Effects of Climate Variability on Crop Yield and its Implications for Smallholder Farmers and Precision Agriculture in Guinea Savanna of Nigeria

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Authors' contributions

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ABSTRACT

This study aimed to examine the effects of climate variability on annual crop yield at smallholder farmers' level in the Guinea Savanna Region of Nigeria, using Niger State as a case study. Climate data (rainfall and maximum temperature) for a period of 38 years (1971-2008) was acquired from National Cereals Research Institute, Bida and Nigeria Meteorological Agency, while crop yield data was acquired from Niger State Agricultural Mechanization Development Authority (NAMDA). Focused Group Discussions (FGDs) were undertaken in 18 communities in six local government areas in Niger State spread across the three agricultural zones in the State to validate the impact of climate change and variability. The climate data was analyzed with the aid of charts. Results showed a generally rising trend in both temperature and rainfall across the State. It shows that rainfall is not only more variable, but its onset and cessation patterns have shifted and its occurrence very inconsistent. Linear relationships between climatic variables and the major crops

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showed moderate to strong positive and negative relationships. However, when crop yields were regressed with the climate variables, only maize (.032), bambara groundnut (.029) and groundnut (.007) were very significant at .05 confidence level (95%). The policy implication of this finding is the need to provide the farmers with local climate information and the need for vigorous pursuance of the development of high yield crop varieties better suited to changing climate conditions in the Guinea Savanna ecological zone by research institutes and other relevant agencies.

1. INTRODUCTION

Africa is one of the most vulnerable continents to climate change and climate variability [1] due to its high dependence on agriculture; which is heavily sensitive to weather and climate variables and its low adaptation capacity [2]. In South Saharan Africa (SSA), climate variability and extreme weather events have been identified as major risks affecting agricultural productivity in the region [1]. Climate change impacts are multi-sectoral, and one of the most critical sectors is agriculture where the impacts are felt through changes in temperature and precipitation, soil moisture and soil fertility, the length of the growing season and an increased probability of extreme climatic conditions [3]. Agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability [1]. Several countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will likely reduce the length of the growing season as well as force large regions of marginal agriculture out of production [1]. These situations are aggravated by the interaction of 'multiple stresses', occurring at various levels. Multiple stresses (stressors) refer to several non-climatic factors which affect farmer's capacity to adapt to climate variability and change, thereby increasing their vulnerability. The stressors include high cost of farm inputs, limited access to markets and increased influence of and changing markets, rising fuel and fertilizer prices, lack of agricultural equipment, and population increase driving fragmentation of landholding. Others are gender-based inequalities**,** unstable political environments, low income, poor access to credit, low level of education and unsustainable management of land [1-7]. Each of these stressors interact with the impacts of climate change to make the conditions of the resources that small-scale farmers depend on less productive and less reliable [7]. A possible remedy may be the advances in the areas of plant genetics which are increasingly trying to create products that adapt to major climate changes. Genetic modification technology has been used to develop herbicide-tolerant and pest-resistant varieties as well as virus- and fungus-resistant crops and to produce crops that are tailored to particular environments, e.g., drought resistant varieties or crops that are tolerant of high soil salinity [8]. Hence, genetically modified crops may offer solutions to very specific climatic conditions prevalent in developing countries, particularly African climates that vary considerably and may allow for more effective control of pests and fungal infections [8]. However, a major challenge with the adoption of genetic modification technology, particularly in developing countries is the heightened debate on health, and environmental risks, threat to biodiversity, increase in social differences, scientific concern, potential threat to the autonomy and welfare of farmers who wish to produce non-GM products and other associated risks as outlined by Hug [8].

Rainfall variability and other climatic risks account for a significant share of agricultural production risk [9]. In Nigeria, as well as other parts of West Africa, climate variability has been the most critical determinant of crop yield [10] given the fact that agriculture is mostly rain-fed. Rain-fed crop production, which is characterized by low input and output, and accounts for more than 95% of the land area cultivated annually in South Saharan Africa [1] and is the basis of subsistence farming in most parts of Nigeria, including the Guinea Savanna region of the country.

Temperature is one of the major environment factors that affect the growth, development and yields of crops especially the rate of development. Crops have basic temperature requirements to complete specific phenophases, particularly anthesis (the duration of life of a flower from the opening of the bud to setting of the fruit) or the whole life cycle, but extremely high and low temperatures may be detrimental to crop growth, development and yield [11]. Temperature increase above the optimum for each accelerates crop yield losses [12].

Threshold temperatures for some crops were highlighted by [12]. For instance, maize pollen viability decreases with exposure to temperatures higher than 35°C. For rice, pollen viability and production declines as daytime maximum temperature exceeds 33°C and ceases when maximum exceeds 40°C. For soybean, as daytime temperature increases from 30 to 35°C, seed set on male-sterile, female fertile soybean plants decreases. Increases of temperature may cause yield declines between 2.5% and 10% across a number of agronomic species throughout the 21st century [12].

