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Trend Dynamics of Rainfall on Vegetation Pattern over Mokwa Local Government Area of Niger State, Nigeria

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Abstract

Over the years, the rainfall trend couples with urbanization as a result of increase in population have been going on in the study area. The increasing population and demand for land is threatening the existence of vegetal cover which demands effective measurement and understanding of the health dynamics of vegetal cover in the study area. The study analyses trend dynamics of rainfall on Vegetation pattern over Mokwa Local Government Area. Gridded satellite daily rainfall data for the periods of 1987-2017 and data from remote sensing images for 1987, 2002 and 2017 were extracted and used. The satellite image was used for Land Use Land Cover (LULC) change and Normalized Difference Vegetation Index (NDVI) analysis, while gridded satellite data was used for Standardized Precipitation Index (SPI) and simple linear regression was used to depict correlation in rainfall and vegetation. Findings revealed that the year 1994 had the highest positive value of SPI (1.62) and lowest value in 2000 (-2.75), 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 between 0.405 and -0.12 in 2017. The results of LULC change show a decrease of 15.5% in vegetation cover from 1987 to 2017 with an increase of 15.42% in non vegetation areas and 0.13% increase was observed in the water body during the study period. The linear regression of R^2=0.743 indicated a positive relationship between rainfall and vegetation cover. It was concluded that the spatial trend in rainfall are not spatially distributed along longitudinal or latitudinal directions. However vegetation cover was found to be decreasing throughout the study period. The study recommends further investigation on urbanization and agricultural activities responsible for vegetation dynamics in the study area.

Keywords: Dynamics, Land Use, Rainfall, Trend, Vegetation

1. Introduction

Over the years, the rainfall trend coupled with urbanization as a result of increase in population has been going on in the study area. The increasing population and demand for land is threatening the existence of vegetal cover which demands effective measurement and understanding of the health dynamics of vegetal cover across the country. In recent times, the dynamics of Land use Land cover and particularly settlement expansion in the study area requires a powerful and sophisticated system such as remote sensing and geographic information system (GIS), which provides a general coverage of large areas analysis. The study aimed at analysis of trend in rainfall and Vegetation dynamics over Mokwa Local Government Area (LGA). Land cover pattern of a place is an outcome of natural and socioeconomic factors and their utilization by man in time and space. Studies have shown that there remain only few landscapes on the earth that is still in their natural state. Man's activities on earth have had a deep effect on the natural environment thus resulting into a non observable pattern in the land use land cover over time. Investigating the state or the amount of vegetation is one of the paramount objectives in the field of land surface related remote sensing applications.

