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Assessment of Drought across Kaduna State, Nigeria Using MODIS Dataset

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Authors' contributions

This work was carried out in collaboration among all authors. Author MNP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SAY managed the analyses of the study. Author ABS managed the literature searches in the study. All authors read and approved the final manuscript

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ABSTRACT

Introduction: Kaduna state in Nigeria is located within the Guinea Savannah of the African Continent. The state is susceptible to desertification and the risks of drought.
Aim and Objectives: The aim of the study is to access magnitude and extent drought in Kaduna state Nigeria using MODIS dataset.
Study Design: The study examined people's perception; precipitation data and satellite imageries for assessing and monitoring drought. Descriptive statistics were used to present the some of the data.
Methodology: The dataset were analysed using Idrisi remote sensing and Geographical Information (GIS) softwares to determine the aerial coverage of drought and its magnitude. Furthermore, run off were determined, VCI calculated, cross-tabulation were made from classified imageries and the views of respondents were also sought to complement the analysis.
Results: The study revealed that there have been several episodes of drought in Kaduna state within the period under review. Runoff decreased from 72.50mm in 2000 to just about 48.00mm in

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2009. The study also revealed that there is a positive relationship (0.72) between rainfall and vegetation vigour/biomas in the state. Similarly, vegetation condition index (VCI) revealed a value 10.2% indicating a severe drought in the state based on Kogans drought classification.
Conclusion: The study concluded that both rainfall and vegetation/biomas vigour are generally decreasing suggesting a strong positive correlation value of 0.71. While a better high spatial resolution satellite dataset be utilised for further studies in this direction, the study also recommends that individuals and organisations be encouraged to engage in the habit of tree planting in order to curtail the decrease in vegetation biomass in the state. In addition, research and extension services should be strongly promoted in order to develop particular breed of seeds that can survive the drought in this period of food insecurity.

Keywords: Drought; rainfall variability; NDVI; vegetation condition index.

ACRONYMS

AVHRR	:	*Advanced Very High Resolution Radiometer*
ENSO	:	*El-Nino Southern Oscilliations*
GIS	:	*Geographical Information Systems*
IPCC	:	*Intergovernmental Panel on Climate Change*
NASA	:	*National Aeronautics Space Administration*
NDVI	:	*Normalised Difference Vegetation Index*
NIMET	:	*Nigerian Meteorological Agency*
NOAA	:	*National Oceanic Atmospheric Administration*
NPC	:	*Nigerian Population Commission*
VCI	:	*Vegetation Condition Index*

1. INTRODUCTION

Drought has a significant impact on civilization throughout history, and it is one of the most difficult phenomena to measure and even to define. Numerous drought indices and indicators have been developed in the last two centuries, based on the sector and location affected the particular application, and availability of data, among other factors [1]. Accordingly, drought can take multiple forms, including meteorological drought (lack of precipitation), agricultural (or soil moisture) drought, and hydrological drought (runoff or streamflow) [2-5].

The complexity of drought often results in a definition that is couched in general terms, such as a marked deficiency of precipitation that results in a water shortage or hydrological imbalance that affects some activity or group [6]. It is best represented by indicators that quantitatively appraise the total environmental moisture status or imbalance between water supply and water demand [3]. Civilization has struggled to develop early warning and other response systems to address drought problem, but the diversity of climates, range of sectors impacted, and inconsistency in available resources and data make drought assessment on a continental scale, let alone on a global scale difficult [7] and [8].

Drought is a normal part of climate, rather than a departure from normal climate [9] and the cumulative effects according to [10] are felt in other disasters such as desertification and famine; prominent in the Sahara and Sub-Sahara. Every continent has regions and climates that are susceptible to drought, including semiarid areas that are especially vulnerable to drought [11]. In Africa especially across the Sahara, drought impacts are largely economic; this is aggravated by the adverse climatic nature of the region affecting quite a number of African populations according to [12]. However, [13] have shown that fluctuations of rainfall has no direct influence of climatic variations in Kaduna State.

In a globally warmed world, the warming can intensify hydrological droughts and alter runoff timing from snowmelt, affecting water management decisions [14], and drought-affected areas will likely increase in extent and the vulnerability of semiarid regions to drought will also likely increase [15]. Although [16] are of the view that the use of snowpack predictions are essential tools for water resources management activities, such as hydropower energy production planning, irrigation and providing early flood warnings in changing climate conditions, these may not necessarily be applicable to the prevailing weather conditions in Kaduna state. As noted by [17][18], some countries are making efforts to adapt to the recent and projected changing climate conditions, particularly through conservation of key ecosystems, early warning systems, risk management in agriculture, strategies for flood drought and coastal management, and disease surveillance systems.

Furthermore, the effectiveness of these collaborative drought monitoring efforts is outweighed by lack of basic information, observation, and monitoring systems; lack of capacity building and appropriate political, institutional, and technological frameworks; low income; and settlements in vulnerable areas, among others [19] and [6]. These shortcomings have inhibited the development of an integrated Global Drought Early Warning. On the other hand, [20], [21], [22] have all shown that NDVI is closely related to biophysical parameters such as photosynthetical active radiation, leaf area index, biomass vegetation etc. and [12] also confirmed that seasonal and sub-seasonal signals of vegetation can be detected from NDVI data and consequently climatic variability related to El - Niño Southern Oscillations (ENSO). According to [23] desertification is one of the most serious problems facing northern Nigeria with dire economic consequences for the nation. The study conducted by [22] using 1km SPOT satellite imageries also indicated that desert encroachment which cuts across the Sahel is currently affecting most of the states in the northern part of the country, particularly the eleven states considered by the Federal Ministry of Environment in Nigeria as the frontline states. Hence, the need for this study using moderate spatial resolution satellite imagery across Kaduna state on the status of drought. Furthermore, [23] have shown that there is currently serious threat of drought in Nigeria due to the encroachment of desertification. The objective of this study is to assess drought across Kaduna state using NDVI from MODIS 250meter spatial resolution datataset as well as rainfall data covering the years between 2000 to 2014.