Crops also have basic rainfall requirements for maximum productivity. Basic rainfall requirements for some crops were highlighted by [13]. Millet requires minimum, maximum and mean tolerance amount of 400 mm, 600 mm and 500 mm respectively. Sorghum requires minimum, maximum and mean tolerance amount of 400 mm, 1000 mm and 700 mm respectively. Cowpea (beans) requires minimum, maximum and mean tolerance amount of 300 mm, 400 mm and 350 mm respectively. Groundnut (peanut) requires minimum, maximum and mean tolerance amount of 500 mm, 700 mm and 600 mm respectively.

Niger State, which is in the heart of the Guinea Savanna belt (regarded as the country's food basket) is of particular concern in this study, owing to its extensive landmass mainly suitable for agriculture (i.e. arable). Agriculture has remained the back bone of the economy of Niger State, as nearly 85 percent of the population depends on it for their livelihood either directly or indirectly on it for their livelihood [14;15]. Over the years, Niger state has remained a leading contributor to agricultural productivity in the country and has outpaced many states in several statistical categories used to gauge the production of major crops [16]. The state has remained a major hub with vast production acreage and the third among rice producing states of the nation [16]. However, about 95% of the land area cultivated annually in Niger State is held by smallholder farmers. Generally, Nigerian agriculture is characterized mainly by farming families who own and cultivate small plots of land (generally between 0.2 ha to 2 ha depending on the choice of crop and ecological zones) using traditional methods of cultivation [17]. Labour, land and capital on these farms are mostly planned around the family and energy input is generally low as farmers rely more on simple tools and technologies [18]. It has been predicted that climate change will particularly have more significant negative impacts on poorer smallholder farm households in developing countries [19,20]. Since agricultural productivity in Nigeria is strongly linked to rainfall variability due to farmers' reliance on rain-fed production, crop yield in Niger State is expected to be compromised in the face of increasing global climatic variability and change. With climate variability and change, agricultural productivity in Niger State may decline with serious implications for food security due to the likely reduction or increased variability in their food supply. The reduction in agricultural productivity and production may mean that millions of low-income people in the State, Nigeria and beyond who depend on crop production from Niger State will be at risk of hunger, undernutrition and poverty. This may necessitate employment diversification, changes in farming and family dynamics, and potentially engender more systematic migratory trends in the farmers' quest for more reliable means of livelihood [7]. In addition, typical of Sub-Saharan Africa as rightly pointed out by Deressa [21], the climate problem in Niger State may be further compounded with so many other constraints such as land degradation due to inappropriate use of land; over-cultivation; inappropriate agricultural policies; tenure insecurity; weak agricultural research; and poor extension services.

Given the above, this study aims to assess the impact of climate variability and change on crop yield at subsistence or smallholder level in Niger State, Nigeria. Furthermore, the implications for precision farming, a farming management concept based on observing and responding to intra-field variations, are highlighted. Precision farming utilizes geo-information technologies (satellite images, information technology, global positioning system etc.) to optimize field-level management, which not only facilitates controlled fertilizer applications but also reduces the negative environmental impacts of farming, among others. This is a very critical adaptation strategy that ensures appropriate technologies are adopted for sustainable farming management practices.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Niger State is situated in the North-central Geopolitical Zone of Nigeria. Its location approximately between latitudes 8°20′N and 11°30′N, and longitude 3°30′E and 7°20′E

makes it lie entirely within the Guinea Savanna belt of the country (see Fig. 1). The State is bordered to the North by Zamfara State, to the North-west by Kebbi State, to the South by Kogi State, to the South-west by Kwara State; while Kaduna State and the Federal Capital Territory border the State to the North-east and South-east respectively. Currently, Niger State has the largest landmass in the country covering a total land area of about 76,363 sq. km (about 9 percent of Nigeria's total land area), with an estimated 80% of the land area suitable for agriculture (i.e. arable).

The two prevailing air masses largely influence the climate of Niger State in Nigeria; the dry North-east trade wind (tropical continental airmass) from the Sahara, and the moist South-west trade wind (tropical maritime) from the Atlantic Ocean. Fig. 2 shows the surface location of the Inter-Tropical Convergence Zone (ITCZ) over Nigeria. Generally, it is situated to the north of West Africa in July and August there by enabling Nigeria to be totally under the influence of Tropical maritime air mass (mT) while in January it is located along the coastal part of Nigeria, with the effect that most of Nigeria comes under the influence of the Tropical continental air mass (cT) during this period. Consequently, Nigeria is subject to marked wet and dry seasons associated with the moist and dry air currents, respectively [22].