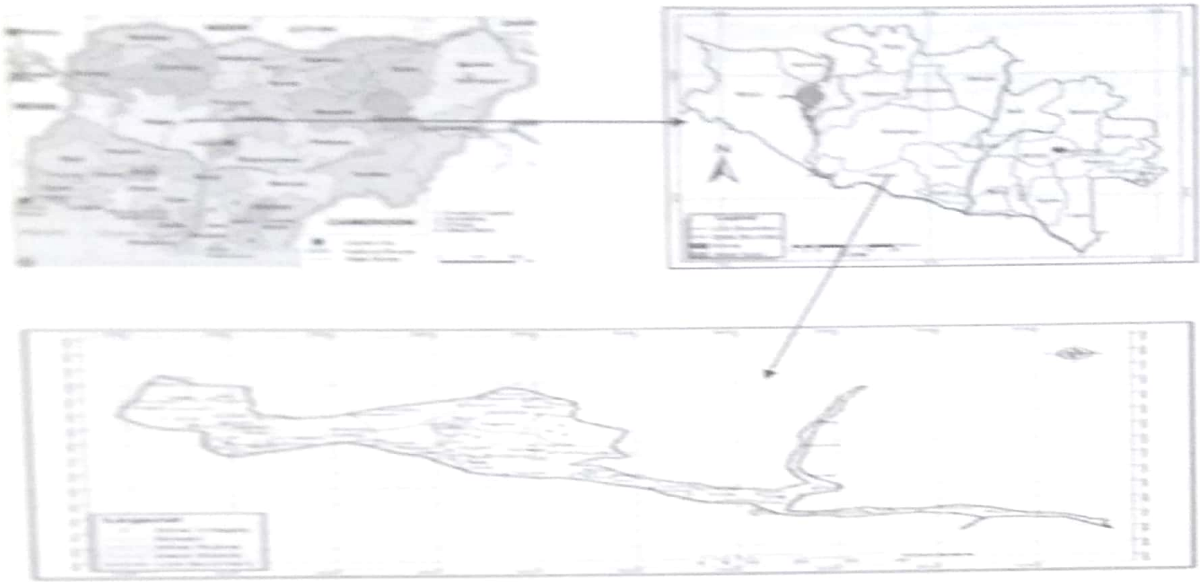
The availability of frequent data that are internally consistent over a sufficient period and provide information on the spatial complexity as well as on the temporal dynamics of vegetation is prerequisite for successful monitoring of vegetation cover (Seiler, 2010). Remote sensing of the vegetation condition is based on the fact that healthy plants have more chlorophyll and therefore absorbs more Visible (VIS) radiation and reflects more Near-InfraRed (NIR) radiation (Rimkus, *et al.,* 2017). High spatial and temporal rainfall trends have been a big problem in monitoring agricultural phenomenon over Africa, because any excessive or deficit of rainfall amount may result to change in vegetation and or failure. It is necessary to emphasize that the vegetation (and hence Normalized Difference Vegetation Index (NDVI) values) 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 *et al.,* 2013). Poor land utilization practices, especially in subsistence farming and nomadic pastoral economies in the majority of the African countries have accelerated the loss of natural vegetation and exacerbated the problem of climate change (Bamba, 2015).

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. It is evident that the Nigerian natural vegetation if not conserved and sustainably managed will lose its natural state (Fashae, *et al.,* 2017). There is therefore an urgent need to create awareness about the consequences of these changes and bring a halt to the trend. Also increase in population has resulted in increase in consumption of wood for domestic purposes aggravate the environmental degradation and land use change. Bush burning and uncontrolled grazing are carried out elsewhere in the study area thereby contributing immensely to the vegetation dynamics.

Many methods and in particular various vegetation indexes have been introduced to quantify certain vegetation parameters. However, all of them take into account that vivid green vegetation shows a specific reflection signal in the red and near infrared part of the electromagnetic spectrum (Seiler, 2010). Therefore, in most cases NDVI values are complexly analyzed with meteorological and agro-meteorological drought indicators such as the Standardized Precipitation Index (Gebrehiwot *et al.*, 2011; Gaikwad and Bhosale, 2014; Stagge *et al.*, 2015). For the analysis of LULC change supervised classification developed spectral signatures of known categories and each pixel allocated to the cover type to which it is most popular. Image classification methods are many, but there is no single "best" method to image classification. However the choice depends on available algorithms within the image-processing software (Horning *et al.*, 2010).Supervised classifications using Maximum Likelihood Classifier (MLC) was used because of its popularity, simplicity and above all its proven high degree of accuracy. The classified land use and land cover maps may contain some sort of errors because of several factors, from classification technique to the method of satellite data capture. This study analyses trend dynamics of rainfall on vegetation pattern over Mokwa LGA of Niger State, Nigeria.

2.0 Study Area

Mokwa Local Government Area (LGA) in Niger state, is located between Longitude 4°45'00" to 5° 45'05'' East and Latitude 8°45' 00'' to 9° 40' 00"North 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).Meteorological research confirms that 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 days of rainy days for 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 major vegetation zone across Niger state. It consists of wood land and light forest. The common tree found in this zone are; Sheabutter, Neou oil, African locus bean or Niffa, Axle-wood and thinning's piliostigma tree. Agriculture is the main economic activity of the people in the study area.



Mokwa LGA

Figure 1 The Study Area (Mokwa Local Government Area, Niger State).

