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Full Length Research Article

# MODELLING THE SIGNATURE OF HUMAN INFLUENCE ON VEGETATION DYNAMIC IN KAMUKU NATIONAL PARK, NIGERIA

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**ABSTRACT**

The sustainable development goal (SDG 15) recognizes the necessity to investigate important biodiversity because of human disturbance. This research models the signature of human influence on vegetation dynamics in the protected area. The Vegetation Index 16-Day from MODIS was used. A novel method for computing the vegetation deficit index (standardized vegetation deficit index: SVDI) on a 3 to 24 month scale was proposed. In addition, NDVI and VCI were used to assess the vegetation condition. Time series decomposition, Mann-Kendall, coefficient of variance, landscape fragmentation matrix, correlation, and wavelet analysis were used. Key informant interviews were conducted to assess the socioeconomic and driving factors of vegetation changes. The findings revealed that across all five period scales of SVDI, and the wavelet result in the last decade, human activities have had a tremendous footprint on the vegetation dynamics. It was also revealed that because of the insecurity that happened in the area, there was vegetation regeneration (from 2015 to 2021), which was revealed in the result of vegetation indices and their spectrum. The changes in vegetation revealed by this studies were justified by the changes perceived by the communities around the national park. The community's livelihood activities were hampered because of the occurrence of insecurity in and around the national park.

**Keyword**: SDVI, Insecurity, landscape matrix, VCI, Regeneration, Livelihood, wavelet analysis

## IINTRODUCTION

Ecosystem provide services that humans rely on for livelihood and well-being ( Weiskopf et al., 2020; Salvati et al., 2019; Sintayehu, 2018; Weiskopf et al., 2020). These include supplies of oxygen, food, water, fiber, shelter and fuel, as well as cultural services. It also provides recreational and tourism potential (Alleway et al., 2019; Manea et al., 2019). Nigeria is one of Africa's most biodiverse countries due to its unique geographic location, which includes a wide range of climates and natural ecosystems. These include semi-arid, forested environments, rich seasonal flood plain environments, vast freshwater swamp, and diverse coastal vegetation (Adedeji et al., 2020; Oyebanji et al., 2021) that are thriving for attraction to eco-hospitality resorts. It also provides medical herbs and food (Ijeomah et al., 2018; Wearing et al., 2020). These potential has led to the establishment of national parks in Nigeria with the objective of preserving, enhancing, protecting, and managing the vegetation and wildlife in the parks (Adora, 2010; Dutse, 2013; Ijeomah et al., 2018; Ijeomah & Henry, 2012).

Nigeria national park authority has continued to prioritize the protection of its resources, park facilities, and tourist safety, all of which are of exceptional biological, scientific, and economic value. It has a diverse range of fauna and flora, as well as natural resources and cultural features. Apart from the major role of protecting the ecotourism resources in the national parks and protected areas, they also play an important role in meeting the needs of underprivileged people who live in and around them and rely heavily on forest resources for survival (Adenle, et al.,2020). This is extremely common in rural areas where there are few economic opportunities ( Ijeomah & Henry, 2012; Yazdanpanah et al., 2016). These parks' values span from the preservation of natural habitats and accompanying flora and wildlife to the preservation of environmental stability in their surrounding areas. Furthermore, they give a unique field that includes a variety of sectors such as conservation education, regional economic development, and sustainable resource use, as well as job creation, revenue generation, research, and monitoring (Abdulkadir, 2015; Ijeomah & Henry, 2012).

The life of the nearby population is entirely reliant on the national park's resources. It explains their irrigation, livestock husbandry, water, forestry, and agricultural project successes (Agyeman, 2014; Ijeomah et al., 2018; Ijeomah & Henry, 2012). However, the continues rise in the human population and demand is putting a strain on ecosystem resources such as forests, water, and soil. For example, the requirement for increased agricultural output depletes surface and groundwater resources, leading to deforestation, overgrazing, and timber overcutting, among other things (Eruotor, 2014; Nababa et al., 2020; Olagbaiye et al., 2021)(Why different font). The park is now faced with threats such as illegal grazing, poaching, shifting cultivation, over-exploitation of indigenous plant species, cattle migration, and uncontrolled poaching (Osinubi et al., 2021). Also, bushfires, decrease in fauna population, exploitation of fuel wood, fishing, and high timber demand are related problems in the park (Ajayi & Oyebade, 2021).

Furthermore, the increasing loss of vegetal resources and its impact on the loss of biodiversity and the provision of ecosystem services has increased international concern. It stresses the formulation of sustainable development goal fifteen (SDG 15), which states that there is a need to monitor and identify the current status of biodiversity due to the global biodiversity declines in recent decades because of human alteration (Herrero et al., 2021; Viana et al., 2022). This has given rise to the need for continued assessment and monitoring of biodiversity, especially the vegetal cover and its dynamics, because it plays a crucial role in maintaining the functioning of the earth's diverse ecosystems (Nababa et al., 2020; Sintayehu, 2018). However, a growing number of studies have shown that vegetation growth has been strongly altered by human activities in recent decades (Essien & Cyrus, 2019; LV et al., 2020; Obiahu & Elias, 2020; Zaharaddeen et al., 2017). Considering the security challenges in the area as a result of the proliferation of arms, which increased the tension in the communities around the park (Babagana et al., 2019; Bala & Tar, 2021). National park has become a safe haven for bandits, which has influenced the activity in or around the park due to safety reasons. (Ajayi & Oyebade, 2021).

This study focused on Kamuku National Park because it is one of the seven national parks that contain the major ecotourism resources in Nigeria (Abdulkadir, 2015; Allu, 2015; Okonkwo, 2014). The park was established in 1936 as the Forest Reserve by the Northern Nigeria Government and was upgraded from a state Game Reserve to a National Park in May 1999 (Abdulkadir, 2015; Adora, 2010). In North West Nigeria, Kamuku National Park is one of the best remaining blocks of Sudan-Guinea Savannah vegetation, with high incidences of insecurity (Oladeji et al., 2021). In addition, the research is based on the hypothesis that the increased incidence of insecurity has reduced the influence of human activities in the protected area, especially on its vegetation dynamics, and enhances the potential resources for ecotourism. Therefore, it assesses its dynamism using remote sensing indices and qualitative analysis. It also proposed a novel method, which is to standardize the vegetation deficit index by using the vegetation indices and an appropriate distribution function by identifying the extreme disturbances of human activities to the vegetation. This has been accompanied by a landscape fragmentation matrix and wavelet analysis to assess the level of vegetation deterioration in the national park. In addition, the time series decomposition was applied to separate the trends, seasonal and residue. This allows one to determine whether there is regeneration or degeneration of vegetation dynamics in the national park using a trend test.

## MATERIAL AND METHOD

Kamuku National Park is located in the north-west part of Birnin-Gwari, The park lies between longitudes 6.15° E and 6.65° E and latitudes 10.68° N and 11.05° N, within the Northern Guinea Savanna Zone, with the mean annual rainfall of 1250 mm. The rainy season is between April and October, while the dry season lasts from November to March. Temperatures range between 30 and 35 degrees Celsius and can reach 42 degrees Celsius in March and April. The park lies within the basement complex region of Nigeria with shallow ferruginous loams and clay soils with areas of overlying laterite (Abdulkadir, 2015). The average weathered zone is less than 20 m frequently outcropping at the surface (Abdulkadir, 2015; Ijeomah et al., 2011).

### Global NDVI dataset

The Vegetation indices of 16-Day composite NetCDF file format from MODIS onboard the Terra platform (MOD13Q1) product was downloaded using Google Earth Engine (GEE). It was atmospherically corrected and the images were smoothened utilizing a Whittaker smoother algorithm. The smoothed MODIS NDVI data was converted to the WGS24 global projection. The spatial resolution of the data was resampled to a 30 m dataset. The maximum value composite (MVC) method was applied to the original time series to resample monthly NDVI datasets for further analysis.

### Method

The NDVI is a Modis global free data set, which was obtained using the Google Earth engine. The vegetation condition index and standardized vegetation deficit index were computed using Python in a Jupyter notebook environment. In addition, statistical analyses such as variability, trend, correlation analysis, and wavelet analysis were conducted. The Python libraries used in conducting this analysis are Numpy, Pandas. Xarray, Rioxarray, Geopandas, Cartopy, Matplotlib, Statsmodels, Scipy, and Pymannkendall. Furthermore, the Landscape Ecology Statistics (LecoS) which is an extension of QGIS software was used for landscape analysis. The procedure of the method in this research is explained in this section.

