Analysis of the Impact of Climatic Variability on Vegetation in Jos Plateau, Nigeria

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Abstract: This study investigated the impact of climatic variability on vegetation dynamics in Jos Plateau State, Nigeria, over a thirty-year period (1994–2024). The specific objectives were to assess the rate of vegetation cover change, examine rainfall and temperature variability patterns, and determine the relationship between vegetation cover dynamics and climatic variables using geospatial techniques. Landsat satellite imagery (TM, ETM+, and OLI) was utilized to derive the Normalized Difference Vegetation Index (NDVI) for vegetation assessment, while rainfall and temperature datasets obtained from NASA were analysed to evaluate climatic trends. Statistical analyses, including trend analysis and Pearson's Product–Moment Correlation Coefficient, were employed to quantify the relationships between vegetation cover and climatic parameters. The findings revealed a substantial decline in vegetation cover from 994.55 km² in 1994 to 440.41 km² in 2024, representing a 55.7% reduction. This decline corresponded with a noticeable decrease in rainfall, which dropped from 62.59 mm to 48.37 mm, and a steady increase in average temperature from 22.04°C to 24.45°C over the same period. Correlation results indicated a strong negative relationship between vegetation cover and temperature, and a positive relationship between vegetation cover and rainfall. The study concludes that climatic variability, compounded by anthropogenic activities such as rapid urbanization, deforestation, and land-use change, has significantly contributed to vegetation degradation in the study area. These findings highlight the urgent need for integrated land-use management, reforestation initiatives, and climate adaptation strategies to mitigate ongoing environmental degradation and promote sustainable ecosystem resilience in Jos Plateau State.

Keywords: *Climate Variability, Vegetation Dynamics, NDVI, Landsat Imagery, Rainfall Variability, Temperature Trends, Geospatial Analysis, Jos Plateau State Nigeria.*

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I. INTRODUCTION

➢ *Background of the Study*

Climate variability over instrumental periods and longer historical timescales is essential for understanding the dynamics of climate systems and their impacts on environmental and socio-economic systems (Oguntunde et al., 2012). Most observational and modelling studies rely on approximately a century of instrumental records to reveal natural climate variability and identify driving mechanisms.

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Such analyses are crucial for predicting global and regional climate variations, assessing human influence, and projecting future anthropogenic climate change. Climate is commonly described using long-term averages of temperature and rainfall, which remain the most practical indicators for evaluating climatic conditions and trends (Akinsanola & Ogunjobi, 2014).

Vegetation cover is a fundamental component of the Earth's environmental system and plays a critical role in regulating climate and sustaining human–environment interactions. Optimal vegetation provides numerous climatic, ecological, and socio-economic benefits, including carbon sequestration, microclimate regulation, biodiversity conservation, and watershed protection (Westphal, 2003; Nowak & Dwyer, 2007; Munyati & Mboweni, 2013; Naibbi et al., 2014). Urban tree cover, defined as the structural layers of leaves, branches, and stems that cover the Earth's surface when viewed from above (Sexton et al., 2013), is particularly important in mitigating urban heat and improving air quality.

Despite its importance, vegetation cover is declining globally, especially in developing countries where anthropogenic pressures such as agricultural expansion, fuel wood extraction, and urbanization are intense (Macaulay, 2014). Between 1990 and 2020, the world lost approximately 178 million hectares of forest—an area nearly equivalent to Libya (FAO, 2020). Africa experienced the highest annual net forest loss between 2010 and 2020, at about 3.9 million hectares per year, with increasing rates over successive decades (FAO, 2020). In Nigeria, vegetation decline has been strongly linked to rising fuel wood demand between 1990 and 2000 (Naibbi & Healy, 2013). According to FAO (2010), Nigeria recorded one of the highest percentages of forest loss among countries with the largest net forest area decline since 1990.

Nigeria possesses diverse forest ecosystems, including swamp forests in the south, tropical rainforests in the southwest and wooded savannah in the north-central region. Forests occupy about 110,890 km², representing approximately 12.18% of Nigeria's total landmass of 910,770 km² (Mfon et al., 2014). Tropical rainforests globally are biodiversity hotspots, hosting about 60% of known plant species, 90% of non-human primates, 40% of birds of prey, and 80% of insects (Park, 1992). Forests provide extensive ecosystem services — provisioning, regulating, cultural, and supporting—that sustain livelihoods and human well-being. They store and purify water, regulate climate, sequester carbon, mitigate floods and droughts, generate rainfall, and supply medicinal and cultural resources (CBD, 2009). The shift from viewing forests solely as timber resources to recognizing their multifunctional ecological value underscores their significance in climate regulation.

Global climate change has intensified concerns regarding temperature and rainfall variability. The global mean surface temperature increased by approximately 0.7°C during the 20th century (IPCC, 2007), though regional variations differ due to land surface characteristics such as albedo, evapotranspiration, and carbon cycling (Meissner et al., 2003; Snyder et al., 2004). Numerous studies across different regions confirm significant temporal and spatial climate variability (Hasanean, 2001; Fan et al., 2020; Ologunorisa, 2004). Rising temperatures and declining rainfall in many regions represent key manifestations of climate change (Audu et al., 2013; Wuyep & Daloeng, 2020).

Temperature and rainfall are central climatic parameters influencing agriculture, water resources, economic productivity, and human comfort. Daily temperature variation is primarily controlled by incoming solar radiation and outgoing long-wave radiation (Ahrens, 2011). However, temperature interacts with other atmospheric processes; for example, high temperatures are often associated with strong high-pressure systems and increased pollution levels under sunny conditions (Bryan et al., 2010). Over long periods, averaged temperature values characterize climatic regimes, although variability occurs at intra-seasonal and inter-annual scales (Walter, 1989; Roy et al., 2009).

Urbanization and land-use changes significantly influence local temperature patterns through modifications in albedo, surface moisture, vegetation cover, and anthropogenic heat release (Thomas et al., 2012). These changes contribute to rising temperatures, which have been linked to increased heat waves, droughts, glacier retreat, and permafrost melting (Timothy, 2010). Global temperatures have increased by about 0.5–0.6°C over the past century and are projected to rise further by 0.3–0.7°C by 2035 (Jaswal et al., 2015). Warming has also contributed to sea-level rise through thermal expansion and ice melt (Udayashankara et al., 2016).

Rainfall trends, defined as long-term directional changes in precipitation (Odjugo, 2010), show complex global patterns. While global averages indicate a slight positive trend, many regions experience declining rainfall (Coumou & Rahmstorf, 2012; Seneviratne et al., 2012; Trenberth, 2012). Notably, extreme rainfall events have increased in frequency and intensity in recent decades (Westra et al., 2013; Taylor et al., 2017; Zilli et al., 2017). The global land fraction experiencing intense rainfall events exceeds expectations based on natural variability alone (Fischer & Knutti, 2014; Espinoza et al., 2018).

Anthropogenic warming has significantly influenced extreme rainfall patterns. The frequency of record-breaking rainfall events increased by about 12% between 1981 and 2010 compared to natural variability expectations (Lehmann et al., 2015). The IPCC Special Report on 1.5°C documents robust increases in extreme rainfall indices such as annual maximum 1-day rainfall (RX1day) and consecutive 5-day rainfall (RX5day) (Hoegh-Guldberg et al., 2018; Schleussner et al., 2017). Attribution studies confirm human influence in many extreme rainfall events, particularly the most intense and rare occurrences (Min et al., 2011; Pall et al., 2011; Trenberth et al., 2015; Fischer & Knutti, 2014). Continued anthropogenic warming is projected to increase the frequency and intensity of rainfall extremes in many regions (Prein et al., 2017; Stott et al., 2016).

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Rainfall variability fluctuations over time and space are particularly pronounced in Nigeria. Seasonal rainfall variability in the Guinea Savannah region has increased as part of broader climate change dynamics (Ayansina et al., 2009). Wuyep and Doloeng (2020) highlight growing temporal and spatial rainfall variability nationwide. These changes are linked to urbanization, land-use change, and vegetation loss (Wang et al., 2012). Temperature–rainfall interactions are complex; high temperatures may enhance evaporation and potentially increase rainfall through condensation, or conversely intensify aridity depending on atmospheric conditions (Nkuna & Odiyo, 2016).

Geographic Information Systems (GIS) and Remote Sensing (RS) have become indispensable tools for monitoring climate variability and vegetation dynamics (UN, 1986). They support studies in atmospheric processes (Fagbeja, 2008), hydrology (Nwilo & Badejo, 1995), biodiversity (Salami & Balogun, 2006), and land-use change (Ehlers et al., 1990; Treitz et al., 1992). By integrating spatial and temporal data, GIS and RS facilitate comprehensive assessment of vegetation loss and its impacts on rainfall and temperature variability.

Climate variability and vegetation dynamics are closely interconnected. Rising temperatures, shifting rainfall patterns, and intensified extremes are increasingly linked to anthropogenic activities, particularly deforestation and urbanization. In Nigeria, where forest resources are under pressure, vegetation loss exacerbates climate variability and weakens ecosystem resilience. The application of GIS and remote sensing provides a robust framework for assessing these changes, particularly in sensitive regions such as the Jos Plateau. Understanding these linkages is essential for sustainable environmental management, climate adaptation, and long-term socio-economic stability.

➢ *Problem Statement*

Recent studies highlight that vegetation cover change has significant environmental impacts across global to local scales, including alterations in regional climate, carbon and hydrological cycles, biodiversity loss through habitat fragmentation, soil degradation, and overexploitation of native species (Lambin et al., 2003). In developing countries, continuous tree cover loss is largely driven by anthropogenic pressures such as fuel wood extraction and land-use change (Macaulay, 2014). Nigeria is experiencing one of the highest rates of deforestation globally due to rising fuel wood demand (FAO, 2010; FRA, 2020). However, up-to-date information on vegetation loss and its relationship with rainfall and temperature variability remains limited (Naibbi et al., 2014). This study examines spatial and temporal trends in vegetation and climate variability in Jos Plateau, Nigeria, using remote sensing, meteorological records, and land-use data to assess long-term trends, inter-annual variability, and vegetation–climate linkages. This study investigates rainfall and temperature variability patterns (1994–2024), assesses vegetation cover change over the same period, and examines the causal relationships between vegetation dynamics and climate variability in the study area.

➢ *Objective*

This study aims to assess vegetation loss and its impacts on rainfall and temperature variability in Jos East, Jos North, and Jos South Local Government Areas of Plateau State, Nigeria. Specifically, it seeks to analyse trends and patterns in rainfall and temperature between 1994 and 2024, evaluate the rate and extent of vegetation cover changes over the same period, and examine the causal relationships between vegetation dynamics and climate variability. By integrating climatic and environmental data, the study intends to provide empirical evidence on how land cover changes influence local climate patterns within the study area

This study focuses on detecting vegetation loss and examining its impacts on rainfall and temperature variability in Jos, Plateau State, Nigeria. Geographically confined to Jos East, Jos North, and Jos South Local Government Areas, the research lies within environmental science, climatology, and geo-informatics. It analyses vegetation dynamics and climate variability over a sufficiently long-term period to capture both short-term fluctuations and long-term trends. Specifically, the study evaluates the rate of vegetation cover change, assesses rainfall and temperature variability patterns, and investigates the relationships between vegetation dynamics and climatic factors.

The significance of this research lies in its contribution to both scientific knowledge and practical decision-making. By providing a place-based assessment of vegetation–climate interactions on the Jos Plateau, the study enhances understanding of land–atmosphere linkages in a region with unique ecological characteristics. Forest ecosystems provide essential services beyond timber production, including climate regulation, water purification, carbon sequestration, and biodiversity conservation, all of which underpin human well-being and sustainable development.

The findings are expected to inform natural resource management, climate adaptation planning, and sustainable land-use strategies in Plateau State and Nigeria at large. By identifying vulnerable areas and key drivers of change, the study will support evidence-based policymaking on afforestation, land-use planning, disaster risk reduction, and climate adaptation. It also aligns with Nigeria’s commitments to global frameworks such as the Paris Agreement, UNFCCC, and the Sustainable Development Goals (Yusuf & Abatan, 2020). The integration of geospatial techniques and statistical trend analysis further advances methodological approaches applicable to similar ecological zones in sub-Saharan Africa.

II. METHODOLOGY

This section describes the geographical characteristics of the study area and outlines the methodological procedures adopted for data collection, processing and analysis. It presents the location, climate, geology, vegetation, soils, population, and human activities of Jos Plateau, followed by a detailed explanation of the research design, data sources, and analytical techniques used to examine vegetation dynamics and climate variability between 1994 and 2024.

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➢ *Study Area*

Jos Metropolis is located between latitudes 9°54′N and 10°10′N and longitudes 8°48′E and 9°30′E. It lies at an average elevation of approximately 1,250 meters above sea level, with Shere Hills reaching the highest peak at about 1,777 meters. The study area covers approximately 1,002.19 km². Its high altitude distinguishes it climatically from surrounding lowland regions.