Source: Niger State Geographic Information System (NIGIS)

3. Materials and Methods

3.1 Data Acquisition

The research used daily satellite grid rainfall estimates data and satellite imagery. The data were source from www.globalweather.tamu.edu. The datasets has a spatial resolution of 0.25^0 consisting of three (3) hourly/daily rainfall estimates from 1979 to 2017. LandSat-5 image Thematic Mapper (TM) for 1987, LandSat 7 Enhance Thematic Mapper Plus (ETM$^+$) for 2002, and LandSat 8 Operational Land Imager (OLI) 2017 all with 30m Resolution, sourced from United State Government via www.usgs.gov were used.

3.2 Methodology

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

$$AR = \sum_{m=j}^{d} R \quad (1)$$

Where, AR is the annual rainfall amount at each data point.

R is the daily rainfall amount at each data point,

d is the number of days, and

I is the months of the year.

n is the total number of years.

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

The Standardized Precipitation Index (SPI) is expressed in the form $\frac{X-\bar{X}}{\sigma}$ (2)

Where σ is the standard deviation

X is annual rainfall for a given period.

$\bar{X}$ is annual mean rainfall for a given period

Negative SPI value represent rainfall deficit (dryness), while positive SPI values indicates rainfall surplus (wetness). The SPI values ranges 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 were computed. For the mapping of spatial pattern of trends from point data, Inverse Distance Weight (IDW) was the interpolation method adopted to monitor the distribution of rainfall which was 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.

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

Where NIR is Near Infrared (fourth band of landSat images) and

VIS is Visible band (third band).

The final NDVI products were depicted in the geographic grid with equal latitude and longitude intervals. The NDVI values ranges from -1 to +1. The negative index value can be recorded over the clear water bodies while values are close to 0 over the land without vegetation. The index value equal to 1 indicates perfect growing vegetation conditions. Rainfall and vegetation value were analyzed by the use of simple linear regression. To Examine the LULC Changes over the Study Area from 1987 – 2017 the images were subjected to the following procedures

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 radiometric correction is meant to adjust the radiation values to the standard values. Failure to observe them or observance with imprecision may render change detection meaningless.

Image Classification Three land cover types were analysed for this research as adopted by Agbor*et al.*, 2012 (Table 1). Supervised classifications using Maximum Likelihood Classifier

(MLC) were used because of its popularity, simplicity and above all its proven high degree of accuracy.

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, grasslands, trees, shrub land, natural and semi- natural vegetations
2	Non Vegetation	All residential, commercial and industrial areas, roads, Settlement and infrastructures
3	water Body	Rivers, streams, dams, lakes and ponds

Source: Ahmad (2018)

Accuracy assessments produce information that describes reality on the study area. References (sample) were identified from Google Earth and using a different training site. This were done using 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

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

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

N = total number of samples.

In order to assess the impact of rainfall trend on vegetation dynamics, the NDVI and SPI values were statistically analysed through the use of simple linear regression to know the level of impacts if there is any in the study areas. The linear regression equation is express in equation 5 as:

$$Y = a + bx \quad (5)$$

Where Y is the dependent variable; x is the independent variable

b is the slope of the line; a is the y intercept

4.0 Results and Discussion

4.1 Results of SPI values for the study area.

The computation of Standardized Precipitation Index for the study area (Figure 2) revealed an increase in rainfall from 1987 to 1996. The year 1994 had the highest positive value of SPI (1.62), while lowest value was in year 2000 (- 2.75), four years (1988, 1989, 1994 and 1995) were observed to be above normal wetness with five years (1999, 2000, 2001, 2011 and 2012) below normal dryness. The temporal trend in rainfall for the study area indicates that the first decade of the study period witness normal wetness of positive SPI value. While the second and third decade witness an alternate positive and negative SPI value meaning that some years were wet while others were dry.

