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AGRICULTURAL VULNERABILITY TO CLIMATE CHANGE IN SOKOTO STATE, NIGERIA

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ABSTRACT

Although climate change is global threat, developing countries have been identified as most vulnerable owing to their low adaptive capacities. In Nigeria, while the impacts of climate cut across diverse sectors, agriculture remains the most susceptible due to the predominance of rainfed agriculture. This paper examines agricultural vulnerability to climate change in eight selected rural settlements in Sokoto State, Nigeria adopting the integrated approach which combines environmental and socio-economic determinants. Monthly rainfall, raindays and temperatures (minimum and maximum) data for Sokoto (1951-2010) were sourced from the archives of the Nigerian Meteorological Agency, Lagos. The annual rainfall, total of raindays and mean temperature were computed and used for the trends analyses of the climatic variables while the annual drought intensities for Sokoto synoptic weather station were computed from the annual rainfall data. Data on the environmental and socio-economic determinants of agricultural vulnerability to climate change were collected from 234 selected farmers using structured questionnaire. Multiple linear regression was used to examine the relationship between the agricultural vulnerability of the sampled farmers and the determinants. Stepwise regression was used to resolve the issue of multi-collinearity in the independent variables and consequently enhance the strength of the model. Results show that while there were downward trends of annual rainfall and raindays in Sokoto, annual mean temperatures show upward trend. Annual droughts were of slight and moderate intensities during the period under review. The results also revealed that unreliable rainfall, desertification, increasing temperatures, scarcity of pastures and inaccessibility to credit facilities accounted for 86% of the variation of agricultural vulnerability to climate change in the selected settlements in Sokoto State. The paper concludes that the determinants of agricultural vulnerability to climate change in the selected settlements in Sokoto State connote environmental and socio-economical stressors. The paper, therefore, recommends development of irrigation projects and planned grazing as well as provision of soft and accessible loan facilities to local farmers on a sustainable basis.

Key words: Climate change, drought, agriculture, vulnerability

INTRODUCTION

Climate change poses a serious danger to livelihoods and food security as well as enhancing risks and vulnerabilities through the increased incidence of environmental disaster and intense weather events [1]. The impacts of climate change basically may be restricted in nature but also with economy-wide implications [2]. With over 70% of Nigerians residing in the rural areas, agriculture remains the primary source of livelihood and it is predominantly small-scaled. Subsistence agricultural practice is characterized by reliance on traditional farming techniques and rainfall for crop moisture needs which make it vulnerable to unreliable rainfall and drought unlike large-scale/commercial farming with larger inputs of irrigation water and chemical fertilizer [3]. Thus, climatic variability and change have increased the vulnerability of agricultural production [4].

The impacts of climate change are spatially heterogeneous across a range of geopolitical scales and it is believed that developing countries will be more at risk because of their reliance on climate-sensitive sectors [5]. While exposures, sensitivities and adaptive capacities are evident at community or local levels, they reflect broader forces, drivers or determinants that shape or influence local level vulnerabilities [6]. It is the interaction of biophysical and socio-economic drivers that influence the level to which regions, communities or households are exposed and susceptible to climate change [7, 8]. Thus, vulnerability is a function of the character, scale, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity [9].

Vulnerability to climate change can be significantly reduced through the timely adoption of adaptation measures [10]. Lack of improved seeds, lack of access to water for irrigation farming, lack of information on weather incidence and lack of credit facilities to acquire modern techniques have been identified as hindrances to adoption of viable adaptation strategies of climate change [11]. Consequently, small-scale farmers suffer more from impacts of environmental shocks than commercial farmers [12]. Thus, it is the poor who depend heavily on natural resources that are mostly sensitive to climate change [11].

Vulnerability to climate change depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions [13]. Adaptations are considered to assess the degree to which they can moderate or reduce negative impacts of climate change, or realize positive effects, to avoid the danger [6]. This is due to the fact that a low capacity to adapt to climate change automatically implies vulnerability [14]. Thus, a community exposed to climate change but with access to irrigation facilities, credit facilities, pesticides, information, storage facilities etcetera will be less vulnerable compared to a community with similar exposure but with less adaptive capacity. There is therefore interdependency of processes driving exposure, sensitivity and adaptive capacity [6].

