FUDMA Journal of Agriculture and Agricultural Technology
ISSN: 2504-9496
Vol. 4 No. 2, December 2018: Pp284-293

COMPARATIVE ANALYSIS OF RAINFALL TREND AND VEGETATION DYNAMICS IN MOKWA AND RIJAU LOCAL GOVERNMENT AREAS OF NIGER STATE, NIGERIA

*Umar A., Muhammed M., Suleiman Y. M. And Abdulkadir A.

Department of Geography, Federal University of Technology Minna, Niger State. Nigeria
*Corresponding Author (08067869941; Email: ahmedumaru4@gmail.com)

Abstract

The study aimed at comparative analysis of trend in rainfall and Vegetation dynamics over Mokwa and Rijau Local Government Areas. Gridded satellite daily rainfall data for the periods of 1987-2017 and data from remote sensing image for 1987, 2002 and 2017 were extracted and used. The Normalized Difference Vegetation Index (NDVI) was used for satellite image, Standardized Precipitation Index (SPI) for gridded satellite data while simple linear regression was used to determine the relationship between rainfall and vegetation. Findings revealed that in Mokwa, 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. While in Rijau, six years were observed to be above normal wetness with three years below normal dryness. In Mokwa, 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. While in Rijau, it was between 0.96 and -0.97 in 1987 but decreased to 0.54 and -0.23 in 2017. The linear regression analysis revealed a value of R^2=0.743 for Mokwa and R^2=0.152 for Rijau. It was concluded that rainfall is the major causative factor in the dynamics of vegetation condition in the study areas, while other meteorological parameters like temperature and humidity as well as anthropogenic activities in the areas may have contributed to vegetation dynamics. The study recommends further investigation on other factors responsible for vegetation dynamics in the study areas.

Keywords; Comparative, trend, Rainfall, Vegetation and Dynamics

INTRODUCTION

Over the years, the rainfall trend coupled with urbanization as a result of increase in population has been going on in the study areas. 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. 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. This is 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).

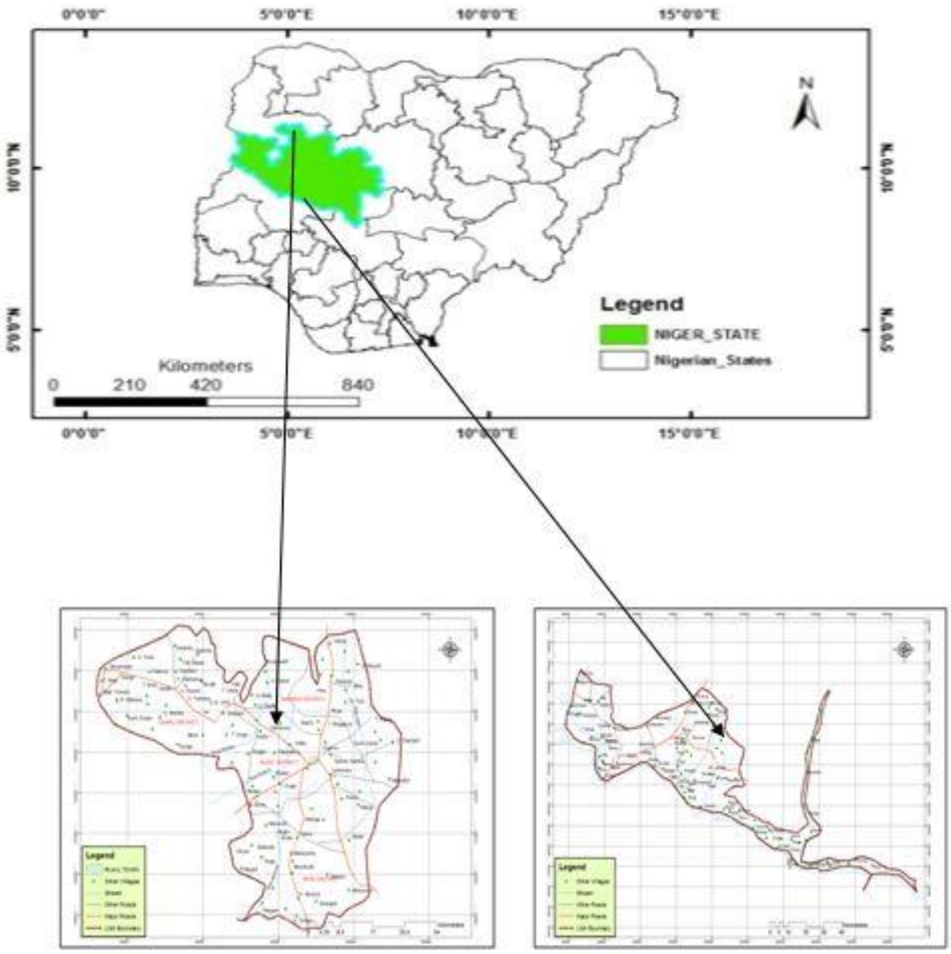
Many methods and in particular various vegetation indexes have been introduced to quantify certain vegetation parameters. However, all of them take into account that vivid green vegetation shows a specific reflection signal in the red and near infrared part of the electromagnetic spectrum (Seiler, 2010). Therefore, in most cases NDVI values are complexly analysed 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).