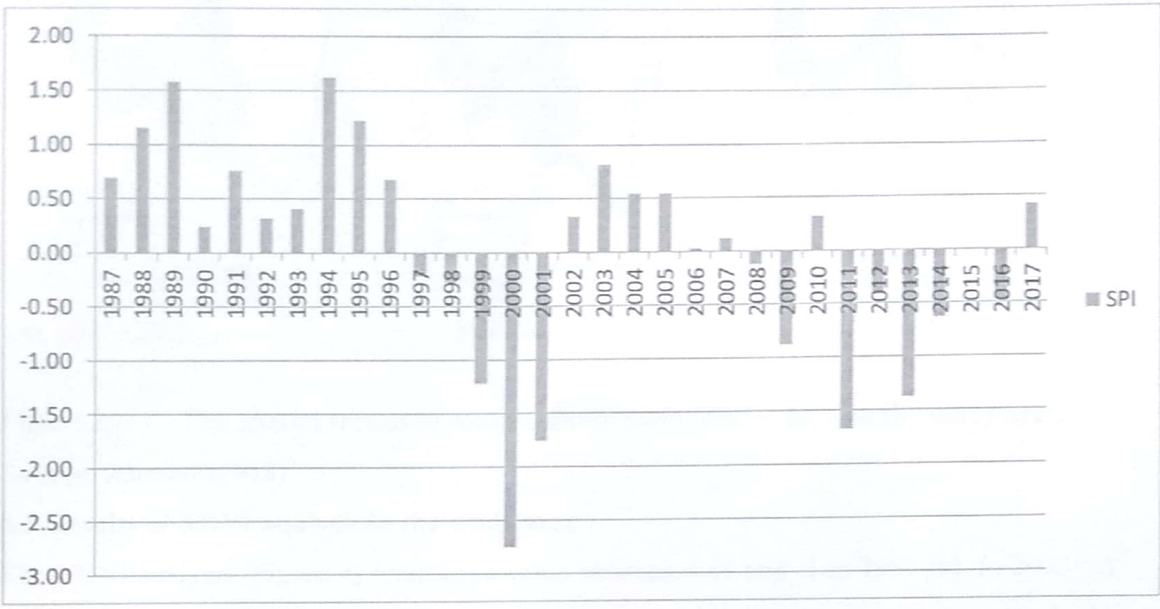
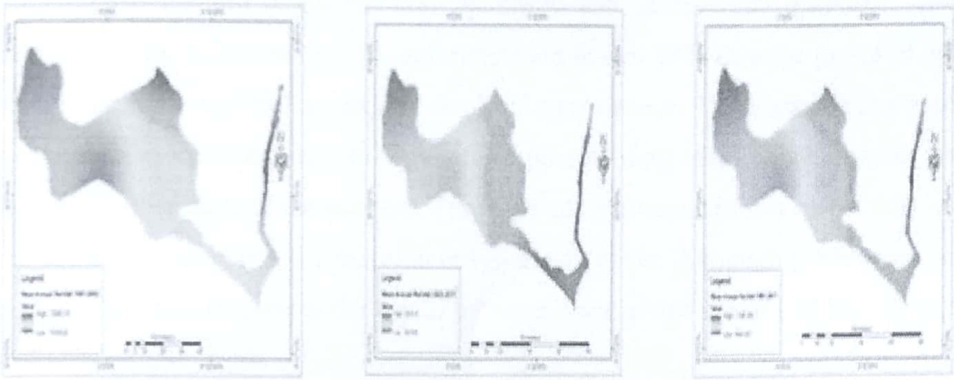


Figure 2 SPI values over the study area

Source: Ahmad (2018)

4.2 The results of spatial trends in mean rainfall from 1987 – 2017 in the study area.

The maps of spatial trend (Figure 3) indicates that the mean annual rainfall from 1987 – 2002 (a) indicates a value of 1500.16mm as the highest occurring in the north – eastern part with the lowest value of 1108.02mm in the north – western parts of the LGA; 2002 – 2017 (b) shows a value of 1275.15mm as the highest occurring in the south – eastern part with the lowest value of 769.08mm in the north – western part of the LGA and 1987 – 2017 (c) revealed 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 LGA. The spatial trends in annual mean rainfall from 1987-2017 shows a wider range of trend of about 444.483mm. This wider range of trend contributes to the fact that some parts of the LGA may witness wetness while other parts may be witnessing dryness. This trend may be attributed to the large area coverage of the LGA. The spatial trend in rainfall may not be attributed to the longitudinal or latitudinal variation as some area of the same longitude and latitude has different amount of mean rainfall. This signals that there may be other factors like temperature variation contributing to increase in rainfall in such areas. Urbanization and deforestation are visibly taking place in the study area as a result of increase in population as confirm by LULC change analysis.