2. LOCATION AND GEOGRAPHICAL SETTING

Kaduna state is located between latitudes 9°02′ and 11°32′ north of the equator and between longitude 6°15′ and 8°50′ east of the prime meridian. Kaduna state is bounded to the north by Katsina, Zamfara and Kano states; to the west by Niger state, to the East by Bauchi and to the south by Plateau, Nassarawa and the Federal Capital Territory, Abuja (Fig. 1). The state has a land area of about 43,460 square kilometres, which makes it the largest in the northwest geopolitical zone and has about 4.7 per cent of the Nigerian land area [24], [25]. The longest distance by road from north to south is about 290 square kilometres and from East to West is about 286 square kilometres [24]. It has three major urban areas; Kaduna, Zaria and Kafanchan which are accessible by different classes of roads, railway lines and airports. Kaduna state possesses a striking variety of natural environment. The topography varies from the Kudaru ring complex hills in the East, to the wide valley plains of the river Kaduna in the west. The geology of the area consists of precambrian rocks of the basement complex. The topography constitutes of rolling lowland plain generally below 610 meters above sea level. This is not unconnected with the prolonged denudation of the basement complex rocks within the area. The area consists of older granites, schist, and quartzite in different compositions. The land gradually slopes down towards the west and the southwest and is drained by two dominant rivers i.e. Rivers Kaduna and Gurara [26].

The study area has an Aw type of Kopen's classification scheme [27] with two distinct seasons, a wet season in summer and a dry season in winter. The area is influenced by two distinct air masses that have much effect on the climate. The northeast trade winds, which are usually dry and dusty, are pronounced between November and March. This period is referred to as Harmattan. The second type is the moisture laden tropical maritime air mass that originates from the Atlantic Ocean [24]. The variations in the onset of rainfall are attributed to the fluctuations of the boundary between these two air masses. Rainfall is heavy in the southern part of the state and reaches an average of 500mm per month between April and September [26]. In the extreme north, the monthly average is 146 mm, while Kaduna metropolis receives a monthly average of 361mm. Temperature varies with season. The highest 31°C temperature is recorded in April while the minimum (16°C) is usually recorded during the harmattan season that is between December and January. The high evaporation during the dry season however, creates water shortage problem especially in Igabi, Giwa, Soba, Makarfi, Ikara and Zaria Local Government Areas [26]. As Kaduna state lies within the northern Guinea Savanna ecological zone, its vegetation is typically of woodland type and deciduous in character. The dominant tree species include *isoberline, doka, bridelis, terminalia, acacia, vitrex* etc. Grasses and shrubs occur in tussocks and the predominant family is the *androgenae*. The soil in most parts of Kaduna state falls under the ferruginous tropical soils. Most of the soils contain 30-40 percent clay at a reasonable depth, because of intensive leaching. The soils in the upland areas are rich in red clay and sand but poor in organic matter. The plains in Kaduna state have under gone considerable changes over the years due to combined actions of both physical and chemical weathering [26].