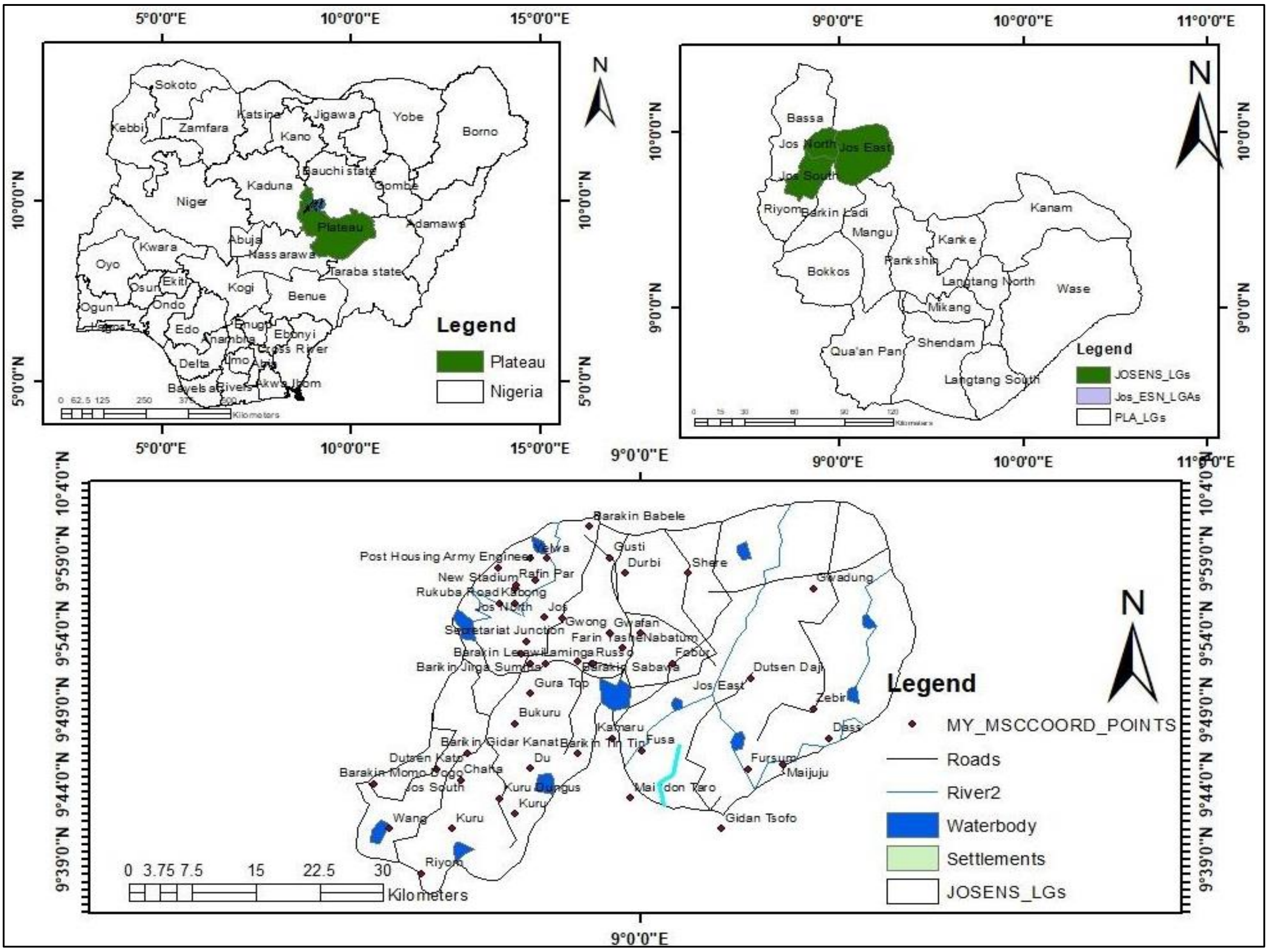

Fig 1 Study Area

Jos falls within the tropical savannah (Aw) climate under the Köppen classification. The area experiences two distinct seasons: a wet season (April–September) and a dry season (October–March). Rainfall peaks in July and August, with annual totals averaging between 1,300 mm and 1,400 mm. The mean annual temperature ranges between 20°C and 26°C, although daytime temperatures may reach 32°C and drop to about 18°C during the dry Harmattan period (December–February). The relatively cool climate compared to other parts of Nigeria is largely influenced by altitude and the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ). Rainfall distribution and cloud cover also moderate temperature patterns.

The study area lies within the Jos-Bukuru Complex, predominantly composed of biotite granite. The geology consists of Precambrian Basement Complex rocks (migmatite, gneiss, and quartzite), intruded by Pan-African granites and later Jurassic Younger Granites. Volcanic rocks such as basalts and rhyolites are also present. Relief is characterized by undulating highlands, rocky outcrops, and dissected valleys. Sedimentary deposits are mainly confined to river alluvium.

The Jos Plateau is dominated by Northern Guinea savannah vegetation, characterized by grasslands interspersed with shrubs and scattered trees. However, mining, agriculture, urbanization, and fuel wood extraction have significantly altered the natural vegetation cover, resulting in fragmentation and deforestation in many areas.

Soils on the Jos Plateau are largely derived from basalt, volcanic ash, and granite parent materials. Basaltic and volcanic ash soils are deeper, richer in organic matter, and more fertile than granite-derived soils. They possess higher cation exchange capacity (CEC), better water retention, and improved nutrient content, making them more suitable for agriculture. Granite-derived soils, on the other hand, tend to be less fertile and present greater constraints for crop production. Moisture content in the region's soils is generally low, indicating high transmissivity and limited water retention in certain areas. Soil texture varies, with many areas characterized by clayey and poorly graded soils.

According to the 2006 national census, Plateau State had a population of 3,178,712, with Jos North and Jos South recording 429,300 and 306,716 people respectively. Recent projections estimate the Jos metropolitan population at over 1 million, while Plateau State's population is estimated at about 4.7 million. Population growth has intensified pressure on land resources.

Major human activities in the Jos Plateau include tin mining, agriculture, livestock grazing, urban development, firewood harvesting, fishing and block moulding industries. These activities have significantly altered land cover, contributing to vegetation loss, soil degradation, and environmental change.

➢ *Research Design*

The study adopted a descriptive research design integrating remote sensing, Geographic Information Systems (GIS) and statistical analysis. The methodological process included data acquisition, pre-processing, image enhancement, NDVI computation, statistical analysis, and interpretation of vegetation–climate relationships.

A field reconnaissance survey was conducted using a Differential Handheld Global Positioning System (DHGPS). Coordinate points of natural and man-made features such as plantations, water bodies, farmlands, and urban areas were collected to support image validation and spatial analysis.

➢ *Data Types and Sources*

Both primary and secondary data were utilized using the Satellite Imagery: (All acquired from USGS; WRS Path 188, Row 53).

- Landsat 5 (TM) – 1994
- Landsat 7 (ETM+) – 2004
- Landsat 8 (OLI) – 2014
- Landsat 8/9 (OLI) – 2024

Climatic Data such as Rainfall and temperature records (1994–2024) were obtained from NASA and NiMet. Other Data such as Administrative maps, GPS coordinate points were used in the analysis.

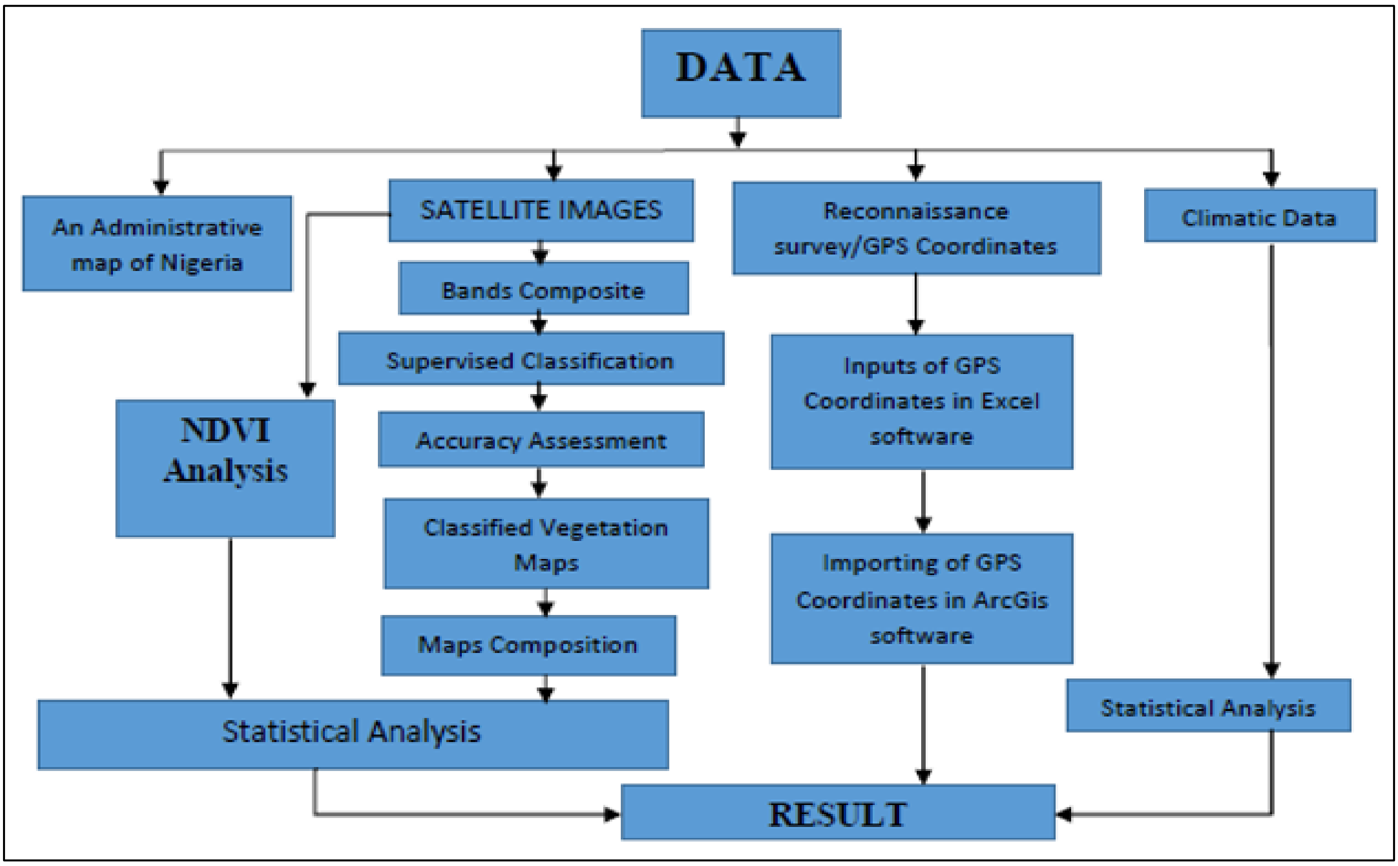

Fig 2 Methodological Flowchart of Data Analysis.

➢ *Data Processing and Analysis*

Satellite images were pre-processed and clipped to the study area. Composite images were generated using RGB band combinations (Bands 2-3-4 for Landsat 5/7 and Bands 3-4-5 for Landsat 8/9).

The Normalized Difference Vegetation Index (NDVI) was calculated using:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad \text{Equ. 1}$$

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For Landsat 5 and 7, Band 4 represented NIR and Band 3 represented RED. For Landsat 8/9, Band 5 was NIR and Band 4 was RED. NDVI maps for 1994, 2004, 2014, and 2024 were generated using ArcGIS Spatial Analyst tools. Climatic data were analysed using descriptive statistics and line graphs in Microsoft Excel to identify trends in rainfall and temperature over the 30-year period.

To examine relationships between vegetation cover and climate variables, the Pearson Correlation Coefficient (PCC) was applied:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2(y-\bar{y})^2}} \text{ ....Equ. 2}$$

Where:

$\bar{x}$ = mean of x variable

$\bar{y}$ = mean of y variable

y = rainfall values

r = correlation coefficient

The correlation was tested at a 95% confidence level to determine whether relationships were statistically significant. Positive or negative correlations were interpreted to understand vegetation–climate interactions.

This section described the physical, climatic, and socio-economic characteristics of the Jos Plateau and detailed the geospatial and statistical methods used in analysing vegetation loss and climate variability. By integrating satellite imagery, meteorological data, field observations, and correlation analysis, the study provides a robust framework for assessing long-term vegetation and climate dynamics between 1994 and 2024.

III. RESULTS AND DISCUSSION

➢ *Vegetation Cover*

The rate of vegetation cover in the study area is shown in Figure 3 to Figure 6 and Table 1 shows the summary of the results of Normalize Differential Vegetation Indices (NDVI) with its statistics and charts from 1994- 2024.

