heat, Decline in Precipitation, Increased Temperature, Changes in Rainfall Patterns, El Niño, and La Niña Events [5], [6].

Climate change is indeed one of the current crises that necessitate collective efforts and collaboration from various stakeholders around the world. e.g., climate advocates, government officials, industry leaders, institutions/academic experts, activists, media, international organizations, business leaders etc.
The purpose of this research is to conduct an analysis of the environmental impact of climate change on Osogbo and its surrounding areas. The study will utilize GIS (Geographic Information System) and remote sensing technology to gather data and information with a view to generate valuable insights and knowledge that can be used to mitigate the adverse effects of climate change in the study area.

In certain areas of the study area, residents have reported experiencing various health issues that are associated with excessive heat. These include heat stress, fatigue, headaches, rashes, dehydration, and increased restlessness. Drought is experienced in all climatic zones, although there is a characteristic variation from one zone to another [7]. The study area has been experiencing a noticeable shortage of water, which can be attributed to a combination of decreased precipitation and increased temperatures.

During the dry season, in many parts of the study area, people hardly have access to enough water to meet their various needs, and many farmers have to source for an alternative method of carrying out their farming operations. In 2001, the town was hit by acute shortage of water in which the residence now has harrowing experience on how to source water for their various needs.

Reference [8] performed research with temperature and land cover change as strategies for monitoring climate change in Owerri, Nigeria. The study viewed the nexus between geospatial methodologies in evaluating change in climate and sustainable development. Reference [9] studied the effects of change in climate where Landsat dataset combined with ancillary data were utilized in analyzing the impacts and trends of Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) as climate change index for 1985, 1995, 2003 and 2010. LST and NDVI patterns were evaluated. Reference [10] attempted as an assessment of the spatiotemporal change of drought in Northern Nigeria within the last decade using Moderate Resolution Spectro-radiometer (MODIS) datasets for 2005, 2010 and 2019.

The rise in global climate change and the continuous increase in water demand in the study area have raised concerns about the potential for increasing drought conditions in the future.

Pertinent to this study are questions bothering on the changes in land cover, temperature pattern, and impacts of droughts in the study area.

This research aims to carry out a geospatial analysis of the environmental impacts of climate change in Osogbo and its environs with a view to providing information towards mitigating the negative effects of climate change in the area under consideration. Objectives to achieve the aim include determining changes in land cover changes within the study area from 1982 to 2022, evaluating the pattern of temperature change, and determining the impact of drought in the area of study in the next twenty years.

2. Study Area

This study covers Osogbo and its environs (Fig 1). Osogbo town covers two Local Government Areas, which are Osogbo and Olorunda Local Government Areas (LGAs). The environs at a buffer of 5 km partly covered nine Local Government Areas (LGAs), which include Irepodun, Oroku, Ifelodun, Boripe, Obokun, Atakumosa West, Ede-South, Ede-North and Egbedore Local Government Areas. Osogbo the capital city of Osun State, Nigeria, is located between latitudes 7° 42’ 20” and 7° 49’ 20” N and longitudes 4° 30’ 20” and 4° 38’ 20” E. It falls within the tropics as categorized by Köppen’s Aw classification, with an annual temperature of 26.1 and an average annual precipitation of 1241 mm. The study area is made up of Precambrian rocks and fairly fertile, clayey, loamy soil obtained from mainly underlain basement complexes. Rivers and streams exist in the study area; prominent is the river Osun [11], [12]. Due to the geographical characteristics of the study area, farming is the main traditional occupation of the inhabitants. Cultivation of cassava is the major farming activity in the area due to the favourable tropical climate. Being the capital city, it serves as the commerce and administration nerve that has attracted a broad range of immigrants. It is prominent for commercial activities where buying and selling are carried out in its environment [13].

3. Methodology

This section explains the methods, procedures and principles employed in accomplishing the aim and objectives of this study.

The data acquisition includes selecting and investigating the imagery products that are suitable for the research work in the specific area of interest. Additionally, factors like spatial, temporal, spectral, and radiometric resolutions are carefully considered during the selection process. Before commencing the work, a thorough examination of the collected data was conducted, ensuring its quality and relevance to the study. The flow chat of the adopted methodology is presented in Fig. 2.