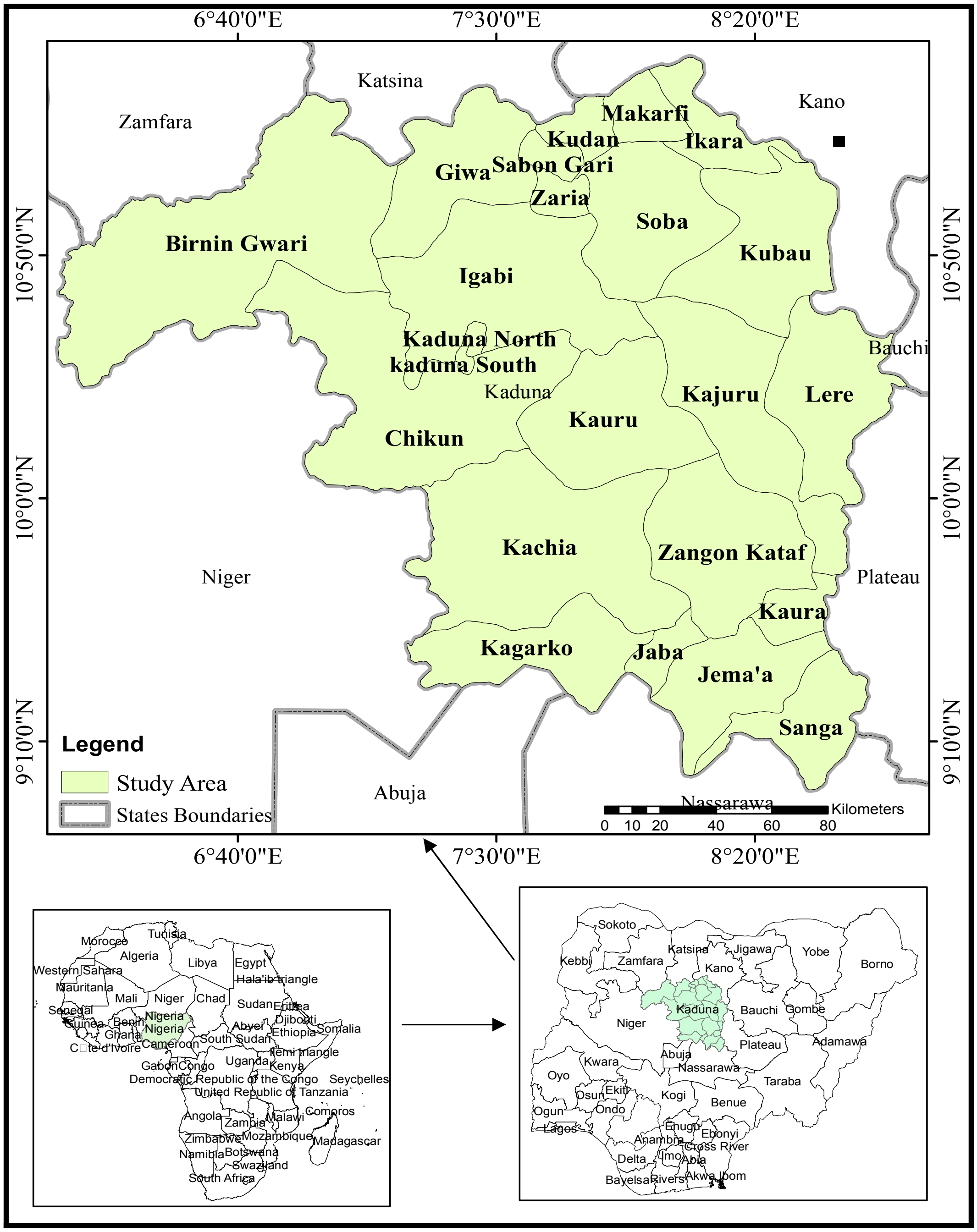

Fig. 1. The Study Area

3. MATERIALS AND METHODS

Datasets utilised in this study include a set of questionnaire, precipitation data and satellite imageries. The questionnaire was composed of well-structured open ended and close ended questions targeted towards people residing in Kaduna state particularly farmers. Perceptions of respondents on the decreasing rainfall in the state was captured through questionnaire. Rainfall data was sourced from Nigeria meteorological stations located in National College of aviation technology Zaria and Kaduna state International Airport for 15 years covering period between 2000 and 2014 (Table 1). Satellite imageries were acquired from Aqua MODIS Corporation from 2000 to 2009 and analysed using the Idrisi GIS and remote sensing software. The Aqua MODIS 250m spatial resolution is in the form of Normalized Difference Vegetation Index (NDVI) covering Kaduna state. While runoff were derived from the NDVI imageries, this NDVI is calculated as NDVI = (infrared - red) / (Infrared + red). This is and index for the quantitative measure which correlates highly with the quantity of living vegetative matter in any region, and derived simply using the red and near infrared wavelength bands of electromagnetic energy [28]. Vegetation Condition Index (VCI) is calculated as the ratio of the NDVI calculated for time series under study compared to its historical range (maximum minus minimum) [29]. All the NDVI and rainfall datasets in the time-series were re-composed into mean and a co-efficient of variation and each were calculated as:

$$COV = \delta/\mu \times 100$$

Where

COV = inter-seasonal-coefficient of Variation
δ = Standard Deviation

and

μ = Mean

Similarly, with a population of 6,066526 [26], the study adopted [30] formula to calculate sample size with 95% confidence level and 5% sampling error assumption.
Thus;

$$n = \frac{N}{1+N\,(e)^2}$$

Where

n = sample size,
N = Population size,
e = Level of significance (set at 0.05 for this study)

$$n = \frac{6{,}066526}{1+6{,}066526\,(0.05)^2}$$

$$= \frac{6{,}066526}{15165.6425}$$

= 400
n = 400

Therefore, the sample size used for this study is 400 respondents.

Table 1. Location and Source of Rainfall data utilised in the study

Source of Rainfall Data	Longitude	Latitude
National College of Aviation Zaria.	11° 8′ 10″	7° 41′ 15″
Kaduna International Airport, Kaduna	10°41'26.99"	7°19' 7.20"

Table 2. Socioeconomic Characteristics of Respondents

Sex	Frequency	Percentage (%)
Female	159	39.75
Male	241	60.25
Total	400	100
Educational Qualification		
Primary education	32	8
Secondary education	146	36.5
Tertiary education	183	45.75
Postgraduate	39	9.75
Total	**400**	**100**

4. RESULTS AND DISCUSSION

4.1 Socioeconomic Characteristics of Respondents

Although satellite imageries are the primary data used in this study, questionnaires were also designed to get views from respondents in order to supplement the analysis of the datasets. The characteristics of the respondents utilised is shown in Table 2.

The study made use of about 60% male respondents during the survey while the female gender made up of just about 40%. Although the gender was skewed towards the male side, the female gender was reasonably captured. The lopsidedness of the gender can be attributed to the fact that the female folks in the study area are in most cases indoors while the men have the responsibility of going out to fern for the families. Thus it was easier to access the males than the females.

Similarly, the educational background of the respondents is Important when it comes to understanding the concept of drought and its occurrence. Table 2 also indicates that majority of the respondents (about 46%) had tertiary education. This means that this fraction of respondents have a high propensity to give accurate, credible and reliable answers. In addition, about 36% of the respondents possessed secondary school education. While about 10% had postgraduate education, just about 8% had at least primary education. This implies that all the respondents were literate.

4.2 Rainfall Variability in Kaduna State

Fig. 2 shows comparative rainfall variability for the two stations in Kaduna state. The trend in Kaduna metropolis and environs show a steady increase from the year 2000 to 2003 (1234 mm, 1185.8 mm, 1317 mm, and 1642 mm) from where it slides down continuously to its lowest in 2008 (752 mm). From 2008 the pattern has been inconsistent with little increases and decreases until in 2013 where the highest amount of rainfall (1753 mm) was recorded and then dropped again in 2014 (1623.6 mm). The level of consistency in the rainfall from the two stations is minimal with a decreasing trend from 2003 to 2008.

Similarly, Zaria and its environment have recorded a more inconsistent rainfall pattern making it very difficult to predict the rainfall. While the highest amount of rainfall received in Zaria was in the year 2012 (1323.1 mm), Kaduna recorded it's highest in 2013 (1753 mm). Similarly, the lowest amount of rainfall recorded for both Zaria and Kaduna was in the year 2008 but with dissimilar amounts 787.1 mm and 752 mm respectively; implying that Kaduna station has both recorded the highest and the lowest amount of rainfall within the period under review. However, the levels of variability differ from place to place. The total annual rainfalls received in both places differ considerably with Kaduna having the highest (18643.4 mm) and Zaria having the lowest (16412.9 mm). Kaduna state therefore, recorded a mean total annual rainfall of 17528.2 mm between 2000 and 2014.

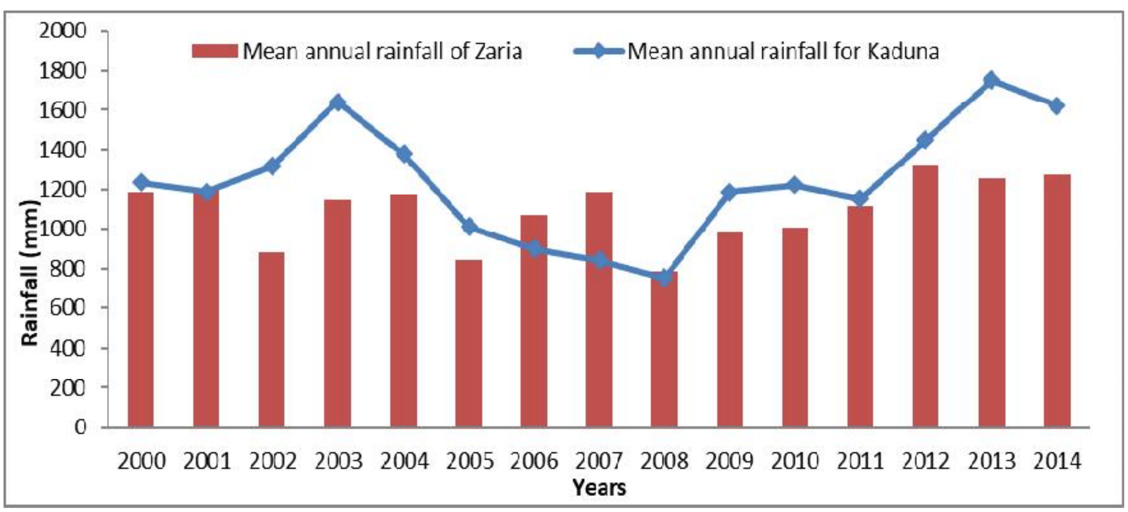

Fig. 2. Comparative line and bar graphs for annual rainfall from Zaria and Kaduna stations

