Vegetation Cover Recovery after Rural Population Displacement: Evidence from Sambisa Forest High Vegetation Index in North Eastern Nigeria

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Abstract

Vegetation in semi-arid zones is identified as the most vulnerable and susceptible to human disturbances and climatic variations. In recent years there have been varying postulations on the rate of depletion of vegetation in semi-arid zones and its ability to recover under favourable climatic conditions and minimal anthropogenic interferences. This study uses 16 years (2003-2019) decadal Normalized Difference Vegetation Index (NDVI) data to analyse trends using linear regression to test for the relationship between annual rainfall and NDVI. Results showed that there has been an increase in vegetation in the study area especially in areas mostly affected by the Boko Haram insurgency such as the Sambisa Forest and its environs by 0.9km^2 per year over a 16 years period (2003-2019). A regression model between annual rainfall and NDVI yielded R^2 of 0.2 suggesting that climatic conditions alone cannot explain for the sudden increase in vegetation but rather a reduction in human interference is contributing to the rapid regeneration of vegetation and forested areas.

Keywords: Vegetation, Boko Haram, Human Disturbance, Climate variability and Sambisa Forest

Introduction

Despite international goals to improve land management, pressure on resources has increased in recent years (UNEP, 2007). Climate change, global rapid population expansion, unprecedented land-use changes and economic developments are major drivers of global land resource depletion and ecosystem degradation, as land use decisions are not recognizing non-economic ecosystem functions and biophysical productivity limits. The increasing global vegetation depletion and degradations is resulting in not only ecological imbalance but also consequent life quality degradation (Muoghalu, 2008, FAO, 2010). The high biodiversity loss in recent past is the major pressing problem of the biosphere. Land use/land cover changes is seen as main cause of species extinction (Slingenberg *et al*, 2009). Catastrophic ecosystem transitions have been documented in several arid and semi-arid regions of the World. These changes often involve the loss of perennial grasses and their replacement with disperse shrubs/herbs or bare ground (Walker, 2002, Mirzabaev *et al*, 2019, Food and Agricultural Organization, 2019). According Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA, 1999) 60% of dry-lands is already degraded, which poses a serious threat to the ecological functions of species, genes and human welfare resulting to an estimated economic value loss of about $42 billion annually.

Since 1960s, African dry land has been the focus of intensive scientific research inspired by recurring drought, human intervention, long term degradation and chronic vulnerability. The studies conducted on African dry land vegetation and ecosystem at large report a divergent finding on West African Sahel vegetation dynamics. United State Geological Agency Survey on land use and land cover changes in West Africa shows significant decline in the past 40years in the amount of West African Sahel natural vegetation. While other studies on African dry land ecosystem reports recovering from drought of 1970s and 1980s, as against the mainstream paradigm of irreversible land degradation in Sahel. The greening scenario is reported in a number of studies (Sequist *et al*, 2008; Ekludh & Olsson, 2003; Anyamba & Tucker, 2005, Heuman *et al,* 2007, Hellden & Tottrup, 2008, Ecklundh & Olsson, 2003, Tene kwetche, 2012, Herrmann et-al, 2005, Olsson *et al*, 2005). These studies reported a surprising increase in Normalize Differential Vegetation Index (NDVI) result in West African Sahel between 1982 and 2008 as against the orthodox view of progressive degradation. Most of the studies attributed the greening of the Sahel to increase rainfall after the 1980s drought, using almost similar methodology. It was generally agreed during Sahel greening symposium in Gustav-Stresemann Institution, Bonn in 2010 that vegetation dynamics in dry lands are not fully understood (Heidi Humer-Gruber, 2010).