The secondary data used in this study include Landsat 4 satellite imagery with a spatial resolution of 30.0 m, Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) satellite imagery with a spatial resolution of 30.0 m, Landsat 8 OLI (Operational Land Imager) satellite imagery with a spatial resolution of 30.0 m, Google Earth Imagery. The Landsat imageries covering the study area with the specified path (190) and row (055) for all the mentioned epochs were downloaded from the USGS Landsat download website (http://earthexplorer.usgs.gov/) using the Google Chrome web browser. The ground coordinate points collected from 62 locations spanning different land cover classes (water bodies, vegetation, and built-up areas) were utilized to assess the overall accuracy and Kappa coefficient.

Satellite images were processed to determine the Land Use Land Cover (LULC), Land Surface Temperature (LST), and Vegetation Condition Index (VCI) of the study area. The Vegetation Condition Index (VCI) was employed to assess drought conditions in the study area, and a map illustrating the extent of drought was generated. VCI is calculated using the Normalized Difference Vegetation Index (NDVI).
4. Presentation of Results

The satellite imagery data from 1982, 2002, and 2022 was utilized to generate Land Use/Land Cover (LULC) maps, Land Surface Temperature (LST) maps, and a Drought map for the study area. These maps were created to evaluate and assess the environmental impact of climate change in the study area. In the study area, the LULC information was derived through visual interpretation techniques using satellite data. The land use land cover of the study area for 1982, 2002, and 2022 are presented in Fig. 3 and Table II shows the areas of classes gained or lost between 1982-2022. The LULC of the study area (Fig. 3) comprises water bodies followed by Built-up/Exposed surface and Vegetation (forest and agricultural land). The result of land use and land cover analysis (Table II) indicates a decrease in vegetation from 47.09 km² in 1982 to 333.38 km² in 2002 and 314.51 km² in 2022. Built/exposed surfaces increased rapidly from 85.64 km² in 1982 to 214.81 km² in 2002 and 231.83 km² in 2022.

According to Table I and Fig. 3, there is a notable and significant change in the Land Use/Land Cover (LULC) classes between 1982 and 2022. Increase in water bodies from 0.96 km² in 1982 to 13.47 km² in 2002 and 15.30 km² in 2022. There was a decrease in vegetation from 47.09 km² in 1982 to 333.38 km² in 2002 and 314.51 km² in 2022. Built/exposed surfaces increased rapidly from 85.64 km² in 1982 to 214.81 km² in 2002 and 231.83 km² in 2022.

5. Land Surface Temperature (LST)

Land surface Temperature (LST) (Fig. 4) analysis for the year 1982 shows that urbanization contributed to the highest land surface temperature seen in some places like Osogbo, Ofatedowhihiles places like Iloro, Eko-ende, Eko-ibode with more vegetation and less development has the lowest temperature. The positive impact of this analysis on the study area is that people, especially farmers, living in places like Osogbo, Ofatedowhihiles can migrate to places like Eko-ende, Iloro, Eko-ajala where there is more vegetation and less built-up.
According to Table III, the analysis of Land Surface Temperature (LST) for the study area in the year 2002 reveals that the temperatures in Osogbo, Ofatedo, and Abere have increased by approximately 1.074 °C compared to the LST recorded in 1982. This shows that human activities in those areas are contributing to the rise in temperature, and the impact, such as heat stress and thermal discomfort, can possibly worsen. One of the reasons could be the massive urban sprawl experienced as a result of Osogbo assuming the status of the state capital of Osun in 1992.

The analysis of Land Surface Temperature (LST) for the year 2022 reveals a noteworthy increase in land surface temperatures across all the locations examined within the study area compared to previous years. Places like Eko-ende, Eko-ajala, Ikirun and iloro, with the lowest LST in 1982 and 2002, experienced rapid increases in 2022.

6. Vegetation Condition Index-Based Drought (VCI)

The VCI-based drought map (Fig. 5) shows that there was no extreme or severe drought in the study area. In contrast, moderate and mild drought conditions were observed in the highly developed areas of the study area, specifically in locations such as Osogbo, Ofatedo, and Abere. Tables IV–VI show the vegetation condition of the study area for the years 1982, 2002 and 2022. The predicted drought condition for the years 2042 and 2046 is presented in Table VII.