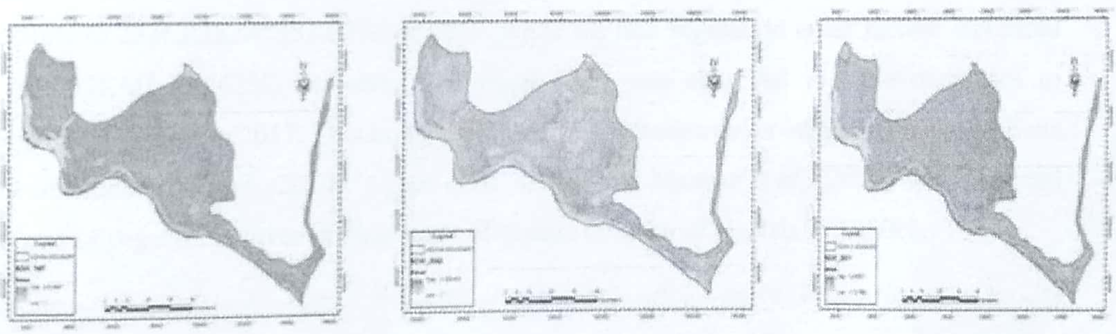
a) (1987 – 2002) b) (2002 – 2017) c) (1987 – 2017)

Figure 3 The spatial trends in mean rainfall from 1987 – 2017 in the study area.

Source: Ahmad (2018)

4.3 Results of NDVI analysis in the study area

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 NDVI analyses in the study area

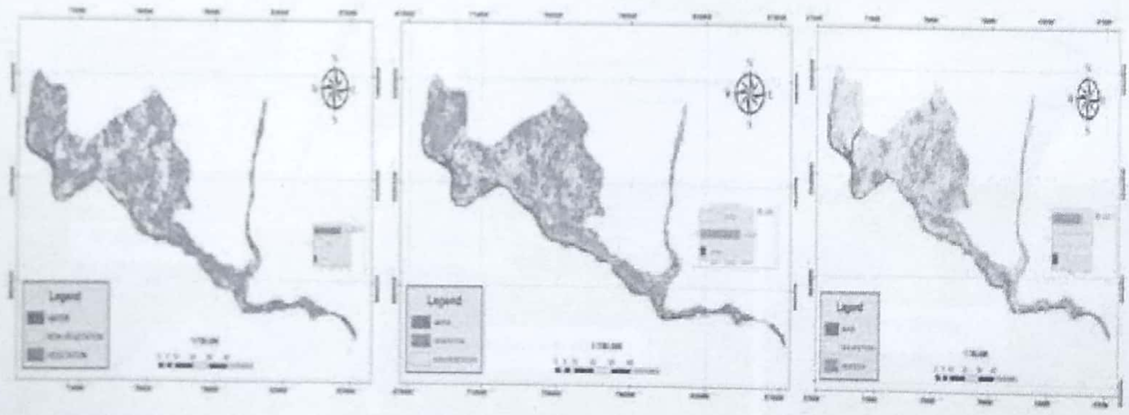
Source: Ahmad (2018)

NDVI values in the analyzed area were determined by the amount of rainfall and other factors such as urbanization, 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 late 1990's rapid urbanization as a result of population increase have been going on in the area. The population increase also resulted to mass deforestation in the area as people compete for fire wood for both domestic and commercial purposes. The rate of deforestation in the LGA took a different dimension in late 2000 as some group of individuals settled around Mokwa – Bokani axis of the local government. These groups of people source their income from fire wood sales in commercial quantity most at time load of trailer for onward movement to other parts of the country. The wide use of charcoal from early 2000 to date has also contributed a lot in time of decrease in vegetation cover. Although government has put in place some agencies to control the trend, however their active control of tree falling has not yielded any positive result.