Niger State experiences a distinct dry season from October – March; when the North-east trade wind is prevalent, and a wet season from April – October; when the South-west trade wind is prevalent. It records varying annual rainfall average of 1,200 mm in the northern part (Northern Guinea Savanna) and about 1,600 mm in the southern part (Southern Guinea). The rainy season lasts for an average of 150 days in the Northern parts of Niger state. Moreover, the southern parts of the State has 210 days average rainy season. Rainfall onset in the northern part of the State is usually in April/May, but in the Southern part of the State, its onset is earlier (March/April). Mean maximum temperature remains high throughout the year, hovering about 32°C, particularly between March and June, while the minimum temperatures usually occur between December and January when most parts of the State come under the influence of the Tropical continental (cT) air mass which blows from the North-East (Harmattan). Generally, the climate, soil and hydrology of the State permit the cultivation of most of Nigeria's staple crops and still allow sufficient opportunities for grazing, freshwater fishing and forestry development. Generally, agricultural activities form the mainstay of the people's economy; as a large proportion of the population (about 85%) directly or indirectly engages in farming, fishing and cattle rearing.

Agriculturally, Niger State is divided into three agricultural zones; Zones 1, 2 and 3. The zones are identified by the most dominant crops grown, even though most crops are grown all over the State. Agricultural Zone, 1 is called rice and tuber zone, because rice is predominantly grown in large quantities across the local governments in the zone, and tuber zone because of the widespread cultivation of cassava in commercial quantities across the zone. Agricultural Zone 2 is called tuber zone because of the large-scale cultivation of yam tubers in the zone. Agricultural Zone 3 is called cereal zone because the zone largely produces cereal crops, especially millet, sorghum, and maize. Crop production in agricultural Zone 1 is supported by Hydromorphic or waterlogged soils (which are poorly drained) especially within the extensive flood plain of the Niger River, and ferrosols developed on sandstone formations. Ferruginous tropical soils basically derived from the Basement Complex rocks and old sedimentary rocks and ideal for the cultivation of guinea corn, maize, millet and groundnut predominate in Agricultural zones 2 and 3. Agricultural Zone 2, however, lies in lower latitudes (Southern Guinea Savanna) and therefore receives more annual rainfall than agricultural zone 3, even though the soil type and nutrient condition are similar. The different zonation probably explained why the zone supports extensive cultivation of tuber crops, particularly yam.

2.2 Data Used

2.2.1 Climate data

Rainfall and temperature of the study area spanning over the period of 38 years (1971 - 2008) were acquired from National Cereals Research Institute, Bida and Nigeria Meteorological Agency. These climate data sets were used to examine climate trends in Niger State during the study period.

2.2.2 Crop yield data

Available crop yield data of Niger State at the smallholder farmers' level spanning ten (10) years from 1999 – 2008 was obtained from Niger State Agricultural Development Project (NSADP) and utilized for analysis. The data comprises the
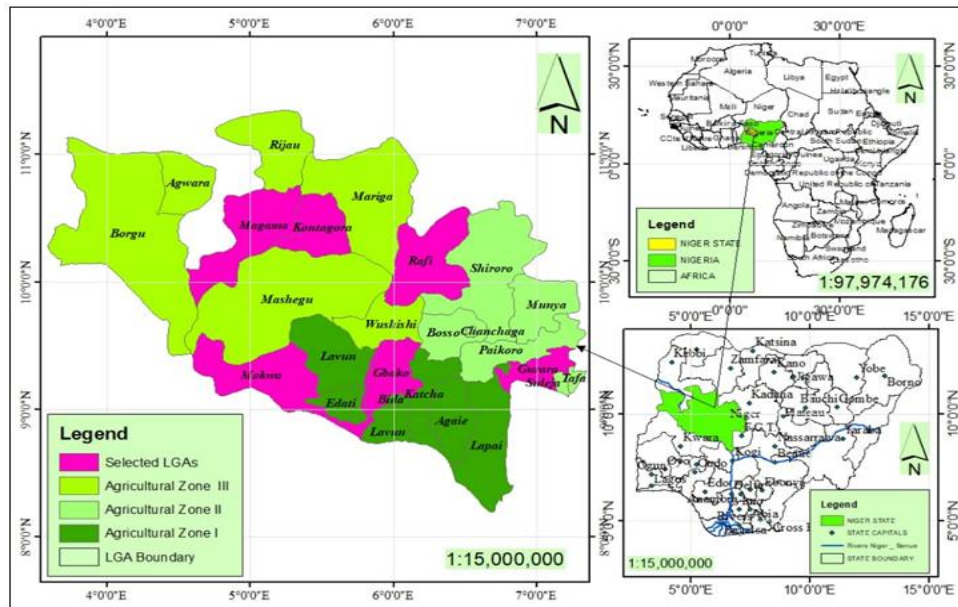
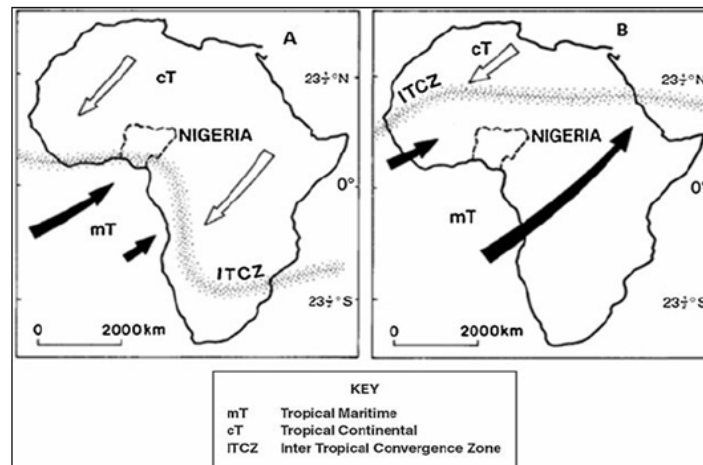**Fig. 1. Niger state showing the study local Government area**