7. Discussion

The research work focuses on conducting geospatial analysis to assess the environmental impact of climate change on Osogbo and its surrounding areas. The analysis includes a Land Use/Land Cover (LULC) assessment, which reveals notable changes in water bodies within the study area over specific time intervals. Also, decrease in vegetation by 141.70 km² (from 1982 to 2002) and 18.87 km² (from 2002 to 2022). Built/exposed surface increased rapidly by 129.17 km² (from 1982 to 2002) and 17.02 km² (from 2002 to 2022).

In 1982, the water bodies were less pronounced because there was more vegetation (riparian forests) covering some parts of the water bodies. Also, the Eko-ende dam located at the Irepodun local government area had not been constructed by then. One possible reason for the decrease in vegetation and the rapid increase in built-up/exposed surfaces between 1982 and 2002 could be attributed to the extensive urban sprawl that occurred when Osogbo became the capital of Osun State in 1992. This urban expansion led to the conversion of natural land covers, including vegetation, into built-up areas. The increased human activities and infrastructure development associated with urbanization can significantly alter land use patterns and result in vegetation loss.

The analysis of Land Surface Temperature (LST) indicates a substantial increase in mean temperature across the
A Geospatial Analysis of Environmental Impacts of Climate Change

Ijaware and Olagboye

Fig. 4. Land Surface Temperature (LST) of the study area for (a) 1982, (b) 2002, and (c) 2022.

(a) (c) (b)

Legend

VCI Based Drought

No Drought

Mild Drought

Moderate Drought

Fig. 5. Vegetation Condition Index (VCI) for (a) 1982, (b) 2002, and (c) 2022.

TABLE II: LAND COVER CHANGE DETECTION FROM 1982 TO 2022

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water bodies</td>
<td>0.96</td>
<td>13.47</td>
<td>12.51</td>
<td>15.31</td>
<td>Gain</td>
</tr>
<tr>
<td>2</td>
<td>Built-up/Exposed</td>
<td>85.64</td>
<td>214.81</td>
<td>129.17</td>
<td>231.83</td>
<td>Loss</td>
</tr>
<tr>
<td>3</td>
<td>Vegetation</td>
<td>457.08</td>
<td>333.38</td>
<td>−141.70</td>
<td>314.51</td>
<td>Gain</td>
</tr>
</tbody>
</table>

study area over the past four decades (from 1982 to 2022). During this period, the mean temperature rose by 10.73 °C, with the most significant warming (11.41 °C) observed in the last two decades (from 2002 to 2022). Locations such as Osogbo, Ofatedo, and Abere experienced the highest Land Surface Temperature (LST), while Eko-ende, Eko-ajala,
TABLE III: LAND SURFACE TEMPERATURE VALUE RANGE OVER THE YEARS

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Year 1982</th>
<th>Year 2002</th>
<th>Year 2022</th>
<th>Increase between 1982 and 2002</th>
<th>Increase between 2002 and 2022</th>
<th>2022 (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest</td>
<td>15.541</td>
<td>13.1009</td>
<td>26.5842</td>
<td>−2.4401</td>
<td>13.4833</td>
<td>15.30</td>
</tr>
<tr>
<td>Highest</td>
<td>28.1125</td>
<td>29.1865</td>
<td>38.5258</td>
<td>1.074</td>
<td>9.3393</td>
<td>314.51</td>
</tr>
<tr>
<td>Mean</td>
<td>21.8268</td>
<td>21.1437</td>
<td>32.5550</td>
<td>−0.6831</td>
<td>11.4113</td>
<td>561.66</td>
</tr>
</tbody>
</table>

TABLE IV: 1982 VEGETATION CONDITION INDEX TO MEASURE LEVEL OF DROUGHT

<table>
<thead>
<tr>
<th>Area affected (m²)</th>
<th>Condition</th>
<th>Percentage (%)</th>
<th>Drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>582521</td>
<td>Not stress vegetation condition</td>
<td>93.33</td>
<td>No drought</td>
</tr>
<tr>
<td>28918</td>
<td>Mild stress vegetation condition</td>
<td>4.63</td>
<td>2.6%</td>
</tr>
<tr>
<td>12696</td>
<td>Moderate vegetation condition</td>
<td>2.03</td>
<td></td>
</tr>
</tbody>
</table>