The plights of farmers and effective adaptation strategies can only be articulated and mainstreamed into the nation's climate change programmes when the determinants of agricultural vulnerability are appraised. This paper, therefore, examines agricultural vulnerability to climate change in Sokoto States, Nigeria

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STUDY AREA

Sokoto State (Figure 1) is located in the Sudano-sahelian Savanna ecological belt of Nigeria with Longitude 11° 3’ to 13° 50 E and Latitude 4° to 6° 40’ N [15]. It encompasses wide-ranging tracts of almost flat to slightly rolling landscape [16]. Rainfall in Sokoto State as in other parts of Nigeria is dominantly controlled by the movement and pulsation of the ITD (Inter-Tropical Discontinuity) [17]. Similar to other extreme northern parts of the country, rainfall in Sokoto State is very erratic and unpredictable with irregular onsets and cessations which adversely affect the duration of the cropping seasons. The wet season lasts from June to September [18]. Annual rainfall ranges between 300mm and 800 mm while mean annual temperature is 34.5 ^{0}C with dry seasons temperatures often exceeding 40 ^{0}C. The grasses with scattered trees which characterized the State have undergone severe modification due to human activities. Agriculture is the mainstay of the people.

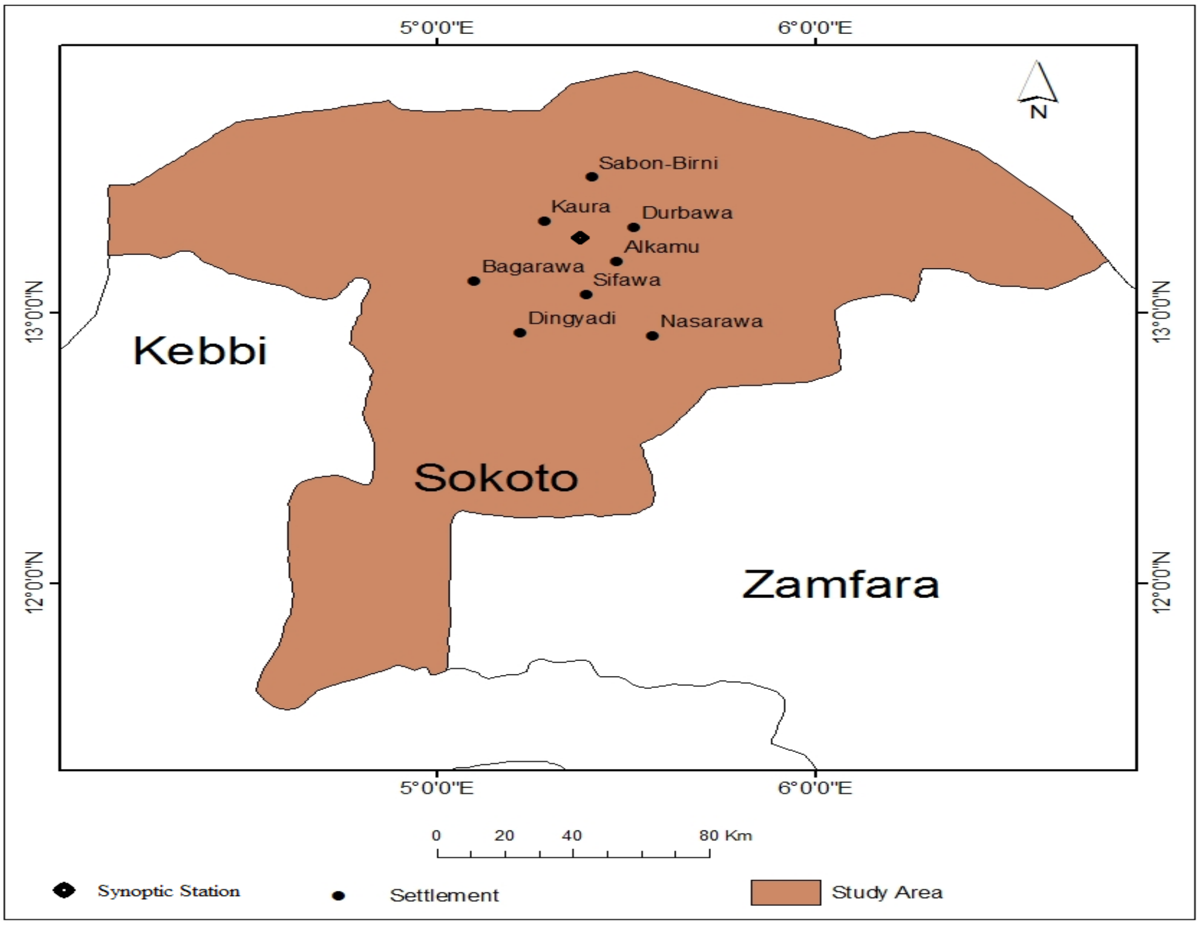

Figure 1: Selected settlements and synoptic weather station for the study

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MATERIALS AND METHODS

Monthly climatic data (maximum and minimum temperatures, rainfall and raindays) for Sokoto were collected from the archives of the Nigerian Meteorological Agency, Lagos. The annual mean of each data were computed from the monthly data. The annual mean temperatures in Sokoto were calculated from the annual mean of minimum and maximum temperatures. The annual trends of the climatic variables (rainfall, raindays and mean temperature) were examined using simple linear regression lines. The growing season and annual intensities in drought in Lokoja synoptic weather station were computed as percentage deviation from the mean seasonal and annual rainfall respectively [19]. The drought intensities were classified as follows:

Drought type	Percentage deviation from the mean
Slight drought	11-25
Moderate drought	26-45
Severe drought	46-60
Disastrous drought	more than 60

Structured questionnaire was used to collect data on the local farmers' agricultural vulnerability to climate change and its determinants in eight randomly selected rural settlements in Sokoto State within 45 km radius of the synoptic weather station (Figure 1). A sample size of 234 which represents 5.04 % of the projected 2010 total household sizes (4,641) of the selected settlements was computed as prescribed [20]. The 234 copies of questionnaire were administered proportionally among the selected settlements based on their household sizes. Systematic sampling technique was used to select farmers in each settlement.

Multiple linear regression was used to examine the relationships between the agricultural vulnerability to climate change and its determinants. The determinants of agricultural vulnerability to climate change (independent variables) in the study are: drought (X_1), access to irrigation water (X_2), desertification (X_3), increasing temperature (X_4), unreliable rainfall (X_5), access to weather forecast (X_6), flooding (X_7), pests and diseases (X_8), increase in weeds (X_9), access to pesticides (X_{10}), access to fertilizers (X_{11}), access to credit facilities (X_{12}), educational attainment (X_{13}), farm size (X_{14}), farming experience (X_{15}), scarcity of pastures (X_{16}), unstable prices (X_{17}), non- diversification (X_{18}), access to storage facilities (X_{19}), erratic power supply (X_{20}), access to land (X_{22}), access to extension services (X_{22}), access to seedlings (X_{23}), availability of labour (X_{24}), declining yield (X_{25}), access to market (X_{26}), age of farmer (X_{27}), access to remittances (X_{28}), cultural barriers (X_{29}) and increasing conflicts (X_{30}). The overall agricultural vulnerability of the farmers to climate change was used as the dependent variable. Stepwise regression was used to resolve the issue of multi-collinearity in the independent variables and consequently enhance the strength of the model.

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The model is given as:

$$Y = \alpha + b_1x_1 + b_2x_2 + b_3x_3 + \dots b_nx_n + e \text{ --- } (1)$$

Where

Y = dependent variable

α = the intercept value

b_1x_1 = partial regression coefficients

e = error term

RESULTS

Annual Rainfall, Raindays and Mean Temperature

While mean annual rainfall during 1951-2010 was 669.13 mm, the linear regression line for annual rainfall reveals a downward trend in Sokoto with a marked negative trend of between 1965 and 1976 and between 1977 and 1991 (Figure 2). The lowest annual rainfall was recorded in 1987 (373.2mm) while the highest annual rainfall was recorded in 2010 (1146.7 mm). The high rainfall recorded in the month of October gave rise to the unprecedented rainfall amount in 2010 [21]. This high positive rainfall deviation resulted to the devastating flood incidence which washed away farmlands and settlements, especially areas adjacent to the Bakolori and Rima Rivers. It is important to stress that decreasing rainfall trend in the absence of irrigation pose a serious threat to agriculture and therefore increase the local farmers' agricultural vulnerability to climate change.