From Figure 3, it was found that the vegetation of 1994 indicated that 55% of the study area has dense and healthy vegetation while 45% of the areas are covered with water bodies and developed area. This implies that dense vegetation in developed areas dominated the study area in the year 1994. This shows that as vegetation cover increases, it promotes higher agricultural yields and reduces rural poverty (Heger, *et al*., 2018). With the development of human society, people are becoming more environmentally conscious and the demand for comfortable climatic conditions is increasing (Cetin et al., 2018).

Figure 4, it was found that the vegetation of 1 indicated that 49% of the study area has dense and healthy vegetation while most of the area of about 51% of the areas are covered with bare surfaces, agricultural lands, water bodies and developed areas. This implies that dense vegetation dominated the study area in the year 2004 unlike the case in 1994. On the other hand, some scholars argue that vegetation loss in the region may be overestimated due to limitations in NDVI classification.

For instance, Ayanlade (2016) cautioned that NDVI readings can be skewed during dry seasons or by cloud cover, potentially under representing vegetation cover. Nevertheless, this study's NDVI maps used consistent seasonal images, minimizing such distortions and supporting the reliability of the decline observed. The vegetation change is closely related to land use change generated by human activities (Cetin et al., 2018).

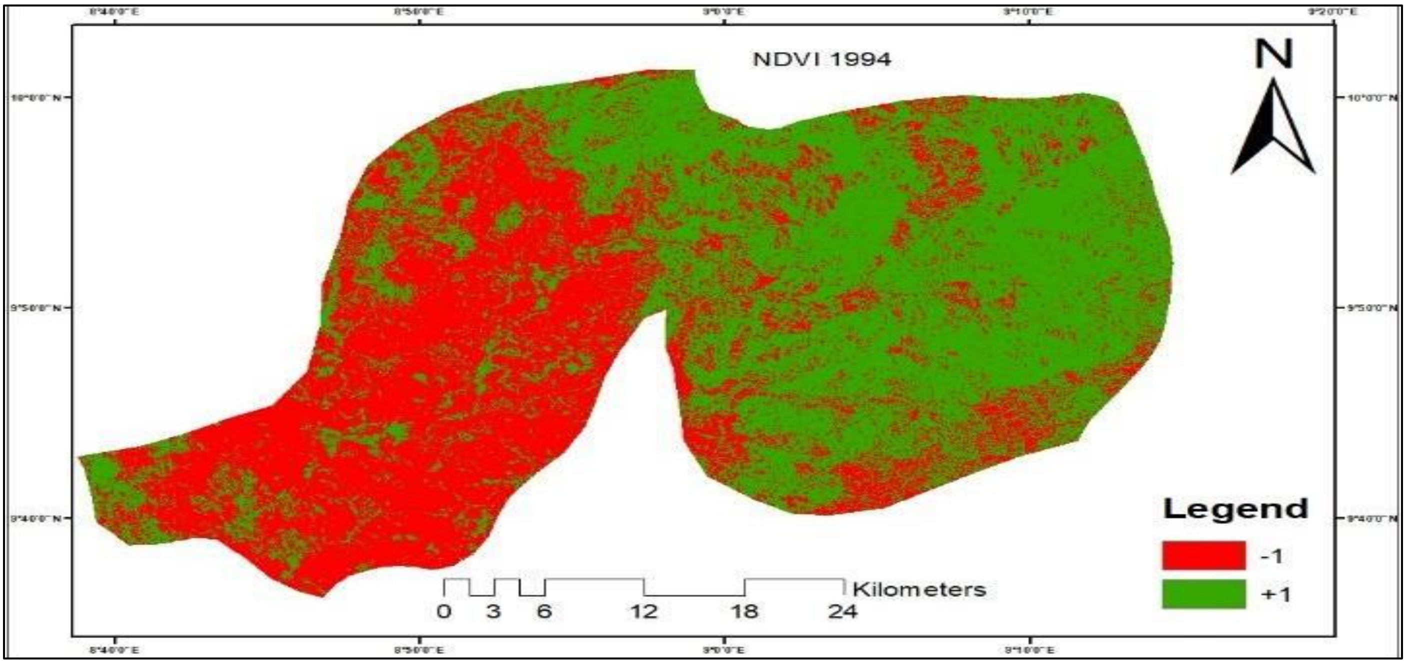

Fig 3 NDVI Map 1994

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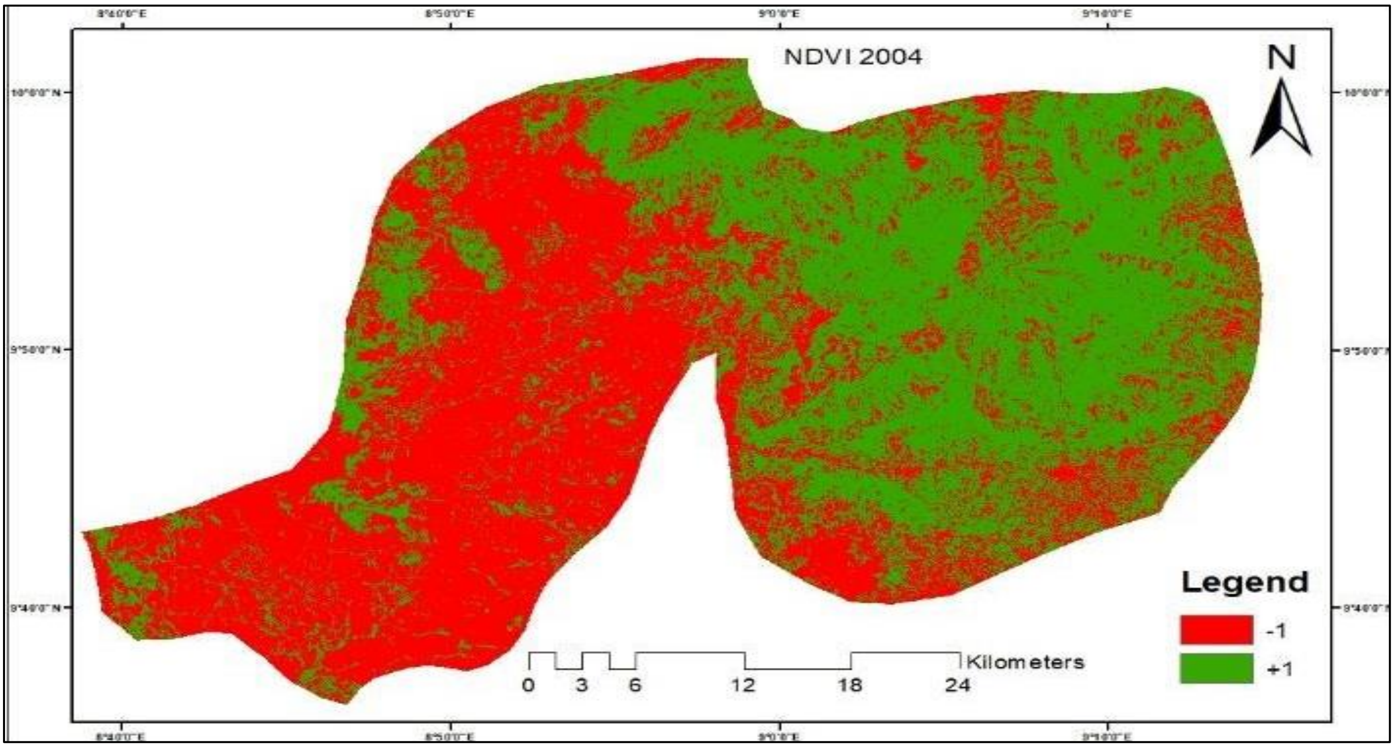

Fig 4 NDVI Map 2004

The vegetation degradation is the alteration of the condition of the forest resulting in a change (as opposed to loss) or reduction in the coverage without necessarily a loss from its original condition but a negative change to its structure (loss of biodiversity or a decrease in biomass) that diminishes its capacity to generate services and products Tovar, (2009).

The findings in Figures 3 to 6 are similar. The results show an in increase in NDVI readings, skewed during dry seasons or by cloud cover, potentially under representing vegetation cover. Nevertheless, this study's NDVI maps used consistent seasonal images, minimizing such distortions and supporting the reliability of the decline observed from 2004 to 2024 respectively. As indicated in Table 1.

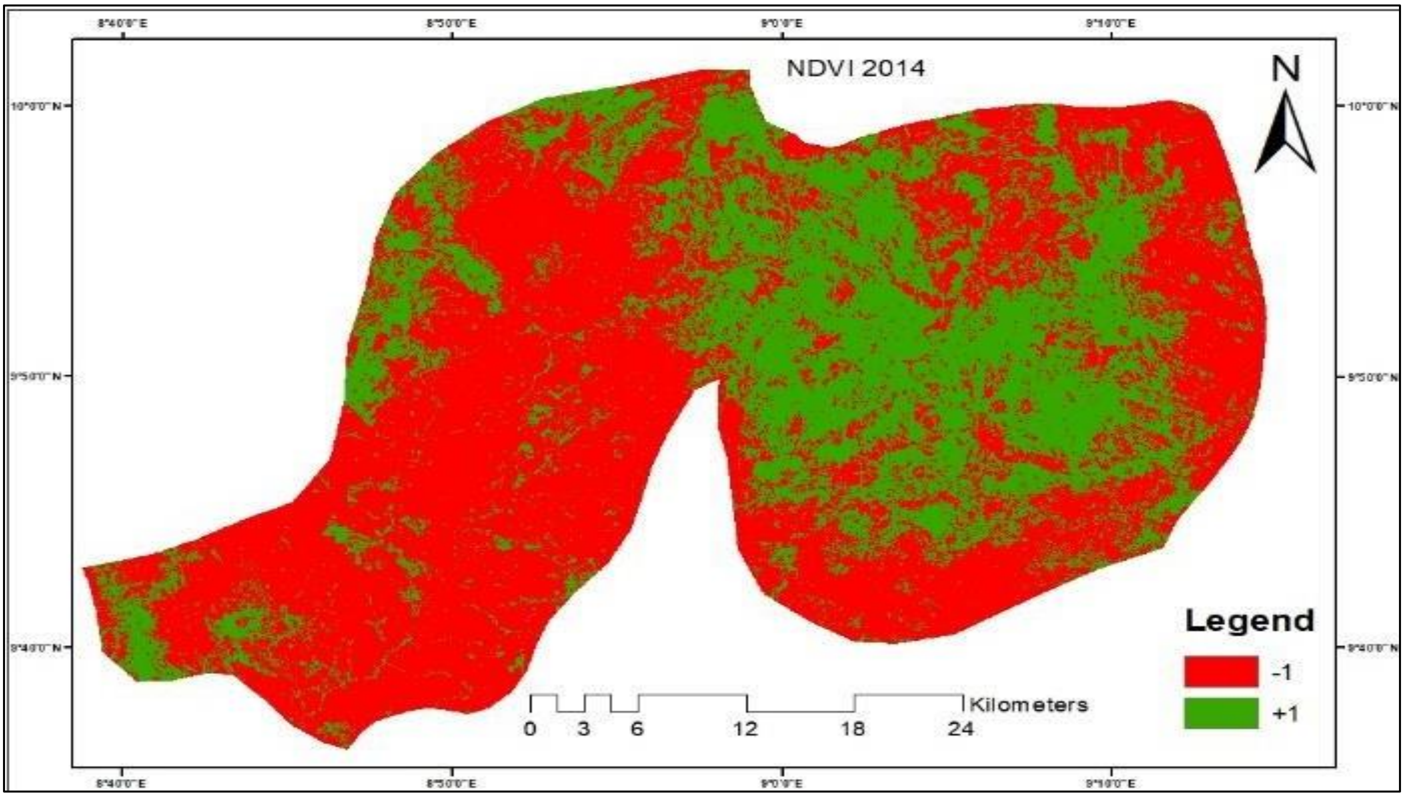

Fig 5 NDVI Map 2014

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The findings indicate a consistent upward trend similar to the findings by Chen *et al*. (2024). Africa had the largest annual rate of net forest loss between 2010 2020, at 3.9 million ha. Moreover, the rate of net forest loss has increased in Africa in each of the three decades since 1990 (FRA 2020). Also, in developing countries, studies revealed that tree cover is being lost continuously owing to various anthropogenic activities as in the research conducted by Macaulay (2014). As asserted by Naibbi and Healy (2013) that vegetation cover was on decline due to exponential increase in demand of fuel wood between 1990 and 2000.

The result show that the study area has experienced major changes in land use and land cover over the last two decades, including a sharp rise in built-up areas and a sharp decline in vegetation cover as supported by Mia et al. (2020). It could be as a result of the decrease in agricultural land and the increase in aquaculture areas lead to a transformation in the local population's occupation over time (Faruque et al., 2022).