It is of great interest to notice that understanding the impact of human activities and climate variability or other natural factors remain a major challenge in ecological disturbance studies. The recent *Boko Haram* crises in North Eastern Nigeria forced thousands of rural dwellers that were depending on environmental resources for their livelihood out of their localities. This set aside vast part of North East Nigeria completely out of production for almost a decade. According to Reuters (2015), at the start of 2015, Boko Haram controlled around 20 local government areas out of 27 LGAs, a territory that is the size of Belgium. Monitoring ecosystem response in these areas will therefore enable quantifying human impact. The main thrust of this study is to examine how vegetation cover in North Eastern Nigeria (the Sahel margin) is responding to increase human pressure and climate variability, as different ecological zones respond differently to disturbance.

Description of Study Area

The study area covers Sambisa Forest and its vicinity of North eastern Nigeria. Located between Lat 11° 15′ 0″N to 11° 00′ 0″ N and longitude 11° 15′ 00″E to 13° 30′ 00″E, falling into administrative boundaries of some local government areas of southern and central Borno state (Askira-Uba, Chibok Bama, Damboa, Gwoza Konduga), Northern Adamawa (Gombi, Madagali and Michika) and southern Yobe State (Gujba and Gulani). The Sambisa covers an area of 518 km^2 (Fig. 1). The climate of the area is dry climate characterized with large diurnal temperature falling to as low as 21.5°C during cold dry season and also rising to as high as 48°C during hot dry season. The rainfall pattern is semi-arid at Northern part and Sudan savannah at the southern part, receiving mean annual rainfall range of 400mm to 800m. The vegetation is typical of the Sudanian Savanna, although the large-scale human activities is turning the northern part of the forest to Sahel savannah like. The major trees and bushes in the forest include *tallow, rubber, wild black plum, birch, date palm, mesquite, acacia, monkey bread, red bushwillow, baobab, jackal berry, tamarind and terminalia* (Mbaya and Malgwi 2010). According to Birdlife International (2015) the forest is habitat to about 62 bird's species including the *guinea fowl, francolin, village weaver, Abyssinian ground hornbill, Arabian bustard, Savile's bustard etc.* The forest was also thought to be the last remaining site of the ostrich in Nigeria.

