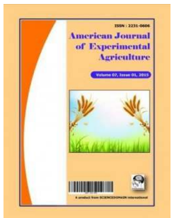

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Effect of Climate Variables on Major Cereal Crops Production in Sokoto State, Nigeria

M. B. Sokoto[1*], L. Tanko[2], L. Abubakar[1], A. U. Dikko[3] and Y. M. Abdullahi[4]

[1]Department of Crop Science, Usmanu Danfodiyo University, Sokoto, Nigeria.
[2]Department of Agricultural Economics and Extension, Federal University of Technology Minna, Nigeria.
[3]Department of Soil Science, Usmanu Danfodiyo University, Sokoto, Nigeria.
[4]Zoology Unit, Usmanu Danfodiyo University, Sokoto, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author MBS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AUD reviewed the experimental design and all drafts of the manuscript. Author LA managed the analyses of the study. Author YMA contributed in data collection. Author LT performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Agriculture largely depends on climate. Hence, climatic factors such as precipitation, solar radiation, wind, temperature, relative humidity solely determine distribution of crops and their productivity. Changes in temperature and precipitation directly affect performance of the crops. The objective of the study is to examine the impact of climatic factors (rainfall, minimum and maximum temperature on cereals production in Sokoto state, Nigeria. Secondary data from 1997-2008 were used in respect of annual yield of Major cereals crops (Maize, Millet, Rice and Sorghum (t ha^{-1}). Data in respect of climate was collected from Sokoto Energy Research Centre (SERC) for the period under review. Data collected was analyzed using descriptive statistics, correlation and

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**Corresponding author: E-mail: mbsokoto2003@yahoo.com;*

regression analysis. The result of the research reveals that there is variation in the trend of the climatic factors and also variation in cereals output. The effect of average temperature on yields has a negative effect on crop yields. Similarly rainfall is not significant in explaining the effect of climate on cereal crops production. The study has revealed to some extend the effect of climatic variables, such as rainfall, relative humidity, maximum and minimum temperature on major cereals production in Sokoto State. This will assist in planning ahead in cereals production in the area. Other factors such as soil fertility, correct timing of planting and good cultural practices (such as spacing of strands), protection of crops from weeds, pests and diseases and planting of high yielding varieties should also be taken in to consideration for increase yield of cereals.

Keywords: Impact; climate; cereals; Nigeria.

1. INTRODUCTION

Agriculture largely depends on climate. Hence, climatic factors such as precipitation, solar radiation, wind, temperature, relative humidity solely determine distribution of crops and their productivity [1]. Kurukulasuriya and Rosenthal [2] observed that changes in temperature and precipitation directly affect crop production and can even alter the distribution of agro-ecological zones; especially in Africa, and agricultural losses can result from climate variability and the increased frequency of changes in temperatures and precipitation (including drought and floods). FAO [3] reported that by 2100, Nigeria and other West African countries are likely to have agricultural losses of up to 4% due to climate change. Cereal crops, or grains are members of the grass family (Poaceae) grown for their hard seeds or kernels, which are used primarily for food. Grains are rich in carbohydrates and contain substantial amounts of protein, as well as some fat and vitamins. They are the staple food for most of the world's population. Over 70 percent of the world's harvested area is planted to grains, for an output of a billion and a half tons a year [4]; Martin et al*.* [5].

Prabhu and Hesey [6] reported reduction in productivity of cereals as a result of land degradation due to intensive cultivation and declining research investment. The Food and Agriculture Organization (FAO) reported that the level of Nigeria’s self sufficiency in cereals has been declining, resulting in rapid growth in the amounts of cereals imports [7]. Scientist across the globe had a growing consensus that in future the world will witness higher temperatures and changing precipitation levels and this could result in decrease in agricultural production [8]. This is particularly common in countries where climate is the primary determinant of agricultural productivity Apata et al*.* [9]. Many African countries that depend on weather-sensitive agriculture such as Nigeria are particularly vulnerable to climate change Dinar et al*.* [10]. The variation in weather and climate has led to a lot of devastating consequences and effects in various parts of the country [11]; these include flooding, deforestation, desertification, erosion, drought, heat stress and erratic rainfall patterns [12]. Khanal [13] Stated that heat stress might result to decrease in crop yield. Matthews et al. [14] observed that yield reduction from a 1℃ rise in the mean daily temperature varied from 5-7% for major crops. The main objective of this study is to determine the effect of climate on cereals production in Sokoto State.