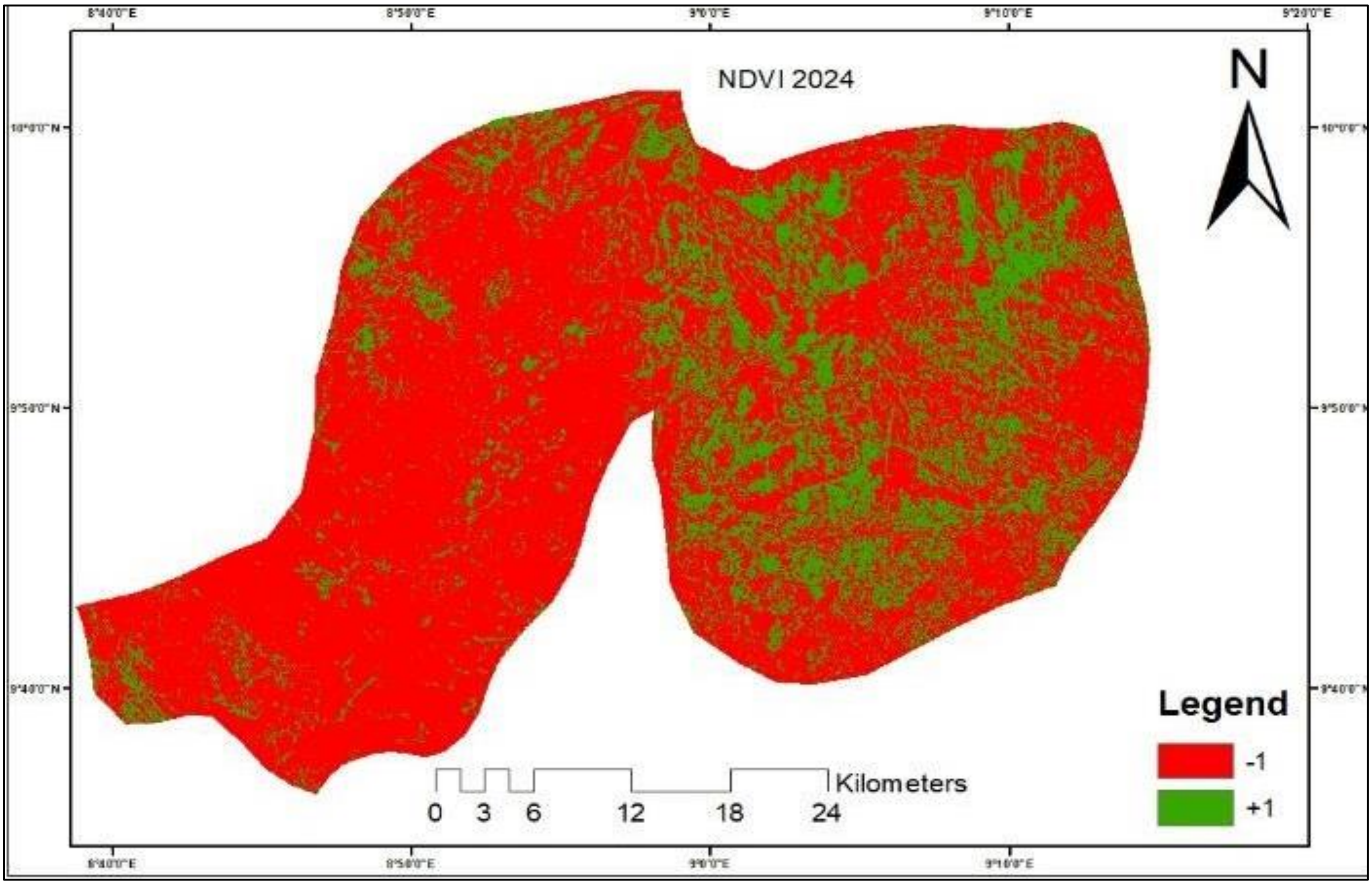

Fig 6 NDVI Map 2024

➢ *NDVI of Vegetation Changes from 1994 to 2024.*

Table 1 revealed a consistent decline in vegetation cover (as also visually shown in figure 7), a reduction in rainfall, and a rise in temperature across Jos East, Jos South, and Jos North LGAs over the thirty-year period from 1994 to 2024. These findings are consistent with numerous studies in Nigeria and other parts of Sub-Saharan Africa, which associate vegetation loss and climate variability with both anthropogenic and natural factors.

Table 1 Summarized the NDVI from 1994- 2024.

NDVI-Value	Area (km^2)	%	Year
-1	785.40	45	1994
1	994.55	55	1994
-1	894.930990	51	2004
1	884.993391	49	2004
-1	1115.298970	63	2014
1	1115.298970	37	2014
-1	1339.551178	76	2024
1	440.407151	24	2024

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However, scholarly perspectives vary regarding the causes, patterns, and consequences of these trends. This is so because according to EFC, (2010), the world continues to lose some 15 million hectares of forests every year.

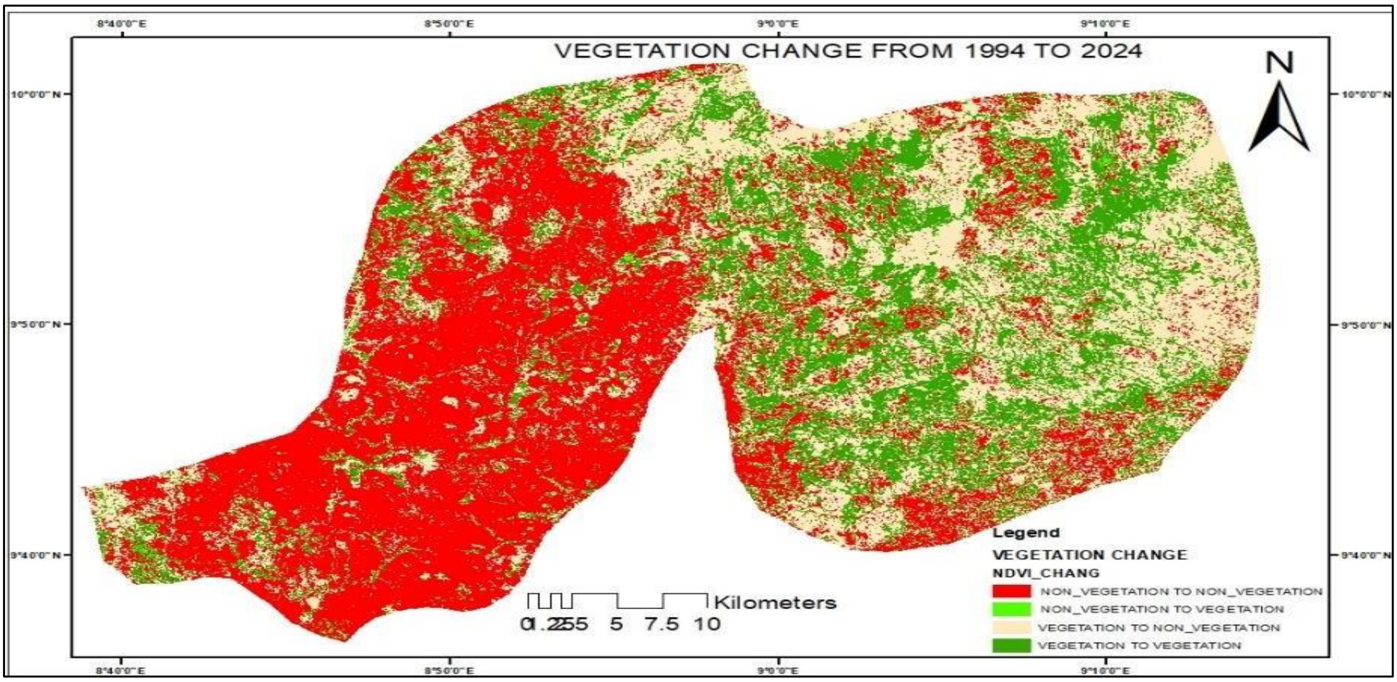

Fig 7 NDVI Vegetation Changes Map from 1994 to 2024

Deforestation over the period 1980 to 1990 reached 8.2% of total forest area in Asia, 6.1% in Latin America and 4.8% in African and most modern deforestation takes place in developing countries, particularly in tropical areas. The high optimum vegetation cover offers climatic, socio-economic and ecological benefits (Naibbi *et al*. 2014). Additionally, this decline is largely explained by a reduction in net radiation, an increase in actual vapour pressure whose net effect also led to decrease in the surface-air temperature difference as supported by Vincent et al., (2019).

Ground trotting was carried out to verify the accuracy of remotely sensed data, such as satellite images, by comparing them to actual ground conditions. This process was crucial for studies like Normalized Differential Vegetation Indexes (NDVI) and land-use/land-cover (LULC) changes, which involve mapping features like rock outcrops, farmlands, and settlements. It ensures that the remote sensing software's classification of these features is correctly and that the resulting maps and analyzed are reliable, helping to understand increased or declined in vegetation and shifts in land use due to factors like population growth and agricultural expansion.

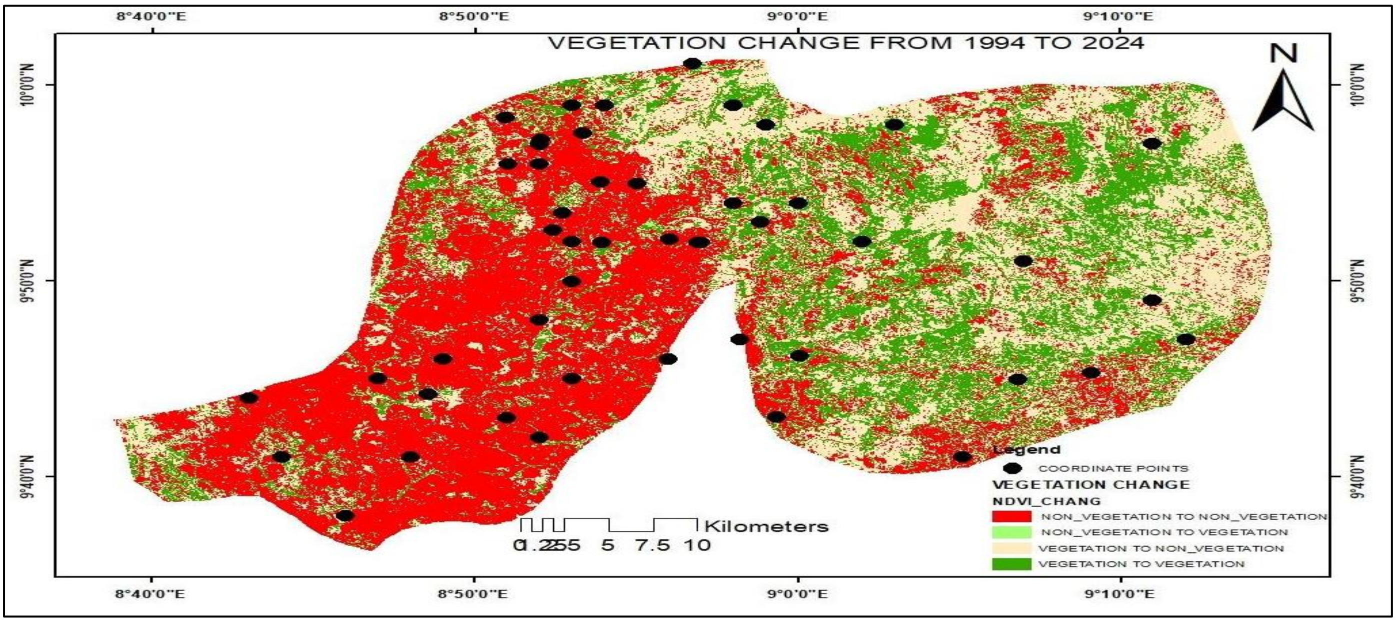

Fig 8 NDVI Vegetation Changes Map and its Ground Trotting Points.

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➢ *The Rate and Pattern of Rainfall, Temperature Variability and Vegetation Cover.*

The estimated rainfall and temperature data for each year from 1994 to 202 is shown in figure 9, by using linear interpolation for each year.

The result from figure 9 reveals a clear trend of declining rainfall and rising temperatures over the 30 year period. Rainfall shows a gradual decrease, starting at approximately 1387.4 mm in 1994, peaking slightly around 1231.4 mm in 2003, then, steadily declining to 1190.3mm in 2024. This overall downward trend suggests a drying climate which may impact local agriculture and water resources as established by Ojo (2021) that the that there are distinct changes in climate variability between the years 2000 and 2019, leading to changes in the land use/land cover of the study area. The observed shift in the trend distribution of rainfall is more distinct than for annual mean rainfall and the global land fraction experiencing more intense rainfall events is larger than expected from internal variability (Fischer and Knutti 2014; Espinoza *et al*. 2018) of which is the variability.