**Fig. 2. Positions to of ITCZ over Nigeria in Nigeria in the months of January (A) and July (B)
Source [23]**

yields of twelve major crops largely cultivated across Niger State in the period under review. The crops are rice, maize, millet, Sorghum, cassava, sweet potato, yam, sugar cane, Bambara groundnut, cowpea (beans), groundnut and soybeans.

2.2.3 Focused group discussion (FGD) data

Focused Group Discussions (FGDs) was conducted with subsistence farmers in nine randomly selected local government areas (LGAs) of Niger State; three (3) from each agricultural zone, cutting across different climatic zones, tribes and cultures. The selected LGAs were Gbako, Lapai and Mokwa (Agricultural Zone 1), Gurara, Rafi and Shiroro (Agricultural Zone 2), Kontagora, Magama and Wushishi (Agricultural Zone 3). The selected local government areas are highlighted in Fig. 1. A Focus Group Discussion (FGD) is a qualitative research method and data collection technique in which a selected group of people discusses a given topic or issue in-depth, facilitated by a professional, external moderator. Open-ended questions were used for data gathering during the discussions.FGD was used because it allows the investigator to solicit both the participants'

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shared narrative as well as their differences in terms of experiences, opinions and worldviews during such discussions. Since FGD technique makes use of the human ability to tell stories, it was particularly suitable in the communities which all had low levels of literacy and/or strong oral traditions. The constraints of the FGD were that it took a great deal of time and efforts for the researchers to assemble the groups and they had less control over the data that was generated.

The FGD data was used to examine the perception of climatic changes as witnessed by all surveyed communities, the impacts these changes have had on the communities, perceived impacts on crop production and yield, the adaptation measures that were put in place by the communities to reduce vulnerability to the observed changes, and the major limitations to the observed adaptations strategies. From each of the nine selected LGAs, two farming communities were randomly chosen. With the assistance of community heads, purposive sampling was used to select between 10 and 15 participants (drawn from the aged, middle-aged, youths and women) made up the focus group discussants for each community). The purposive sampling put into consideration the participants' local knowledge, life-experience, and particular characteristics or role in the communities. The community heads who command respect and were also part of the participants ensured orderly organization of the discussions in all the communities. In Niger, State men are more involved in crop production than women owing to religious and cultural inclinations. Each focused group consisted of two females, two youths, two aged and the rest (six or more) middle-aged men who are more involved in crop production.

2.3 Data Analysis

Long-term trend calculation was performed on the time series rainfall and temperature data and results were presented using charts. The Pearson Product Moment Correlation Coefficient (r) algorithm in the Statistical Package for Social Sciences (SPSS) was used to correlate crop yield data with the climate data for the ten-year period to establish linear relationships rainfall, temperature and the major crops grown using. The equation is given below after [24].

$$r = \frac{N\sum xy - \sum x \sum y}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}} \quad (1)$$

Where:
N = Number of observations

x = Climatic elements (rainfall and temperature)
y= Crops yields

Minitab statistical software was employed to regress rainfall and temperature, which were used as predictor variables with crop yields at the significance level of 0.05.The R-square (R-SQ) was used to establish the contribution of the predictor variables to the crop yield.

The focused group data were analyzed from the notes taken and information recorded during fieldwork in various communities. Comparison, inferring, analogies were drawn from the data.

3. RESULTS AND DISCUSSION

3.1 Analysis of Climatic Data

Results of the analysis of rainfall and temperature, which are the major climatic variables affecting crop yield show strong annual variations. Fig. 3 shows that the temperature is not only variable, but also generally increasing; in line with [25] who observed increasing temperature trends in similar locations in Nigeria. The mean maximum temperature of the 38-year period considered (1971-2008) was 33.78∘C. Annual positive deviations (increase) from the mean maximum temperatures are on the increase in recent times (1993-2008), when only one year (2006) recorded maximum temperature less than the mean (Fig. 4). The temperature anomalies agrees with the observation by the smallholder farmers and also supported by [26] who found out that starting from the 1970s there has been a general temperature shift in Northern Nigeria, with temperatures showing an increase (significant at the 95% confidence level) everywhere in northern Nigeria.