2. METHODOLOGY

2.1 Study Area

Sokoto State is located in the extreme northwest of Nigeria. The State is located between Latitude 13°05’ N and Longitude 05°15’E, it occupies 25,973 square kilometers. Sokoto State shares its borders with Niger Republic to the North, Zamfara State to the East, Kebbi State to the South-East and Benin Republic to the West. As of 2005 it has an estimated population of more than 4.2 million. Sokoto State is in the dry Sahel, surrounded by sandy savannah and isolated hills. With an annual average temperature of 28.3℃ (82.9℉), maximum daytime temperatures are generally under 40℃ (104.0℉) and the dryness makes the heat bearable. The warmest months are February to April when daytime temperatures can exceed 45℃ (113.0℉). The rainy season is from June to October. The showers rarely last long and are a far cry from the regular torrential rain known in wet tropical regions. From late October to February, during the *cold season*, the climate is dominated by the Harmattan wind blowing Sahara dust over the land. The dust dims the sunlight thereby lowering temperatures significantly and also leading to the inconvenience of dust everywhere in houses. The general dryness of the region allows for few crops, millet being the most abundant, complemented by rice, corn, other cereals and beans. Apart from tomatoes few vegetables grow in the region [15].

2.2 Data Collection and Analysis

The study was designed to cover a period of 12 years (1997 – 2008). Series data in respect of annual yields (t ha^{-1}) of Maize, Millet, Sorghum and Rice was obtained from the Sokoto Agricultural Development Project (SADP); the data on climate was collected from Usmanu Danfodiyo University Sokoto Energy Research Centre (SERC). The data collected was analyzed using descriptive statistics (describe the data), correlation analysis was used to test the relationship between variables and regression analyses was used to test the effect and causal relationship between the variables using STATA software version 13. Descriptive graph is used to show the trend of Climatic factors which are rainfall, minimum and maximum temperature and humidity.

3. RESULTS AND DISCUSSION

3.1 Crops Yield and Climatic Data

The crop yield per hectare in Sokoto from 1997-2008 is indicated in Table 1. The results indicated variation in grain yield of the crops during the period under review. Maize produced the highest yield (1.45 t ha^{-1}) in 2008 and lowest yield (1.0 t ha^{-1}) in 2001. The highest yield from millet (1.5 t ha^{-1}) was in 2008 and lowest (0.88 t ha^{-1}) in 1997. The highest out put of Rice (2.60 t ha^{-1}) and Sorghum (1.3 t ha^{-1}) was in 2008 and lowest yield of Rice (0.7 t ha^{-1}) and Sorghum (0.5 t ha^{-1}) was in 1998 and 1999 (Table 1). Grain yield was highest across all the crops in 2008 due to lower maximum temperature and relatively lower relative humidity.

Fig. 2 indicates the average climatic data from 1997-2008. The amount of rain was within the average of 600 mm from 1997-2003, which was fallowed by a drought in 2004 (316.6 mm). There was a dramatic increase in rain fall in 2005 (1012 mm). Dramatic increase in rain could be as a result of global worming and climate change. The highest maximum temperature was in 2007 (34.65℃) and lowest (32.52℃) in 2008, while the lowest minimum temperature was 22.8℃ in 2007 and highest minimum temperature in 24.55 in 1998. Relative humidity was highest (76.63%) in 1997 and lowest (70.79%) in 2000.