### Indices computation for the analysis

The NDVI dataset was obtained from global free data, but normally it can be computed as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

The processed NDVI data were subjected to various algorithms in order to compute additional indices such as the vegetation condition index and the standardized vegetation deficit index. that NDVI, VCI, and SVDI can reveal the vigor, condition, deficit, and health of vegetation. From the smoothed NDVI long-term time series (2000–2021), the Vegetation Condition Index (VCI) for the study area was calculated using the following equation:

$$VCI = \left(\frac{\text{NDVIi} - \text{NDVImin}}{\text{NDVImax} - \text{NDVImin}}\right) X\ 100\%$$

Where NDVIi is the monthly NDVI value, NDVImax and NDVImin are the absolute long-term maximum and minimum NDVI respectively calculated for each pixel and monthly from multi-year NDVI data and i defines the NDVI for the ith month.

The standardized vegetation deficit index was computed based on the standardized precipitation index (SPI) procedure. Therefore, it is assumed as a probability index, which considers NDVI as the input. Initially, the gamma distribution was used to fit the long-term NDVI data using the following equation:

$$f(NDVI;\ \alpha;\ \beta) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} NDVI^{\alpha-1} e^{-NDVI/\beta}\ for\ NDVI, \alpha, \beta > 0$$

Where, α and β are the shape and scale parameters respectively; and Γ (α) is the gamma function. The resulting parameters were then used to derive the cumulative probability for non-zero NDVI using the following equation:

$$f(NDVI;\ \alpha;\ \beta) = \int_{0}^{NDVI} f(NDVI;\ \alpha;\ \beta) dNDVI$$

Then

$$f(NDVI;\ \alpha;\ \beta) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_{0}^{NDVI} NDVI^{\alpha-1} e^{-NDVI/\beta} dNDVI$$

The cumulative probability was transformed into a standardized normal distribution so that the SVDI mean and variance were zero and one, respectively. The current study employed the approximate transformations provided by Mishra and Desai (2006) to transform the cumulative probability distribution into a standardized normal distribution, which were given in equations:

$$SVDI = -\left(K - \frac{c_o + c_1 k + c_2 k^2}{1 + d_1 k + d_2 k^2 + d_3 k^3}\right)$$

$$When\ k = \sqrt{ln\left(\frac{1}{\left(H(NDVI)\right)^2}\right)}\ for\ 0 < H(NDVI) \leq 0.5$$

$$SVDI = +\left(K - \frac{c_o + c_1 k + c_2 k^2}{1 + d_1 k + d_2 k^2 + d_3 k^3}\right)$$

$$When\ k = \sqrt{ln\left(\frac{1}{\left(H(NDVI)\right)^2}\right)}\ for\ 0 < H(NDVI) \leq 0.5$$

Where, $c_o$ = 2.515517, $c_1$ = 0.802853, $c_2$ = 0.010328, $d_1$ = 1.432788, $d_2$ = 0.189269, $d_3$ = 0.001308. The SVDI values were calculated for multiple monthly time scales (3, 6, 9, 12, and 24-month time scales). In this study, the SDVI is used to identify the footprint of human activities on vegetation. If the period of high vegetation vigor coincides with the period when intense insecurity happens in the area, then it implies that the prior period is the period of human activities affecting the vegetation vigor.

**Computation of Vegetation fragmentation**

A threshold of greater than 0.2 vegetation indices (NDVI) was used to delineate the distribution of vegetation and exposed soil. This result was subjected to landscape metrics to determine the level of deterioration and regeneration of vegetation in the national park. For landscape analysis, the Landscape Ecology Statistics (LecoS) extension of QGIS software was used. The landscape metrics indices that were used are presented in table 1.

**Statistical analysis**

Variability analysis involves the use of the coefficient of variation (CV) of inter-annual data of vegetation indices. The coefficient of variation (CV) will provide a measure of year-to-year variation in the vegetation index. The CV is expressed as:

$$\overline{NDVI} = \frac{\sum NDVI}{N}$$

$$SD_{NDVI} = \sqrt{\frac{\sum(X - \overline{NDVI})^2}{N}}$$

$$CV = {SD_{NDVI}}/{\overline{NDVI}} \times 100$$

Where:

NDVI = Yearly NDVI variable
N = Number of years in the sample
SD = Standard Deviation
CV = Coefficient of Variance

**Table 1:** The Selected Landscape Matrix Indices

| Analysis scale | Metrics |
|---|---|
| Class | Landscape Proportion |
| Class | Edge density |
| Landscape/Class | Mean patch area |
| Landscape/Class | Number of Patches |
| Landscape/Class | Largest Patch Index |
| Landscape/Class | Overall Core area |
| Landscape/Class | Fractal Dimension Index |
| Landscape/Class | Mean patch shape ratio |
| Landscape/Class | Patch cohesion index |
| Landscape/Class | Effective Meshsize |
| Landscape/Class | Splitting Index |
| Landscape | Shannon Diversity index |
| Landscape | Shannon equitability index |
| Landscape | Simpson index |

Source: author compilation

Time series analysis

Time series decomposition was conducted to reveal the time series characteristics of the indices. These characteristics include trends, seasonality, and residues. To achieve this, the following equation was used:

$$Data = pattern + error \vdash \rightarrow f(trend - cycle, seasonality, error)$$

Therefore

$$Yt = f(St, Tt, Et)$$

Additive decomposition

$$Yt = St + Tt + Et$$

Multiplicative decomposition

$$Yt = St * Tt * Et$$

Subsequently, the Mann-Kendall (M-K) rank correlation test was used to determine the direction and significance of the trend in vegetation indices. A detailed procedure for Mann Kendall can be found in the (Abdussalam & Zaharaddeen, 2017; Ismail et al., 2019; Zaharaddeen et al., 2017). In addition, a correlation analysis between the monthly values of NDVI, VCI and SVDI for time-scales from 3 to 24 months was performed. For each grid cell, the maximum correlation coefficient was retained and assessed as significant if a P-value less than 0.05.

**Wavelet analysis**

Wavelet analysis is the time localization of the spectral components that transform the time–frequency of the signal. This was done by decomposing signals in such a way that the signal trends and details are represented in time. Therefore, the variation of their amplitude with time is plotted to extract regions of strong concentration of power. The major reason for considering the wavelet transform for this work is that it is a robust method for signal analysis. It is used to identify the high signal and periodicity of a variable spectrum. A more detailed theoretical background of wavelet analysis can be found in the work of Adepitan & Falayi, (2019); Baidu et al., (2017). In this study, the scaled averaged wavelet power is used to present the fluctuations in power over the most significant frequency of vegetation vigor that is obtained from the global wavelet power spectrum. This allows us to identify the period with high vegetation vigor as a result of human activities being reduced due to insecurity. Therefore, if the period coincides with the period when the intense insecurity happens in the area, then it implies that the prior period is the period of human activities affecting the vegetation vigor.

**Socio economic characteristics and drivers of vegetation changes information**

The information on the drivers of vegetation changes, the contribution and extent of the security issues to the community destruction and their livelihoods, as well as the vegetation cover changes, were obtained using key informant interviews. During the interviews, questions were translated into the native language in order to get an appropriate response. Some of the questions were: what are the social characteristics of people (majority in gender, age, education level, occupation, and others); what is their economic status (an average income level)? What are the major activities they depend on for their livelihood (such as farming, trading, lumbering, and others)? How do these activities contribute to the vegetation's dynamism (does it increase or decrease the vegetation)? What are the major challenges that affect their livelihood (concerning vegetation change and insecurity)? How do they think that these challenges have influenced the vegetation dynamic? What do they think are the causes of vegetation change? What are the consequences of the vegetation change within the area? The responses were carefully categorized based on the thematic areas to have a clear elucidation and harmonized information that was discussed. The thematic areas are: socio-economic characteristics, major activities for livelihood, drivers for vegetation changes, nature of insecurity and its influence.

## RESULTS AND DISCUSSION

**Inter Annual Variability of Vegetation Dynamics**

The annual variability of vegetation dynamics in Kamuku national park was assessed from 2000–2021 using NDVI, SVDI and VCI. Descriptive statistics and correlation analysis were used to describe the inter-annual variability (table 1) and the relationship between the indices (table 2), respectively.

