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Trend dynamics of rainfall on vegetation pattern in parts of Niger State, Nigeria

Umar, A.[1], Muhammed, M.[1] & Ishiaku I. [2]

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ABSTRACT

An increasing population and demand for land are threatening the existence of vegetal cover not only in the study area but the world over. This threat to vegetal cover calls for a sufficient understanding and measurement of the dynamics of vegetal cover. This study aimed at analyzing the trend in rainfall and vegetation dynamics over Mokwa Local Government Area of Niger State, Nigeria. The study used gridded satellite daily rainfall data for the period of 31 years (1987-2017). Data of remote sensing images for the periods of 1987, 2002 and 2017 were extracted and used for Land Use Land Cover (LULC) change and Normalized Difference Vegetation Index (NDVI) analysis. Standardised Precipitation Index (SPI) and simple linear regression were used in rainfall and trends analysis. Findings show that the year 1994 had the highest positive value of SPI (1.62) and lowest value was witnessed in 2000 (-2.75). The result showed that four years were observed to be above normal wetness with five years below normal dryness. The NDVI value was observed to be between 0.81 and -1 in 1987 but decreased to NDVI values between 0.405 and -0.12 in 2017. LULC change shows a decrease of 15.5% in vegetation cover from 1987 to 2017. Similarly, an increase of 15.42% in non-vegetation areas and a 0.13% increase were observed in the water body during the study period. The linear regression of R^2=0.743 indicated a significant positive relationship between rainfall and vegetation cover. It was concluded that the trend in rainfall is not spatially distributed along with longitudinal or latitudinal directions.

***Keywords**: Images, Land Use, Rainfall, Trends, Vegetation*

1.0 INTRODUCTION

Urbanisation and its attendant increase in population have increased the demand for land all over the world, thus threatening the existence of vegetal cover. The land cover pattern of a place is an outcome of natural and socioeconomic factors and their utilisation by man in time and space. It has shown that there remain only a few landscapes on the earth that is still in their natural state (Fashae *et al.*, 2017). According to Fashae, *et al.*, 2017) man's activities on earth have had a substantial effect on the natural environment, thus resulting in a non-observable pattern in the land use land cover over time. He also submitted that investigating the state or the amount of vegetation is one of the paramount objectives in the field of land surface-related remote sensing applications.

Studies suggest that globally, climate influences natural vegetation changes. Bagherzadeh *et al.*, (2020) opined that investigating vegetation fluctuations could illuminate the changes in the regional or local climate. One of the fundamental variables in understanding vegetation changes is rainfall. Indeed it is believed that understanding rainfall and vegetation interaction is of great importance to implementing any adaptation and mitigation measures for terrestrial ecosystems (Chen *et al.*, 2020). An essential tool for analyzing vegetation changes and its interaction with climate is NDVI. According to Chen *et al.*, (2020), the NDVI helps to indicate environmental changes that occur due to natural factors such as vegetal and climatic changes.

In Africa, poor land utilisation practices, especially in subsistence farming and nomadic pastoral economies have accelerated the loss of natural vegetation and aggravated the problem of climate change (Bamba, 2015). Although this challenge exists, monitoring of high spatial and temporal rainfall trends about the environment has been a big problem in Africa, because of deficit in data (Usman *et al.*, 2013). Remote sensing of the vegetation condition based on the healthy plants offered an opportunity of analyzing the vegetation and rainfall dynamics (Rimkus *et al.*, 2017). Normalised Difference Vegetation Index (NDVI) analysis and its response to the meteorological conditions in a given year depends on the geographical region and environmental factors such as vegetation type, soil type and land use (Usman, *etal.*, 2013).