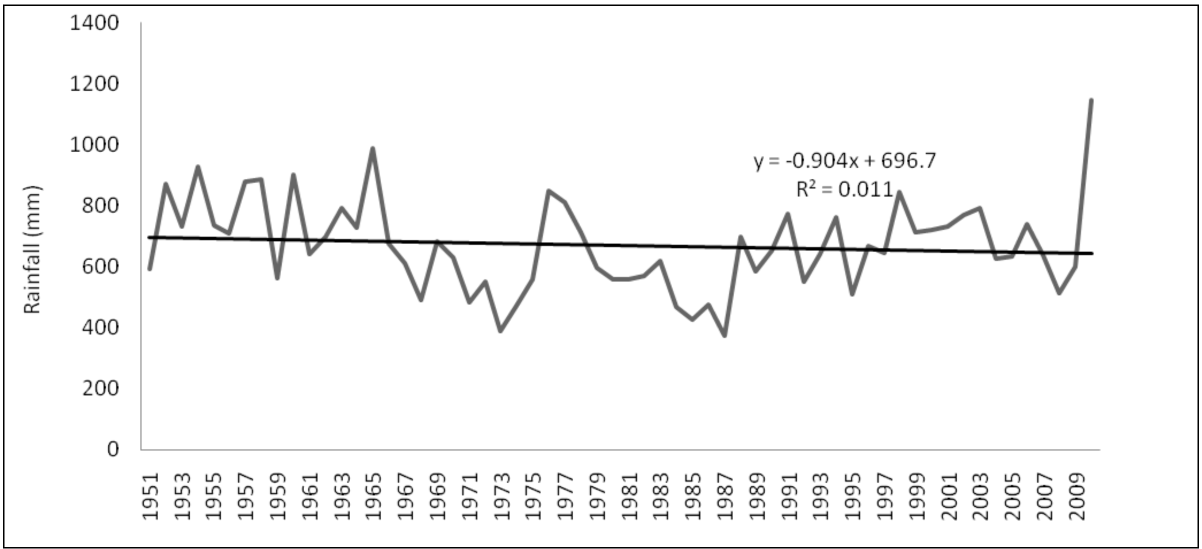

Figure 2: Annual rainfall trend in Sokoto (1951-2010)

Like annual rainfall trend, the linear regression line for annual raindays in Sokoto reveals downward trend during 1951-2010 (Figure 3). The highest raindays were recorded in 1961 (64) while the lowest were recorded in 1983 (29). The high annual rainfall witnessed in 2010 was not matched with high number of raindays. The implication of this pattern is that rainfall may not be witnessed when desired for agricultural production (especially during the planting season). Apart from the fact that a well distributed rainfall during the growing season is more agriculturally advantageous, concentration of rainfall of high intensity such as was witnessed in October, 2010 could result in flooding.

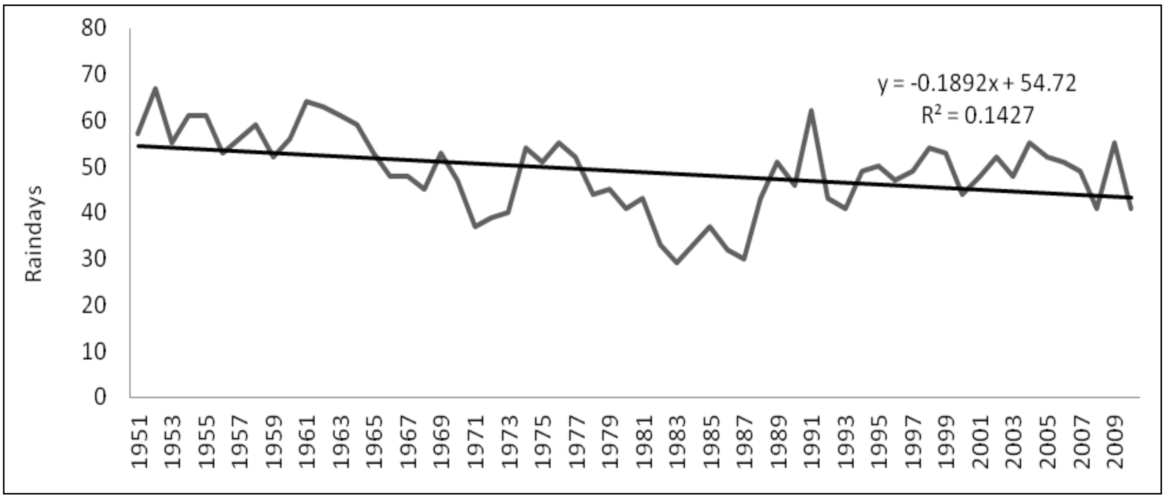

Figure 3: Annual raindays trend in Sokoto (1951-2010)

The simple linear regression line reveals that annual mean temperatures in line with global warming show increasing trends in Sokoto. While the warmest year was 2009, the coolest was 1955 with annual mean temperatures of 30 ^{0}C and 26.7 ^{0}C respectively. The five highest annual temperatures occurred between 1973 and 2010. Thus, annual mean temperatures show inverse relationship with annual rainfall and raindays in Sokoto. Increasing annual mean temperatures trends could be adverse since, high air temperatures induce high rate of evapo-transpiration which could lead to crop moisture stress in absence of adequate moisture depicted in Sokoto with scenario of decreasing trends of rainfall and raindays and poorly developed irrigation schemes.