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 areas thereby contributing immensely to the vegetation dynamics.

This study establishes a comparative relationship between trend in rainfall and vegetation dynamics in Mokwa and Rijau Local Government Areas of Niger State, Nigeria.

Study Area

Mokwa LGA is located in the southern part of Niger State 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 4,338km². Rainfall usually starts by April/May and stops in October. It usually recorded an average of 200 days of rainy days for a year with an average mean annual rainfall of 1,300mm. The vegetation of the study area falls within the vegetation zone of Guinea Savanna which is a major vegetation zone across Niger state. Rijau LGA on the other hand is isolated in northern parts of Niger State located between Longitude 4°70’05” to 5° 47’00’’ East and Latitude 10°70’ 05’’ to 11° 35’ 02”North and covers a total land area of 3,196km². The average annual rainfall of Rijau LGA is 1100mm with about 180 of rain days. The rain starts from May/June and stops in October. The vegetation of Rijau also falls within the vegetation zone of Guinea Savanna which is a major vegetation zone across Nigeria(Adefolalu, 1986) (Figure 1).



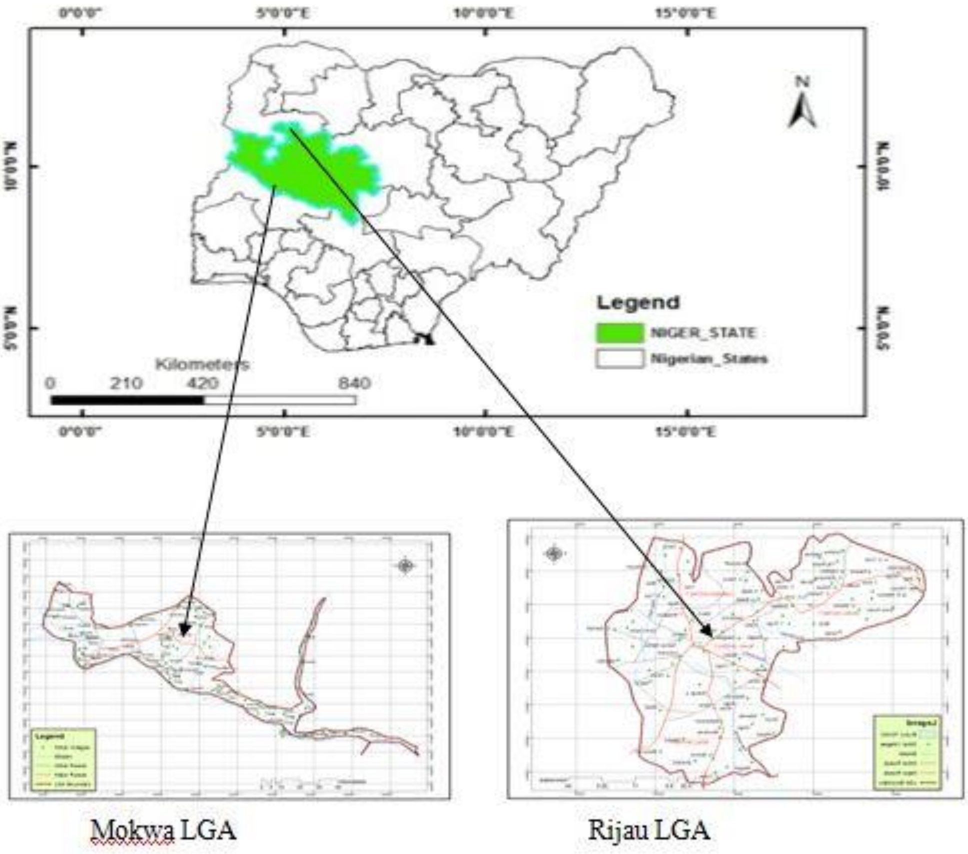


Figure 1: Map of the study areas

Source: Niger State Geographic Information System (NIGIS)

MATERIALS AND METHODS

Data Acquisition

This research uses satellite grid rainfall estimates data and satellite image. Daily rainfall satellite estimate for the study areas were used. 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 the 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.

Data Analysis

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

$$AR = \sum_{n=1}^{d} R \qquad (1)$$

Where, AR is the annual rainfall amount at each station.

R is the daily rainfall amount at each station,

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; $X - \bar{X} / \sigma$ (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.

Table 1 SPI Climatic Index Values and their Drought Indicators

Climatic index	Drought indication
2.00 and above	extremely wet
1.50 to 1.99	very wet
1.00 to 1.49	moderately wet
- 0.99 to 0.99	near normal
- 1.00 to – 1.49	moderately dry
- 1.50 to – 1.99	severely dry
- 2.00 and less	extremely dry

Adopted from. McKee *et al*. (1993)

From the mean annual rainfall values from 1987 – 2017, the average rainfall for the study areas 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 each of 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.

$$NDVI = NIR- VIS/NIR+VIS \quad (3)$$

Where Near Infrared is the fourth band of landSat images and Visible is the 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.

Comparisons were done between the two study areas to see the similarities and the differences through the use of bar graph and tables.

RESULTS AND DISCUSSION

Results of SPI values for Mokwa and Rijau LGA.
The computation of Standardized Precipitation Index for Mokwa and Rijau LGA as shown in Figure 2 revealed an increase in rainfall from 1987 to 1996. In Mokwa LGA 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 with five years (1999, 2000, 2001, 2011 and 2012) below normal dryness. Rijau LGA revealed an increase in rainfall from 1987 to 1997. The year 1989 had the highest positive value of SPI (1.70), while the lowest value was in the year 2000 (- 2.29), six years (1988, 1989, 1993, 1995, 1996 and 2003) were observed to be above normal wetness with three years (2000, 2011 and 2013) below normal dryness.

The temporal trend in Mokwa LGA 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 may be wet while others may be dry.