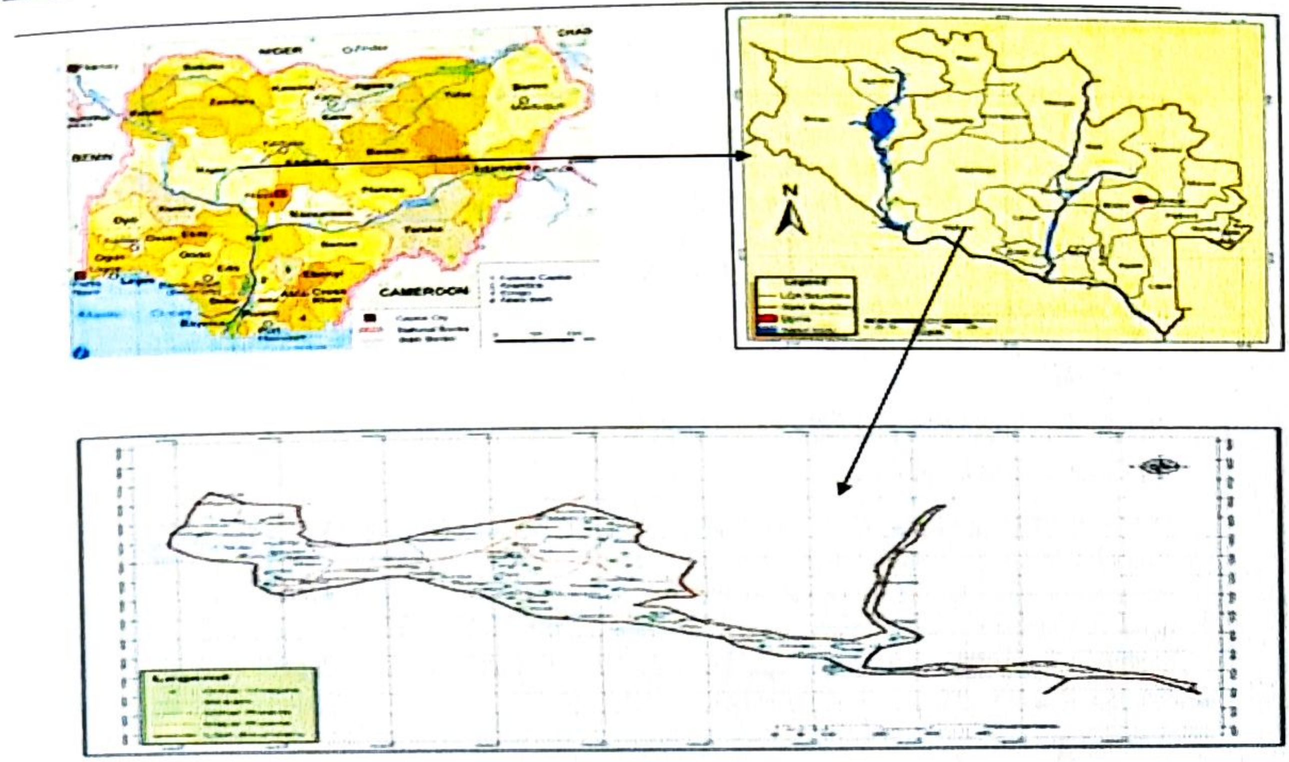
In recent times, the dynamics of Land use Land cover and particularly settlement expansion in the study area requires a robust and sophisticated system such as remote sensing and geographic information system (GIS), which provides a spatial coverage analysis. Historical baselines of forest cover are needed to understand the causes and consequences of recent changes and to assess the effectiveness of land-use policies (Kim *et al.*, 2014). There are now more concerns about vegetation changes and its attendant consequences on the environment. Several studies (Aweda and Adeyewa, 2011; Fashae *etal.*, 2017; Ochege and Okpala-Okaka, 2017; Usman *et al.*, 2012) in Nigeria have shown evidence of vegetation changes. It is therefore essential to continue in the monitoring of the Nigerian natural vegetation for its conservation and sustainable management (Fashae *et al.*, 2017). Empirical findings that create awareness about the consequences of environmental changes are essential in our contemporary changing world.

Similarly, an increase in population which resulted in an increase in consumption of wood for domestic purposes aggravate the environmental degradation and land-use change in this study area. Among the human factors are bush burning and uncontrolled grazing carried out elsewhere in the study area, thereby contributing immensely to the vegetation dynamics. Although, many research works were carried out on trend in rainfall and vegetation dynamics of a particular region among them is the work of Fashae, *et al.* (2017) and Usman, *et al*, (2013)but, all failed to use gridded satellite daily rainfall data which gives good coverage of rainfall data within short distances. Hence, the current study seeks to use gridded satellite daily rainfall data to analysed the relationship of trend dynamics of rainfall and Vegetation over Mokwa Local Government Area (LGA). Thus, the objectives of the study are to examined: the spatial trends in mean rainfall, rainfall anomalies (SPI) and landuse and land cover changes in the study area.