**Table 1:** Descriptive Statistics of Vegetation Dynamics Indices

| Indices | Min | Max | Mean | Var | STD |
|---|---|---|---|---|---|
| SVDI 24 | -1.72 | 0.98 | 0.01 | 0.38 | 0.61 |
| SVDI 12 | -1.02 | 0.73 | 0.07 | 0.21 | 0.46 |
| SVDI 9 | -7.51 | 5.86 | 0.54 | 12.91 | 3.59 |
| SVDI 6 | -0.44 | 0.30 | 0.03 | 0.05 | 0.22 |
| SVDI 3 | -0.36 | 0.24 | 0.02 | 0.03 | 0.17 |
| VCI | 58.27 | 63.39 | 61.30 | 1.75 | 1.32 |
| NDVI | 0.46 | 0.52 | 0.50 | 0.00 | 0.02 |

**Table 2:** Relationship between the Vegetation Dynamic Indices

| Indices | SVDI 24 | SVDI 9 | SVDI 12 | SDVI 6 | SVDI 3 | VCI | NDVI |
|---|---|---|---|---|---|---|---|
| SVDI 24 | **1** | | | | | | |
| SVDI 9 | **0.411** | **1** | | | | | |
| SVDI 12 | **0.621** | **0.705** | **1** | | | | |
| SVDI 6 | 0.189 | **0.695** | **0.421** | **1** | | | |
| SVDI 3 | 0.011 | **0.516** | 0.242 | **0.800** | **1** | | |
| VCI | -0.042 | **0.463** | 0.189 | **0.726** | **0.905** | **1** | |
| NDVI | -0.042 | **0.463** | 0.189 | **0.726** | **0.905** | **1.000** | **1** |

The variation of NDVI of the entire Kamuku national park is illustrated in table 1. It was discovered that the NDVI indicated a high level of vegetation vigor in the study area. Similarly, the area has a healthier vegetation condition (VCI > 50), as the forest and conserved area is still maintaining its natural regeneration, In addition, it can be clearly seen that the level of decline was low in SVDI 9 months, while the remaining SVDI showed a near normal level of decline in vegetation in the study area.

In addition, the correlation coefficient was used to establish the relationship between the indices under study (table 2) because it measures the degree of association between the variables (Olson et al., 2019; Rousta et al., 2020). It was also revealed that the standardized vegetation deficit index of 9 months has a significant relationship with the other indices, though it was weak in the relationship with the NDVI and VCI. The SVDI 6 month had a strong relationship with the SVDI 3 month, NDVI and VCI, although the SVDI 3 month had the strongest relationship with the NDVI and VCI.

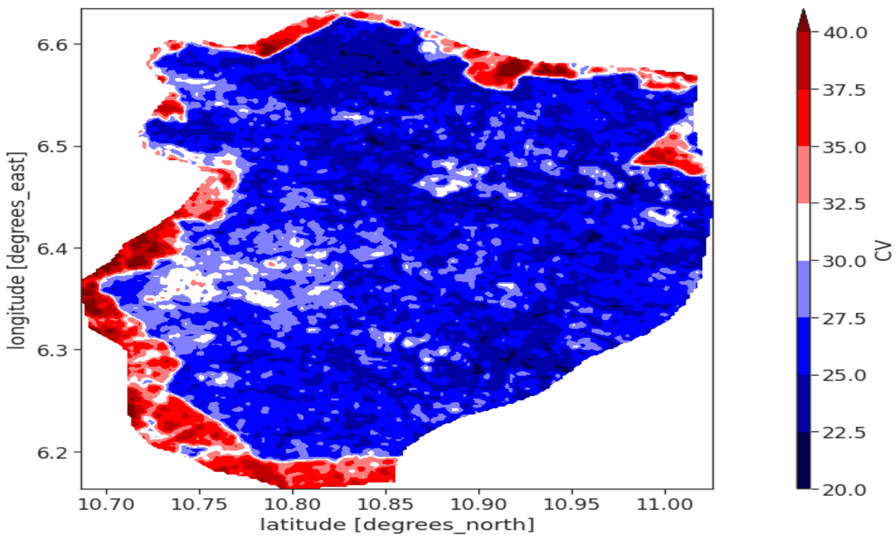


**Figure 1:** Inter Annual Spatial

**Variability of Vegetation Condition**

Furthermore, the spatial inter-annual variability of vegetation conditions in Kamuku National Park was assessed using coefficient variability from 2000 to 2021 (figure 1). It was revealed that the majority and core area of the study area had low variability of vegetation cover, whereas the border of the study area had high variability, with the exception of the south-east of the study area. This implies that the vegetation condition at the border of the study area is more deteriorated than the core of the area. The time series of the standardized vegetation deficit index was plotted to show the extent of the variability and possible regeneration of the vegetation in the study area (figure 2). The SVDI 3 month shows a fluctuation in vegetation deficit. Similarly, the 6 and 9 months SVDI revealed a fluctuation of vegetation condition, while the 12 and 24 months SVDI revealed a clear temporal transition of vegetation condition from decline to regeneration. It is obvious that the vegetation regenerated around 2018 to 2021. The time series decomposition of the vegetation indices was computed to check the trend, seasonality, and residue (figure 3). It revealed that the standardized vegetation deficit index of the vegetation condition has a positive trend, which implies an increased trend. While the vegetation condition index and normalized difference vegetation index showed no trend. However, the trend observed in SVDI was not significant, yet figure 4 also shows that the vegetation conditions were disrupted from 2009 to 2013, while from 2014 to 2021 there was a recovery of vegetation conditions in the l park.

The wavelet analysis was conducted on the NDVI and SDVI to identify the high frequency of signal (figure 6A-F). It is evident that the high frequency of the NDVI spectrum was from 2001 to 2007 and from 2015 to 2020, with a periodicity of between 8 and 16 months (figure 6A). The SDVI 3, 6, and 9-month had a homogeneity of high frequency from 2000 to 2021, with a 16-month periodicity (figure 6B-6D). In addition, figure 6E revealed that the SDVI 12 month has a high frequency from 2000 to 2002 and from 2009 to 2020 with a period of 16 months, while the SDVI 24 month has a high magnitude from 2000 to 2003 and from 2011 to 2018 and up to 2022 with a period between 8 and 16 months (figure 6F).