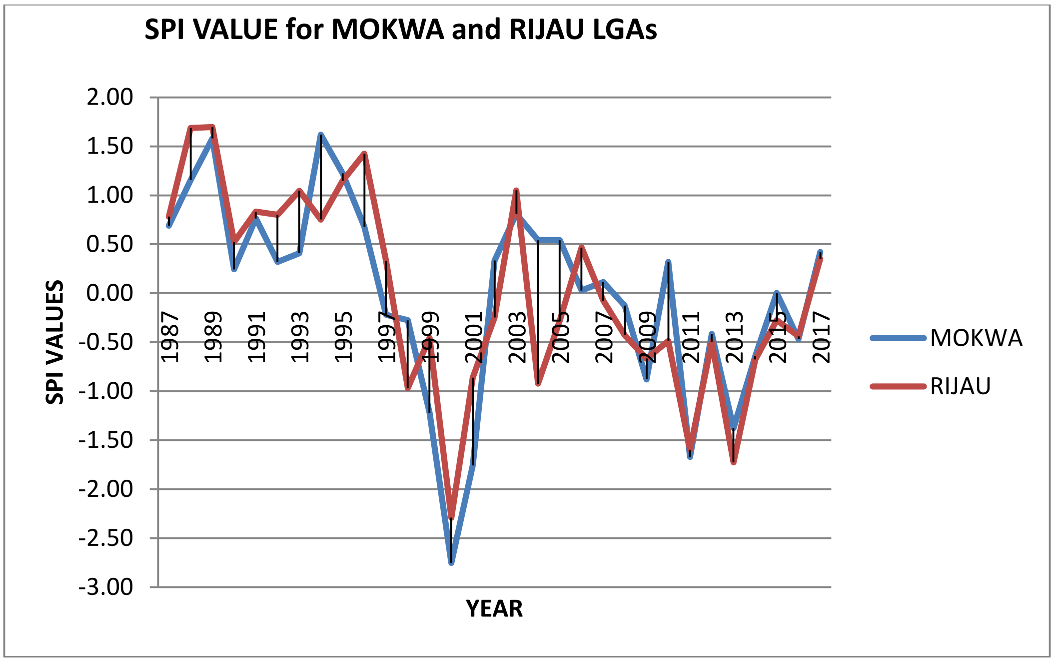


Figure 2: **SPI values for Mokwa and Rijau LGA.**
Source: Field Survey(2018)

The results of spatial trends in mean rainfall from 1987 – 2017 in Mokwa and Rijau LGA.
The maps of spatial trend (Figure 4.2) indicate that the mean annual rainfall for Mokwa from 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; 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 and 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. While the mean annual rainfall for Rijau from 1987 – 2017 (c) revealed a value of 1087.61mm as the highest occurring in the eastern part with the lowest value of 1018.00mm in the western part of the LGA; 1987 – 2002 (a) indicates a value of 1300.77mm as the highest occurring in the south – eastern part with the lowest value of 1143.48mm in the north, while the north – western parts shows moderate values between the two extremes and 2002 – 2017 (b) showed a value of 920.39mm as the highest occurring in the north – western parts and southern parts with the lowest value of 652.335mm in the northern part.

The spatial trend in annual mean rainfall from 1987-2017 in Mokwa 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 the area. Urbanization and deforestation are visibly taking place in area as a result of increase in population. While Rijau's spatial trend in mean annual rainfall 1987-2017 indicates a slight range of trend of 69.61mm. The slight trend may signal that the LGA may witness rainfall at equal amount and at the same time.