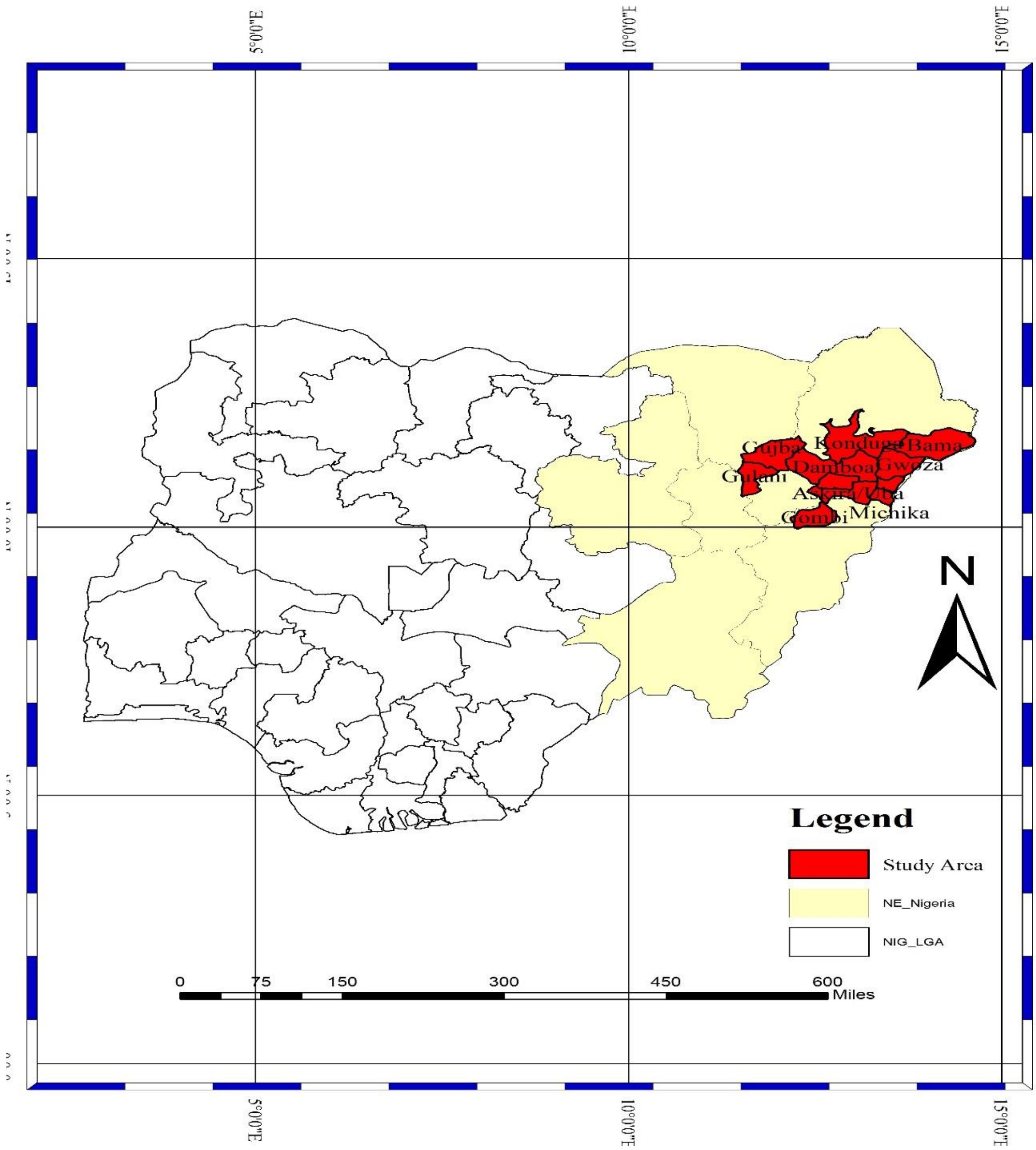


Fig. 1. Map of the Study area

Methodology

A variety of materials were used to collect the required data. AVHR and MODIS NDVI data set were downloaded from United State Geological Survey website. The images were pre-processed, rectified and geo-referenced to the UTM map projection (zone 32), Minna Nigeria horizontal datum, and Clark 1880 ellipsoid, using remote sensing and GIS software. The monthly rainfall of 2003 to 2017 from Maiduguri, Potiskum and Nguru NiMET stations, NEDZAP, and Maiduguri International Airport weather stations

Table 1: Data used and source

1.0 Data Used	Source
2018 high resolution google images	Pro4.4 google earth software
Decadal AVHR and MODIS NDVI	USGS website
Rainfall records of 2003 to 2017	NiMet

High resolution google images, 2018 decadal AHVR and MODIS NDVI model were generated through the use of Pro4.4 google earth software from USGS website as presented in Table 1

Data Analysis

The NDVI and LSWI were calculated from the surface reflectance of Red, NIR, and SWIR bands of Landsat TM/ETM sensor with the following formulas:

$NDVI = (NIR-R)/ (NIR +R)$

$LSWI = (NIR-SWIR)/ (NIR +SWIR)$

The NDWI is expressed as follows (McFeeters 1996):

$$NDWI = \frac{\text{Green}-\text{NIR}}{\text{Green}+\text{NIR}}$$

Where NIR, R, and SWIR are the reflectance in the NIR, Red, and SWIR bands, respectively, while Green is a green band such as TM band 2, and NIR is a near infrared band such as TM band 4.

NDVI values range from -1 to 1

Where

NDVI< 0 = water bodies

0 > NDVI < 0.2 = Less vegetation

0.2 > NDVI <0.4 = Medium vegetation

0.4 > NDVI < 0.8 = High Vegetation

NDVI > 0.8 =Rainforest

Descriptive statistical tools such as mean, maximum, minimum, skewedness, coefficients of variance, standard deviation and Kurtsis analyzing temporal trend distribution pattern of the wetland's component during the study period. Linear regression inferential statistical were used in analyzing temporal variability trend pattern of the wetlands components.