3.2 Correlation Analysis

The correlation analysis is presented in Table 2. Rainfall is positively but weakly correlated (0.04) with sorghum, this indicates that sorghum require minimum rainfall. Rainfall is negatively correlated with maize (-0.87), millet (-0.11) and rice (-0.05). The negative correlation could be as a result of the use of different varieties such as drought tolerant that require minimum rain fall, medium and short duration cultivars that could mature in short period. Erratic nature of the rain and lack of distribution of rainfall within the phenology of the crops growth could also be a factor because some times rains came at harvest period or even after harvest. Rainfall is not significant in explaining the effect of climate in cereal crops production. The result is not compatible with that of Ayinde et al. [16] were rainfall was significant in explaining the effect of climate in crop yield. Yamoah et al. [17] and [18] observed that effect of average temperature on yields has a negative effect on crop yields.

Both maximum and minimum temperatures were negatively correlated with crops yield under review.

Table 1. Crop yield (ha-1) of major cereal crops in Sokoto from 1997-2008

Year	Maize	Millet	Rice	Sorghum
1997	1.2	0.9	0.8	0.5
1998	1.2	0.9	0.7	0.5
1999	1.3	0.9	0.7	0.6
2000	1.3	0.9	0.7	0.6
2001	1.0	0.9	0.8	1.3
2002	1.3	0.9	0.9	1.2
2003	1.3	0.9	0.8	0.6
2004	1.3	0.9	1.3	0.6
2005	1.3	0.9	1.5	0.6
2006	1.3	1.1	2.0	0.7
2007	1.3	1.4	2.5	1.1
2008	1.5	1.5	2.6	1.3

Table 2. Correlation analysis

Crops	Rainfall (mm)	Maximum temperature °C	Minimum temperature °C	Rainfall
Maize	-0.87	-0.65*	-0.42	-0.51
Millet	-0.11	-0.72*	-0.28	-0.50
Rice	-0.05	-0.56*	-0.32	-0.39
Sorghum	0.04	-0.47*	-0.09	-0.41

Correlation significant at 0.05 level (2 tailed)