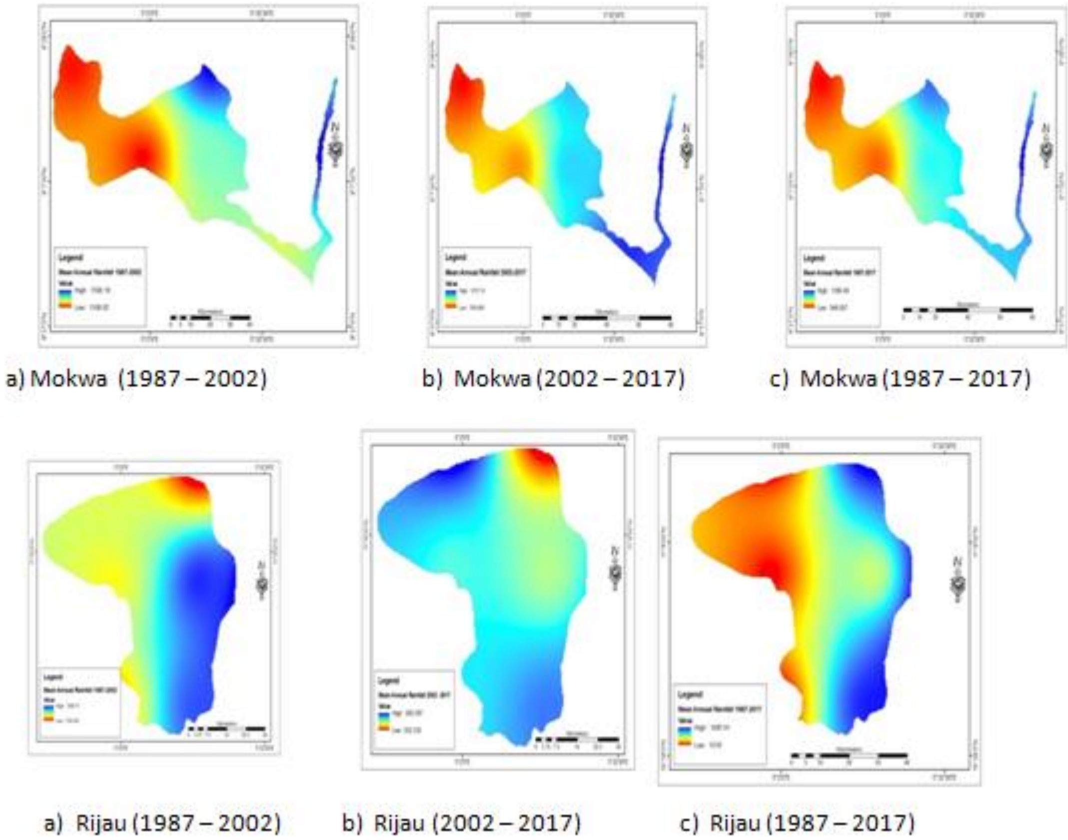


Figure 3:The spatial trends in mean rainfall from 1987 – 2017 in Mokwa and Rijau LGAs.
Source: Field Survey (2018)

Results of NDVI Analysis for Mokwa and Rijau LGA.

The NDVI analysis (Figure 4) indicates that Mokwa records between 0.81 and -1 NDVI value in 1987 (a) but decreased to between 0.405 and -0.12 in 2017 (c). In 2002 (b) the