2.0 MATERIALS AND METHODS

2. 1 Study Area

Mokwa Local Government Area in Niger State is located between Longitude 4°45'00" to 5° 45' E and Latitude 8°45' to 9° 40' N and covers a total land area of 4,338km^2. The population by 2006 National Population Census is 242,858 with a projected population of 341,200 by 2016 (National Population Commission of Nigeria) (Figure 1). Rainfall is highly seasonal and controlled by the irregular movement of the Inter-Tropical Discontinuity (ITD). Onset is usually by April/May and cessation in October with an average record of 200 rainy days for a year with an average mean annual rainfall of 1,300mm (Adefolalu, 1986). However, the temperature rarely falls below 20°C. The wet season average temperature is about 20°C. The peak is 38°C in February to March and 35°C in November to December while the mean relative humidity is 33-83%. The vegetation of the study area falls within the vegetation zone of Guinea Savanna, which is a significant vegetation zone across the Niger state. The study area consists of woodland and light forest. The common trees found in this zone include Sheabutter, African locus bean or Niffa, Axle-wood and thinning piliostigma tree. Agriculture is the main economic activity of the people in the study area.



Mokwa LGA

Figure 1: Geographical Location of the Study Area

2.2 Data Acquisition

The research used daily satellite grid rainfall estimate data and satellite imageries. The data was sourced from www.globalweather.tamu.edu. The datasets have a spatial resolution of 0.25°consisting of three (3) hourly/daily rainfall estimates from 1979 to 2017. This study also used data from Landsat-5 image, Thematic Mapper (TM) for 1987, Landsat 7 Enhanced Thematic Mapper Plus (ETM^{+}) for 2002, and Landsat 8 Operational Land Imager (OLI) 2017 all with 30m Resolution (USGS via www.usgs.gov)

2.3 Methods of Data analysis

Data on the annual mean rainfall amount for the entire study area (1987–2017) was computed and analysed. The annual rainfall values were computed for each data point from the daily rainfall amount using equations 1.

$$AR = \sum_{n=1}^{d} R \qquad \text{Eqn. 1}$$

Where:

AR= annual rainfall amount at each data point.

R= the daily rainfall amount at each data point,

d= the number of days, and

I=the months of the year.

N=the total number of years.

SPI is a normalised index representing the probability of occurrence of an observed rainfall amount when compared with the rainfall climatology at a specific geographical location over a long – term reference period.

The Standardised Precipitation Index (SPI) is expressed in the form = $\frac{x-\bar{x}}{\sigma}$ Eqn. 2

Where σ is the standard deviation

X = annual rainfall for a given period.

$\bar{x}$ = annual mean rainfall for a given period

Negative SPI value represents rainfall deficit (dryness), while positive SPI values indicate rainfall surplus (wetness). The SPI values range from -2.00 to 2.00 representing extremely dry and extremely wet, respectively. From the mean annual rainfall values from 1987 – 2017, the average rainfall for the study area was computed. Inverse Distance Weight (IDW) was the interpolation method adopted to monitor rainfall distribution data acquired from nine rainfall data points within the study area. The analysis was done using ArcGIS 10.3 analysis tool. NDVI was calculated as the difference between reflectance in Near-Infrared and Visible radiation.

$$NDVI = \frac{NIR-VIS}{NIR+VIS} \quad \text{(Eqn 3)}$$

Where NIR = Near Infrared (fourth band of Landsat images)

VIS = Visible band (third band).