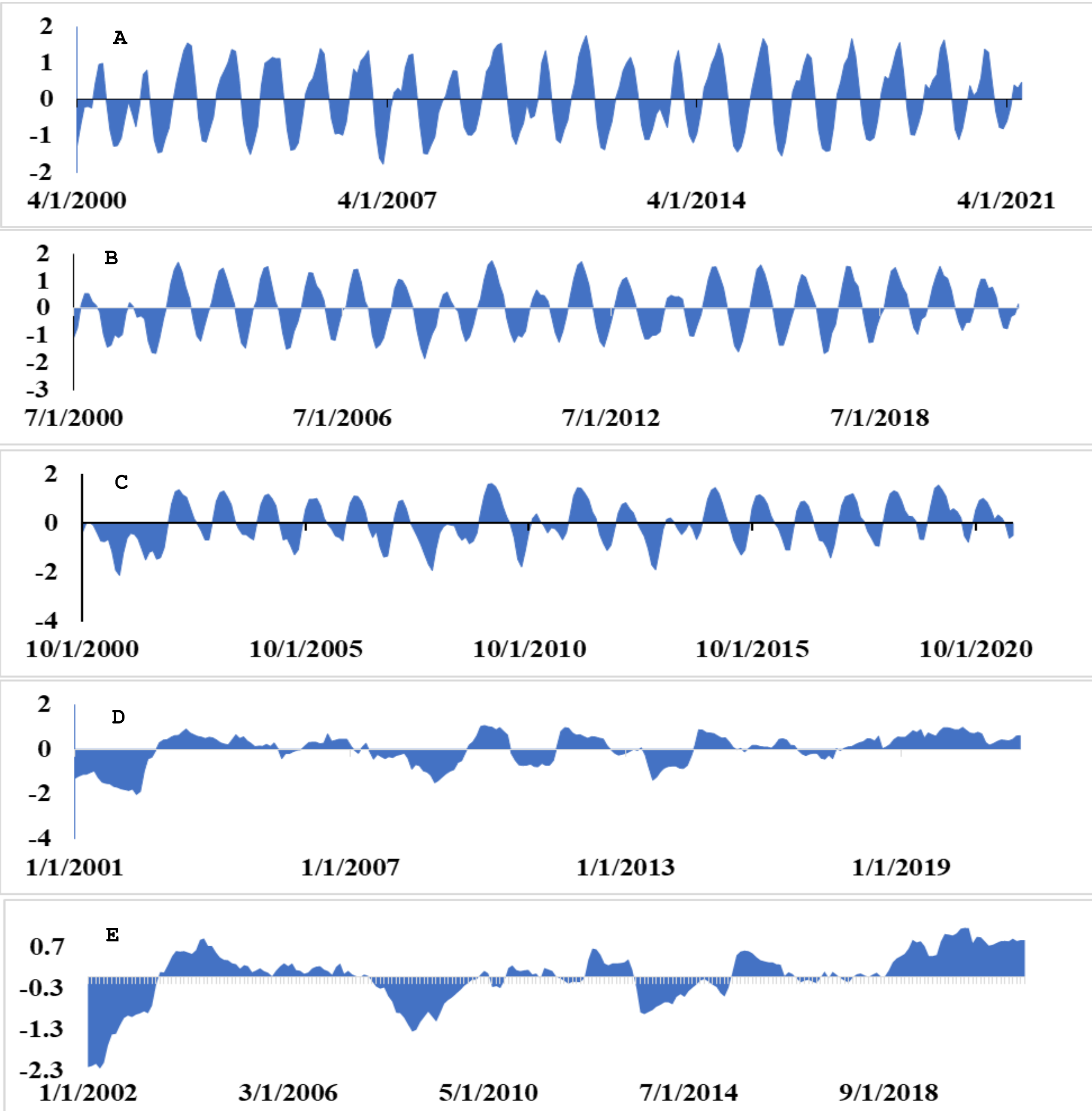


**Figure 2:** Standardize vegetation deficit index (a) 3 month (b) 6 month (c) 9 month (d) 12 month and (e) 24 month

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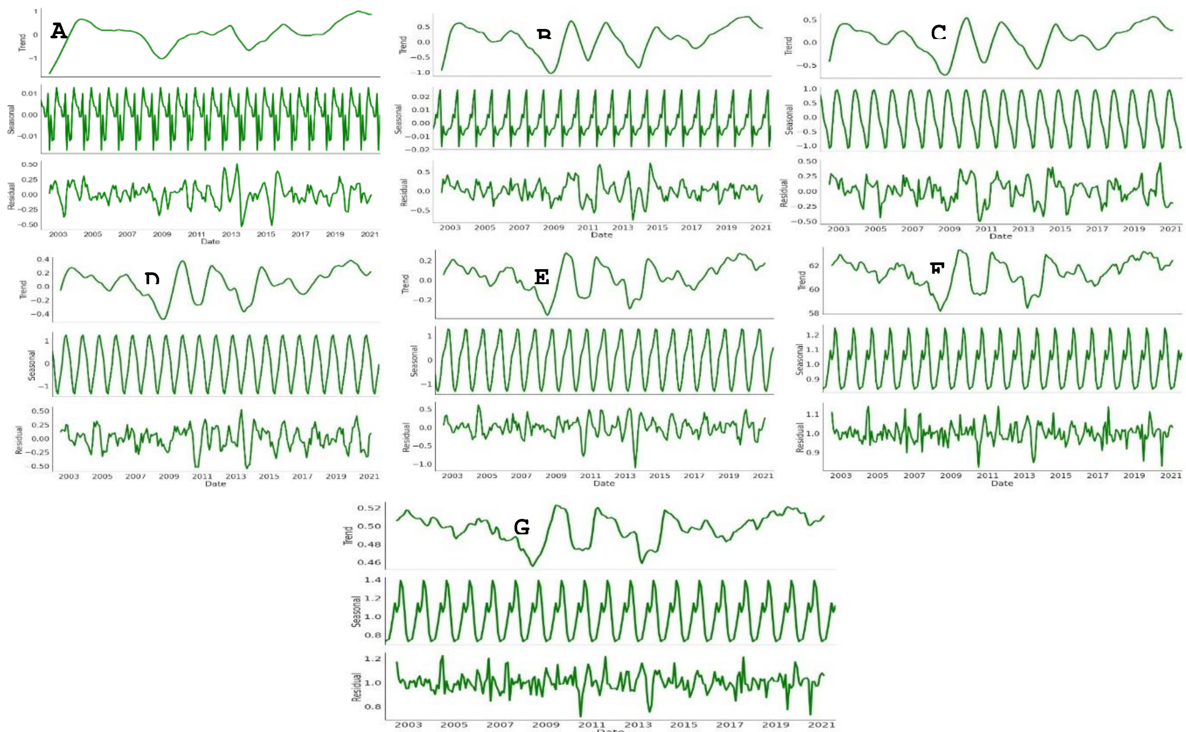


**Figure 3:** time series decomposition of the vegetation indices under study: (A) SVDI 24 (B) SVDI 12 (C) SVDI 9 (D) SVDI 6 (E) SVDI 3 (F) VCI and (G) NDVI

**Seasonal variability of vegetation dynamics in Kamuku National Park**

The seasonal variation of vegetation dynamics in Kamuku National Park was assessed using the normalized difference vegetation index, vegetation condition index, and standardized vegetation deficit index. The result revealed that the level of vegetation has varied across seasons (figure 4a). The high NDVI value was recorded in autumn while the low NDVI value was obtained in winter (DJF). The level of vegetation is obviously declining in SDVI 12 months in the winter and spring (figure 4B). It was also revealed that a high deficit of vegetation was observed across seasons. The healthier vegetation was identified in the autumn (SON) season, while the most disrupted vegetation was in the winter and spring. Despite the general condition of the vegetation observed (figures 4a, b, and c), it is obvious that the level and magnitude of encroachment into the national park can be seen in the west-south direction.

Further SDVI of 3, 6, 9 and 24 months of vegetation was assessed (figure 5). The level of deficit of vegetation was high during the dry season (DJF: Winter, MAM: Spring) as compared to the rainy season (JJA: Summer, SON: Autumn), especially for 3 and 6 months (figure 5A and B). However, within the 6 months, the level of healthier vegetation was observed in winter, followed by the autumn season. As the lag of a month shifted for the standardized vegetation deficit index from three to nine, the level of the deficit varied from one season to the others.

**Fragmentation of Vegetation in Kamuku National Park**

The landscape metrics reporting the level of fragmentation of vegetation in the study area. The dominance indices (Landscape Proportion, Largest Patch Index, and Overall Core area) of the vegetation condition indicates that there was gradual increase of these indices from 2015 to 2021 with a positive trend. Therefore, the dominance indices indicated that there is more vegetation during the period, (regeneration period between 2015 and 2021). The Edge density, mean patch area, Number of Patches and Patch cohesion index result are shows in figure 7. It revealed that there is decreased of Edge density towards 2021, with a negative trend. Mean patch area also revealed a gradual increased and a significant trend, which implies that a high value of Mean patch indicates low fragmentation while a low value indicates high fragmentation. In addition, the Number of Patches shows a low value for the vegetation in the study area. The result revealed a gradual decreased of Patch cohesion index in the study area.

Furthermore, the landscape metric reflects the complexity in the study area. The mean patch shape ratio has a higher value towards 2021, with a sharp increase. It also revealed a significant positive trend in the study area. In addition, the Fractal Dimension Index and Effective Meshsize revealed a positive trend, which implies an increased trend in the study area. While the Splitting Index has a negative trend and a gradual decline towards 2021. To provide information on the diversity in the study area, the Shannon diversity index, Shannon equitability index, and Simpson index were used (figure 7). It revealed an increase in diversity, as well as an increasingly equitable distribution of landscape area

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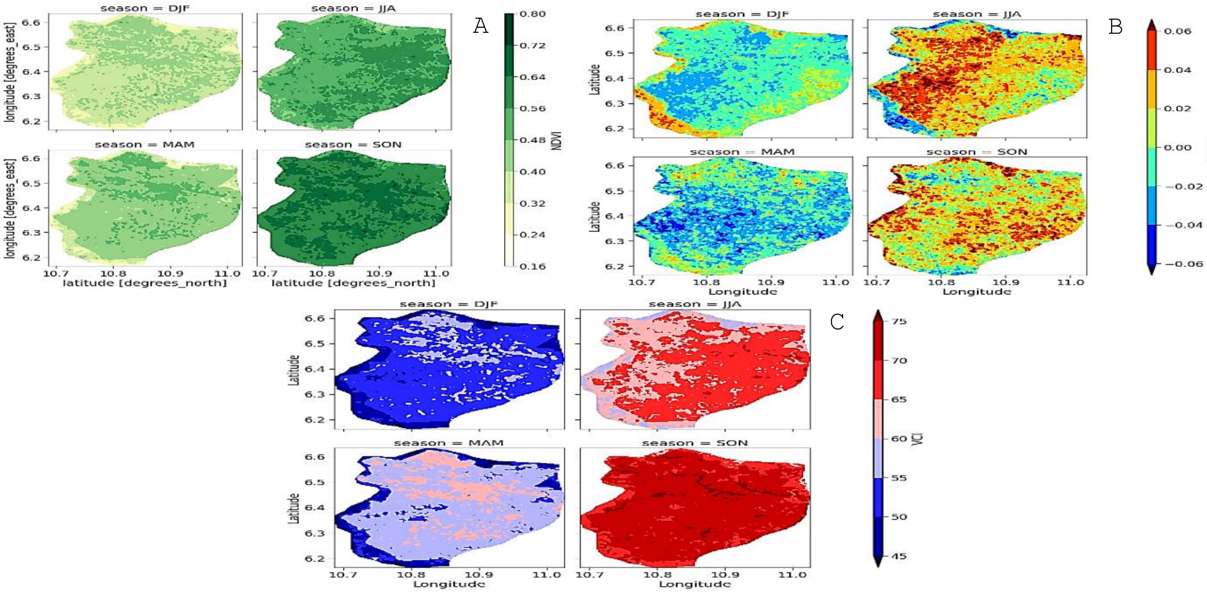