The mean rainfall for the period is 1093.82 mm. Fig. 5 graphically revealed that the rainfall trend in the State during the period under consideration has been on the increase [25, 27, 28]. Also, in line with documented evidence [29], the study shows that precipitation has much larger spatial and temporal variability than temperature. Fig. 6 shows deviations from the mean. Contrary to the opinion of the communities that rainfall has decreased in the State, the rainfall amount showed slight increases in recent times. The farmers' perception may be hinged on the observed decrease in the number of rainy days, rather than its amount. The higher rainfall recorded in some of the most recent years may be explained by the fact that higher temperatures increase evaporation into the atmosphere and

thus, the water-holding capacity of the atmosphere also increased, and this increased rainfall variability, with more intense rainfall and more droughts [30].

Fig. 7 presents the mean rainfall anomaly of the study area over the study period. The anomaly is consistent with the movement of Inter-Tropical Divergent (ITD). The areas south of the study areas which fall largely within Niger State Agricultural Zones 1 and 2 showed a positive rainfall anomaly. In contrast, areas extreme north of the study area which fall within the Northern Guinea Savanna and Niger State Agricultural Zone 3 showed negative anomaly. This reveals that drought is more severe in the extreme northern part of the study area.

Poor rainfall distribution coupled with drought periods, particularly inter-seasonal dry spells is known to amplify the problem of moisture stress [31;32] and have been identified as the drivers of crop failure [33]. Rainfall decrease and
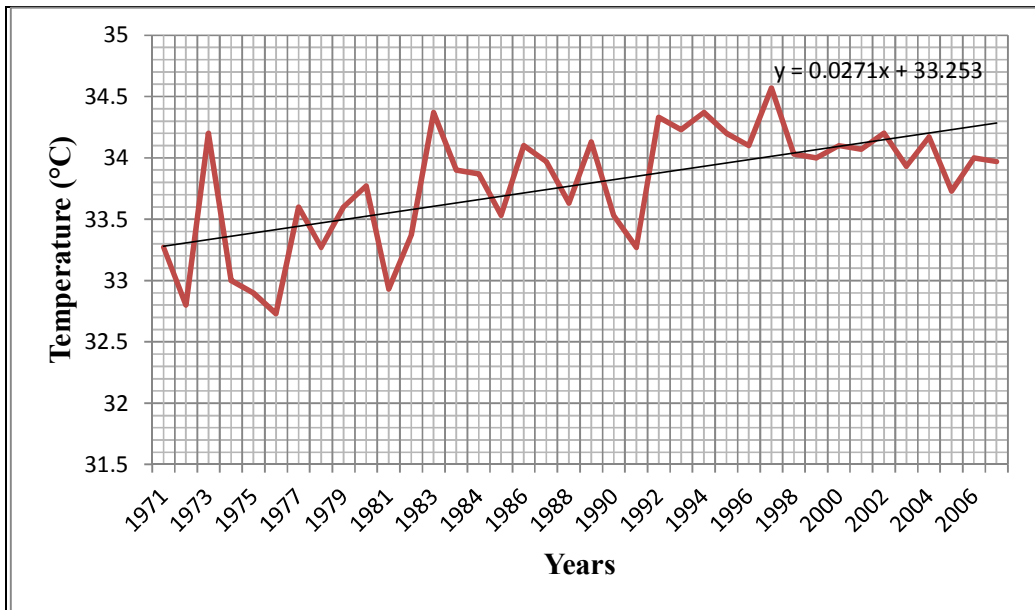

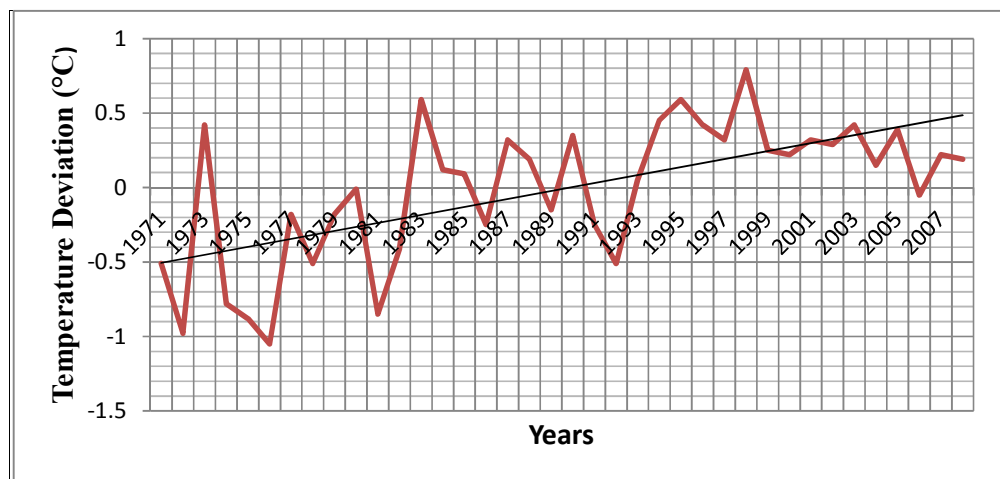**Fig. 3. Mean maximum annual temperature of Niger State from 1971-2008**