The final NDVI products were depicted in the geographic grid with equal latitude and longitude intervals. The NDVI values range from -1 to +1. The negative index value can be recorded over the transparent water bodies, while values are close to 0 over the land without vegetation. The index value equal to 1 indicates perfect growing vegetation conditions. Simple linear regression was used to analyze rainfall and vegetation values. To examine the LULC changes over the study area from 1987-2017, satellite images were subjected to the following procedures:

a) Image analysis

Image analysis involves information extraction from satellite imagery which is preceded by image pre - processing steps such as image registration, radiometric correction, image enhancement and display (Rodriguez-Galiano *et al.*, 2012). Image registration is meant to correct image displacement, while the radiometric correction is intended to adjust the radiation values to the standard values. Failure to observe them or observance with imprecision may render change detection meaningless.

b) Image Classification

Three land cover types were analysed for this research (Table 1). The analysis of supervised classifications was done using maximum likelihood classifier (MLC) because of its popularity, simplicity and above all its proven high degree of accuracy.

Table 1: Land Use and Land Cover Classification

Table 1. Land Use and Land Cover Classification

S / No	Land Cover Type	Description of the Land Cover Types
1	Vegetation	All Agricultural lands, forest, grassland, trees, shrublands, natural and semi natural vegetations.
2	Non Vegetation	All residential, commercial and industrial areas, roads, settlement and infrastructures.
3	Water Bodies	Rivers, streams, dams, lakes and ponds.

c) Accuracy assessments

Produce information that describes reality in the study area. References (sample) were identified from Google Earth using a different training site. The sample was done with the Kappa coefficient (k). The kappa coefficient is a measure that considers significantly unequal sample sizes and likely probability of expected values for each class. Mathematically the equation is express in equation 4

$$K = \frac{d-q}{N-q} \quad \text{Eqn.(4)}$$

Where d = total number of cases in diagonal cells of the error matrix,

N = total number of samples.

$q = \sum_{k=1}^{n} Xi + X + \frac{J}{n}$

The NDVI and SPI values were correlated using simple linear regression to know the level of impacts if there is any in the study areas. The analysis was to assess the impact of rainfall trend on vegetation dynamics. The linear regression equation is express in equation 5 as:

$Y = a + bx$ Eqn. (5)

Where Y = vegetation

x = rainfall

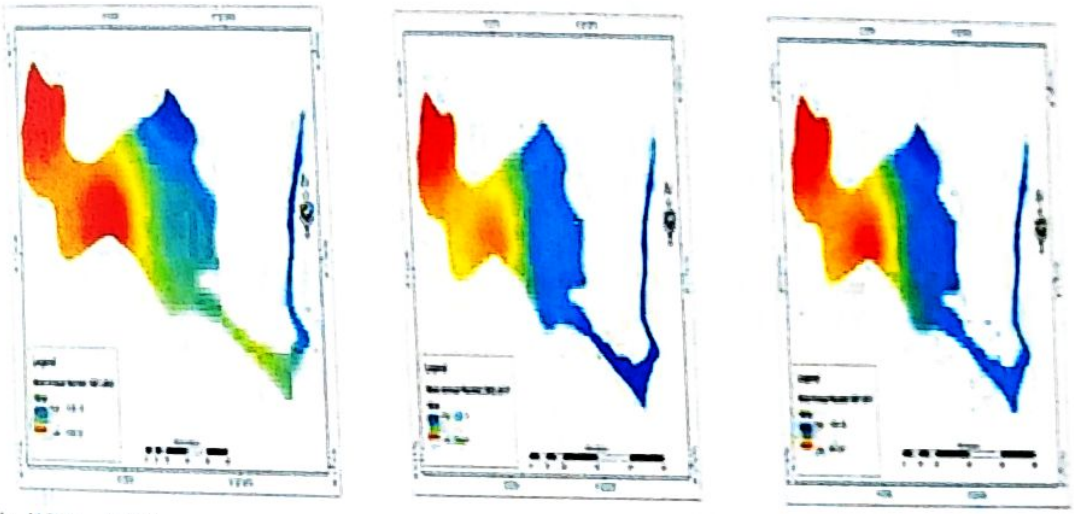
b = slope

a = intercept

3.0 RESULTS AND DISCUSSIONS

3.1 Spatial Trends in Mean Rainfall (1987– 2017)

The spatial trend of the annual rainfall from 1987–2017 is represented in Figure 2(a-c).