4.4 The LULC Changes in the study area for 1987, 2002 and 2017

From the various spatial temporal analysis of categorical LULC of the LGA it is obvious that the land use has been changing in size noticeably over the years.

The result of LULC in Table 2 shows a decrease in vegetation cover from 2999.43KM^2 (69.12%) in 1987 to 2615.81KM^2 (60.30%) in 2002 (Figure 5). As the vegetation cover decreases, the non vegetation areas continue to increase from 1008.42KM^2 (23.20%) in 1987 to 1344.78KM^2 (31.00%) in 2002, while Water body was observed to have increase from 330.55KM^2 (7.62%) in 1987 to 376.10KM^2 (8.67%) in 2002. The vegetation cover further decreases to 2326.03KM^2 (53.62%) in 2017, while the non vegetation areas further increased to 1675.33KM^2 (38.62%), however, the water body was observed to have decreases to 336.19KM^2 (7.75%) in 2017. This high percentage of vegetation cover is in agreement with the work of Suleiman, *et al.* (2014), Agbor *et al.* (2012) and Mansur *et al.* (2017) who reported high rate of vegetation cover in most parts of guinea savanna of Nigeria in 1980ce.



1987 LULC　　2002 LULC　　2017 LULC

Figure 5　　**LULC Change analysis in the study area**

Source: Ahmad (2018)

Table 2 Summary Statistics of LULC Distribution of Mokwa (1987, 2002 and 2017)

Classification Type Area Cover in	1987 (KM^2)	(%)	2002 (KM^2)	(%)	2017 (KM^2)	(%)	Change (KM^2)	(%)
Vegetation	2999.43	69.12	2617.81	60.3	2326.03	53.62	672.39	15.5
Non Vegetation	1008.42	23.26	1344.78	31	1676.33	38.62	668.92	-15.42
Water Body	330.55	7.6	376.1	8.67	336.19	7.75	5.64	-0.13
Total	4338	100	4338	100	4338	100	1347	

Source: Ahmad (2018)

A decrease of 15.5% was recorded in vegetation class from 1987 to 2017. However increase of 15.42% in non vegetation areas was observed from 1987 to 2017. While 0.13% increase was observed in the water body.

Accuracy assessment of the classified Images of 1987, 2002 and 2017 in the Study Area