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As the IPCC SR15 reports robust increases in observed rainfall for annual maximum 1-day rainfall (RX1day) and consecutive 5-day rainfall (RX5day) (Hoegh-Guldberg *et al*. 2018; Schleussner, *et al*. 2017). The changes are due to the dynamics of the atmosphere amplify or weaken future rainfall extremes at the regional scale (O'Gorman 2015; Pfahl *et al*. 2017). Continued anthropogenic warming is very likely to increase the frequency and intensity of extreme rainfall in many regions of the globe (Mohan and Rajeevan 2017; Prein *et al*. 2017). More so, Damilola et al., (2025) showed that area experienced rainfall fluctuations, significant monthly decrease and temperature rise in many months increase.

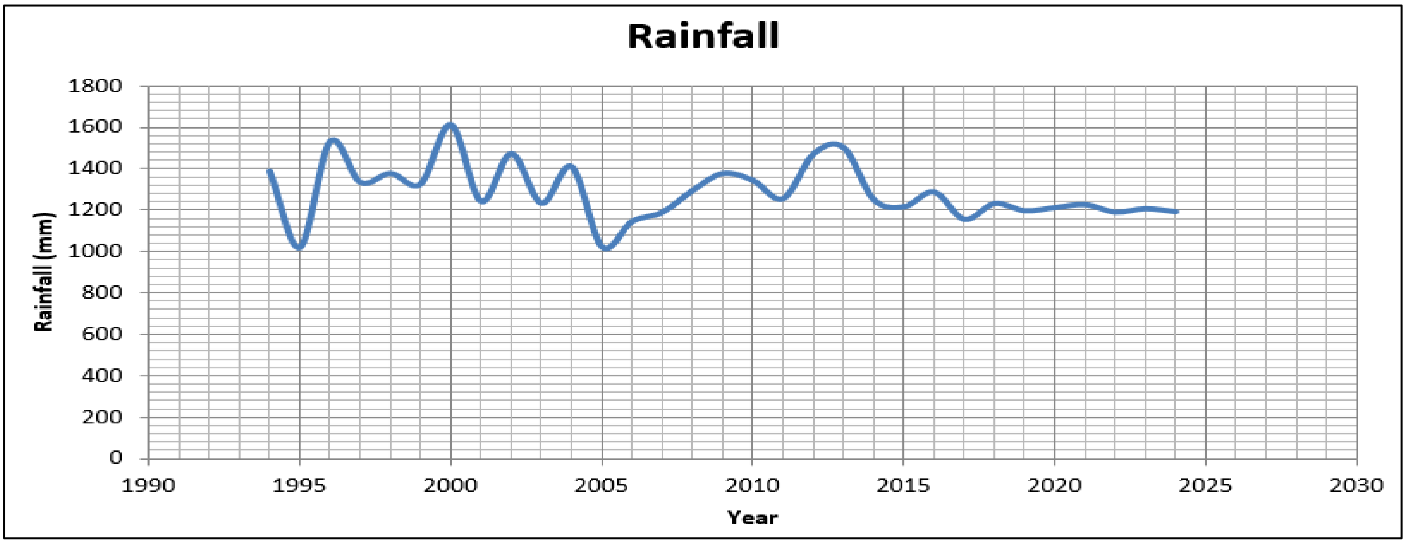

Fig 9 Rainfall Changes from 1994 to 2024

The Normalized Difference Vegetation Index and supervised classification of land cover also revealed a decline in vegetation health and loss of forested land to non-forest uses such as farmlands and built-up lands over time and concluded that the impact of climate change on the forest environment has been exacerbated by pressure for urban growth and probably a poorly monitored quest for land resource. Conversely, temperature as shown in figure 10 exhibits a consistent upward trajectory, increasing from about 22.04°C in 1994 to 24.45°C by 2024. The steady rise in temperature could exacerbate evapotranspiration rates, further stressing vegetation and water availability. This result is so because research has shown that the global climate has changed rapidly with the global mean temperature increasing by 0.7°C within the last century (IPCC 2007). As put by Wuyep and Daloeng, (2020) that increasing temperature and decreasing rainfall in most part of the world are the greatest impacts of climate change and these bring about negative or positive ecological impacts in different parts of the world (Idowu, *et al*, 2011). The global temperatures are estimated to have increased by 0.5-0.6°C over the last century and are estimated to increase by 0.3-0.7°C by 2035 (Jaswal *et al*, 2015).

The inverse relationship between rainfall and temperature is typical of regions experiencing climate variability or change. The data implies potential environmental stress, with declining precipitation and increasing heat posing challenges for ecosystem sustainability and local livelihoods in the Jos LGAs. This

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underscores the need for adaptive strategies to manage water resources and protect vegetation cover amid changing climatic conditions. Climate change, with changing temperature and rainfall levels, has mostly affected Land Use Land Cover (LULC) throughout the whole world (Al-Najjar, 2019; Pradhan, et al., 2020) as presented in Table 7. As Temesgen et al. (2018) found that rainfall–vegetation interaction regulates temperature anomalies during extreme dry events in the Horn of Africa.

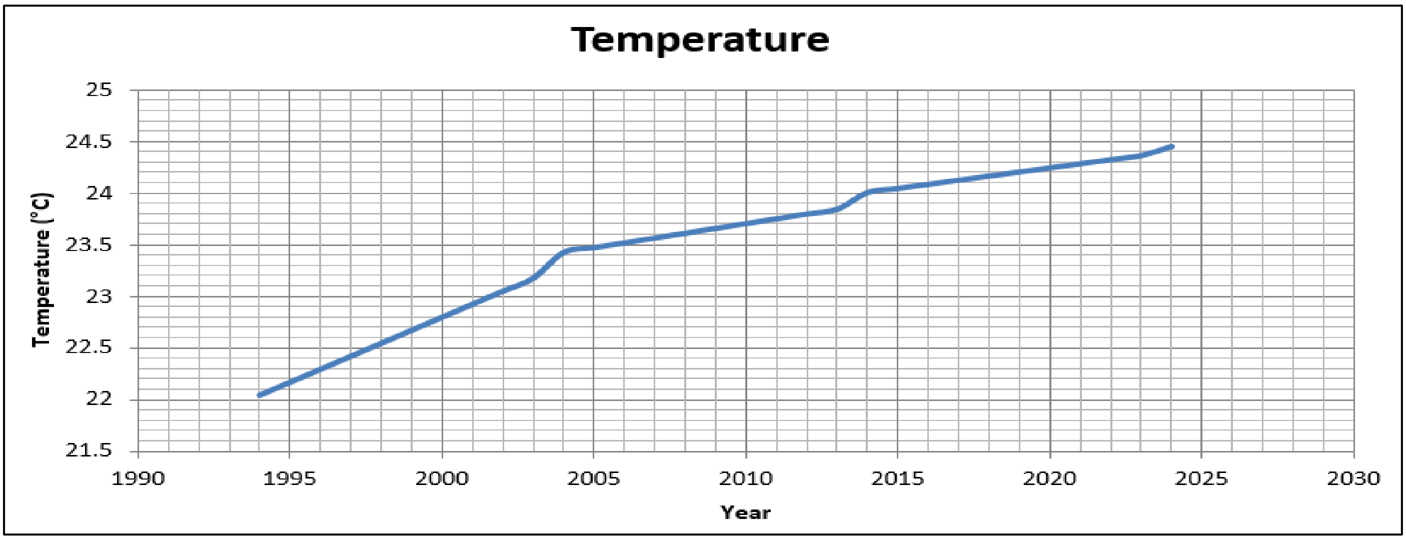

Fig 10 Temperature Changes from 1994 to 2024

The results from figure 11 reveals a consistent decline in vegetation cover from 994.55 km² in 1994 to 440.41 km² in 2024, indicating significant degradation of green areas over three decades. This loss is especially sharp between 2004 and 2013, suggesting intensified environmental pressures during that period. The observed decline in vegetation from 994.55 km² in 1994 to 440.41 km² in 2024 represents over 55% loss in green cover. This finding aligns with the work of Olorunfemi et al. (2017), who reported a significant reduction in vegetation due to increased urbanization and agricultural encroachment on the Jos Plateau.

Similarly, Adeoye et al. (2020) concluded that deforestation, fuel wood harvesting, and population pressure are the dominant drivers of vegetation loss in central Nigeria. The vegetation loss in this study particularly corresponds with urban growth corridors in Jos North and Jos South, where infrastructural development has outpaced environmental planning. The decline is largely explained by a reduction in net radiation, an increase in actual vapor pressure whose net effect also led to decrease in the surface-air temperature difference (Vincent et al., 2019).

Rainfall also exhibits a gradual decrease; this reduction in precipitation likely contributes to the diminishing vegetation, as less moisture limits plant growth and ecosystem resilience. Emlaei, et al., (2022) also founds that spatial pattern of annual precipitation showed decreasing amounts in the three studied years from the northwest to the south and climate change plays an essential role in this reduction. Conversely, temperature shows a clear upward trend, rising from 22.04°C in 1994 to 24.45°C in 2024. This gradual warming increases evapotranspiration and stress on local flora, further accelerating vegetation loss.

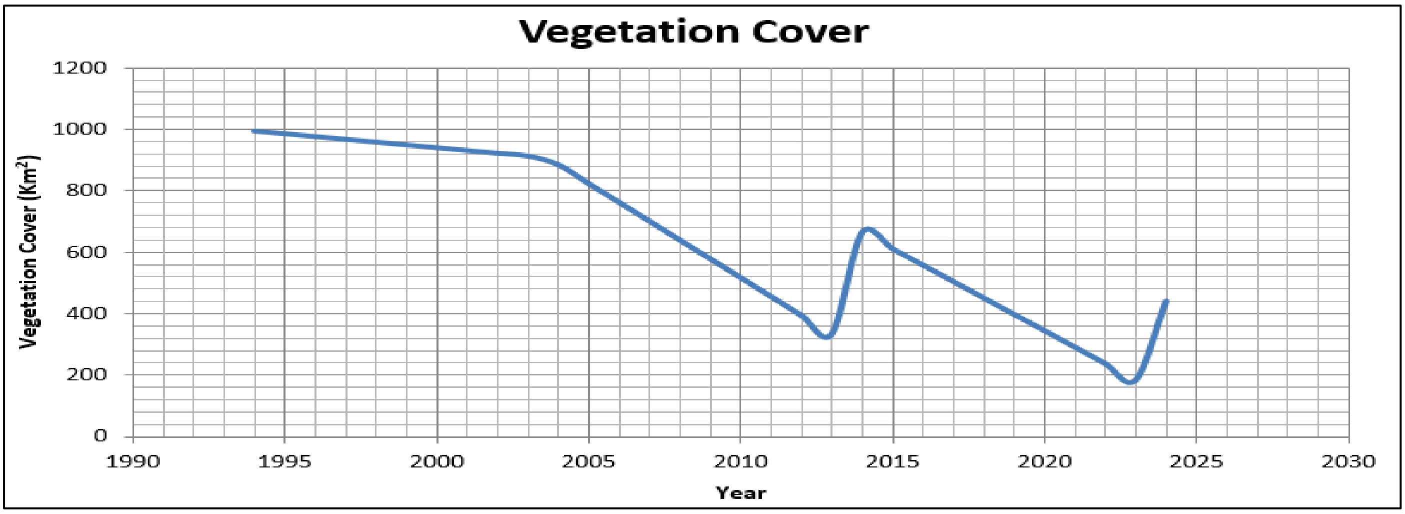

Fig 11 Vegetation Cover from 1994 to 2024

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The combined pattern indicates a drying and warming climate with shrinking vegetation cover in the region. These trends suggest increasing vulnerability of local ecosystems to climate variability and human impact, highlighting the need for targeted conservation and climate adaptation efforts in Jos East, Jos South, and Jos North LGAs. Vegetation cover has been declining steadily over the 30-year period, decreasing by about 26.81 km² per year. This indicates significant vegetation loss, which may be due to land use change, deforestation, or climate factors.

Rainfall exhibited considerable fluctuations throughout the study period, with values ranging from a minimum of 1017.9 mm in 1995 to a peak of 1611.5 mm in 2000. Despite this variability, no clear downward trend is evident. Instead, rainfall remained moderately stable after 2010, averaging around 1200 mm with reduced inter-annual fluctuations compared to the earlier years. This suggests that rainfall availability has been relatively consistent in the long term, and changes in vegetation cover cannot be explained solely by rainfall variability. Rainfall has become more stable but at a slightly lower average compared to the late 1990s. Rainfall shows a consistent negative trend, reducing by approximately 0.50 mm per year. This suggests progressive drying conditions over time, which may influence agriculture, water resources, and ecosystem health.