a) (1987 –2002) b) (2002 – 2017) c) (1987– 2017)

Figure 3: the Spatial Trends in Mean Rainfall (1987 – 2017)

The mean annual rainfall was 1500.16mm in the north-eastern part of the study area. The lowest mean rainfall was 1108.02mm in the North-western part of the study area from 2002 – 2017. Figure 2(b) shows mean rainfall of 1275.15mm as the highest occurring in the south-eastern part , with the lowest value of 769.08mm in the north-western part while Fig 2c shows a value of 1390.49mm as the highest occurring in the south-eastern part, with the lowest value of 946.007mm in the north-western part of the Local Government Area. The spatial trends in annual mean rainfall from 1987-2017 shows a broader trend of 444-483mm. The broader range indicates that some parts of the LGA may experience wetness when other parts experience dryness. The differences in the pattern of rainfall could be as a result of extensive area coverage of the study area.

It is noteworthy that areas of same longitudinal and latitudinal band experienced variation in mean rainfall. This finding is consistent with Ibrahim *et al.*, (2020) who found variability in the rain across the same latitudinal band in Savanna zones of Nigeria. The coordinate variation in rainfall indicates there may be other factors like temperature variation contributing to an increase in rainfall in such areas.

3.2. Rainfall Anomalies (SPI) in the study area

The computation of the Standardised Precipitation Index for the study area (Figure 3) revealed an increase in rainfall from 1987 to 1996.

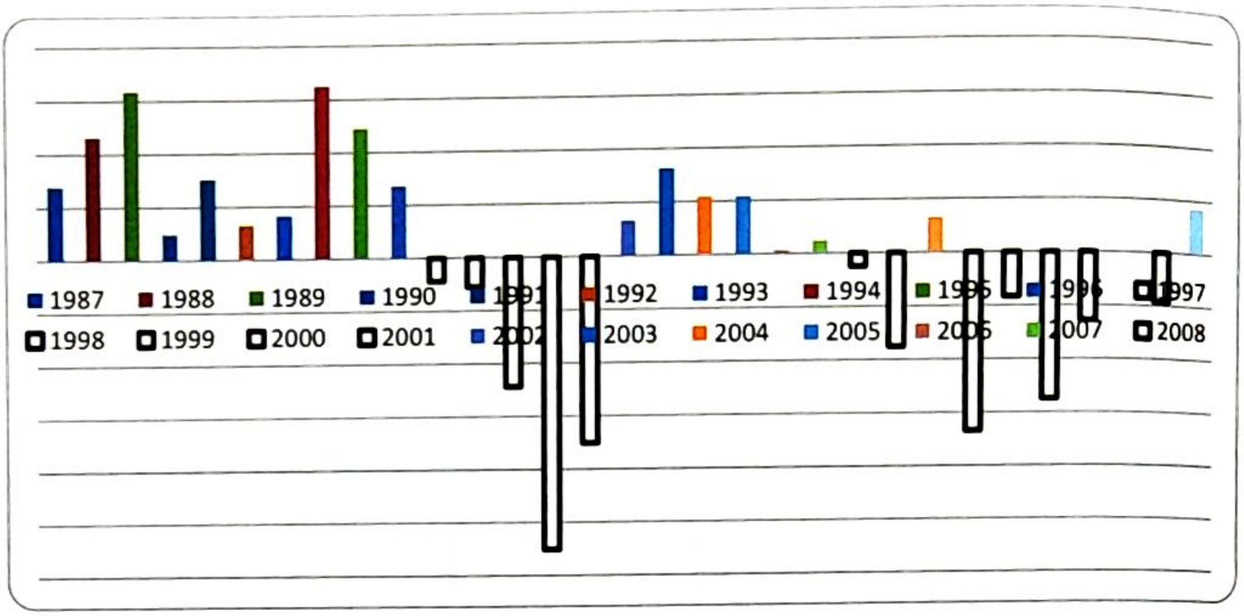
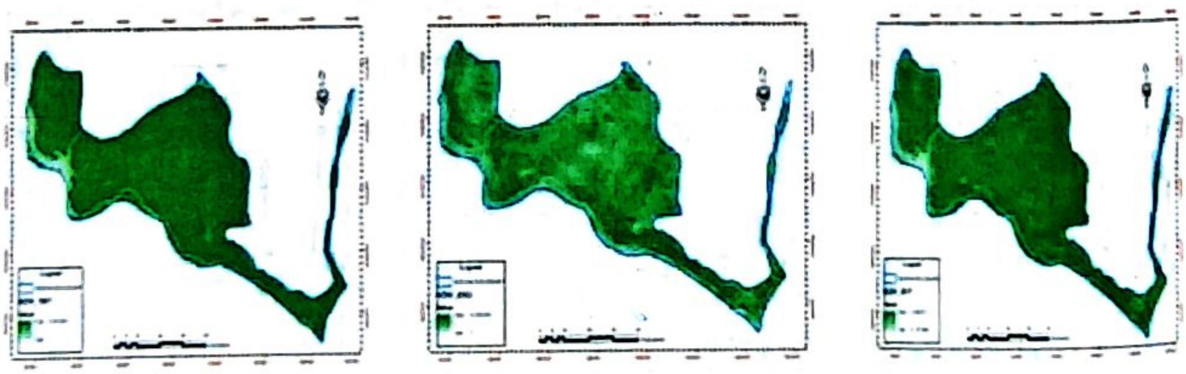