NDVI value was observed to be between 0.52 and -1. While in Rijau LGA the NDVI value was observed to be between 0.96 and -0.97 in 1987 (a) but decreased to between 0.54 and -0.23 in 2017 (c). In 2002 (b) the NDVI value was observed to be between 0.76 and -0.96.

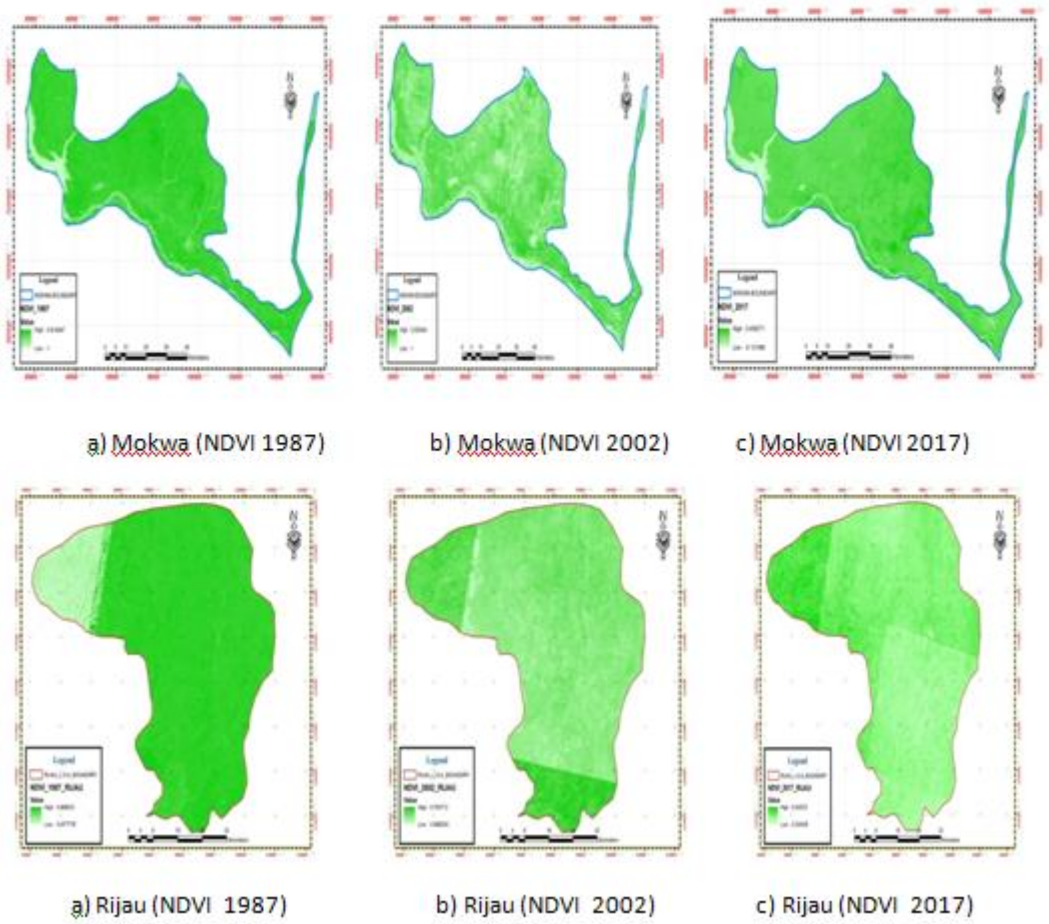


Figure 4: NDVI analysis for Mokwa and Rijau LGA.
Source: Field Survey(2018)