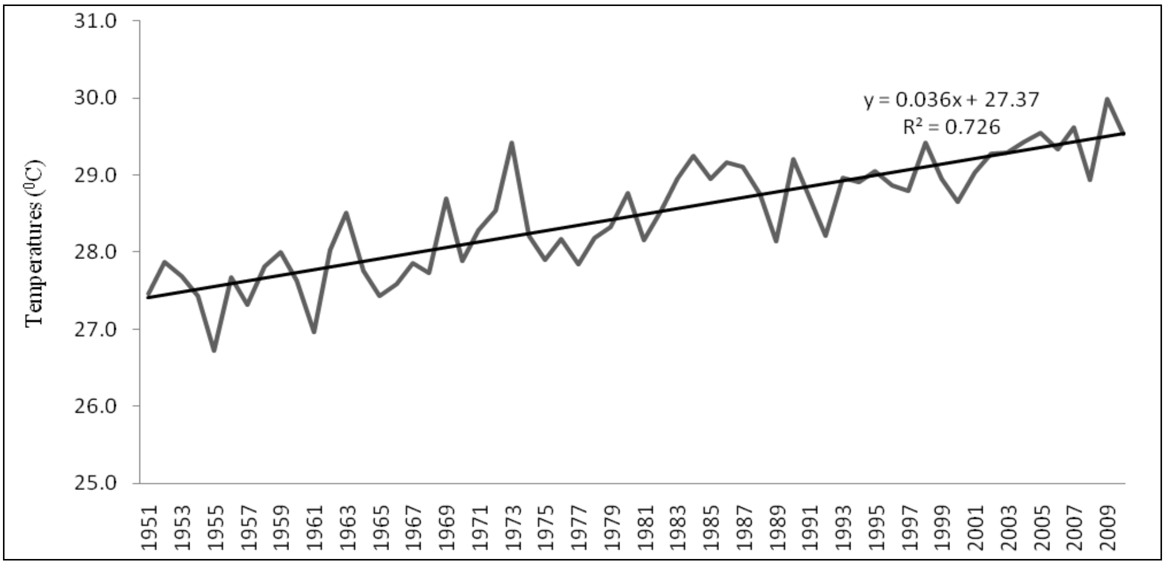

Figure 4: Annual mean temperatures trend in Sokoto (1951-2010)

Annual Drought Intensities

During the 1951-2010 period, annual drought intensities were of the slight and moderate intensities (Table 1). While slight drought occurred in 12 years, moderate drought occurred in 8 years. While the longest stretch of drought of moderate intensities occurred from 1984 to 1987, the largest stretch of drought of slight intensities occurred from 1975 to 1982. It is reiterated that the distribution of rainfall during the growing season is significant to crop yield and the overall crop production. Consequently, that the drought incidences in Sokoto are of slight and moderate intensities do not imply that crop moisture needs are adequately met. Dry spells which are rainfall deficiencies below the scale of drought reduce crop yield. The occurrence of dry spells and droughts justify the need for supplemental irrigation [22]. However, the production of cereals is predominantly in the hands of peasant farmers and the technologies are basically traditional methods [23].

Socio-demographic Characteristics of the Respondents

Out of the 234 respondents, age group 40-49 representing 68 (29%) of the respondents form the largest while 5 (2%), 37 (16%), 48 (20%), 30 (13%), 46 (20%) represented age groups less than 20, 20-29, 30-39, 50-59 and 60 and above respectively (Figure 5). It can therefore be deduced that the agricultural workforce in the selected settlements is characterized mainly by people of less than 50 years of age which implies a young and a vibrant workforce.