**Figure 4:** Seasonal variation of (A) NDVI (B) SVDI (C) VCI

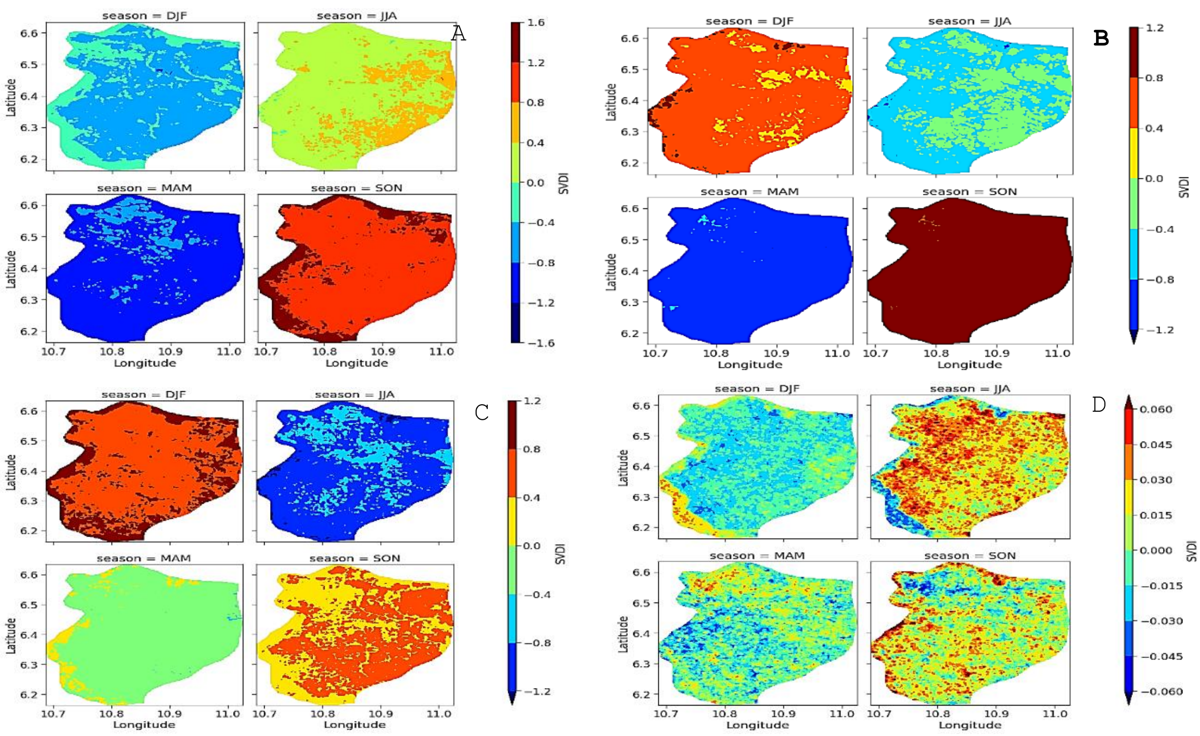


**Figure 5:** Seasonal variation of SVDI (A) 3 month (B) 6 month (C) 9 month (D) 24 month

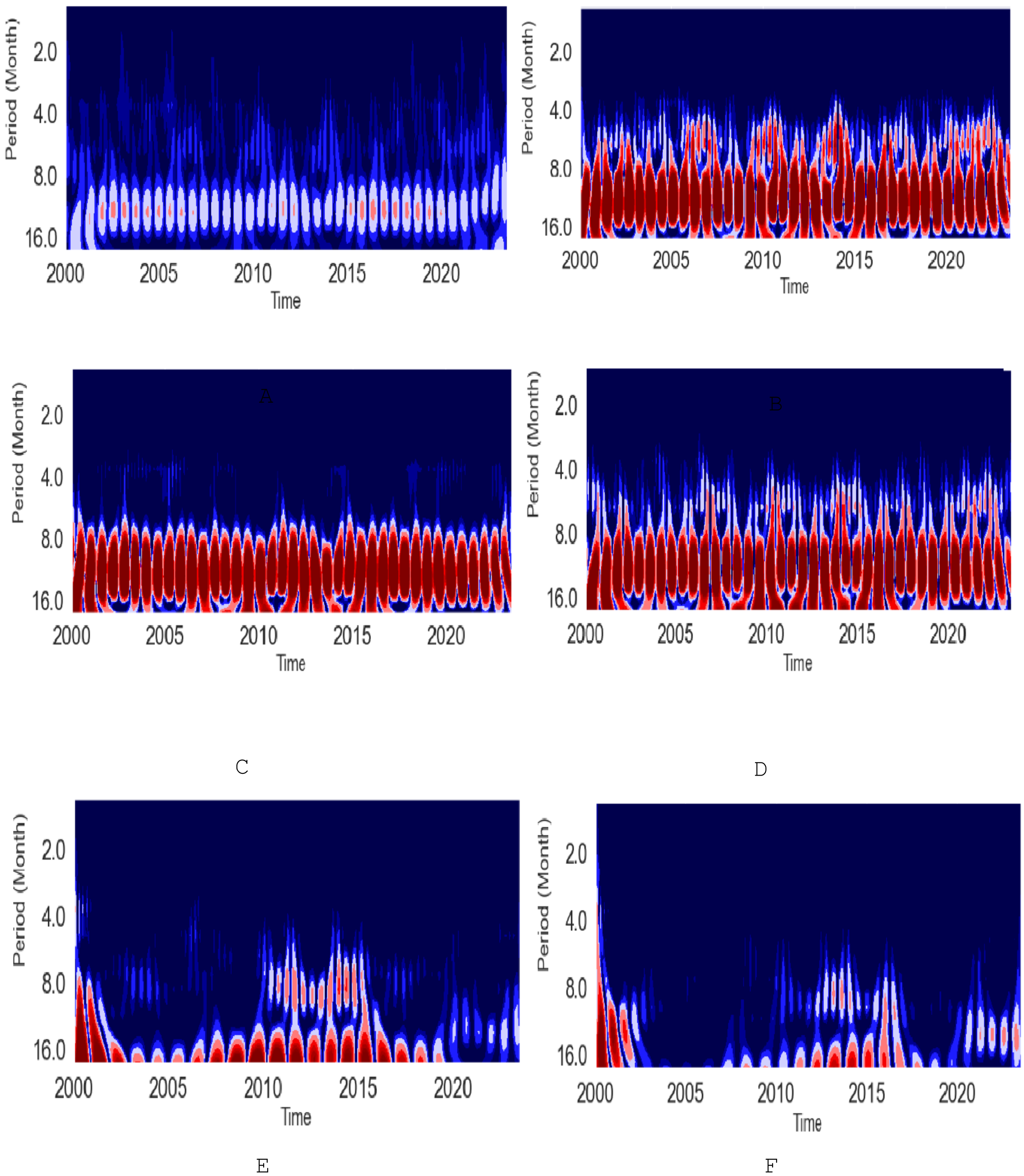


**Figure 6:** wavelet spectrum of (A) NDVI (B) SDVI 3 (C) SDVI 6 (D) SDVI 9 (E) SDVI 12 and (F) SDVI 24 month in Kamuku national park, Nigeria