Fig. 4. Deviations from mean maximum temperature in Niger State from 1971-2008
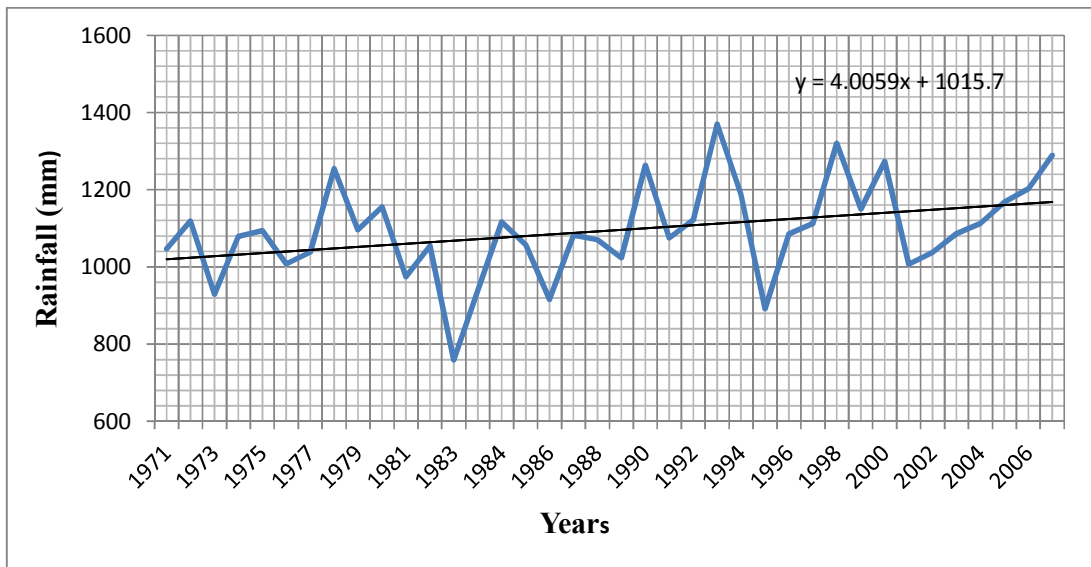
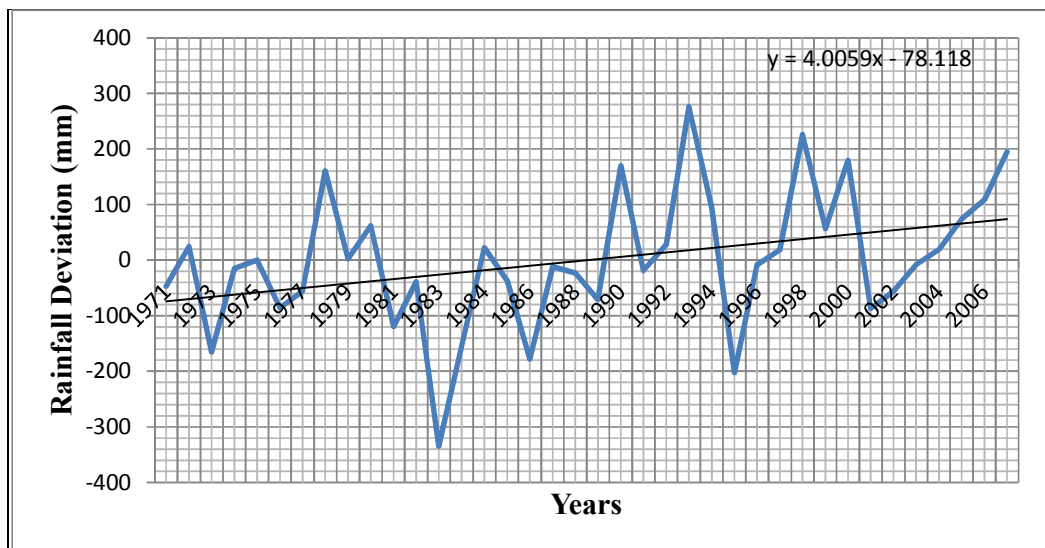**Fig. 5. Total annual rainfall of Niger State from 1971-2008**

Fig. 6. Deviations from mean rainfall in Niger State from 1971-2008

inter-annual variability has also been known to have significant impacts on global and regional food production particularly the common staple food crops performance in the tropical sub-humid climatic zone [34]. In Niger State, the negative effects of inter-annual rainfall variability are most common among the rural farming communities.