Figure 3: SPI Values over the Study Area

The year 1994 had the highest positive value of SPI (1.62), while the lowest value was in the year 2000 (- 2.75), four years (1988, 1989, 1994 and 1995) were observed to be above normal wetness, while 1999, 2000, 2001, 2011 and 2012) had below normal dryness. The temporal trend in rainfall for the study area indicates that the first decade of the study period witnessed normal wetness of positive SPI value. While the second and third decades had alternate positive and negative SPI values, meaning that some years were wet while others were dry.

3.3. The Vegetation Anomaly Index

The NDVI analysis (Figure 4) indicates a value between 0.81 and -1 in 1987 (a). In 2002 (b) the NDVI value was observed to be between 0.52 and -1. It further decreases to between 0.405 and -0.12 in 2017 (c).



a) (NDVI 1987) b) (NDVI 2002) c) (NDVI 2017)

Figure 4: Normalised Difference Vegetation Index Maps (1987-2017)

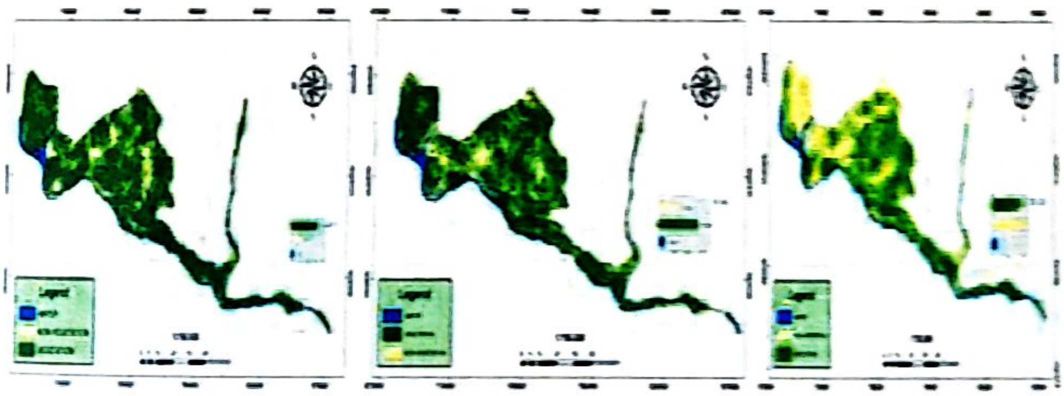
NDVI values were determined by the amount of rainfall and other factors such as urbanisation, population increase and agricultural activities. On average, the active rainy season in the study area lasts from the end of April or beginning of May until the middle or end of October. The spatial pattern of the NDVI trend is closely related to the spatial trend of rainfall. The NDVI analysis indicates that a high value of NDVI 0.8 in 1987 was drastically decreased to 0.4 in 2017. This high rate of decrease in vegetation cover may not be unconnected to the fact that since the late 1990's rapid urbanisation as a result of population increase has been going on in the area. The population increase may also be responsible for massive deforestation in the area as people compete for firewood for both domestic and commercial purposes.