Temperature showed a clear and continuous upward trend across the three decades. It rose from 22.0 °C in 1994 to 24.4 °C in 2024, indicating a warming rate of about 0.08 °C per year. Unlike rainfall, which fluctuated, temperature increased steadily without reversal or stagnation. This persistent rise in temperature likely contributed significantly to vegetation stress and decline, as higher temperatures increase evapotranspiration, soil moisture loss, and overall ecosystem vulnerability. Temperature has been rising steadily, increasing by about 0.081°C per year. This aligns with patterns of global warming and may be contributing to vegetation declined and reduced rainfall. Overall Pattern:

- Vegetation ↓ (Strong decline)
- Rainfall ↓ (Very strong decline)
- Temperature ↑ (Strong increase)

These trends indicate a warming and drying climate, with corresponding loss of vegetation cover in the study area during a period under study.

From 1994 to 2024, vegetation cover, rainfall and temperature exhibited distinct but interconnected patterns of variability. Vegetation cover showed a relatively stable trend in the 1990s, maintaining around 950 – 1000 km², but after 2004 it entered a steep and persistent decline, reaching as low as 183 km² in 2023 before showing a slight recovery to 440 km² in 2024. Rainfall fluctuated widely throughout the study period, ranging between about 1000 mm and 1600 mm, with peaks in years such as 2000 (1611.5 mm) and 2013 (1501.6 mm), but since 2010 it stabilized around 1200 mm with reduced variability. In contrast, temperature exhibited a steady and uninterrupted rise, increasing from about 22.0 °C in 1994 to 24.4 °C in 2024. Overall, the trends suggest that while rainfall variability did not follow a consistent decline, the continuous increase in temperature, in combination with other possible anthropogenic pressures, has coincided with a sharp reduction in vegetation cover. This indicates that warming temperatures and human-induced land use changes are more critical drivers of vegetation loss in the area than rainfall availability alone.

➢ *The Relationship Between Decreased in Vegetation Cover, Rainfall and Temperature Variability.*

Figure 12, 13 and 14 show the results for the relationship between decreasing in vegetation cover, rainfall and increasing temperature variability in Jos East, Jos South and Jos North LGAs during the period under study.

The result shows that from 1994 to 2024 reveals clear trends in vegetation cover decrease, rainfall decline, and temperature increase in Jos East, Jos South, and Jos North LGAs. Vegetation loss shows a sharp decrease between 1994 and 2004, followed by a more gradual decline towards 2024. This pattern suggests an initial rapid degradation of vegetation, possibly due to intensified land use or environmental stress, with the rate slowing as less vegetation remains. This finding is similar to Damilola et al., (2025) showed that area experienced rainfall fluctuations, significant monthly decrease and temperature rise in many months increase.

The Normalized Difference Vegetation Index and supervised classification of land cover also revealed a decline in vegetation health and loss of forested land to non-forest uses such as farmlands and built-up lands over time and concluded that the impact of climate change on the forest environment has been exacerbated by pressure for urban growth and probably a poorly monitored quest for land resource. This shows what the effect of forests on climate where forest loss leads to dire consequences (Ojo, 2021). Vegetation influences temperature through direct absorption and reflection of incident solar radiation and through evapotranspiration by determining the amount of thermal energy dissipated through the evaporation of water (Senior et al., 2017).

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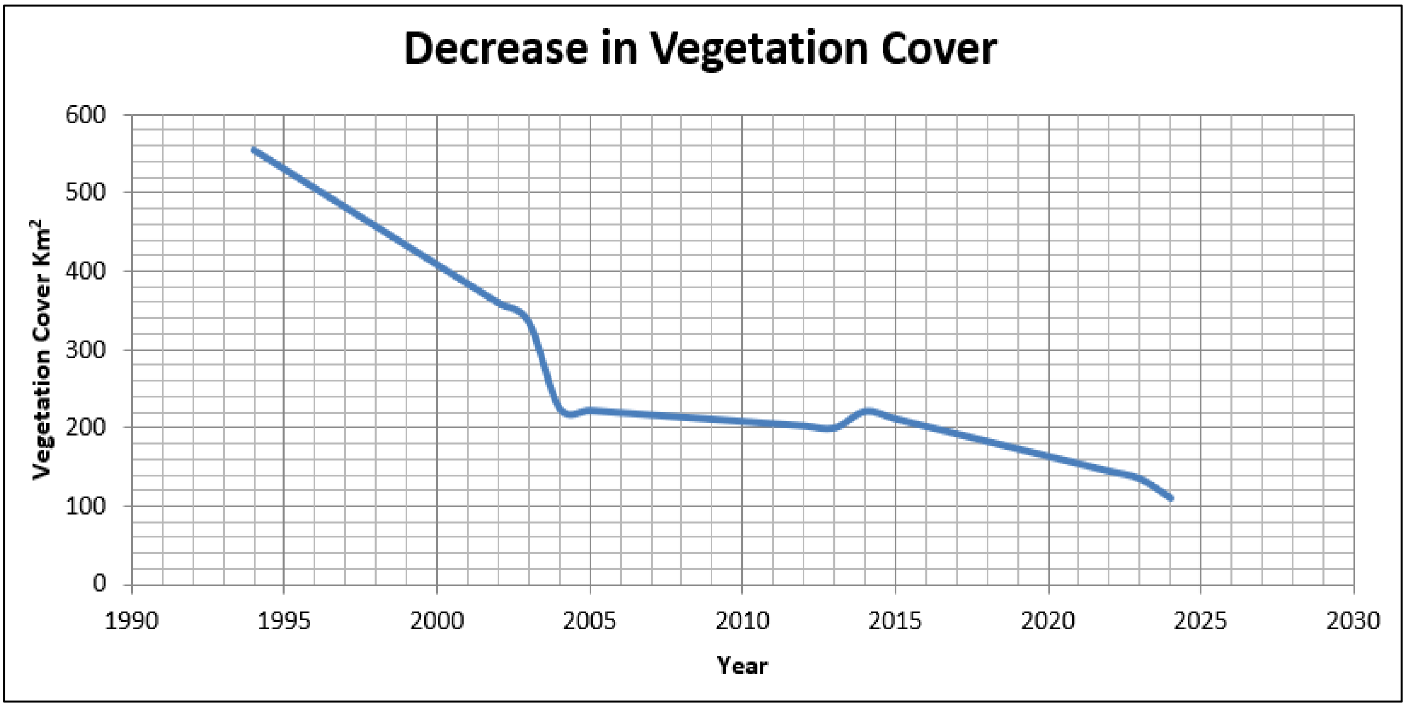

Fig 12 Decrease in Vegetation Cover from 1994 to 2024

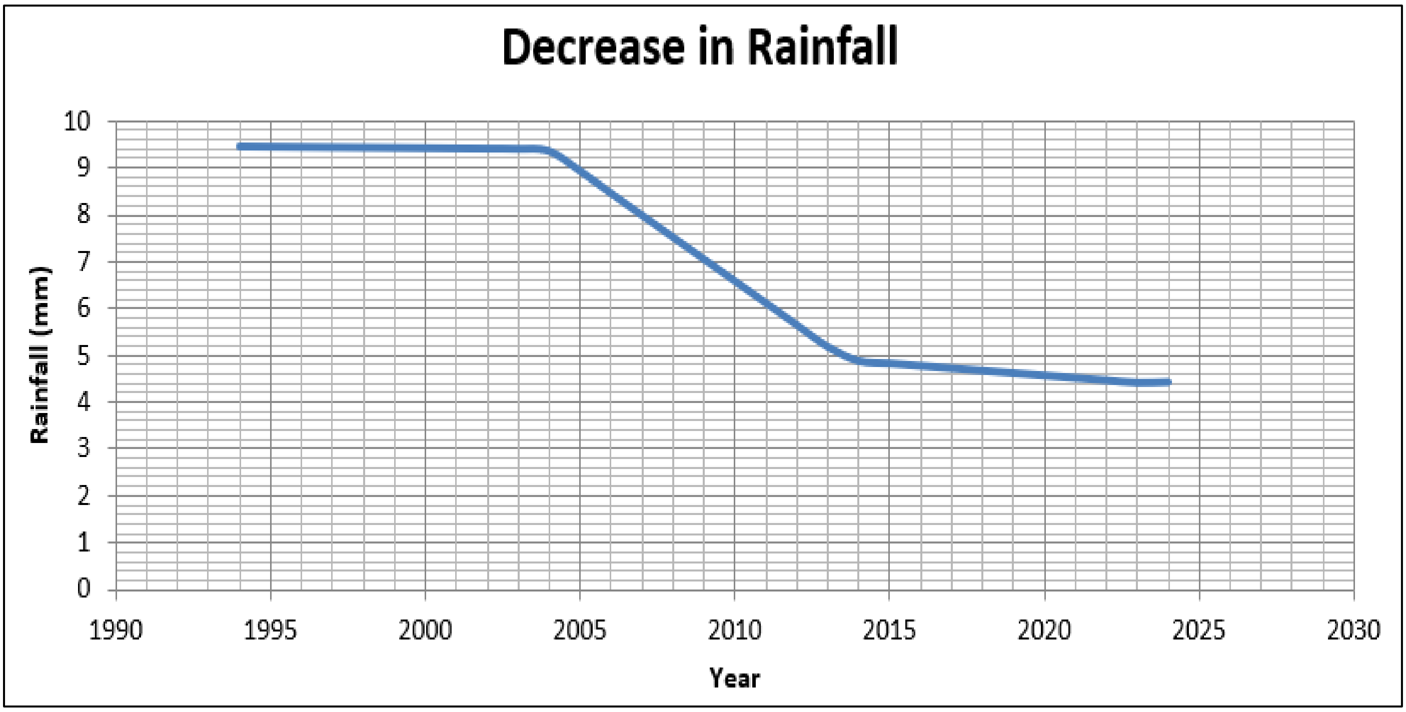

Fig 13 Decrease in Rainfall from 1994 to 2024

Rainfall exhibits a steady decrease throughout the period, indicating a drying trend in the region's climate. This reduction in rainfall likely contributes to the vegetation loss, as water availability is a critical factor for plant growth and ecosystem health. Amogne et al., (2017) the result revealed that declining trend for annual and kiremt rainfall was found to be statistically significant while that of belg was not significant. Rousta et al., (2022) revealed that precipitation had little effect on vegetation cover during winter, but was the main controlling factor of vegetation cover in spring. Surface temperature was identified as the primary factor influencing vegetation cover. Additionally, there is an association between NDVI and rainfall rate s in slam & Mamun, (2015).

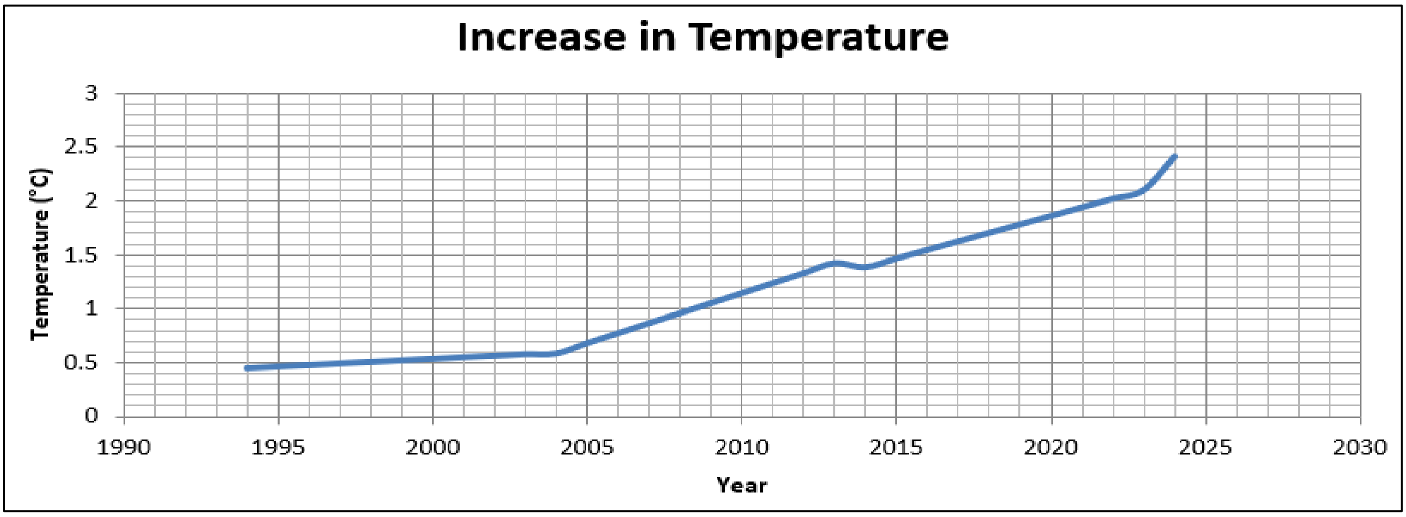

Fig 14 Increase in Temperature from 1994 to 2024

The temperature steadily increases, with a notable acceleration after 2014. Rising temperatures can exacerbate vegetation stress by increasing evapotranspiration and soil moisture loss, further impacting vegetation sustainability. Together, these patterns illustrate a strong relationship between climate variability and environmental degradation. The combined effects of decreasing rainfall and increasing temperature are likely key drivers behind the significant reduction in vegetation cover observed over the 30-year period, underscoring the urgency of climate adaptation and environmental management in the study area. As supported by the World Bank Report, (2020) that the specific impacts of vegetation loss on climate and rainfall pattern distribution in Jos, Plateau State are temperature variance. Studies have revealed that the significant differences in climate conditions and human activity intensities across different regions may lead to regional variations in the impacts of climate change and human activities on vegetation change (Li et al., 2012). Modupe Areola and Mayowa Fasona (2017) revealed the correlations between rainfall and vegetation were found to be very negligible (mostly zero), except for the forested wetland around the Lake Chad where stronger positive coefficient of correlation were found. While in Ojo, *et al.*, (2021), the results indicated a significant relationship between climatic variables and land use/land cover change.