national park, Nigeria

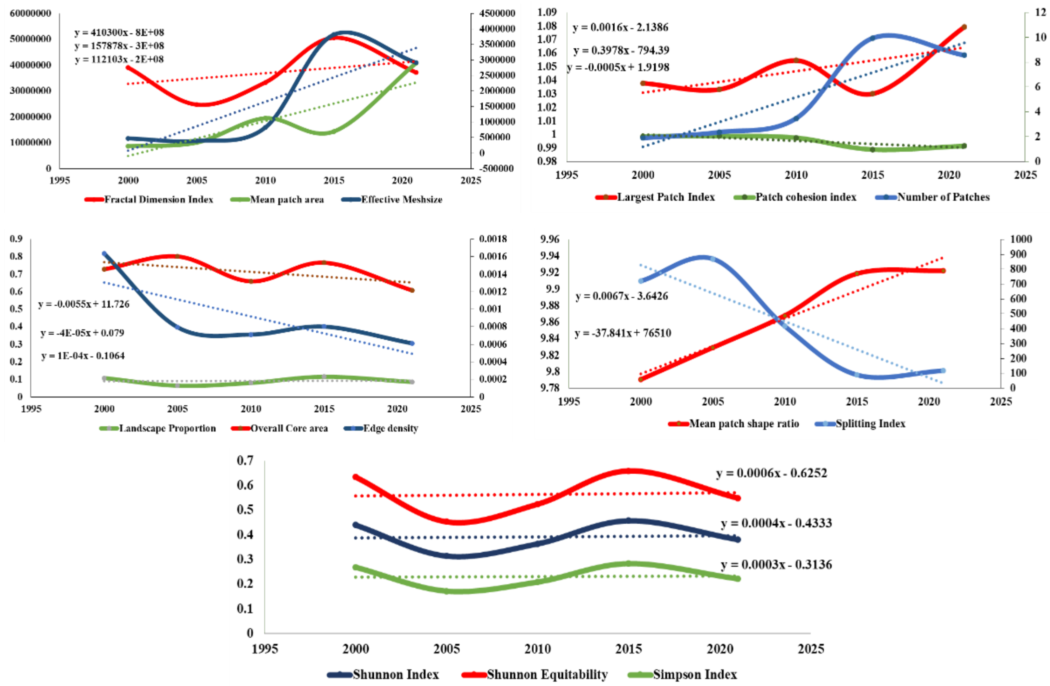


**Figure 7:** fragmentation index of vegetation in Kamuku

**Socio economic characteristics and drivers of vegetation cover changes**

The respondent interviews reported that the majority of the people that were actively involved in the activities around the park were youths (male and female). Early marriage has greatly contributed to the population around the park, the communities surrounding the national park are majorly polygamous, with an average of twelve people per house. Furthermore, the majority of the community were those with no formal education, though few had education up to the tertiary level. It was also revealed that the occupations of people living in communities around the Park are farming, logging, trading, mining, fishing, and blacksmithing among others. Although farming was their major occupation because they inherited it from their parents, the rural community in northern Nigeria mostly depends on farming as their major source of livelihood because of the availability of large land areas suitable for farming (Adenle et al., 2020; Adepoju et al., 2019).

They reported that the major insecurity in the area was kidnapping, banditry, cattle rustling, and arm robbery. The park served as a hideout for people engaged in these cruel, unhuman activities. They ascertained that, as such, their activities for livelihood have been detrimental and some of the communities had to evacuated. The respondents also reported that the incidences of insecurity that are happening in the area have deteriorated the status of livelihoods in the local government. The respondents lamented that the insecurity is heightening due to the presence of dense vegetation in the area and Kamuku national park in particular, especially since the park is adjoined with the Kwiambana forest in a neighboring state.

The intensity and severity of insecurity occurred more frequently around 2014 up to date. It was established that it started as arm robbery and escalated to cattle rustling, the cattle rustlers move from one locality to another, rustling the communities' cattle. Subsequently, a more frequent and deadly occurrences is the banditry and kidnappings are happening in the area. The response is that the majority of the localities around the Kamuku national park are being wiped away, and the people had to relocate to the nearby town (some of these localities are Gwaska, Kungi, Kwasakwasa, Nabango, Layin Maigwari, Old Birnin Gwari among others).

Furthermore, the respondents interviewed confirmed that they had noticed changes in vegetation cover in the park, especially at its boundary. It is believed that the population increase around the park may have influenced the changes in vegetation cover and, consequently, the biodiversity in general (LV et al., 2020; Nwilo et al., 2020). The majority of respondents alluded that human activities such as agriculture, fuel wood harvesting, charcoal production, logging, and bush burning are the primary drivers of vegetation cover changes in the park. They emphasized that agricultural activities was one of the major causes of vegetation cover changes, which was expected to result in biodiversity loss. They lamented that due to the farming practices around the park, there could also be destruction of land and deforestation. This is because most farmers in rural communities in Nigeria often engage in slash and burn when cultivating the land, which could lead to the loss of many species (Dussol et al., 2021; Ketterings et al., 1999; Tschakert et al., 2007).

Logging, fuel wood harvesting, and charcoal production also contribute immensely to driving forest change. It affects the sustainability of forest cover as well as biodiversity. The responders lamented that bush burning is seen as a factor that causes vegetation changes, as it's an act of setting the natural forest on fire by man in search of food (such as rabbits, bush rats, and many more). Moreover, they reported that mining is also regarded as a factor that affects vegetation cover, many of these natural minerals resources are found in the park for different reasons of accumulation, compaction, and cementation of different components.
The result of the study revealed that the vegetation declined from 2003 to 2015, while there was regeneration of vegetation up to 2020. This result is similar to that of Adepoju et al., (2019), who found that the vegetation had declined in the savanna. Also, Yager et al., (2022); Hula, (2010) and Adenle et al., (2020) found a decrease in vegetation in Cross River State, Benue State, and the Nigerian Guinea Savanna at large, respectively and this attributed to human activities such as agriculture, illegal logging and fuel wood harvesting which has contributed to the decrease in vegetation. Several studies state that human activities play a significant role in vegetation dynamics (Cai et al., 2015; He et al., 2015; Isa & Danjuma, 2018; Naeem et al., 2020; Yang et al., 2016). According to the Udofia and Udoh, (2021) , conducted a study in the southern part of Nigeria and found that agriculture was the major human activity affecting the vegetation cover and its resources. Illegal logging and fuel wood harvesting were reported as key causes of vegetation changes (Cai et al., 2015). Musa & Solomon, (2011) reported that mining activities contributed to vegetation decline in Bukuru, Jos Plateau State. Similarly, Khadijat et al., (2021) found that if the current human activities continue, the forest cover will continue to be endangered, thus leading to a decrease in dense forest, plantation, and sparse vegetation in Ibadan, Nigeria. For this reason, it leads to the exposure of land to direct sunlight, rain, and wind storms, which cause soil erosion and degradation, which in turn affect forest productivity (Nwilo et al., 2020; Obiahu & Elias, 2020; Zaharaddeen et al., 2017). In the act or process of harnessing the natural endowment by man, the vegetation tends to be directly affected by the process (Bangira et al., 2019; Mosbahi & Benabdallah, 2020; Obodai et al., 2019). In addition, this result is supported by the perceived changes in vegetation by the respondent during the interview.
The results obtained from the interview, it was revealed that insecurity is an inevitable phenomenon, but if its severity and persistence are high, it affects the development as well as socio economic characteristics and livelihood activities of that particular place. In the area of study, the responder reported that the severity of insecurity was more around 2014 to date. A similar result was found by Chukwuma & Francis, (2014) where they reported that in the presence of insecurity, the activities of that area are affected negatively. For the sake of livelihood, people have to move away from the homes, which proliferated the creation of IDPs (Adora, 2010; Bala & Tar, 2021; Ojo, 2020; Tar & Safana, 2021).

**Conclusion**
The loss of vegetal resources leading to the loss of biodiversity and the provision of ecosystem services, has generated a great concern for immediate resolution. A proposed novel method of calculating the vegetation deficit index (standardized vegetation deficit index: SVDI) was used. NDVI, VCI, and SVDI were also computed to examine the influence of human activities on vegetation dynamics. The findings reveal that the last decade has had a tremendous footprint of human activities on the vegetation dynamics. It revealed that due to the insecurity happening in the area, there is vegetation regeneration, which is revealed by the results of vegetation indices and wavelet results. This might likely leave the mark of the influence of climate change in the park. The community's livelihood activities were hindered because of the occurrence of insecurity in and around the national park. The changes in vegetation observed in the studies were justified by the changes perceived by the communities around the national park. As a result, this study provides a baseline for the state of protected areas as well as an updated time series of vegetation changes. The approach used in this study may be applied in other protected areas in Nigeria and the world at large to assess the status of vegetation dynamics.

**Ethical requirement**
The research is conducted on modeling the signature of human activities on vegetation in protected are. A case study of Kamuku national park, Nigeria. Please, your sincere response to these questions are required. Information supplied was use strictly for academic purpose. Any information regarded to personality will not be published. Your assistance and cooperation is highly appreciated.