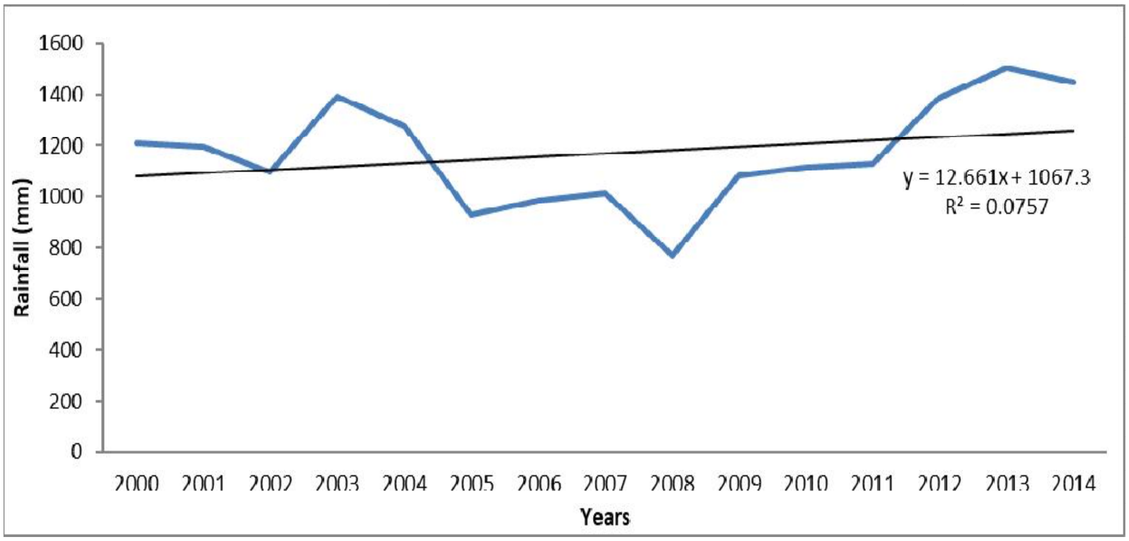

Fig. 3. Annual rainfall for Kaduna State

Fig. 3 shows the annual rainfall trend for Kaduna state. This was derived by computing the yearly total rainfall for Zaria and Kaduna for the period under review. Consequently, the lowest amount of rainfall recorded in Kaduna state as whole was 769.55 mm in 2008, while the highest amount of rainfall recorded for the same period in Kaduna state was 1502.9 mm in 2013. Thus, the trend indicates that rainfall decreased between 2003 and 2008 across the state. However, from 2009 to 2013 there was an inconsistent increase in rainfall recorded followed by a slight decrease in 2014.

4.3 Surface Runoff from NDVI Imageries

From the NDVI imageries, the amount of runoff was derived. Figs. 4, 5 and 6 show the amount of runoff (surface overflow) in the study for the year 2000, 204 and 2009 respectively. From the 2000 imagery the runoff for the year was between 1 mm – 73 mm from an annual rainfall of 1194.1 mm. In 2004 the runoff decreased from 72.50 mm in 2000 to just about 62.00mm in 2004. Fig. 5 shows a decrease of 6.5mm accounting for a 9.4% change in runoff.