The Vegetation index temporal variability trend was measured using linear regression trend

Linear regression

$Yt = f(T)$

Where Yt = high vegetation index

T = time

Explicit for

$Y_t = \lambda_o + \lambda_1 T$

i. Correlation statistical tool was used to measure the linear relationship between climatic factors and wetlands component. Total annual rainfall of Kano, Jos, Potiskum, Nguru, downstream (Nguru), upstream (Kano, Jos), August rainfall of Jos, downstream temperature, wetlands components memory were correlated with wetlands components (size, vegetation and water area).

$$r = \frac{N\Sigma XY - \Sigma(X)\Sigma(Y)}{\sqrt{[N\Sigma X^2 - \Sigma(X^2)][N\Sigma Y^2 - \Sigma(Y^2)]}}$$

where;

N = Number of Pears data

X = x-score and

Y = y-scores.

Multivariate linear regression statistical tools were used in estimating the impact of climatic factors on High vegetation. The model of the estimated relationship between dependent and independent variables.

Result of the Findings

Impact of Boko-haram incidence on vegetation

The impact of Boko-haram insurgency on vegetation cover was estimated by comparing the high vegetation index of pre-Boko-haram period (2003-2010) and Boko-haram period vegetation index (2011-2019). The results of the Sambisa Forest high vegetation area analysis are presented in Table 2 and figure 3.

Table 2: Descriptive Statistics of Sambisa Forest High Vegetation Canopy Area (2003-2019)

	Mean	**Max**	**Min**	**Stdv**	**C.V**	**Skewn**	**Kurt**
High Vegetation area (km^2)	6.01	22.7	0.35	6.1	36.8	1.5	1.8

Source: Authors' Analysis.

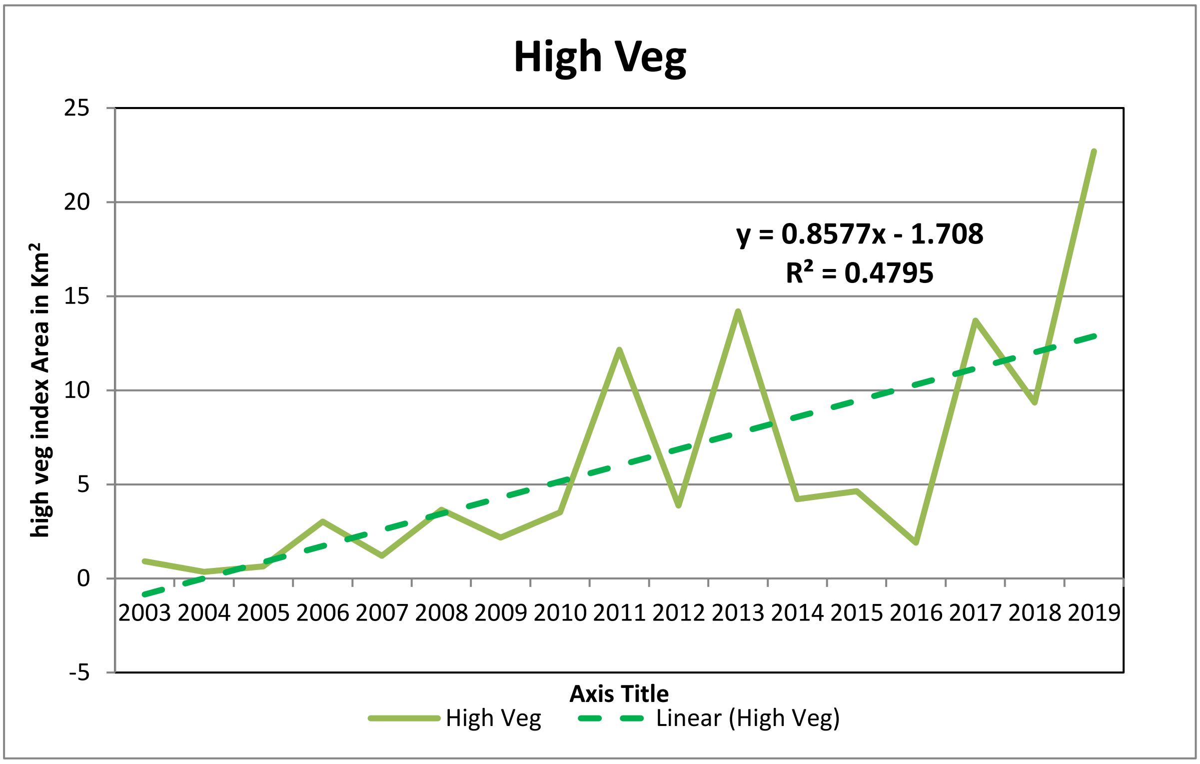
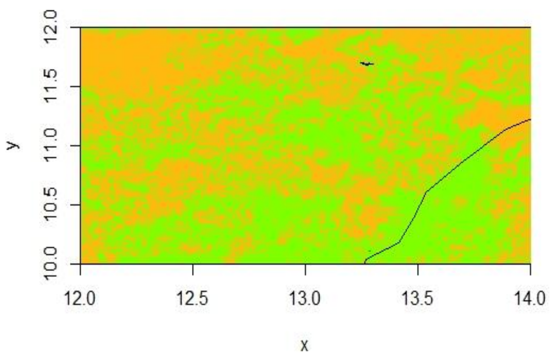
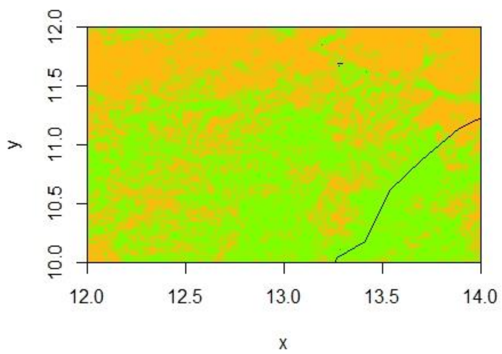