➢ *Statistical Result and Analysis*

The regression results indicate that vegetation cover is a strong (Dependents) predictor of both rainfall and temperature variability patterns in the study area during period under study. For rainfall, the value of 0.927 suggests that 92.7% of the variation in rainfall is explained by vegetation cover, with a statistically significant positive relationship ($p < 0.001$). This means that as vegetation cover increases, rainfall tends to rise, highlighting the role of vegetation in enhancing atmospheric moisture and precipitation. For temperature, the value of 0.815 indicates that 81.5% of temperature variation is explained by vegetation cover, and the relationship is significantly negative ($p < 0.001$). This implies that an increase in vegetation cover contributes to a reduction in temperature, likely due to increased shading and evapotranspiration. Overall, the findings reinforce the ecological importance of vegetation in regulating microclimate, sustaining rainfall, and mitigating local temperature rise in the Jos Plateau region.

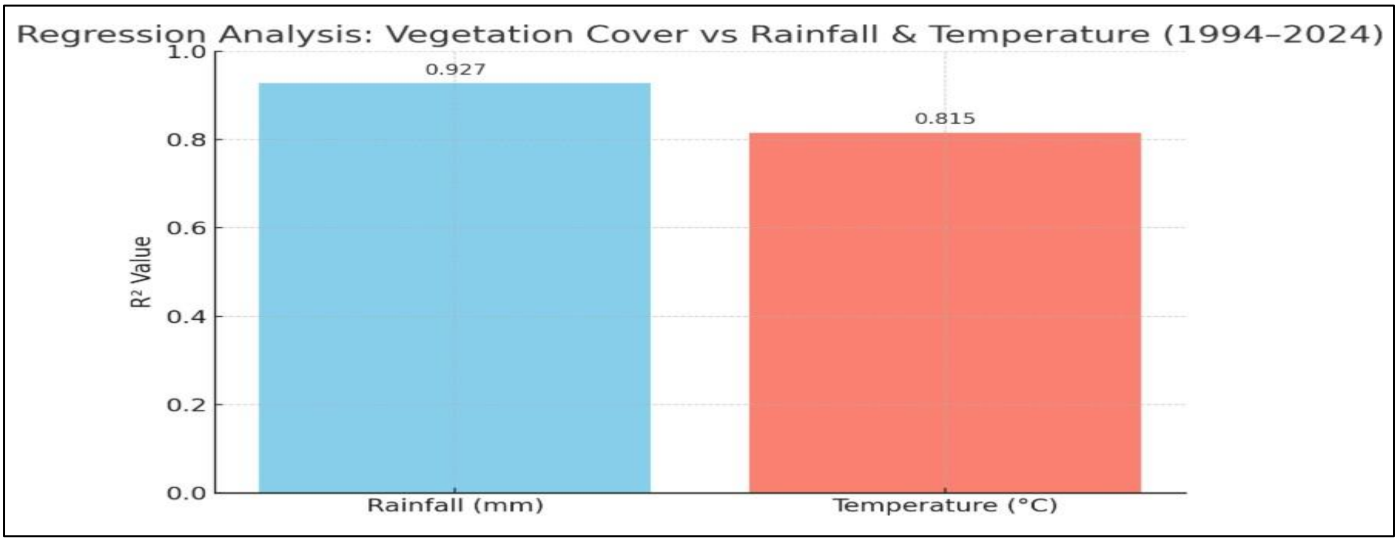

Fig 15 Vegetation Cover vs. Rainfall & Temperature

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Rainfall (R^2 = 0.927) → the bar showed 92.7% of rainfall variation is explained by vegetation cover. This means vegetation has a very strong influence on rainfall in the study area during a period under study.

Temperature (R^2 = 0.815) → the bar showed 81.5% of temperature variation is explained by vegetation cover. Although slightly lower than rainfall, it's still a very strong relationship.

The chart visually emphasizes that vegetation cover is a powerful (dependents) predictor for both variables, but the relationship with rainfall is slightly stronger than with temperature.

IV. CONCLUSION

The study concludes that significant vegetation degradation has occurred in Jos East, Jos South, and Jos North LGAs between 1994 and 2024. NDVI analysis clearly demonstrates a substantial transition from vegetated to non-vegetated land surfaces. This decline corresponds with decreasing rainfall trends and rising temperatures over the same period. The combined effects of climatic variability and human-induced land-use changes appear to be driving vegetation loss in the region. Reduced rainfall limits soil moisture availability and plant growth, while rising temperatures increase evapotranspiration rates, intensifying environmental stress. At the same time, deforestation, overgrazing, urban expansion, mining, and agricultural encroachment further exacerbate land degradation.

The study highlights that vegetation health is closely linked to climatic stability. Disruptions in rainfall and temperature create compounded effects on land productivity, biodiversity, and ecosystem services. As vegetation declines, the capacity of the land to regulate microclimates, sequester carbon, and support livelihoods diminishes. This increases vulnerability to drought, soil erosion, and reduced agricultural output. Furthermore, the findings suggest that without proactive intervention, continued warming and rainfall variability may accelerate environmental degradation in the study area. The research therefore underscores the importance of integrated environmental management strategies that address both climate adaptation and sustainable land use.

In summary, the study provides empirical evidence of long-term ecological change in the Jos Plateau region and establishes a clear linkage between vegetation dynamics and climate variability. These insights serve as a foundation for informed decision-making aimed at promoting environmental sustainability and resilience.

RECOMMENDATIONS

This section recommend for policy and practice. The research investigated vegetation loss and its impacts on rainfall and temperature in Jos East, Jos South, and Jos North Local Government Areas of Plateau State, Nigeria, over a thirty-year period (1994–2024). By integrating NDVI derived vegetation data with rainfall and temperature records, the study examined long-term environmental changes and their interrelationships.

Based on the findings and conclusions of this study, the following recommendations are proposed:

- *Promote Reforestation and Afforestation Programs.*

Government agencies, non-governmental organizations, and community groups should invest in large-scale tree planting and forest restoration initiatives. Reforestation and afforestation programs can restore degraded lands, improve soil fertility, enhance biodiversity, and regulate local microclimates. Priority should be given to degraded and erosion-prone areas.

- *Implement Sustainable Land-Use Planning.*

Authorities should enforce strict land-use regulations to control deforestation, urban sprawl, and indiscriminate land conversion. Urban planning frameworks should incorporate green belts, forest reserves, and conservation zones. Environmental Impact Assessments (EIAs) must be mandatory for major development projects to minimize ecological damage.

- *Develop Climate-Resilient Agricultural Practices.*

Farmers should be supported through training and extension services that promote climate-smart agriculture. Techniques such as agroforestry, mulching, conservation tillage, crop rotation, and the use of drought-resistant crop varieties can reduce dependency on rainfall and minimize vegetation loss. Access to irrigation and water conservation technologies should also be expanded.

- *Strengthen Environmental Monitoring Systems.*

A consistent and institutionalized remote sensing and GIS-based monitoring system should be established to track changes in vegetation, rainfall, and temperature. Regular environmental reporting will enable policymakers to make data-driven decisions and respond promptly to emerging environmental threats.

- *Increase Public Awareness and Community Participation.*

Public awareness campaigns should educate communities about the consequences of land degradation and climate change. Community-based forest management and participatory conservation programs should be encouraged. Incentives such as tree-planting subsidies and environmental stewardship awards can enhance local involvement.

- *Enhance Research Collaboration and Technical Partnerships.*

Collaboration between government agencies, universities, research institutions, and international climate organizations should be strengthened. Such partnerships can provide technical expertise, advanced climate modelling tools, early warning systems, and improved data-sharing mechanisms. Continuous research will improve understanding of vegetation–climate interactions and inform adaptive strategies.

REFERENCES

[1]. Ahrens, C. D. (2011). *Meteorology today: An introduction to weather, climate, and the environment* (10th ed.). Brooks/Cole.

[2]. Akinsanola, A. A., & Ogunjobi, K. O. (2014). Analysis of rainfall and temperature variability over Nigeria. *Global Journal of Human-Social Science: B Geography, Geo-Sciences, Environmental Science & Disaster Management*, *14*(3), 1-18.

[3]. Al-Najjar, H. A. (2019). Impact of climate change on land use/land cover change in arid regions. *Environmental Monitoring and Assessment*, *191*(12), 1-15. https://doi.org/10.1007/s10661-019-7234-x

[4]. Amogne, A. S., Bayu, W., & Tana, T. (2017). Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. *Weather and Climate Extremes*, *19*, 29-41. https://doi.org/10.1016/j.wace.2017.12.002

[5]. Audu, E., Isikwue, M. O., & Eweh, J. E. (2013). Climate change impacts on agricultural production in Nigeria. *International Journal of Agriculture and Crop Sciences*, *6*(12), 805-814.

[6]. Ayanlade, A. (2016). Remote sensing approaches for land use and land surface temperature assessment: A review of methods. *International Journal of Image and Data Fusion*, *7*(1), 78-94.

[7]. Ayansina, A. D., Ogunbo, S. T., & Sandah, M. Y. (2009). Seasonal rainfall variability in Guinea savannah part of Nigeria. *Nigerian Journal of Basic and Applied Science*, *17*(2), 218-225.

[8]. Bryan, B. A., Harvey, N., Belperio, T., & Bourman, R. (2010). Distributed process modeling for regional assessment of coastal vulnerability to sea-level rise. *Environmental Modeling and Assessment*, *15*(1), 37-53.

[9]. Cetin, M., Adiguzel, F., Kaya, O., & Sahap, A. (2018). Mapping of bioclimatic comfort for potential planning using GIS in Aydin. *Environment, Development and Sustainability*, *20*(1), 361-375.

[10]. Chen, Y., Wang, S., Ren, Z., Huang, J., Wang, X., Liu, S., Deng, H., & Lin, W. (2024). Quantitatively analyzing the driving factors of vegetation change in China: Climate change and human activities. *Science of The Total Environment*, *908*, 168-180. https://doi.org/10.1016/j.scitotenv.2023.168180

[11]. Coumou, D., & Rahmstorf, S. (2012). A decade of weather extremes. *Nature Climate Change*, *2*(7), 491-496.

[12]. Damilola, A. O., Taiwo, O. J., & Chukwudi, C. N. (2025). Climatic variability and associated changes in a Nigerian nature forest reserve. *Environmental Monitoring and Assessment*, *197*(1), 45-62.

[13]. Ehlers, M., Jadkowski, M. A., Howard, R. R., & Brostuen, D. E. (1990). Application of SPOT data for regional growth analysis and local planning. *Photogrammetric Engineering and Remote Sensing*, *56*(2), 175-180.

[14]. Emlaei, S., Babaei, H., & Tajrishy, M. (2022). Impact of climate change as well as land-use and land-cover changes on water yield services in Haraz Basin. *Water Resources Management*, *36*(7), 2365-2385.

[15]. Espinoza, J. C., Segura, H., Ronchail, J., Drapeau, G., & Gutierrez-Cori, O. (2018). Evolution of wet-day and dry-day frequency in the western Amazon basin: Relationship with atmospheric circulation and impacts on vegetation. *Water Resources Research*, *54*(5), 4023-4041.

[16]. Fagbeja, M. A. (2008). Application of remote sensing and GIS in atmospheric studies. *Nigerian Journal of Space Research*, *5*(1), 34-49.

[17]. Fan, X., Duan, Q., Shen, C., Wu, Y., & Xing, C. (2020). Global surface air temperature change patterns in CMIP6 models: Are they model dependent? *Journal of Climate*, *33*(23), 10561- 10583.

[18]. Faruque, M. J., Ahamed, T., & Noguchi, R. (2022). Mapping the changes in land use and land cover of the south-western coastal region of Bangladesh using Landsat time series data. *Remote Sensing Applications: Society and Environment*, *25*, 100659.

[19]. Fischer, E. M., & Knutti, R. (2014). Detection of spatially aggregated changes in temperature and precipitation extremes. *Geophysical Research Letters*, *41*(2), 547-554.

[20]. Food and Agriculture Organization. (2010). *Global forest resources assessment 2010*. FAO Forestry Paper 163.

[21]. Food and Agriculture Organization. (2020). *Global forest resources assessment 2020*. FAO Publications.