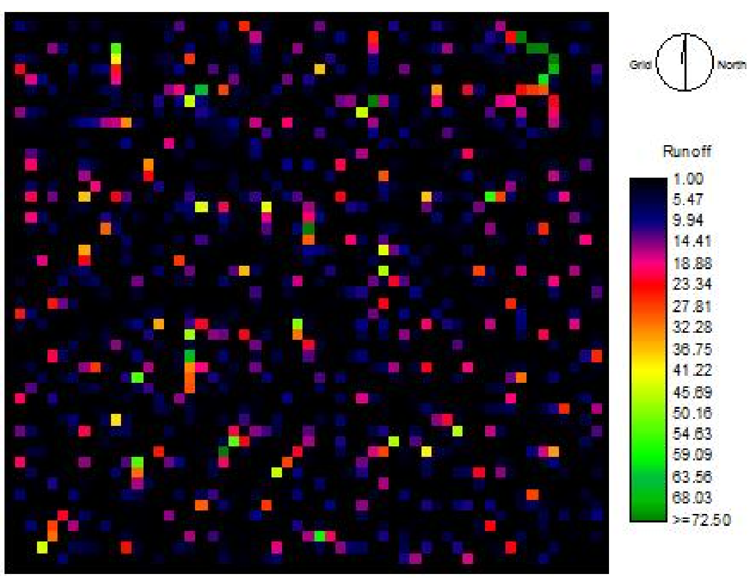

Fig. 4. Runoff based on NDVI image in 2000

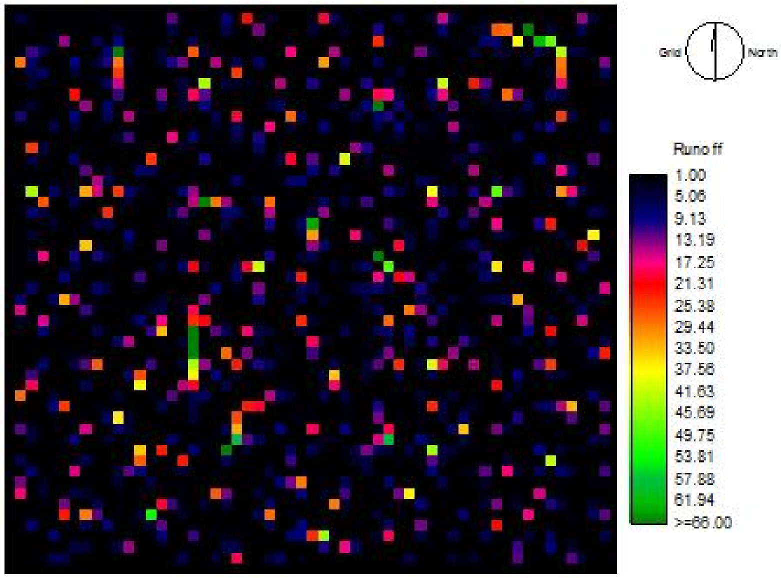

Fig. 5. Runoff based on NDVI image in 2004

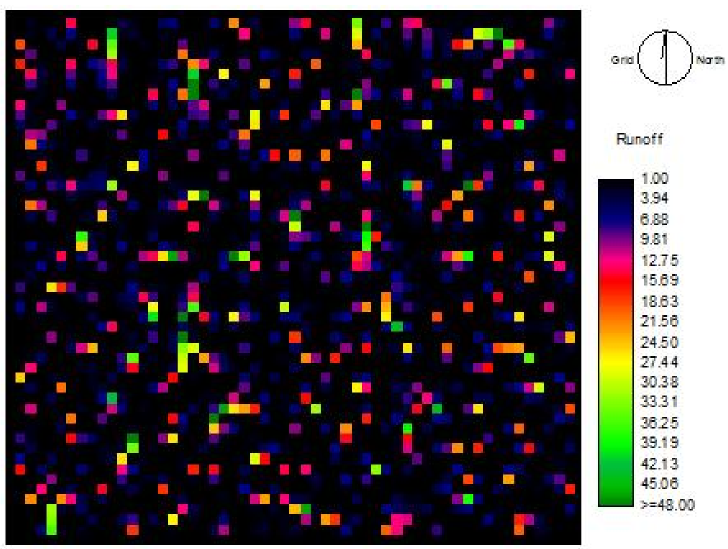

Fig. 6. Runoff based on NDVI image in 2009

Thus, from 2004 to 2009 run off reduced by 18 mm (i.e. from 66mm to 48mm respectively). This is higher compared to 2000 to 2004 with 6.5 mm. Again from 2000 to 2009, runoff reduced from 72.50 mm to 48.00 mm (Fig. 6); a difference of 24.5 mm.

However, of particular interest is the differences between the changes from 2005 to 2009 and that of 2000 to 2004. This seems to correspond to the rainfall and NDVI trends shown in Fig. 3.

4.4 Classification of Annual NDVI Mean Image

The annual NDVI mean image was classified based on the broad land cover and vegetation types in the state (Table 3). The classification indicates that the most dominant vegetation type in Kaduna state is scanty vegetation and grasses (54.25%), medium vegetation (3.2%), bare surfaces (12.64%), moderate vegetated surfaces (0.17%) and water bodies (0.13%). These are however, spread across (Fig. 7).

In deriving the short and long term changes in vegetation NDVI, the imageries were grouped into quasi 5-years and 10-years periods respectively. This is to minimise cloud contamination of the dataset. Thus, the mean NDVI of the end years of each quasi time period were calculated (after [31], and is illustrated in Table 4. Fig. 8 shows the short-term change (2000-2004) in vegetation NDVI across Kaduna state.

Table 3. Classification of Vegetation (NDVI)

Vegetation Class	Size (Hectares)	Percentage
Scanty Vegetation	4,977,432	54.25
Medium Vegetation	2,984,018	32.52
Bare Surface	1,159,816	12.64
High Vegetation	27,275	0.30
Moderate Vegetation	15,232	0.17
Water Bodies	12,146	0.13
Total	**9,175,918**	**100**

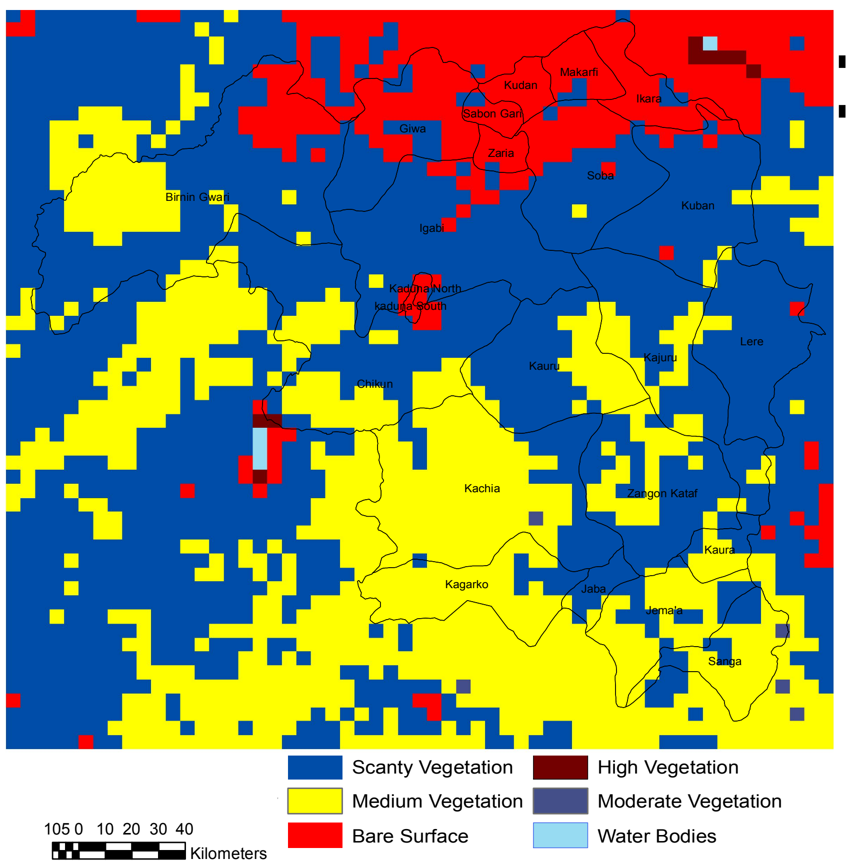

Fig. 7. Classified Vegetation NDVI Map of the study area

Table 4. Absolute and relative changes from annual NDVI images

Annual mean images (end-point years)	Quasi 5-year period (5-year period)	Quasi 10-year period (10-year period)
2000/2001 2004/2005 2008/2009	2004/2005 Minus 2000/2001 (2000 to 2004)	2008/2009 Minus 2000/2001 (2000 to 2009)