Figure 3: High vegetation area temporal variability trend (2003-2019)

Source: Authors' Analysis.

The results of the high vegetation area presented in Table 2 reveal that higher vegetation area fluctuates from 0.35km^2 in 2004 to maximum of 22.7km^2 in 2019. Rapid recovery was observed from 2011 to 2019. The period recorded a dramatic increase above the mean, but a decrease of 35%, 30%, 27% and 68% below the mean was observed in year 2012, 2014, 2015 and 2016 respectively. A surprising increase of 378% from 9.35Km^2 in year 2018 to 22.7km^2 in 2019 high vegetation canopy area was observed. Kurtosis of 1.8, throughout the study period reveals leptokurtic, meaning that the high vegetation canopy area temporal trend during the study period was somewhat sudden and shows dramatic fluctuation within the period. The results of high vegetation area size temporal trend reveal a variability coefficient of 36.8%, at 0.9 km^2 annual increasing trend. The photos of annual vegetation index of study area is presented in fig 2.





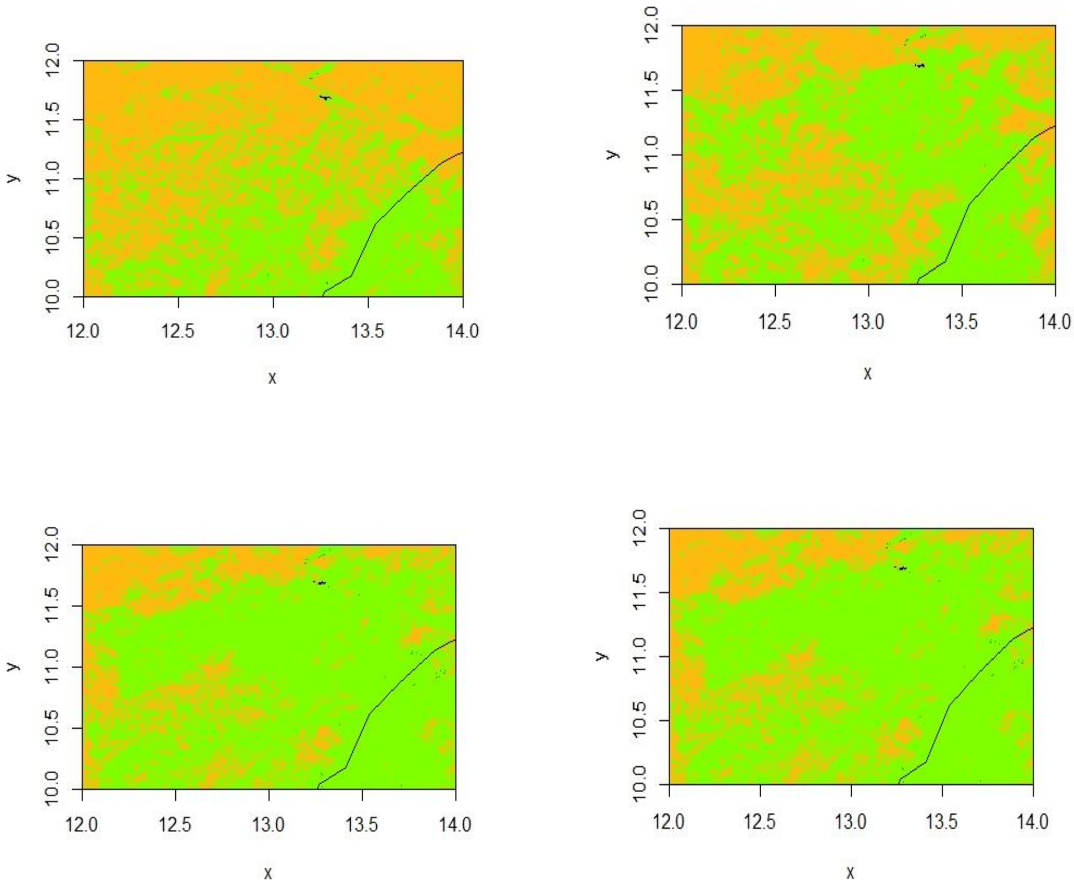


Fig 2: NDVI Photos of 2003, 2007, 2012, 2015, 2017, 2018, Showing the Vegetation index of pre, during and post Boko haram period.

Rainfall variability trend and pattern

The climate of the study area is Sudano-Sahel type characterize with a very high variability (Jajere *et al*, 2022; Maria *et al*, 2005). The results of the monthly rainfall distribution and annual variability is presented in Table 3 and figure 4.

Table 3: Monthly rainfall distribution in the study area of 2003 to 2017.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Mean	0	0	0	8.3	25.1	93.3	170.6	206.6	106.8	19.4	0	0	630.1
Max	0	0	0	60.9	75.2	371.6	297.2	295.3	210.9	81.7	0	0	925.7
Min	0	0	0	0	1.6	8.5	79.1	118.4	31	0	0	0	454.1
Stdv	0	0	0	17.3	23.5	88.8	72.7	54.7	51.9	31.2	0	0	141.3