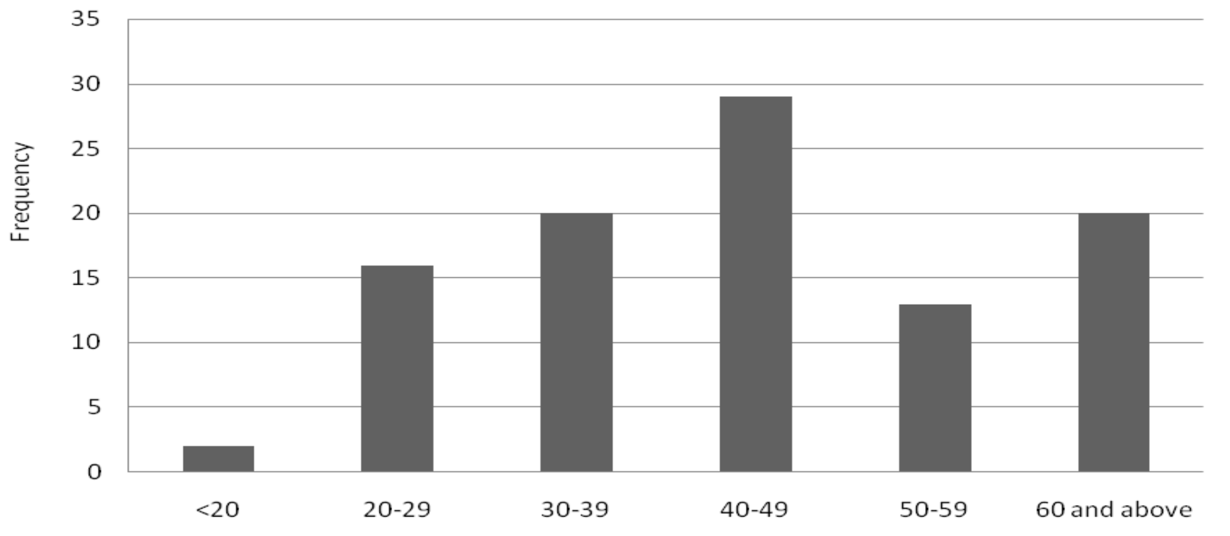

Figure 5: Age distribution of the respondents

The educational distribution of the respondents reveal that 114 (48.7%) representing the largest proportion have no formal education while those with primary and secondary education were 51 (21.8%) each (Figure 6) and only 18 (7.7%) of the respondents have tertiary education. The high proportion of respondents with no formal education in the State is an indicator of low agricultural adaptive capacity to climate change since the higher the educational attainment of a farmer, the more knowledgeable and amenable to accepting alternating strategies.

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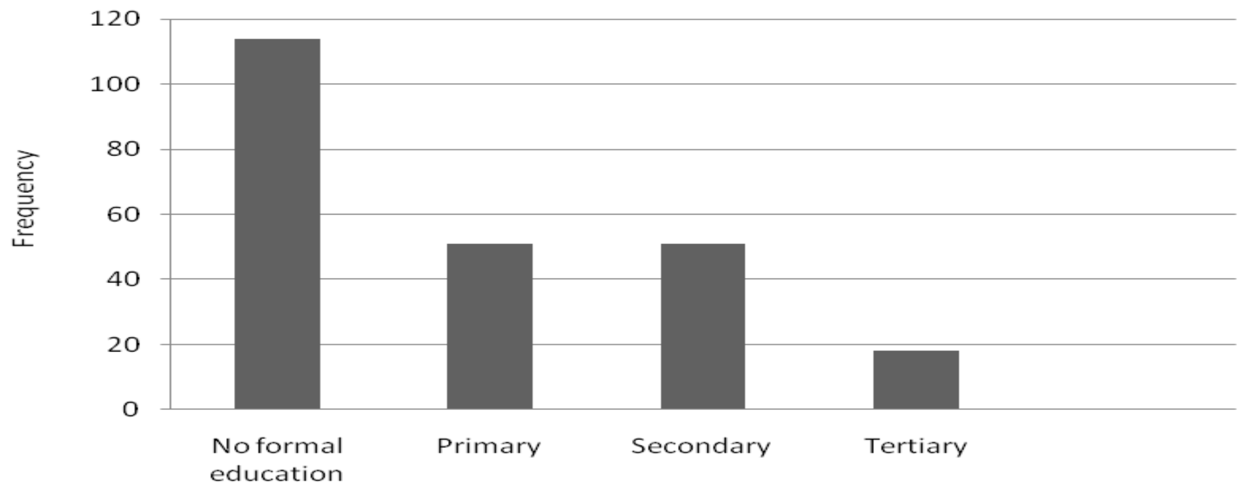

Figure 6: Educational distribution of the repondents

The monthly income levels of the respondents reveal that 70 (29.9%) representing the largest proportion fall within ₦10,000 -19, 000 while 45 (19.2%), 20 (8.5%), 57 (24.4%), 21 (9.0) and 21 (9.0) belong to less than ₦10, 000, ₦20, 000 - 29, 000, ₦30, 000 - 39, 000, ₦40, 000 - 49, 000, ₦50, 000 and above income groups respectively (Figure 7). Thus, 115 (77.2%) of the selected respondents in earn less than ₦20, 000 monthly. The official exchange rate stands at ₦ 198 to a US dollar as at 21st of February, 2015. This implies that majority of the sampled farmers do not earn above 100 US dollar per month.