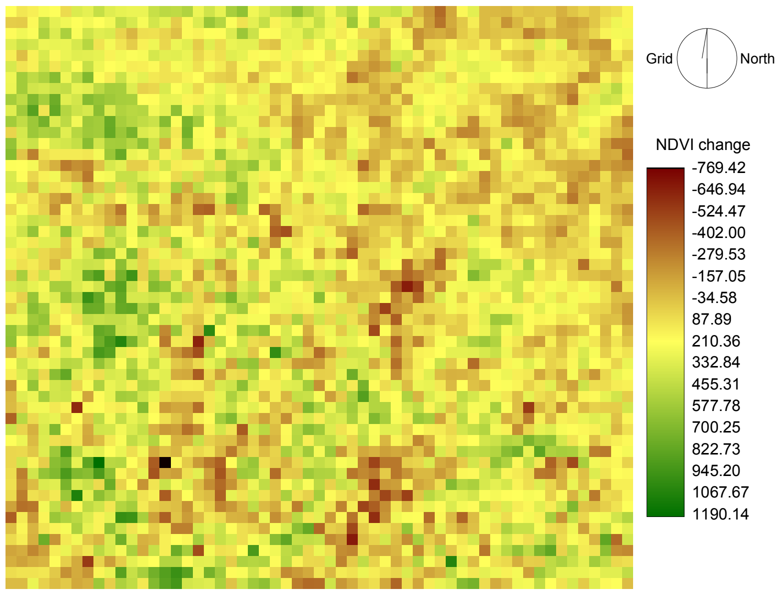

Fig. 8. Quasi 5-year change image (2000/2001 to 2004/2005)

Table 5. Descriptive statistics from annual NDVI mean composites

Annual Mean Composite images	Min. Val.	Max. Val.	Mean	SD
Quasi-5 years	-769.42	1990.14	610.36	1951.30
Per-pixel change	-1584.54	1584.55	0.005	2240.89
Proportionate long term change	-0.41	0.38	-0.015	0.56

To enhance a more visual comparison of the images, the annual mean NDVI composites of the end point years were classified on an interval of three NDVI units using the information from the minimum and maximum value range (Table 5).

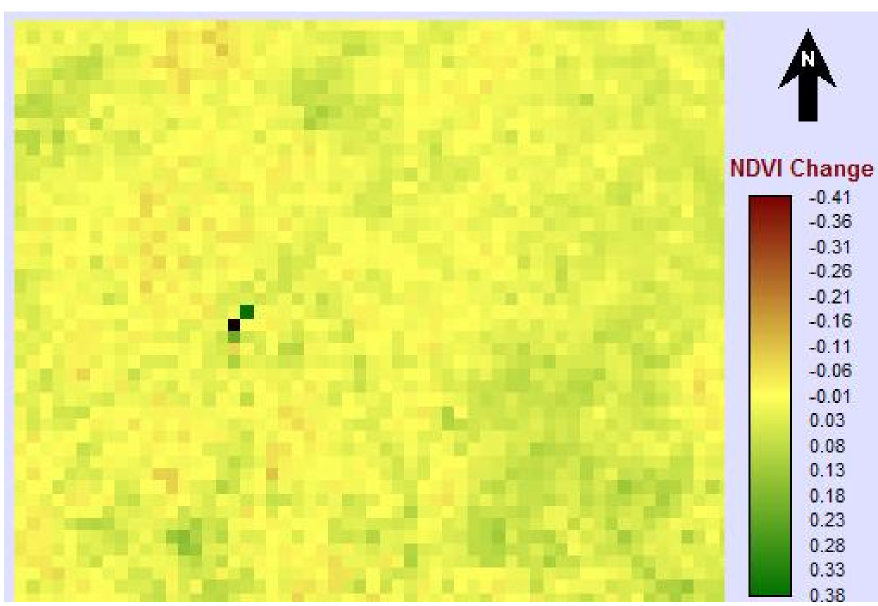

Fig. 9. Proportionate long term change image

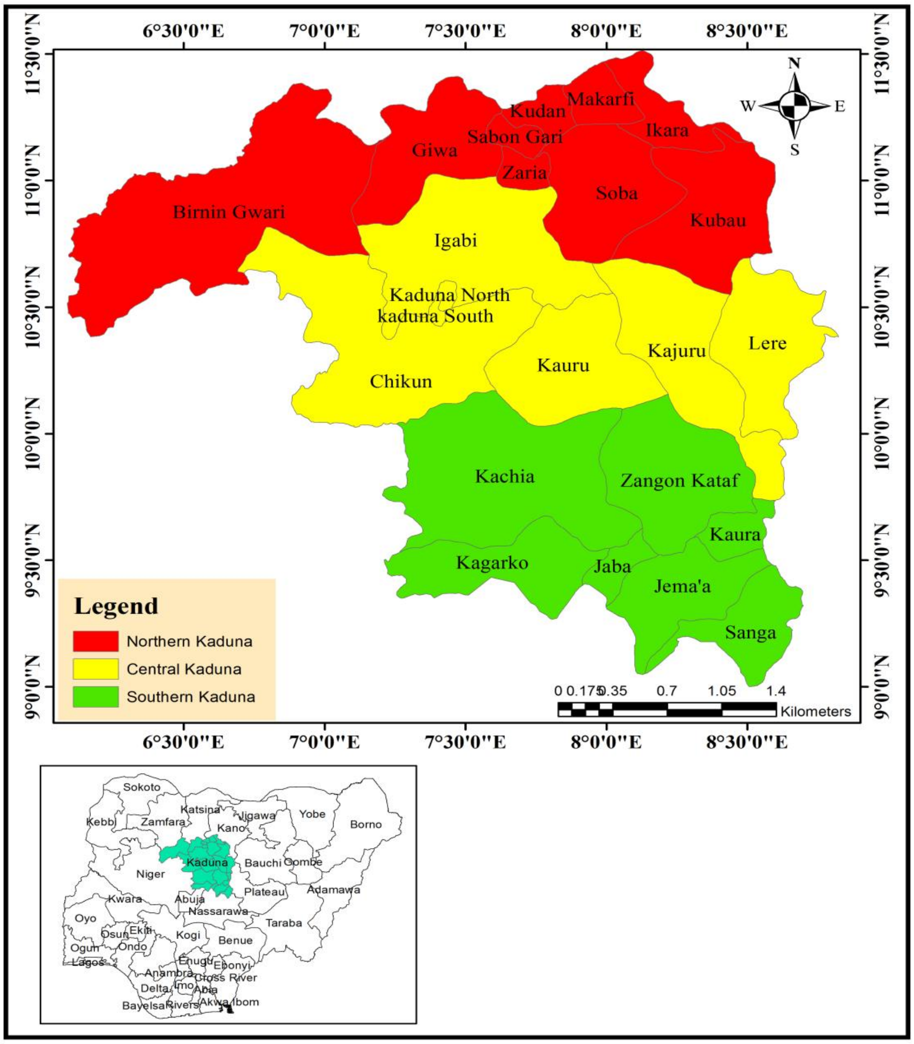

Fig. 10. Study area showing the Southern, Central and Northern part of Kaduna State