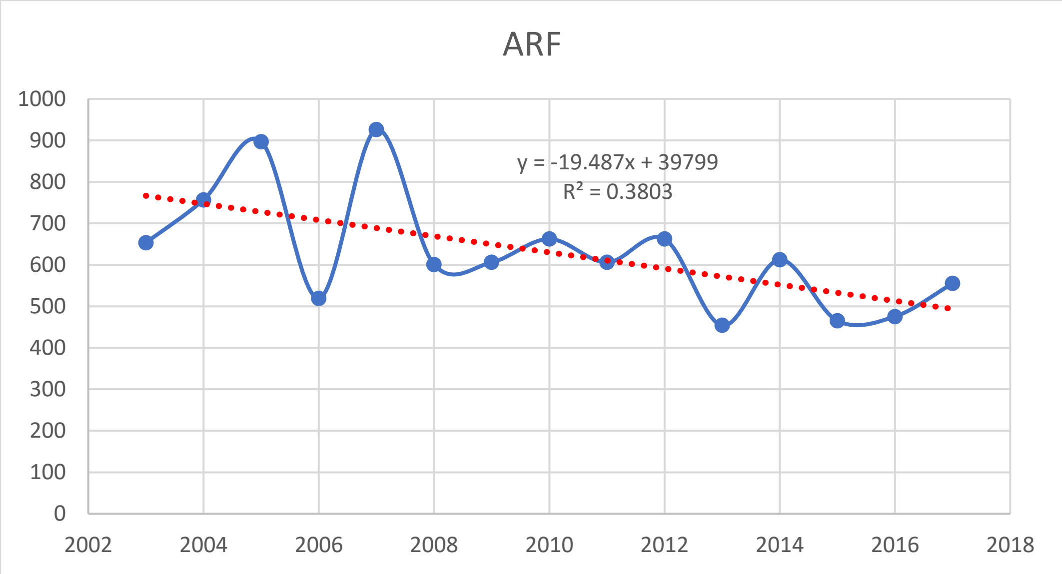


Fig 4: Annual rainfall variability trend in the study area between 2003 and 2017

The results of annual rainfall variability trend during the study period revealed a negative trend in annual amount. An annual decreasing trend of 19mm was observed, which revealed a shift in the study area rainfall to a dry climate. The result of variability trend revealed a larger annual variability of 38%. The results of descriptive statistics of the monthly rainfall distribution in Table 3 revealed total annual rainfall fluctuate from maximum of 928mm to 454mm as revealed by standard deviation value of 141. On monthly basis July and August are wettest months as are only months that records above 51mm thresh whole through the study period. June and September rainfall falls as low as 9mm and 31mm respectively.