TABLE V: 2002 VEGETATION CONDITION INDEX TO MEASURE LEVEL OF DROUGHT

<table>
<thead>
<tr>
<th>Area affected (m²)</th>
<th>Condition</th>
<th>Percentage (%)</th>
<th>Drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>357416</td>
<td>Not stress vegetation condition</td>
<td>57.27</td>
<td>No drought</td>
</tr>
<tr>
<td>180573</td>
<td>Mild stress vegetation condition</td>
<td>28.93</td>
<td>15.13%</td>
</tr>
<tr>
<td>86146</td>
<td>Moderate vegetation condition</td>
<td>13.8</td>
<td></td>
</tr>
</tbody>
</table>

TABLE VI: 2022 VEGETATION CONDITION INDEX TO MEASURE LEVEL OF DROUGHT

<table>
<thead>
<tr>
<th>Area affected (m²)</th>
<th>Condition</th>
<th>Percentage (%)</th>
<th>Drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>267797</td>
<td>Not stress vegetation condition</td>
<td>42.91</td>
<td>No Drought</td>
</tr>
<tr>
<td>192743</td>
<td>Mild stress vegetation condition</td>
<td>30.88</td>
<td>4.67%</td>
</tr>
<tr>
<td>163595</td>
<td>Moderate vegetation condition</td>
<td>26.21</td>
<td></td>
</tr>
</tbody>
</table>

TABLE VII: 40 YEARS PREDICTION BASED ON 40 YEARS PAST TREND

<table>
<thead>
<tr>
<th>Year</th>
<th>Average</th>
<th>2042</th>
<th>2062</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>2.6%</td>
<td>15.13%</td>
<td>4.67%</td>
</tr>
<tr>
<td>2002</td>
<td>7.4%</td>
<td>12.14%</td>
<td>19.61%</td>
</tr>
</tbody>
</table>

8. SUMMARY OF FINDINGS

The purpose of this study was to assess the environmental impact of climate change on Osogbo and its surrounding areas using Geographic Information Systems (GIS) and remote sensing technology. Analysis of the LULC of the study area shows that the vegetation decreased from 84% in 1982 to 59% in 2002 and 56% in 2022. The built-up/exposed surface increased from 15.28% in 1982 to 38% in 2002 and 41.28% in 2022. The water bodies also increased from 0.17% in 1982 to 15.31% in 2022.

In contrast, the increase in water bodies in the study area can be primarily attributed to the construction of a new dam and the expansion of built-up areas. These factors have resulted in changes in land cover and the creation of new water bodies.

The analysis of the Land Surface Temperature (LST) map spanning the past 40 years indicates a significant shift in the mean temperature of the study area. Specifically, the mean temperature increased from 21.14 °C in 2002 to 32.14 °C in 2022. This upward trend suggests a substantial warming trend over the studied period, highlighting the influence of climate change on the local thermal environment.

The Vegetation Condition Index (VCI) based drought map reveals that extreme or severe drought conditions were not observed in the study area. However, moderate and mild droughts were observed in certain parts of the study area, confirming the presence of drought events.

9. CONCLUSION

The utilization of geospatial technology is paramount in comprehending and evaluating the environmental consequences of climate change. By harnessing the power of satellite imagery, geographic information systems (GIS), and other geospatial tools, researchers and policymakers can analyze alterations in land use, land cover, temperature patterns, and other pertinent environmental indicators. These analyses provide valuable insights into the magnitude and severity of climate change impacts, including the occurrence of drought, on the environment.

Moreover, geospatial technology aids in identifying regions that are particularly susceptible to climate change effects, allowing decision-makers to prioritize resources and develop effective adaptation and mitigation strategies.

By harnessing the capabilities of remote sensing, Geographic Information Systems (GIS), and other geospatial tools, governments, organizations, and communities can significantly enhance their understanding and management of drought impacts. Geospatial technology can support drought monitoring, forecasting, and risk mapping, which are essential for early planning and response. It can also promote water conservation practices and
increase community involvement in drought management efforts.

Satellite imagery, combined with ground-based observations and other climate data sources, forms a comprehensive and multi-dimensional understanding of climate change. It empowers scientists, policymakers, and organizations with the information necessary for effective climate change mitigation, adaptation strategies, and policy decisions. Ground truth is a term commonly used in various remote sensing techniques.

Overall, the integration of geospatial technology with environmental science is essential for effective climate change research, planning and policymaking.

By continuing to utilize geospatial tools and leverage geospatial data, we can enhance our understanding of the environmental impacts of climate change and create a sustainable future for all.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

REFERENCES