3.4. The Land Use/Land Cover Changes in the study area (1987 – 2017)

The result of LULC presented in Table 2 and Figure 5shows a decrease in vegetation cover from 2999.43km^2 (69.12%) in 1987 to 2615.81km^2 (60.30%) in 2002 and further decreased to 2326.03km^2 (53.62%) in 2017.

Table 2. Summary Statistics of LULC in the Study Area (1987- 2017).

Classification type	1987		2002		2017		Change	
Area	(KM2)	(%)	(KM2)	(%)	(KM2)	(%)	(KM2)	(%)
Vegetation	2999.43	69.12	2617.81	60.30	2326.03	53.62	672.39	15.5
Nonvegetation	1008.42	23.26	1344.78	31.00	1676.33	38.62	668.92	-15.42
Water Body	330.55	7.6	376.10	8.67	336.19	7.75	5.64	-0.13
Total	4338	100	4338	100	4338	100	1347	



1987 LULC 2002 LULC 2017 LULC

Figure 5: LULC maps of the study area

The decrease in vegetation cover correspond to continue increase in non-vegetation areas from 1008.42 km^2 (23.20%) in 1987 to 1344.78km^2 (31.00%) in 2002 and 1675.33km^2 (38.62%). Water bodies increased in aerial extent from 330.55 km^2 (7.62%) in 1987 to 376.10 km^2 (8.67%) in the year 2002 and 336.19km^2 (7.75%) in 2017. The result is in agreement with the work of Suleiman *et al.* (2014), Agbor *et al.* (2012) and Mansur *et al.*, (2017). A decrease of 15.5% was recorded in the vegetation class from 1987 to 2017. However, an increase of 15.42% in non-vegetation areas was observed between 1987 - 2017. In contrast, a 0.13% increase was observed in the water body.

3.4.1 Accuracy assessment of the classified Imageries

The overall accuracy of the classified images 77% (1987), 78% (2002) and 80% (2017) with a Kappa coefficient of 0.712, 0.738, and 0.760 respectively