3.2 Correlation Analysis

The linear relationships between rainfall and temperature variability with the yield of 12 major crops that were grown across Niger State during the ten-year period showed that the various

crops differ markedly in their response to the climate change. Table 1 shows the results of correlation between the climatic variables with the cultivated crops.

Maize (*Zea mays*) with a correlation coefficient r = 0.720 shows a strong positive linear relationship with rainfall (Table 1). This implies that years with higher rainfall would produce relatively higher maize yield per hectare, all things being normal. In the same vein, Millet (r = 0.422), Sorghum (r = 0.471) and yam (r = 0.453) all show moderate positive linear correlations with rainfall, implying that decreased rainfall has

negative implications on the yield of the crops. There is a need to explore cultivating low rainfall tolerant species of these crops as an adaptation strategy. The development of such varieties or species of crops by research institutes is therefore very expedient in this era of climate change.

On the contrary, the analysis reveals that Bambara groundnut (*Voandzeia subterrarean*) and groundnut show moderate negative linear correlation (r = -0.631) and strong negative linear correlation (r = -0.837) respectively with rainfall, indicating that higher rainfall tends to decrease the yield of the two crops. These varieties of crops would therefore thrive well in low rainfall situations as an adaptation strategy. The remaining crops show weak and very weak positive and negative correlations with rainfall variations. However, with assertions that crops respond nonlinearly to changes in their growing conditions, exhibit threshold responses and are subject to combinations of stress factors that affect their growth, development and yield [35], combinations of a number of interacting factors with both climatic and non-climatic components may have been responsible for this relatively low coefficient of correlation between rainfall amount and the crop yields.

Mean annual maximum temperatures were correlated with annual cultivated crops because the seasonal temperature has been identified as an important climatic factor which can have profound effects on the yield of crops [36]. Table 1 shows that in Niger State, temperature variations have both negative and positive effects on crop yield, although very few crops show significant correlation. Only yam (r = -0.496) and beans (r = 0.431) show moderate negative linear and positive linear correlations with annual temperature respectively, implying that rising temperatures negatively affect yam yield and vice-versa for beans. The development of/and the cultivation of heat-tolerant varieties of yam, therefore, becomes imperative for the smallholder farmers in Niger State. Thus, changes in the frequency of extreme events that are expected to occur in a changing climate are important for yield, stability and quality [35].

3.3 Results of Regression Analysis

Table 2 represents the regression analysis of temperature, rainfall and the coefficient of variation (R-SQ) which is the contribution of temperature and rainfall to the yield. The regression analysis reveals that temperature

variation did not contribute meaningfully to variations in crop yield at a significant level of .05 (95%). The yield of three crops were, however, very dependent on rainfall. Maize (.032), Bambara Groundnut (.029) and Groundnut (.007) exhibited a strong dependence on rainfall. It implies that although soil nutrient and other non-climatic factors have some control on the yield of the crops, climatic controls (rainfall and temperature) contribute 50.8%, 54.1% and 69.3% to the yield of maize, Bambara groundnut and groundnut respectively. With increasing variability and change in climate, the potential threat to crop yield may be very severe.

Since relationships have been established between crop yields and climatic variables, the policy implication should be that the development of high yield crop and animal varieties better suited to changing climate conditions should be vigorously pursued by research institutes and agencies, while the developed varieties are promptly introduced to the farmers in order to reduce crop losses and to boost food production. It is also very expedient that forecasts and early warnings on rainfall onset and cessation by NIMET are well communicated and made available, particularly to the grassroots and subsistence farmers, who need such information to make decisions on the variety of crop to plant and when to begin their farming operations in a given cropping season. Here lies the critical role that the adoption of precision farming can play to boost food security in the food basket of Nigeria.