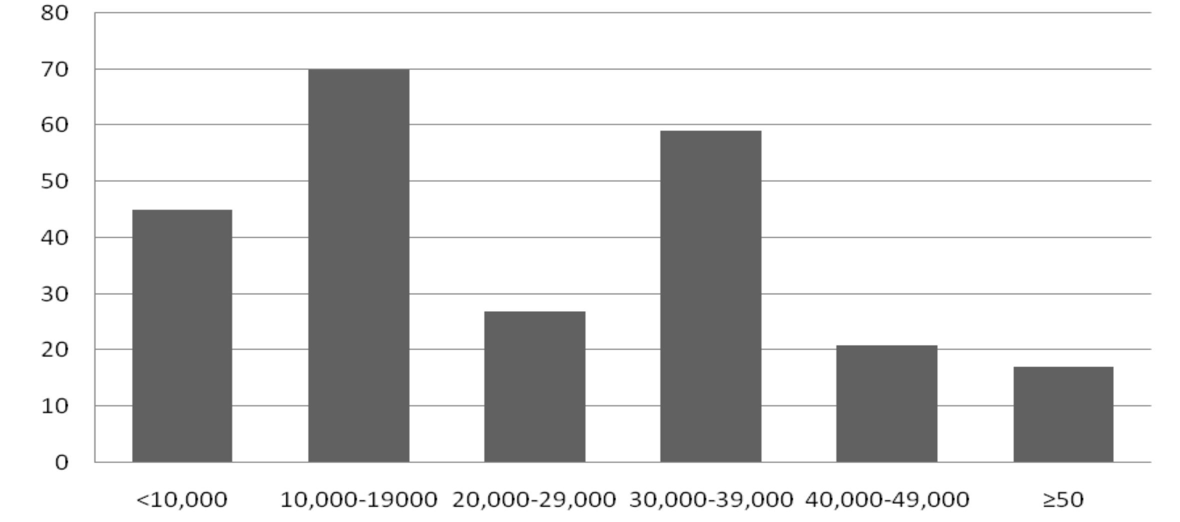

Figure 7: Monthly income (naira) distibution of the respondents

Determinants of Agricultural Vulnerability to Climate Change

Table 2 reveals the multiple linear regression model summary. R square is 0.860 which means that unreliable rainfall (X_5), desertification (X_3), increasing temperatures (X_4), scarcity of pastures (X_{16}) and inaccessibility to credit (X_{12}) facilities explain 86% of the agricultural vulnerability of the selected farmers to climate change in Sokoto State.

Table 3 reveals the F-values (1219.50, 632.89, 440.95, 337.16 and 279.46) which are significant ($P < 0.05$). This implies that unreliable rainfall (X_5) and desertification (X_3), increasing temperatures (X_4), scarcity of pastures (X_{16}) and inaccessibility to credit facilities (X_{12}) have significant relationships with the farmers' agricultural vulnerability to climate change and consequently constitute the main determinants of agricultural vulnerability to climate change among the selected settlements in Sokoto State.

Table 4 reveals the values for predicting the dependent variable given a score of the independent variable. The beta column contains the standardized coefficients of unreliable rainfall (X_5), desertification (X_3), increasing temperatures (X_4), scarcity of pastures (X_{16}) and inaccessibility to credit facilities (X_{12}). The standardized coefficients of X_5, X_3, X_4, X_{16} and X_{12} are 0.907, 0.080, -0.082, 0.166 and-0.132 respectively. The overall multiple regression equation takes the form: $Y = 0.057 + (0.907x_5) + (0.080x_3) + (-0.082x_4) + (0.166x_{16}) + (-0.132x_{12})$ ----- (2)

This implies that given a unit increase in the value of X_5, agricultural vulnerability to climate change will increase 0.907 units while holding X_3, X_4, X_{16} and X_{12} constant. Similarly, if X_3 increase by one unit, agricultural vulnerability to climate change will increase by 0.080 while holding X_4, X_{16} and X_{12} constant and so on and so forth.

DISCUSSION

Unreliable rainfall has been reported as one of the evidences of climate change in the semi-arid ecological zone [24, 25, 26]. The outcome of the multiple linear regression clearly indicate that the local farmers know the significance of rainfall to their agricultural activities and are very conversant with rainfall pattern in Sokoto since their agricultural activities are mainly rainfed. Studies have shown that the semi-arid belt of Nigeria, where Sokoto State is located is faced with intensifying desertification [27]. This has resulted in loss of arable land, induce outmigration of farmer to more favourable environments, increasing conflicts and increasing incidence of migratory pests' attacks as reported in previous studies [28, 29, 11]. Thus, desertification and its associated challenges have led to farmers' vulnerability to climate change.

The semi-arid ecological zone of Nigeria is notable as a major source of animal protein with natural pastures forming the main source of livestock feed. These pastures like other plants depend on rainfall to thrive. It is therefore not surprising that scarcity of pastures is one of the main determinants of agricultural vulnerability to climate change in Sokoto. One of the consequences of desertification is southward migration of nomads to the more humid southern parts of the country with high incidences of clashes with sedentary farmers [29].

Inaccessibility to credit facilities remains one of the most critical factors militating against agricultural expansion among small-scale farmers in Nigeria. This challenge is heightened by increasing environmental threats due to climate change and the need for adaptation. Access to credit facilities is vital to the adaptive capacity of local farmers to climate change since it will enhance their ability to adopt innovations and technologies [11, 30, 31]. Although several studies have advocated the provision of credit facilities to local farmers for enhanced adaptive capacities [11, 32], the inability of small-scale farmers to provide collateral has derailed the realization of the objective of successive credit initiatives by government [33]. Apart from the fact that most financial institutions are domiciled in urban areas, loans are subject to fluctuating interest rates hinged on inflation as well as administrative bottle neck procedures.