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**REFERENCES**
Abdulkadir, I. W. (2015). *Community Participation In The Management Of Kamuku National Park, Birnin Gwari Lga, Kaduna State, Nigeria* (Vol. 97, Issue 12). Ahmadu Bello University, Zaria.
Abdussalam, A. F., & Zaharaddeen, I. (2017). Temporal Variation of Reference Evapotranspiration in Lower River Kaduna Catchment Area , Nigeria. *Archives of Current Research International*, *8*(1), 1–11. https://doi.org/10.9734/ACRI/2017/32984
Adedeji, O., Olusola, A., James, G., Shaba, H. A., Orimoloye, I. R., Singh, S. K., & Adelabu, S. (2020). Early warning systems development for agricultural drought assessment in Nigeria. *Environmental Monitoring and Assessment*, *192*(12). https://doi.org/10.1007/s10661-020-08730-3
Adenle, A. A., Eckert, S., Adedeji, O. I., Ellison, D., & Speranza, C. I. (2020). Human-induced land degradation dominance in the Nigerian Guinea Savannah between 2003 – 2018. *Remote Sensing Applications: Society and Environment*, *19*. https://doi.org/10.1016/j.rsase.2020.100360
Adepitan, J. O., & Falayi, E. O. (2019). Variability changes of some climatology parameters of Nigeria using wavelet analysis. *Scientific African*, *2*, e00017. https://doi.org/10.1016/j.sciaf.2018.e00017
Adepoju, K., Adelabu, S., & Fashae, O. (2019). Vegetation Response to Recent Trends in Climate and Landuse Dynamics in a Typical Humid and Dry Tropical Region under Global Change. *Advances in Meteorology*, *2019*. https://doi.org/10.1155/2019/4946127

Adora, C. U. (2010). Managing Tourism in Nigeria: The Security Option. *Management Science and Engineering*, *4*(1), 14–25.

Agyeman, Y. B. (2014). *The Role of Local Knowledge in Sustaining Ecotourism Livelihood as an Adaptation to Climate Change* [UWSpace]. http://hdl.handle.net/10012/8107

Ajayi, O. O., & Oyebade, J. O. (2021). Promoting Human Security in Nigeria: The Role of Tourism. *Political Economy of Resource, Human Security and Environmental Conflicts in Africa*, 213–235. https://doi.org/10.1007/978-981-16-2036-2_9

Alleway, H. K., Gillies, C. L., Bishop, M. J., Gentry, R. R., Theuerkauf, S. J., & Jones, R. (2019). The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature. *BioScience*, *69*(1), 59–68. https://doi.org/10.1093/biosci/biy137

Allu, E. L. (2015). Linking Climate Change and Sustainable Tourism: the Way Forward for Nigeria. *International Journal of Research in Engineering & Technology*, *3*(9), 2321–8843.

Babagana, M., M. J., M., Ismail, M., Mohammed, B. G., Gujja, A. A., & M. A., A. (2019). Assessment of Socioeconomic Problems Facing Returnees Displaced by Boko Haram Insurgency in Gujba Local Government Area of Yobe State, Nigeria. *International Journal of Contemporary Research and Review*, *10*(01), 20288–20305. https://doi.org/10.15520/ijcrr.v10i01.640

Baidu, M., Amekudzi, L. K., Aryee, J. N. A., & Annor, T. (2017). Assessment of long-term spatio-temporal rainfall variability over Ghana using wavelet analysis. *Climate*, *5*(2), 30. https://doi.org/10.3390/cli5020030

Bala, B., & Tar, U. A. (2021). The Giant of Africa? Explaining the Nigerian Governance, Security, and Development Paradox. *The Governance, Security and Development Nexus*, 315–339. https://doi.org/10.1007/978-3-030-49348-6_16

Bangira, T., Alfieri, S. M., Menenti, M., & van Niekerk, A. (2019). Comparing thresholding with machine learning classifiers for mapping complex water. *Remote Sensing*, *11*(11). https://doi.org/10.3390/rs11111351

Cai, H., Yang, X., & Xu, X. (2015). Human-induced grassland degradation/restoration in the central Tibetan Plateau: The effects of ecological protection and restoration projects. *Ecological Engineering*, *83*, 112–119. https://doi.org/10.1016/j.ecoleng.2015.06.031

Chukwuma, A., & Francis, N. (2014). *Cattle Rustling and Dialectics of Security in Northern Nigeria*. *2*(3).

Dussol, L., Vannière, B., Purdue, L., Orange, F., Testé, M., Castanet, C., Garnier, A., Lemonnier, E., & Théry-Parisot, I. (2021). How to highlight slash-and-burn agriculture in ancient soils? A modern baseline of agrarian fire imprint in the Guatemalan lowlands using charcoal particle analysis. *Journal of Archaeological Science: Reports*, *35*. https://doi.org/10.1016/j.jasrep.2020.102725

Dutse, U. Y. (2013). Potential Challenges of Climate Change to the Nigerian Economy. *IOSR Journal Of Environmental Science, Toxicology And Food Technology*, *6*(1), 07–12. https://doi.org/10.9790/2402-0610712

Eruotor, V. (2014). *The Economic Importance Of Tourism In De-Veloping Countries Case study : Lagos , Nigeria .*

Essien, E., & Cyrus, S. (2019). Detection of Urban Development in Uyo (Nigeria) Using Remote Sensing. In *Land* (Vol. 8, Issue 6). https://doi.org/10.3390/land8060102

He, C., Tian, J., Gao, B., & Zhao, Y. (2015). Differentiating climate- and human-induced drivers of grassland degradation in the Liao River Basin, China. *Environmental Monitoring and Assessment*, *187*(1). https://doi.org/10.1007/s10661-014-4199-2

Herrero, M., Thornton, P. K., Mason-D'Croz, D., Palmer, J., Bodirsky, B. L., Pradhan, P., Barrett, C. B., Benton, T. G., Hall, A., Pikaar, I., Bogard, J. R., Bonnett, G. D., Bryan, B. A., Campbell, B. M., Christensen, S., Clark, M., Fanzo, J., Godde, C. M., Jarvis, A., … Rockström, J. (2021). Articulating the effect of food systems innovation on the Sustainable Development Goals. *The Lancet Planetary Health*, *5*(1), e50–e62. https://doi.org/10.1016/S2542-5196(20)30277-1

Hula, M. A. (2010). Population Dynamics And Vegetation Change In Benue State, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries*, *2*(1).

Ijeomah, H. M., Alarape, A. A., & Augustine, U. O. (2018). Ecotourism Potentials of Plateau State , Nigeria : A Monitoring Survey. *Asia Pacific Journal of Tourism Research*, *16*(2), 37–41. https://doi.org/10.1080/10941665.2011.556338

Ijeomah, Henry Mmaduabuchi, Alarape, A. A., & Augustine, U. O. (2011). Ecotourism potentials of Plateau State, Nigeria: A monitoring survey. *Asia Pacific Journal of Tourism Research*, *16*(2), 153–166. https://doi.org/10.1080/10941665.2011.556338

Ijeomah, M., & Aduabuchi, H. (2012). Impact of Tourism on Livelihood of Communities Adjoining Ecodestinations in Plateau State, Nigeria. *CULTUR: Revista de Cultura e Turismo*, *6*(3), 55–71.

Isa, Z., & Danjuma, B. (2018). Regressive vegetation cover status in river Kaduna catchment area Kaduna, Nigeria. *Environmental and Earth Sciences Research Journal*, *5*(3), 58–65. https://doi.org/10.18280/eesrj.050302

Ismail, M., Abdussalam, A. F., & Isa, Z. (2019). Spatial And Temporal Variability Of 40 Years Temperature And Precipitation In The. *FUDMA Journal of Science*, *3*(3), 1–11.