3.4 Analysis of FGD Results

The FGD revealed that smallholder farmers in the eighteen communities surveyed had witnessed some pronounced changes in climate variables from 1971 till 2008. Fifteen (15) out of the eighteen (18) communities have witnessed a temperature increase over time. All the communities have witnessed decreasing rainfall, shortened growing season due to late onset of rainfall and early rainfall cessation as well as its variability, and increasing occurrence of wind storms. Furthermore, five communities emphasized pronounced intra-seasonal dry-spell during the rainy season. The impacts of these observed changes on agricultural production in Niger State, as perceived by the smallholder farmers include reduced and/or variable food crop and tree crop yield, partial or total crop failure, the evolution of new species of weed, and increase in type and incidence of plant and animal diseases, insects and nematodes infestation.
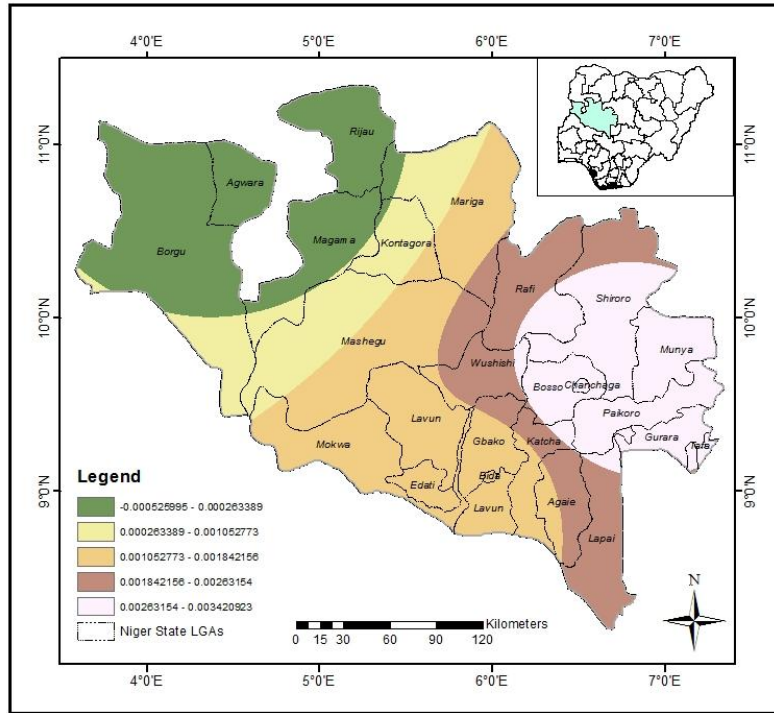
Fig. 7. Rainfall anomaly of the study area from 1971 to 2008

Table 1. Correlation coefficients of climatic variables and major crops grown in Niger state

Crop	Correlation with rainfall	Correlation with temperature
Rice	-0.191	-0.200
Maize	0.720	-0.074
Millet	0.422	0.128
Sorghum	0.471	0.163
Cassava	0.221	-0.146
Sweet Potato	-0.123	-0.227
Yam	0.453	-0.496
Sugarcane	0.081	0.035
Bambara Groundnut	-0.631	-0.228
Beans	-0.343	0.431
Groundnut	-0.837	0.259
Soya Beans	0.340	0.068

Table 2. Results of regression analysis

Crop	Temperature	Rainfall	R-SQ (%)
Maize	0.33	0.032*	50.8%*
Rice	-0.68	0.55	9.0%
Millet	0.68	0.22	22.1%
Sorghum	0.87	0.16	28.7%
Cassava	-0.31	0.60	6.8%
Sweet Potato	-0.71	0.65	7.9%
Bambara Groundnut	-1.48	0.029*	54.1%*
Beans	1.11	0.30	24.1%
Groundnut	0.36	0.007*	69.3%*
Soy Beans	0.40	0.370	12.0

Significant at .05 level

3.5 Implications for Precision Farming

Generally, precision farming practices employ a four-stage process that combines various techniques to observe spatial variability: geolocation of data using GPS receiver and remotely sensed images with appropriate spatial and geometric resolutions that indicate smallholder farm level details (e.g. crop biophysical parameters), characterization of variability (e.g. climatic conditions, soil, cropping practices, weeds and diseases), decision making on the most suitable strategy to adopt in tackling the observed variability and the implementation of problem-solving practices. For example, the results presented in this paper showed that if all other factors are conducive, the yield of crops such as maize increase if rainfall amounts increase, but there would be a need to adopt the use of heat-tolerant species for crops such as yams, and where the length of the growing season becomes shorter, the adoption of early maturing species are recommended. However, where non-climatic factors such as application of fertilizer, an infestation of weeds, among others affect yield despite the above adaptation strategies, precision farming techniques can be used to identify problem areas and appropriate solutions implemented, e.g. site-specific application of fertilizer. The smallholder (peasant) farmer, extension workers and researchers can collaboratively explore this adaptation strategy which accommodates the needs of crops, soils and the farmer's quest to produce profit-generating good quality crops at a lower cost.

4. CONCLUSION

The research described in this paper has highlighted the potential impacts of climate variability on smallholder farmer's level crop production in the Guinea Savanna Ecological zone of Nigeria using Niger State as a case study. The study reveals that mean annual maximum temperature and rainfall amounts have increased in recent years and have some negative effects on some crops. The implication of the temperature increase on yields of crops that are widely grown in the State is the need for heat tolerant species to be adopted and planted by farmers, who depend on climate for agriculture. The farmers' perceptions on rainfall are contrary to the empirical evidence of rainfall amount in the study areas. Therefore, the reported failure in crops by farmers might be as a result of factors other than climatic variability. The study challenged the earlier believes that local farmers have understanding of climate change in relation to crop yields. Generally, the local farmers' knowledge of climate variability is not sufficient for decision-making. The study recommends sensitization of local farmers on climate information; particularly the annual seasonal rainfall prediction (SRP) by the nation's meteorological agency which provides information such as rainfall onset, cessation and distribution for improved quality and quantity of crop yield in the study area. With good decision, increase in rainfall could be potentially good for rain-fed farmers.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENTS

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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