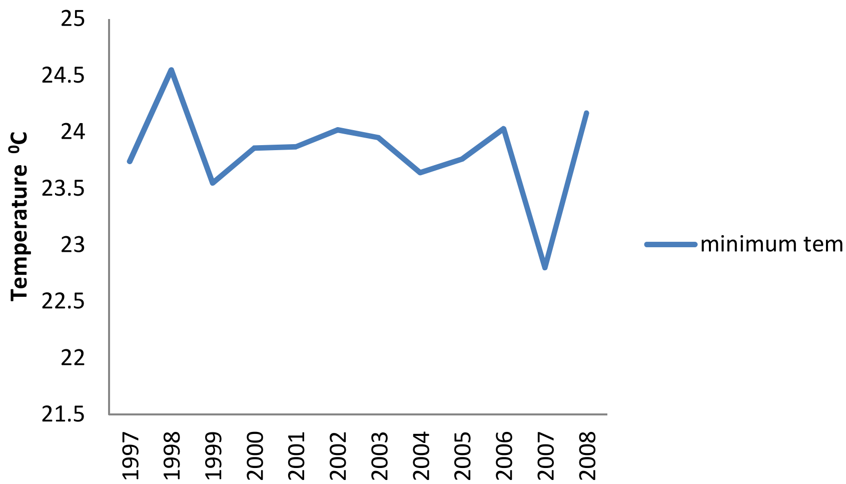

Fig. 1. Average minimum temperature for Sokoto from 1997 to 2008

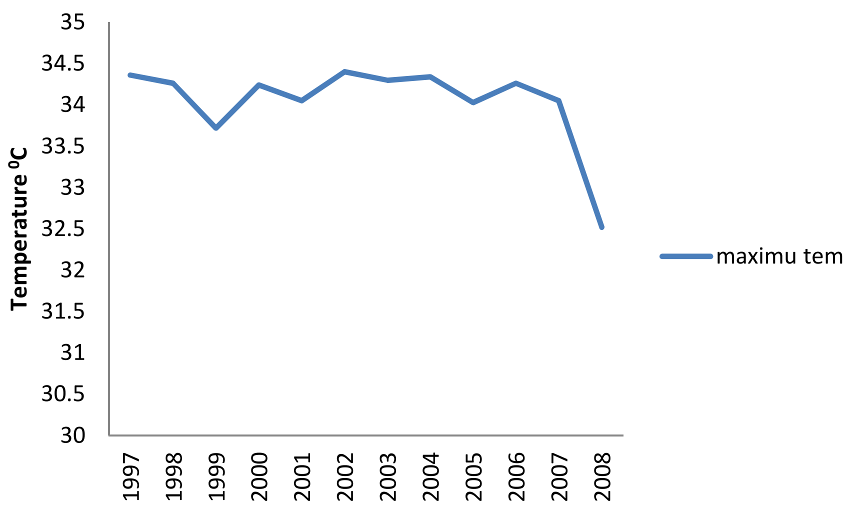

Fig 2. Average maximum temperature of Sokoto from 1997-2008

Maximum temperature (-0.65) for maize, (-0.72) for millet, (-0.57) rice and (-0.5) sorghum. Minimum temperature (-0.42) for maize, (-0.28) for millet, (-0.32) rice and (-0.09) sorghum. This indicates that increase in temperature result to decrease in grain yield. Relative humidity is also negatively correlated with crop yield (-0.51) for maize, (-0.50) for millet, (-0.39) rice and (-0.41) sorghum (Table 2). The effect of average temperature on yields has been widely studied and generally has a negative effect on crop yields Yamoah et al*.* [17]; [18].

Table 3. Regression analysis for the crops and climatic factors

Variables	Maize				Millet				Rice				Sorghum			
	Coefficient	**SE**	**T**	**P value**	**Coefficient**	**SE**	**t**	**P value**	**Coefficient**	**SE**	**t**	**P value**	**Coefficient**	**SE**	**t**	**P value**
Temperature(Max)	-0.56	0.04	-1.70	0.13	-0.69	0.09	-2.71	0.03	-0.57	14.44	-1.84	0.10	-0.31	0.26	-0.87	0.41
Temperature(Min)	-0.01	0.05	0.03	0.99	-0.28	0.10	--1.20	0.26	-0.34-	12.08	-1.13	0.29	-0.11	0.31	-0.34	0.73
Relative Humidity	-0.29	0.01	-0.90	0.42	-0.14	0.03	-0.53	0.69	-0.08	10.57	-0.26	0.80	-0.36	0.09	-0.96	0.36
Rainfall	-0.07	0.00	-0.25	0.81	-0.09	0.00	-0.36	0.72	-0.04	0.79	-0.14	0.88	0.15	0.00	0.42	0.68
R^2	0.47				0.65				0.48				0.32			
Adjusted R^2	0.17				0.45				0.18				-0.05			
F	1.94				3.63				1.61				0.85			