Relationship between high vegetation index and rainfall

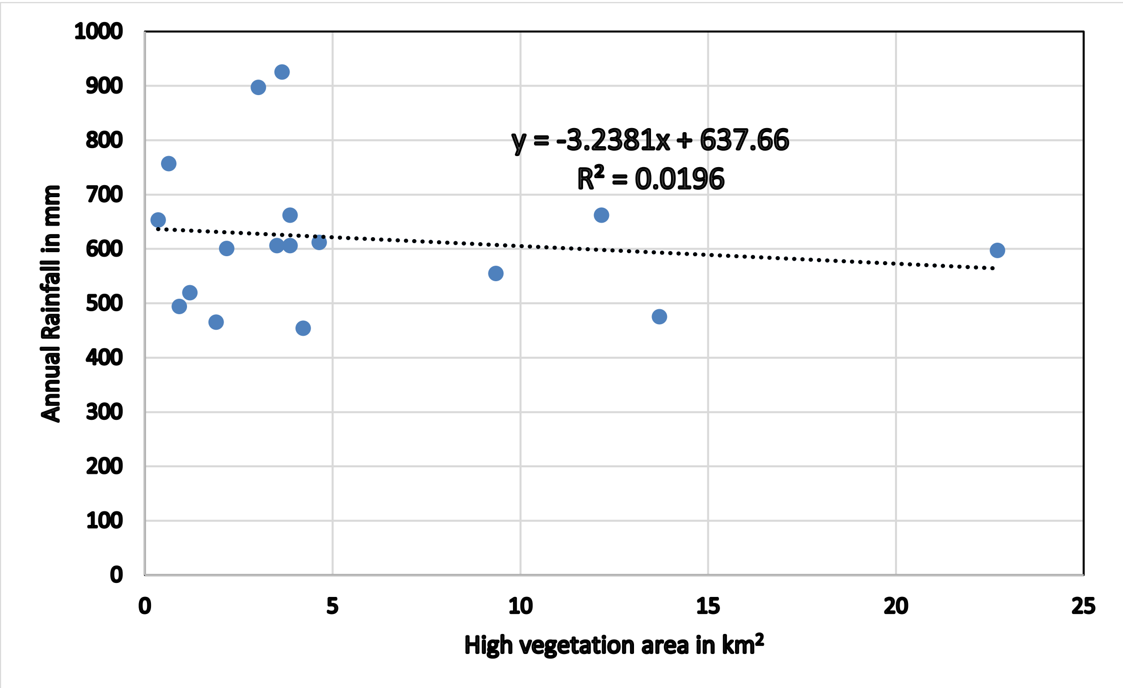


Figure 5: The relationship between Rainfall and vegetation cover (2003-2019)

Source: Authors' Analysis.

The result of the linear regression model presented in figure 5 reveals that the impact of rainfall on vegetation index is statistically insignificant. The R^2 value of 0.02, showed that rainfall variability cannot explain the vegetation cover changes of the Sambisa forest and its environment while, several empirical studies on relationship between vegetation and rainfall reported rainfall variability as the major driver of vegetation cover in West African Sudano-Sahelian savannah (Ekludh & Olsson, 2003; Anyamba & Tuckers, 2005; Herrmann *et al*, 2005; Olsson *et al*, 2005; Heuman *et al*, 2007; Hellden & Tottrup, 2008; Sequist *et al*, 2008; Tene Kwetche, 2012; Husai *et al*, 2014). These studies reported a surprising increase in NDVI results in West African Sahel between 1982 and 2008 as against the orthodox view of progressive degradation. Thus, most of these studies attributed the greening to increase in rainfall after 1980s drought, using almost similar methodology.

Therefore, as indicated by weak R^2 value (coefficient of 0.02), the observed vegetation cover dynamics relationship with rainfall variability in Sambisa Forest area between 2010 and 2019, reveals that the large-scale vegetation index variability is not rainfall derived changes. The Boko haram insurgences moved their headquarters to Sambisa Forest in 2011, and thus displaced the surrounding communities out of their habitats. The reduction in rural livelihood activities that depend on the environment (such as cultivation, grazing, and fuel wood cutting among others) enabled the rapid vegetation recovery. What can be inferred from these results is that human activity is a major driver of ecological degradation in the ecological zone. Therefore, policies and programmes that can reduce human activities will be the most suitable strategy of ecosystem conservation and recovery than afforestation projects that are consuming huge resources with little positive impact.

Conclusion

This study has examined the response of vegetation cover to human and climatic variability disturbance in Sambisa Forest from 1973 to 2017. It is evident from the results of the analyses that human disturbance remains a serious impediment to improved vegetation cover in the northern Sudan Savannah land of Africa. The impact of climate change pattern and rainfall attribute on vegetation cover in the study area could only be manifesting slowly as the impact is not significant.

The reduction in rural livelihood activities that depends on mother earth (such as cultivation, grazing, and fuel wood cutting among others) due to Boko haram insurgency enabled the rapid vegetation recovery. What can be inferred from these results is that human activities are major drivers of ecological degradation in the ecological zone. Sequel to this obvious discovery, it can therefore be concluded that vegetation cover in the study area responded more to human activities than climate variability.

Recommendations

The following recommendations are made based on the study's major observations and findings:

i. Policies and programmes that can reduce human activities should be the most suitable strategies of ecosystem conservation and recovery than afforestation projects that are consuming huge resources with little positive impact. So, they should be encouraged.

ii. Research and development should focus on sustainable afforestation projects and to develop strategies that relieve disturbance of vegetation and permit the restoration of stressed and dysfunctional forest reserves.

iii. Appropriate afforestation techniques should be made available to the populace.

iv. It is necessary to carry out further research on human impacts on the landuse and vegetation cover changes of the basin area, assessment of the social-economic impacts of the landuse and landcover changes on the basin areas as well as the post-dam environmental impact.

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