The upward trend of annual mean temperatures in Sokoto could intensify evapo-transpiration and lead to wilting of crops in the absence of irrigation. This could heighten agricultural vulnerability to climate change in the face of declining rainfall coupled with predominance of rainfed agriculture.

CONCLUSION

The paper examined agricultural vulnerability to climate change in Sokoto State. The results show that while there were downward trends of annual rainfall and raindays in Sokoto, annual mean temperatures show upward trend. Annual droughts were of slight and moderate intensities during the period under review. The results also revealed that unreliable rainfall, desertification, increasing temperatures, scarcity of pastures and inaccessibility to credit facilities are the main determinants of agricultural vulnerability to climate in Sokoto. The paper therefore, concludes that the determinants of agricultural vulnerability to climate change in the Sokoto State connote environmental socio-economical stressors. It is recommended that more irrigation projects should be developed to cover additional arable land. Furthermore, planned grazing should be encouraged and soft and accessible loan facilities should be made available to local farmers on a sustainable basis.

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The author wishes to thank the Nigerian Meteorological Agency for the climatic data used in this study and Mr. Arinze Amako for his efforts during the fieldwork.

Table 1: Annual drought intensities in Sokoto

Year	Drought index	Classification
1951	11.8	Slight
1959	16.16	Slight
1968	26.96	Moderate
1971	27.83	Moderate
1972	17.94	Slight
1973	42	Moderate
1974	29.43	Moderate
1975	16.56	Slight
1979	11	Slight
1980	16.68	Slight
1981	16.77	Slight
1982	14.95	Slight
1984	30.21	Moderate
1985	36.25	Moderate
1986	28.89	Moderate
1987	44.23	Moderate
1989	12	Slight
1992	17.95	Slight
1995	23.81	Slight
2008	23.09	Slight

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.917[a]	.840	.839	.29409
2	.920[b]	.846	.844	.28961
3	.923[c]	.852	.850	.28433
4	.925[d]	.855	.852	.28209
5	.927[e]	.860	.857	.27792

a. Predictors: (Constant), X_5

b. Predictors: (Constant), X_5, X_3

c. Predictors: (Constant), X_5, X_3, X_4

d. Predictors: (Constant), X_5, X_3, X_4, X_{16}

e. Predictors: (Constant), X_5, X_3, X_4, X_{16}, X_{12}

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Table 3: ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	105.473	1	105.473	1219.50	.000[a]
	Residual	20.065	232	.086		
	Total	125.538	233			
2	Regression	106.164	2	53.082	632.89	.000[b]
	Residual	19.375	231	.084		
	Total	125.538	233			
3	Regression	106.944	3	35.648	440.95	.000[c]
	Residual	18.594	230	.081		
	Total	125.538	233			
4	Regression	107.316	4	26.829	337.16	.000[d]
	Residual	18.222	229	.080		
	Total	125.538	233			
5	Regression	107.928	5	21.586	279.46	.000[e]
	Residual	17.611	228	.077		
	Total	125.538	233			

a. Predictors: (Constant), X_5

b. Predictors: (Constant), X_5, X_3

c. Predictors: (Constant), X_5, X_3, X_4

d. Predictors: (Constant), X_5, X_3, X_4, X_{16}

e. Predictors: (Constant), X_5, X_3, X_4, X_{16}, X_{12}

f. Dependent Variable: Agricultural vulnerability to climate change

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Table 4: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.057	.074		.766	.444
	X_5	.957	.027	.917	34.921	.000
2	(Constant)	-.063	.084		-.745	.457
	X_5	.943	.027	.903	34.357	.000
	X_3	.065	.022	.075	2.870	.004
3	(Constant)	.049	.090		.546	.585
	X_5	.942	.027	.902	34.975	.000
	X_3	.079	.023	.092	3.502	.001
	X_4	-.091	.029	-.081	-3.107	.002
4	(Constant)	.000	.092		.004	.997
	X_5	.938	.027	.899	35.032	.000
	X_3	.073	.023	.085	3.236	.001
	X_4	-.102	.029	-.090	-3.460	.001
	X_{16}	.066	.030	.056	2.162	.032
5	(Constant)	.001	.091		.016	.987
	X_5	.947	.027	.907	35.646	.000
	X_3	.069	.022	.080	3.085	.002
	X_4	-.091	.029	-.082	-3.141	.002
	X_{16}	.194	.055	.166	3.557	.000
	X_{12}	-.141	.050	-.132	-2.814	.005

a. Dependent Variable: Agricultural vulnerability to climate change

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