Ketterings, Q. M., Tri Wibowo, T., Van Noordwijk, M., & Penot, E. (1999). Farmers' perspectives on slash-and-burn as a land clearing method for small-scale rubber producers in Sepunggur, Jambi Province, Sumatra, Indonesia. *Forest Ecology and Management*, *120*(1–3), 157–169. https://doi.org/10.1016/S0378-1127(98)00532-5

Khadijat, A., Anthony, T., Ganiyu, O., & Bolarinwa, S. (2021). Forest cover change in Onigambari reserve, Ibadan, Nigeria: Application of vegetation index and Markov chain techniques. *Egyptian Journal of Remote Sensing and Space Science*, *24*(3), 983–990. https://doi.org/10.1016/j.ejrs.2021.08.004

LV, Z., Zuo, J., & Rodriguez, D. (2020). Predicting of Runoff Using an Optimized SWAT-ANN: A Case Study. *Journal of Hydrology: Regional Studies*, *29*, 100688. https://doi.org/https://doi.org/10.1016/j.ejrh.2020.100688

Manea, E., Di Carlo, D., Depellegrin, D., Agardy, T., & Gissi, E. (2019). Multidimensional assessment of supporting ecosystem services for marine spatial planning of the Adriatic Sea. *Ecological Indicators*, *101*, 821–837. https://doi.org/10.1016/j.ecolind.2018.12.017

Mosbahi, M., & Benabdallah, S. (2020). Assessment of land management practices on soil erosion using SWAT model in a Tunisian semi-arid catchment. *Journal of Soils and Sediments*, *20*(2), 1129–1139. https://doi.org/10.1007/s11368-019-02443-y

Musa, H. D., & Solomon, N. J. (2011). An Assessment of Mining Activities Impact on Vegetation in Bukuru Jos Plateau State Nigeria Using Normalized Differential Vegetation Index (NDVI). *Journal of Sustainable Development*, *4*(6). https://doi.org/10.5539/jsd.v4n6p150

Nababa, I. I., Symeonakis, E., Koukoulas, S., Higginbottom, T. P., Cavan, G., & Marsden, S. (2020). Land Cover Dynamics and Mangrove Degradation in the Niger Delta Region. In *Remote Sensing* (Vol. 12, Issue 21). https://doi.org/10.3390/rs12213619

Naeem, S., Zhang, Y., Tian, J., Qamer, F. M., Latif, A., & Paul, P. K. (2020). Quantifying the impacts of anthropogenic activities and climate variations on vegetation productivity changes in China from 1985 to 2015. *Remote Sensing*, *12*(7). https://doi.org/10.3390/rs12071113

Nwilo, P. C., Olayinka, D. N., Okolie, C. J., Emmanuel, E. I., Orji, M. J., & Daramola, O. E. (2020). Impacts of land cover changes on desertification in northern Nigeria and implications on the Lake Chad Basin. *Journal of Arid Environments*, *181*, 104190. https://doi.org/https://doi.org/10.1016/j.jaridenv.2020.104190

Obiahu, O. H., & Elias, E. (2020). Effect of land use land cover changes on the rate of soil erosion in the Upper Eyiohia river catchment of Afikpo North Area, Nigeria. *Environmental Challenges*, *1*, 100002. https://doi.org/https://doi.org/10.1016/j.envc.2020.100002

Obodai, J., Adjei, K. A., Odai, S. N., & Lumor, M. (2019). Land use/land cover dynamics using landsat data in a gold mining basin-the Ankobra, Ghana. *Remote Sensing Applications: Society and Environment*, *13*, 247–256. https://doi.org/https://doi.org/10.1016/j.rsase.2018.10.007

Ojo, J. S. (2020). Governing "Ungoverned Spaces" in the Foliage of Conspiracy: Toward (Re)ordering Terrorism, from Boko Haram Insurgency, Fulani Militancy to Banditry in Northern Nigeria. *African Security*, *13*(1), 77–110. https://doi.org/10.1080/19392206.2020.1731109

Okonkwo, H. C. (2014). *The Socio-Economic Contribution Of Tourism To Nigeria And North Cyprus : A Comparative Approach The Socio-Economic Contribution Of Tourism To Nigeria And North Cyprus : A Comparative Approach*. Cyprus International University Institute Of Graduate Studies And Research.

Oladeji, S. O., Awolala, D. O., & Alabi, O. I. O. (2021). Evaluation of sustainable ecotourism practices in Oke-Idanre Hills, Ondo-State, Nigeria. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-021-01550-6

Olagbaiye, A. E., Olasore, A. J., Adedayo, T., & Alabi, P. O. (2021). *Drought Monitoring in Northern Nigeria Using Four ( 4 ) Indices*. *1*(1).

Olson, D., Chatterjee, A., Franzen, D. W., & Day, S. S. (2019). Relationship of drone-based vegetation indices with corn and sugarbeet yields. *Agronomy Journal*, *111*(5), 2545–2557. https://doi.org/10.2134/agronj2019.04.0260

Osinubi, T. T., Osinubi, O. B., Tabash, M. I., Ajayi, A. O., & Tran, D. K. (2021). The Impact of Corruption on Tourism Sector in Nigeria: Empirical Insights by Using an Autoregressive Distributed Lag Bounds (ARDL) Testing Approach. *International Journal of Hospitality and Tourism Administration*. https://doi.org/10.1080/15256480.2021.1905583

Oyebanji, O. O., Salako, G., Nneji, L. M., Oladipo, S. O., Bolarinwa, K. A., Chukwuma, E. C., Ayoola, A. O., Olagunju, T. E., Ighodalo, D. J., & Nneji, I. C. (2021). Impact of climate change on the spatial distribution of endemic legume species of the Guineo-Congolian forest, Africa. *Ecological Indicators*, *122*. https://doi.org/10.1016/j.ecolind.2020.107282

Rousta, I., Olafsson, H., Moniruzzaman, M., Zhang, H., Liou, Y. A., Mushore, T. D., & Gupta, A. (2020). Impacts of drought on vegetation assessed by vegetation indices and meteorological factors in Afghanistan. *Remote Sensing*, *12*(15). https://doi.org/10.3390/RS12152433

Salvati, L., Zambon, I., Pignatti, G., Colantoni, A., Cividino, S., Perini, L., Pontuale, G., & Cecchini, M. (2019). A Time-Series Analysis of Climate Variability in Urban and Agricultural Sites (Rome, Italy). In *Agriculture* (Vol. 9, Issue 5). https://doi.org/10.3390/agriculture9050103

Sintayehu, D. W. (2018). Impact of climate change on biodiversity and associated key ecosystem services in Africa: a systematic review. *Ecosystem Health and Sustainability*, *4*(9), 225–239. https://doi.org/10.1080/20964129.2018.1530054

Tar, U. A., & Safana, Y. I. (2021). Forests, Ungoverned Spaces and the Challenge of Small Arms and Light Weapons Proliferation in Africa. *The Palgrave Handbook of Small Arms and Conflicts in Africa*, 223–243. https://doi.org/10.1007/978-3-030-62183-4_11

Tschakert, P., Coomes, O. T., & Potvin, C. (2007). Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecological Economics*, *60*(4), 807–820. https://doi.org/10.1016/j.ecolecon.2006.02.001

Udofia, O. A., & Udoh, J. C. (2021). An Assessment Of Vegetation Change And Perceived Drivers In Essien Udim Lga Of Akwa Ibom State, Nigeria. *Journal of Global Agriculture and Ecology*, *11*(3), 24–33.

Viana, C. M., Freire, D., Abrantes, P., Rocha, J., & Pereira, P. (2022). Agricultural land systems importance for supporting food security and sustainable development goals: A systematic review. *Science of the Total Environment*, *806*. https://doi.org/10.1016/j.scitotenv.2021.150718

Wearing, S., McDonald, M., Schweinsberg, S., Chatterton, P., & Bainbridge, T. (2020). Exploring tripartite praxis for the REDD + forest climate change initiative through community based ecotourism. *Journal of Sustainable Tourism*, *28*(3), 377–393. https://doi.org/10.1080/09669582.2019.1676251

Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., Hyde, K. J. W., Morelli, T. L., Morisette, J. T., Muñoz, R. C., Pershing, A. J., Peterson, D. L., Poudel, R., Staudinger, M. D., Sutton-Grier, A. E., Thompson, L., Vose, J., Weltzin, J. F., & Whyte, K. P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Science of the Total Environment*, *733*. https://doi.org/10.1016/j.scitotenv.2020.137782

Yager, G. O., Alarape, A. A., Onaji, O. J., & Acha, S. (2022). Impact of Anthropogenic Activities on Vegetation Cover and

Mammalian Herbivores in Afi Mountain Wildlife Sanctuary, Cross River State, Nigeria. *World News of Natural Sciences*, *41*.

Yang, Y., Wang, Z., Li, J., Gang, C., Zhang, Y., Zhang, Y., Odeh, I., & Qi, J. (2016). Comparative assessment of grassland degradation dynamics in response to climate variation and human activities in China, Mongolia, Pakistan and Uzbekistan from 2000 to 2013. *Journal of Arid Environments*, *135*, 164–172. https://doi.org/10.1016/j.jaridenv.2016.09.004

Yazdanpanah, H., Barghi, H., & Esmaili, A. (2016). Effect of climate change impact on tourism: A study on climate comfort of Zayandehroud River route from 2014 to 2039. *Tourism Management Perspectives*, *17*, 82–89. https://doi.org/https://doi.org/10.1016/j.tmp.2015.12.002

Zaharaddeen, I., Muhammad, S. O., Abdussalam, A. F., Richard, A. G., & Kagarko, I. I. (2017). Estimation of Biophysical Properties in Lower River Kaduna Catchment Area Kaduna , Nigeria. *Asian Journal of Environment & Ecology*, *4*(1), 1–13. https://doi.org/10.9734/AJEE/2017/32960