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

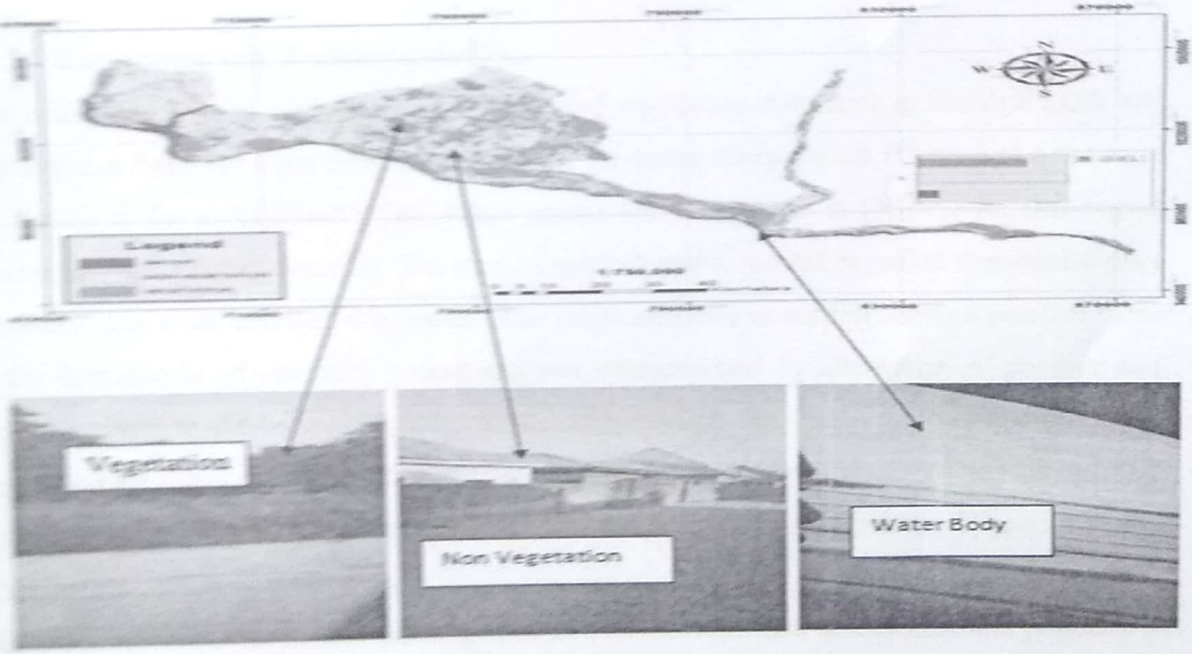


Figure 6 Accuracy assessments of the classified images

Source: Ahmad (2018)

4.5 Results of 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 which is in agreement with the work of Bamba, (2015) who found linear correlation between rainfall and NDVI to be high in large areas of the savannah region mainly it achieve 0.8 over Ghana and Nigeria. The high values are mainly observed in region where the annual rainfall is around 1000 mm. So the vegetation growing depends directly on rainfall.

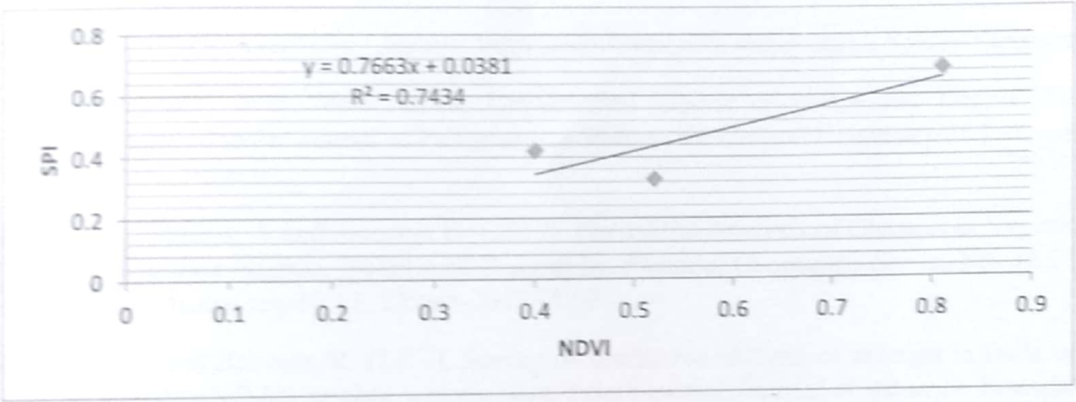


Figure 7 Linear Regressions for the study area.

Source: Ahmad (2018)

5. Conclusion and Recommendations

The study was able to analyze rainfall trend and vegetation dynamics in Mokwa LGA and observe that there has been different pattern for the entire study period. There was a decrease in rainfall in the second half of the study period and a decrease in (NDVI) for that region concurrent with rainfall decrease. The map of spatial trend in rainfall revealed that rainfall over the study area is not spatially distributed. The temporal trend in rainfall shows a positive trend in the first decade of the study period and was characterized by alternation of positive and negative trends in the last two decades of the study period. The NDVI analysis indicates that the vegetation cover over the study area has continued to decrease throughout the study period. Positive linear relationships were observed between rainfall and vegetation dynamics in the study area.

The study recommends further investigation on other factors such as urbanization, population increase and agricultural activities as rainfall alone cannot be responsible for vegetation dynamics in the study area.

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.

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