4.5 Relative and Absolute NDVI Changes

To derive short term change image, the original residual image for the quasi five year change (2004/2005) was divided by the 2000/2001 NDVI image to derive a 'per-pixel' change imagery to show the relative changes between 2000 and 2004 (Fig. 8) which shows the relative changes of the quasi five-year period. The NDVI units in northern Kaduna area are of lower values indicating lesser vegetation biomass compared with the NDVI values in southern part of Kaduna with high values indicating more vegetation biomass. The similar procedure was applied to the quasi 10-year period (Fig. 9) to derive the proportionate long-term changes from 2000 to 2009 (Fig. 9. [31].

Table 5 shows descriptive statistics of the mean NDVI composite images (quasi-5 years) with a mean of 610m while the change per pixel was about 0.005m. However, the longer-term change (2000-2009) indicated a negative vegetation biomass change of -0.015 within the study area.

On the other hand, the view of the respondents (Table 6) indicate that (85%) of them observed that the rainfall was decreasing in some locations in the northern part of Kaduna state (Fig. 10). This is likely to correspond with the views of [8] [32] on the desertification problem particularly in the northern states. Accordingly, it corresponds with 11% of the respondents view of observed decreasing rainfall in central Kaduna. However, 4% of the respondents are of the view that they have not seen much changes with regards to the decreasing rainfall in Southern part of Kaduna although many parts of the state witnessed some episodes of decreasing rainfall largely beyond dry spells. Furthermore, 60% of the respondents are of the view that decrease in rainfall occurred in the form of late onset, light showers and early cessation which also corresponds to variations of NDVI and rainfall in the study area (Fig. 11). And as part of adaptation strategies for the people they are of the view that certain genetically modified tress of economic importance should be planted by people in different localities across the state.

Table 6. Respondents' views on Decreasing Rainfall

Areas of decreasing rainfall	Frequency	Percentage
Northern Kaduna	341	85.25
Central Kaduna	44	11.00
Southern Kaduna	15	3.75
Total	**400**	**100**
Observed declined in rainfall		
2000-2004	54	13.50
2005-2009	241	60.25
2010-2014	105	26.25
Total	**400**	**100**

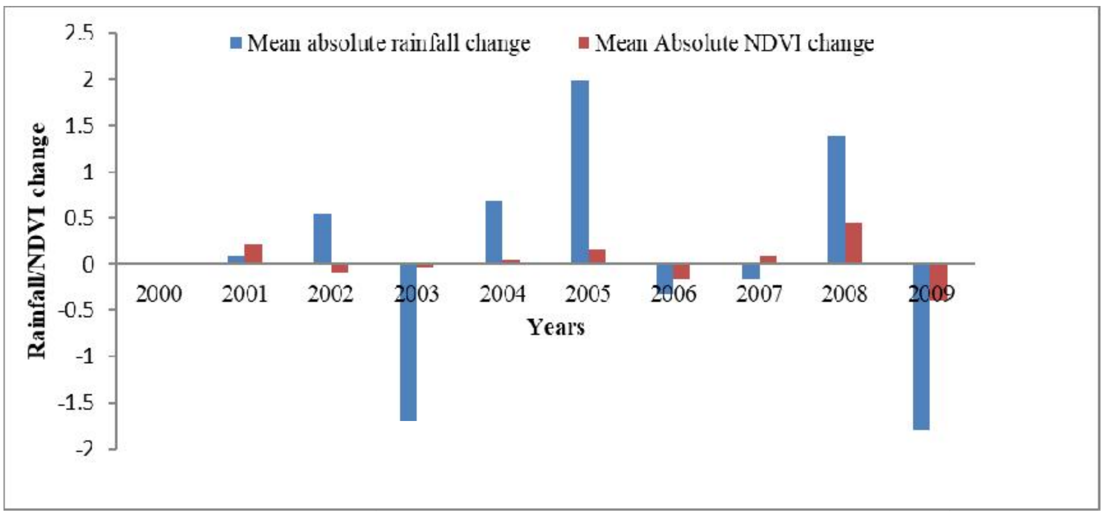

Fig. 11. Mean absolute rainfall and NDVI

Table 7. Vegetation Condition Index of Kaduna

Group	Range of values	Price Related Differential	Coefficient of Dispersion	Coefficient of Variation
				Median Centered
2000	.000	1.000	.000	.
2001	.000	1.000	.000	.
2002	.000	1.000	.000	.
2003	.000	1.000	.000	.
2004	.000	1.000	.000	.
2005	.000	1.000	.000	.
2006	.000	1.000	.000	.
2007	.000	1.000	.000	.
2008	.000	1.000	.000	.
2009	.000	1.000	.000	.
Overall	.997	1.010	.074	10.2%

In furtherance to this assessment of drought in Kaduna state, and considering that Vegetation Condition Index (VCI) is as an indicator of the magnitude of drought, the VCI was computed as ratio of the NDVI collected in a given period compared to its historical range (maximum minus minimum) derived over several years of record (as in the case of the time series of this study).