NDVI values in the analyzed areas are 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 areas 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 for Mokwa 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. While in Rijau a high value of NDVI 0.96 in 1987 was drastically decreased to 0.54 in 2017. This high rate of decrease in vegetation cover may be attributed to wide use of charcoal from early 2000 to date. Also increase in agricultural activities may also be contributing in reducing the vegetation cover. Decrease in rainfall amount in late 2000 may also have contributed to the growth of vegetation as all the plants are directly dependent on rainfall for survival. A summary of the NDVI values for both Mokwa and Rijau LGA indicating the high and low values is presented in Table 4.1

Table 2 Summary of the NDVI values for Mokwa and Rijau

Year	Mokwa (High)	Mokwa (Low)	Rijau (High)	Rijau (Low)
1987	0.81	-1.0	0.96	-0.97
2002	0.52	-1.0	0.76	-0.96
2017	0.40	-0.12	0.54	-0.23

Source: Field Survey (2018)

Results of Linear Regressions for Mokwa and Rijau LGA.

The linear regression analysis (Figure 5) revealed a value of R^2 = 0.743 for Mokwa which indicates a perfect 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 area of the savannah region. 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. While in RijauR^2 = 0.152 was observed,indicating weak positive relationship between rainfall and vegetation dynamics which implies that aside from rainfall, other factors may be contributing to the vegetation loss such as high temperature due to high rate of deforestation in the area.NDVI results indicate a clear reduction in the density and distribution of vegetation since the beginning of the study period and towards the end of the study period.

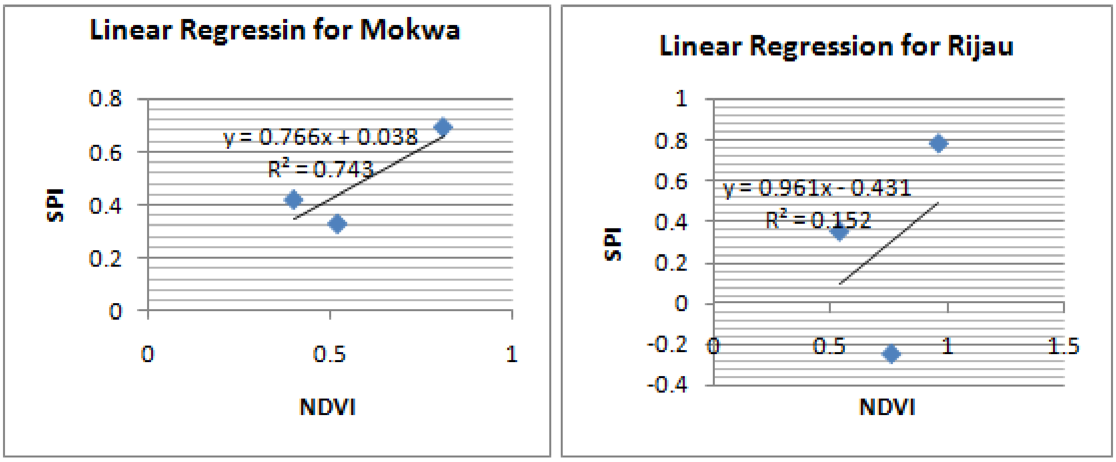


Figure 5: Linear Regressions for Mokwa and Rijau LGA.

Source: Field Survey(2018)

CONCLUSION AND RECOMMENDATIONS

The study was able to analyze and compare rainfall trend and vegetation dynamics in Mokwa and Rijau LGA and observe that there has been different but similar 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 the rainfall over the study areas 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 areas has continued to decrease throughout the study period.Mokwa LGA witnesses a high trend in rainfall and vegetation dynamics than Rijau LGA with a low trend in rainfall and vegetation dynamics.Linear relationships were observed between rainfall and vegetation dynamics in both Mokwa and Rijau local government areas.

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

The state ministry of Environment and Agriculture with other relevant agencies should advocate for afforestation practice in both study areas so as to reclaim the lost forest.

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