[22]. Hasanean, H. M. (2001). Fluctuations of surface air temperature in the Eastern Mediterranean. *Theoretical and Applied Climatology*, *68*(1-2), 75-87.

[23]. Heger, M. P., Julca, A., & Paddison, O. (2018). *The economic case for landscape restoration in Africa*. World Bank Publications.

[24]. Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., Diedhiou, A., Djalante, R., Ebi, K. L., Engelbrecht, F., Guiot, J., Hijioka, Y., Mehrotra, S., Payne, A., Seneviratne, S. I., Thomas, A., Warren, R., & Zhou, G. (2018). Impacts of 1.5°C global warming on natural and human systems. In *Global warming of 1.5°C* (pp. 175-311). IPCC.

[25]. Idowu, O. A., Orimogunje, O. O., & Odekunle, T. O. (2011). Impact of climate change in Nigeria. *Iranian Journal of Energy and Environment*, *2*(2), 145-152.

[26]. Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: The physical science basis*. Cambridge University Press.

[27]. Jaswal, A. K., Koppar, A. L., & Bhan, S. C. (2015). Evolution of surface air temperature trends over India during 1971-2010. *Journal of Earth System Science*, *124*(4), 729-747.

[28]. Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources*, *28*(1), 205-241.

[29]. Lehmann, J., Coumou, D., & Frieler, K. (2015). Increased record-breaking precipitation events under global warming. *Climatic Change*, *132*(4), 501-515.

[30]. Li, S., Yang, S., Liu, X., Liu, Y., & Shi, M. (2012). NDVI-based analysis on the influence of climate

change and human activities on vegetation restoration in the Shaanxi-Gansu- Ningxia region, Central China. *Remote Sensing*, *7*(9), 11163-11182.

[31]. Macaulay, B. M. (2014). Tree cover loss and agricultural expansion in Nigeria. *Environmental Management*, *54*(3), 480-496.

[32]. Meissner, K. J., Weaver, A. J., Matthews, H. D., & Cox, P. M. (2003). The role of land surface dynamics in glacial inception: A study with the UVic Earth System Model. *Climate Dynamics*, *21*(7-8), 515-537.

[33]. Mfon, P., Adesina, F., & Njar, G. (2014). Forest loss and degradation in Nigeria: Drivers, consequences and policy responses. *Forest Policy and Economics*, *44*, 54-61.

[34]. Mia, M. S., Uddin, M. J., & Khan, M. S. A. (2020). Land-use change in the coastal area of Cox's Bazar, Bangladesh using remote sensing and GIS technology. *Journal of Coastal Research*, *36*(2), 356-368.

[35]. Modupe Areola, F., & Mayowa Fasona, M. (2017). Sensitivity of vegetation to annual rainfall variations over Nigeria. *Remote Sensing Applications: Society and Environment*, *8*, 186- 199.

[36]. Mohan, T. S., & Rajeevan, M. (2017). Past and future trends of hydroclimatic intensity over the Indian monsoon region. *Journal of Geophysical Research: Atmospheres*, *122*(2), 896-909.

[37]. Munyati, C., & Mboweni, G. (2013). Variation in NDVI values with change in spatial resolution for semi-arid savanna vegetation: A case study in northwestern South Africa. *International Journal of Remote Sensing*, *34*(7), 2253-2267.

[38]. Naibbi, A. I., & Healy, T. R. (2013). Northern Nigeria land cover change detection. In *Land cover change detection using remote sensing* (pp. 145-178). Springer.

[39]. Naibbi, A. I., Healey, R. G., & Ahmad, A. (2014). Land cover change detection in the savanna region of northern Nigeria using medium resolution satellite imagery. *Geocarto International*, *30*(7), 751-766.

[40]. Nkuna, T. R., & Odiyo, J. O. (2016). Filling of missing rainfall data in Luvuvhu River Catchment using artificial neural networks. *Physics and Chemistry of the Earth*, *100*, 330-339.

[41]. Nowak, D. J., & Dwyer, J. F. (2007). Understanding the benefits and costs of urban forest ecosystems. In *Urban and community forestry in the northeast* (pp. 25-46). Springer.

[42]. Nwilo, P. C., & Badejo, O. T. (1995). Impacts of oil spills along the Nigerian coast. *Environmental Management*, *19*(6), 851-857.

[43]. Odjugo, P. A. O. (2010). Regional evidence of climate change in Nigeria. *Journal of Geography and Regional Planning*, *3*(6), 142-150.

[44]. O'Gorman, P. A. (2015). Precipitation extremes under climate change. *Current Climate Change Reports*, *1*(2), 49-59.

[45]. Oguntunde, P. G., Abiodun, B. J., Olukunle, O. J., & Olufayo, A. A. (2012). Trends and variability in pan evaporation and other climatic variables at Ibadan, Nigeria, 1973-2008. *Meteorological Applications*, *19*(4), 464-472.

[46]. Ojo, T. O. (2021). Impact of climate change on land-use and land-cover of Yewa South Local Government Area, Nigeria. *Environmental Challenges*, *5*, 100-115.

[47]. Ojo, T. O., Babalola, T. E., & Ogunjobi, K. O. (2021). Modeling the relationship between climatic variables and land use/land cover classes in Yewa South Local Government Area of Ogun State. *Modeling Earth Systems and Environment*, *7*(4), 2405-2420.

[48]. Ologunorisa, T. E. (2004). An assessment of flood vulnerability zones in the Niger Delta, Nigeria. *International Journal of Environmental Studies*, *61*(1), 31-38.

[49]. Olorunfemi, I. E., Fasinmirin, J. T., & Olufayo, A. A. (2017). Spatial and temporal trend analysis of temperature and rainfall over the Jos Plateau, Nigeria. *Theoretical and Applied Climatology*, *130*(1-2), 305-319.

[50]. Pall, P., Aina, T., Stone, D. A., Stott, P. A., Nozawa, T., Hilberts, A. G., Lohmann, D., & Allen, M. R. (2011). Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, *470*(7334), 382-385.

[51]. Park, C. C. (1992). *Tropical rainforests*. Routledge.

[52]. Pfahl, S., O'Gorman, P. A., & Fischer, E. M. (2017). Understanding the regional pattern of projected future changes in extreme precipitation. *Nature Climate Change*, *7*(6), 423-427.

[53]. Pradhan, B., Rizeei, H. M., Abdulle, A., Alamri, A. M., & Lee, C. W. (2020). Land subsidence susceptibility mapping using support vector machine and GIS in Iran. *Science of The Total Environment*, *704*, 135-148.

[54]. Prein, A. F., Rasmussen, R. M., Ikeda, K., Liu, C., Clark, M. P., & Holland, G. J. (2017). The future intensification of hourly precipitation extremes. *Nature Climate Change*, *7*(1), 48- 52.

[55]. Rousta, I., Doostkamian, M., Taherian, A. M., Haghighi, E., Ghafarian Malamiri, H. R., & Ólafsson, H. (2022). Investigation of the relationship between climatic parameters and vegetation cover changes in the watersheds of the Caspian Sea. *Applied Sciences*, *12*(9), 4567.

[56]. Roy, S. S., Mahmood, R., Niyogi, D., Lei, M., Foster, S. A., Hubbard, K. G., Douglas, E., & Pielke Sr, R. (2009). Impacts of the agricultural Green Revolution–induced land use changes on air temperatures in India. *Journal of Geophysical Research*, *114*(D20), D20102.

[57]. Salami, A. T., & Balogun, E. E. (2006). Application of remote sensing and GIS to biodiversity assessment in Nigeria. *International Journal of Applied Earth Observation and Geoinformation*, *8*(2), 131-144.

[58]. Schleussner, C. F., Lissner, T. K., Fischer, E. M., Wohland, J., Perrette, M., Golly, A., Rogelj, J., Childers, K., Schewe, J., Frieler, K., Mengel, M., Hare, W., & Schaeffer, M. (2017). Differential climate impacts for policy-relevant limits to global warming: The case of 1.5°C and 2°C. *Earth System Dynamics*, *7*(2), 327-351.

[59]. Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., Reichstein, M.,

Sorteberg, A., Vera, C., & Zhang, X. (2012). Changes in climate extremes and their impacts on the natural physical environment. In *Managing the risks of extreme events and disasters to advance climate change adaptation* (pp. 109-230). Cambridge University Press.

[60]. Senior, R. A., Hill, J. K., González del Pliego, P., Goode, L. K., & Edwards, D. P. (2017). A pantropical analysis of the impacts of forest degradation and conversion on local temperature. *Ecology and Evolution*, *7*(19), 7897-7908.

[61]. Sexton, J. O., Song, X. P., Feng, M., Noojipady, P., Anand, A., Huang, C., Kim, D. H., Collins, K. M., Channan, S., DiMiceli, C., & Townshend, J. R. (2013). Global, 30-m resolution continuous fields of tree height, tree cover and surface water for 2000 to 2012 derived from Landsat data. *Remote Sensing of Environment*, *139*, 248-267.

[62]. Snyder, P. K., Delire, C., & Foley, J. A. (2004). Evaluating the influence of different vegetation biomes on the global climate. *Climate Dynamics*, *23*(3-4), 279-302.

[63]. Stott, P. A., Christidis, N., Otto, F. E., Sun, Y., Vanderlinden, J. P., van Oldenborgh, G. J., Vautard, R., von Storch, H., Walton, P., Yiou, P., & Zwiers, F. W. (2016). Attribution of extreme weather and climate-related events. *Wiley Interdisciplinary Reviews: Climate Change*, *7*(1), 23-41.

[64]. Taylor, M. A., Clarke, L. A., Centella, A., Bezanilla, A., Stephenson, T. S., Jones, J. J., Campbell, J. D., Vichot, A., & Charlery, J. (2017). Future Caribbean climates in a world of rising temperatures: The 1.5 vs 2.0 dilemma. *Journal of Climate*, *26*(17), 6362-6378.

[65]. Temesgen, H., Mbow, C., Dercon, G., & Yengoh, G. T. (2018). Rainfall–vegetation interaction regulates temperature anomalies during extreme dry events in the Horn of Africa. *Global and Planetary Change*, *167*, 35-45.

[66]. Thomas, A., Bond, A., & Hiscock, K. (2012). A multi-season comparison of GPP from Landsat 5 TM and MODIS across European countries. *International Journal of Remote Sensing*, *33*(20), 6406-6422.

[67]. Timothy, M. (2010). *Climate change impacts on mountain ecosystems*. UNEP Publications.

[68]. Tovar, R. (2009). *Forest definitions and their impact on forest assessment*. FAO Technical Paper.

[69]. Treitz, P. M., Howard, P. J., & Gong, P. (1992). Application of satellite and GIS technologies for land-cover and land-use mapping at the rural-urban fringe: A case study. *Photogrammetric Engineering and Remote Sensing*, *58*(4), 439-448.

[70]. Trenberth, K. E. (2012). Framing the way to relate climate extremes to climate change. *Climatic Change*, *115*(2), 283-290.

[71]. Trenberth, K. E., Fasullo, J. T., & Shepherd, T. G. (2015). Attribution of climate extreme events. *Nature Climate Change*, *5*(8), 725-730.

[72]. Udayashankara, T. H., Kiran, T. M., Hema, A. B., & Dipak, P. (2016). Climate change impacts on coastal regions. *Environmental Science and Policy*, *64*, 52-68.

[73]. Vincent, L. E., Respect, M., & Kinoti, M. (2019). Impact of land use and land cover transitions and climate on evapotranspiration in the Lake Naivasha Basin, Kenya. *Science of The Total Environment*, *682*, 19-30.

[74]. Walter, H. (1989). *Vegetation of the earth and ecological systems of the geo-biosphere* (3rd ed.). Springer.

[75]. Wang, X., Piao, S., Ciais, P., Li, J., Friedlingstein, P., Koven, C., & Chen, A. (2011). Spring temperature change and its implication in the change of vegetation growth in North America from 1982 to 2006. *Proceedings of the National Academy of Sciences*, *108*(4), 1240-1245.

[76]. Westphal, C. (2003). *Urban forest management and environmental benefits*. Island Press.

[77]. Westra, S., Alexander, L. V., & Zwiers, F. W. (2013). Global increasing trends in annual maximum daily precipitation. *Journal of Climate*, *26*(11), 3904-3918.

[78]. World Bank, (2020). *Climate change action plan 2021-2025: Supporting green, resilient, and inclusive development*. World Bank Publications.

[79]. Wuyep, S. Z., & Daloeng, D. D. (2020). Climate change impacts on vegetation and agricultural systems in Nigeria. *Agricultural and Forest Meteorology*, *288*, 107-118.

[80]. Zilli, M. T., Carvalho, L. M., Liebmann, B., & Silva Dias, M. A. (2017). A comprehensive analysis of trends in extreme precipitation over southeastern coast of Brazil. *International Journal of Climatology*, *37*(5), 2269-2279.