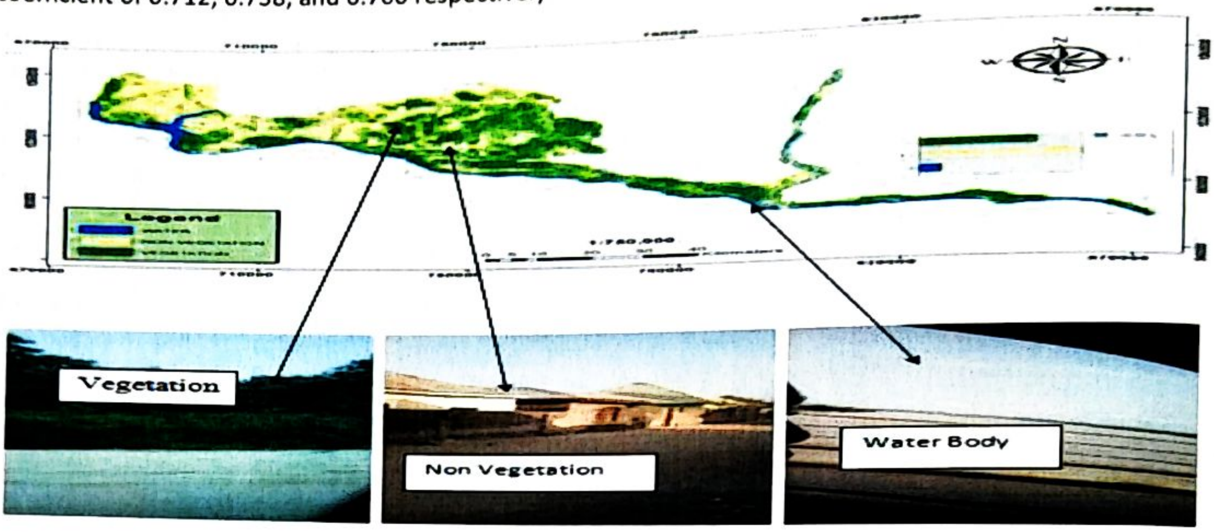


Figure 6: Accuracy assessments of the classified imageries

3.5. Linear Regression for the study area.

The linear regression analysis (Figure 7) revealed a value of R^2 = 0.743, which indicates a positive relationship between rainfall and vegetation dynamics. The result is in agreement with the work of Bamba, (2015) who found a linear correlation between rainfall and NDVI to be high in large areas of the Savanna region of Ghana and Nigeria. The high values are mainly observed in the region where the annual rainfall is around 1000 mm. So, the vegetation growing depends directly on rains.

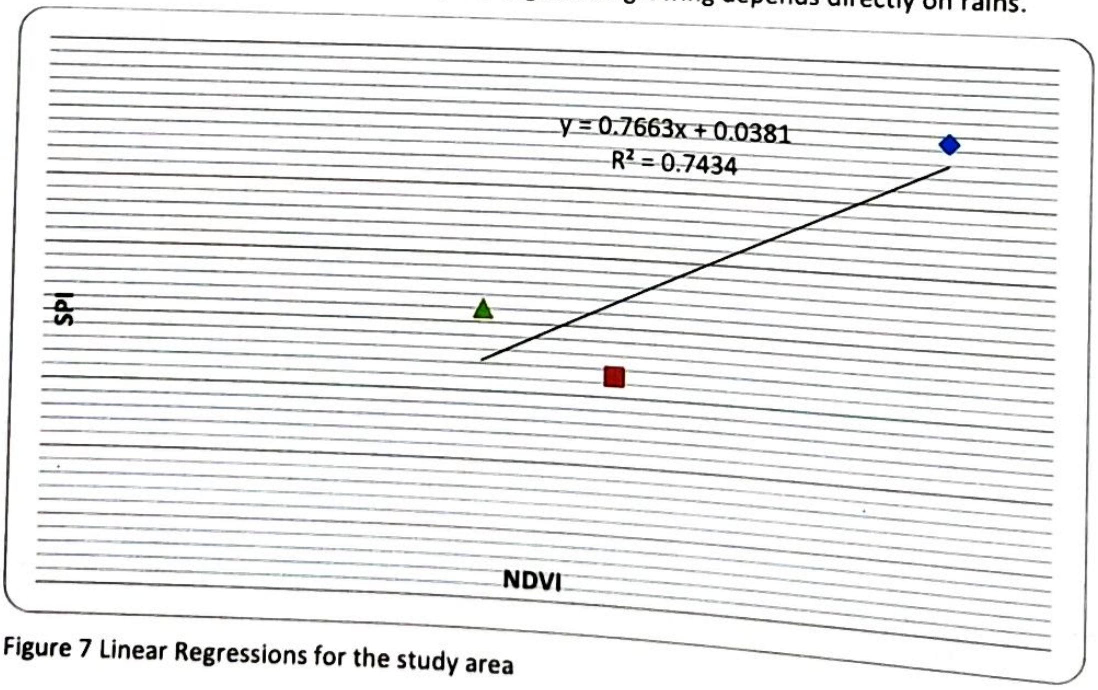


Figure 7 Linear Regressions for the study area

4.0 CONCLUSION AND RECOMMENDATIONS

The study analysed rainfall trend and vegetation dynamics in Mokwa LGA and observe that there has been a different pattern for the entire study period. The study found a positive relationship in rainfall and NDVI in the second half of the study period. Findings also indicated that the trend in the rain is not spatially distributed. A positive trend in temporal rainfall was detected in the first decade of the study period. The trend was characterised by the alternation of positive and negative trends in the last two decades of the study period. The vegetation cover over the study area has been found decrease throughout the study period. Positive linear relationships were observed between rainfall and vegetation dynamics in the study area. We recommend that the State Ministries of Environment and Agriculture with other relevant agencies should advocate for afforestation practice in the study area so as to reclaim the lost forest. Urban expansion due to population increase should be checked through re-planning of town so as to fill the undeveloped areas within the town. However, a decrease in vegetation cover was observed throughout the study period.

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