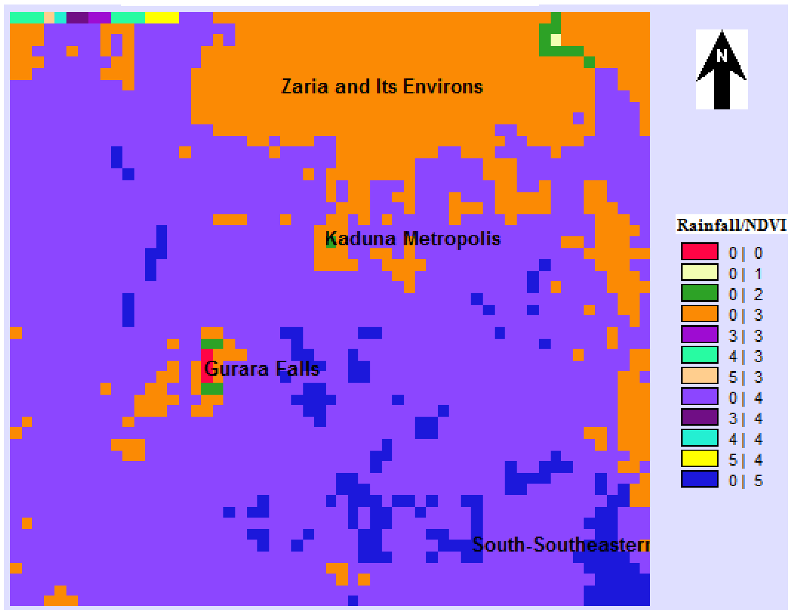

Fig. 12. Cross-tabulation of rainfall/NDVI across Kaduna state

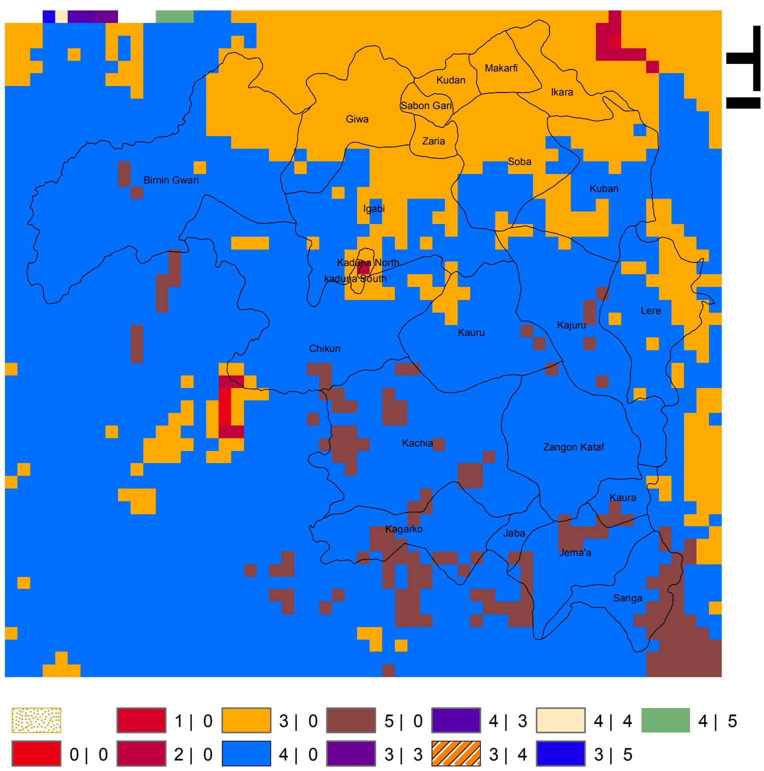

Fig. 13. Cross-classified image of rainfall and NDVI

According to [29] possible VCI values range from 1 to 100. VCI values of 35% and under indicate drought although long-term changes in NDVI data have been evaluated in several studies with some inconclusive results. This according to [12] is as a result of differences in the tools used, data processing techniques and the length and time of the analysed time series. Table 7 thus, shows the vegetation condition index across Kaduna state. As earlier mentioned by [29] VCI ranges between 1 to 100% such that a vegetation condition index of 70% indicates very luxuriant vegetation. Accordingly, a VCI of 35% and less indicates drought. Hence, Table 7 showing the VCI for Kaduna state of 10.2% points to drought being experienced in the state. Furthermore, based on another study conducted across Sokoto Region using EVI dataset from MODIS by [32], both vegetation EVI and rainfall recorded high coefficient of variation over the southern parts of the region including some parts of Kaduna state, although some of the changes were without definite pattern with regards to drought. However, [33] showed that the Southwest and Southeast regions of Nigeria experience negative change, while the Northern Nigeria experiences little or no change in vegetation greenness.

4.6 Cross-Tabulation of Vegetation Change Based on Rainfall/NDVI

Figs. 12 and 13 show the cross tabulation of rainfall and NDVI. The result was three broad major categories; little change, moderate change and high change. Three major classes 0:3, 0:4 and 0:5 classes were identified and classified as little, moderate and high/broad change respectively (Fig. 14). The little change class covers about 6.5 million hectares of land. This class is predominantly grasses and shrub whose growth (size/height) remains relatively low despite positive change in rainfall. Therefore, increase in rainfall is likely to produce little observable growth in NDVI. The moderate change class covers greater part of northern Kaduna with isolated parts to the west and eastern part of Kaduna covering about 2.1 million hectares. This class is covered by short grasses and well dispersed trees of average sizes and heights. This vegetation class is very sensitive to even a little amount of moistures such that a little rainfall that will cause grasses to sprout up covering the entire area thereby increasing the spectral signature of vegetation biomas to be recorded by satellite sensor.

Fig. 14. Classified NDVI change image

The change in these parts is sharp and recognisable because the entire area was initially dry and bare. The broad/high change class exists in clusters found mostly in southern part of the study area. This covers just about 523,286 hectares of the entire Kaduna state. This class comprises of forests with tall trees of different sizes. Some of these trees are deciduous in nature but as soon as the rains set in they are covered with dense leaves thereby increasing the chlorophyll content to allow better spectral signature to be recorded by satellite sensor. During the dry season however, these areas are recorded with minimum NDVI values.

5. CONCLUSION

Results from this study were based on analysis on NDVI and rainfall datasets and views from respondents within the study area. It can be concluded that rainfall variability across Kaduna state affected annual precipitation generally. One of the notable factors affecting the decrease in annual precipitation which varies from year to year and very visible especially in 2002, 2005 and 2008 are as a result of the interplay of other climatic elements such as temperature, ENSO, relative humidity etc.

On the other hand, with a VCI of 10.2% for Kaduna State this may suggest another reason why even part of the forested and woodland areas in the southern Kaduna state is affected by desertification due to unsustainable management which poses threat of drought, and in particular, the northern part of Zaria and environments although more studies is required to re-confirm this. Furthermore, as part of adaptation strategies for the people it is recommended that certain genetically modified tress of economic importance to the people be planted in addition to mass tree plantations and shelterbelts programmes which should be emphasied, and where necessary, more funding injected to the ecological funding programme of the country. Such funds when provided should be monitored for proper utilisation across the country so as to combat this menace. Very high spatial resolution satellite data should be utilised as recommendation to detect certain species of plants under the threat of desertification and drought in Kaduna state.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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