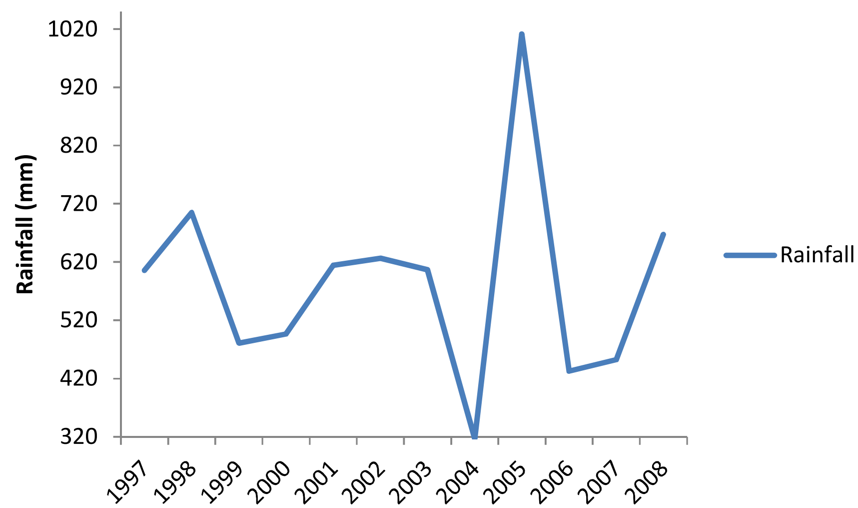

Fig. 3. Average annual rainfall of Sokoto from 1997 to 2008

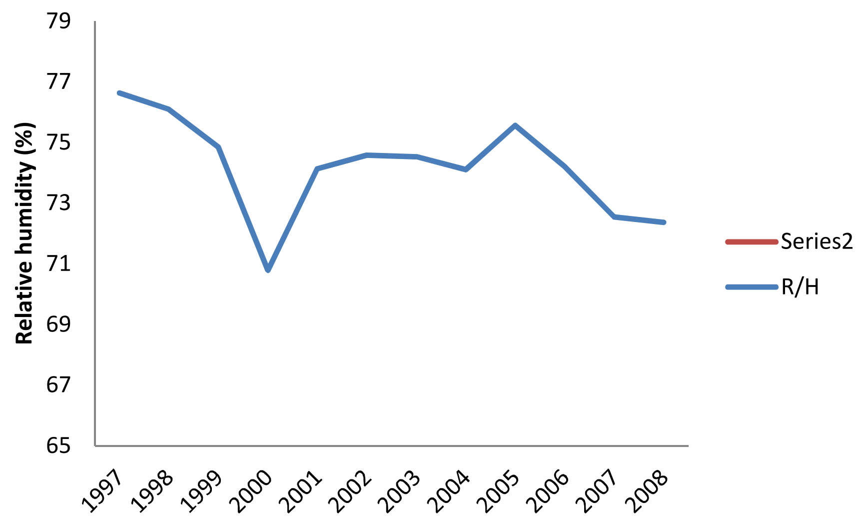

Fig. 4. Average relative humidity of Sokoto from 1997 to 2008

3.3 Regression Analysis for the Crops and Climatic Variables

The result of Regression analysis is presented in Table 3. The result indicated that only maximum temperature is statistically significant in explaining changes in millet yield. This implies that increase in maximum temperature will result to decrease in millet yield. Minimum temperature has a positive effect on maize yield. Rainfall and maximum temperature are not significant in explaining the effect of climate on cereals production in Sokoto State. The result is similar to that of Ayinde et al*.* [19] but is not compatible to that of Ayinde et al*.* [16] where rainfall was significant in explaining the effect of climate on agricultural production. This could be as a result of the use of drought tolerant cultivars, early and extra-early cultivars which could reduce the impact on rainfall on crop production. The regression analysis further revealed that maize, millet, rice and sorghum have coefficient of determination of 0.50, 0.70, 0.50, and 0.32, respectively. This indicates that 50, 70, 50 and 32% of the variance in maize, millet, rice and sorghum can be, respectively explained by the climatic parameters under study (Table 3). The implication is that 50, 30, 50 and 68 of the variance in maize, millet, rice and sorghum can be, respectively explained by other factors not included in the study. The study has actually revealed that other factors, such as solar radiation, type of soil, soil fertility and farm methods may also be responsible for crop yield.

4. CONCLUSION AND RECOMMENDATIONS

The results of the study mainly focused on explaining the effects of climatic variables, such as rainfall, relative humidity, maximum and minimum temperature on major cereals production in Sokoto State. This will assist in planning ahead in cereals production in the area. Other factors such as soil fertility, correct timing of planting and good cultural practices (such as spacing of strands), protection of crops from weeds, pests and diseases and planting of high yielding varieties should also be taken in to consideration for increase yield of cereals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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