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AN ASSESSMENT OF CLIMATIC VARIATIONS AND IMPLICATIONS ON CROP YIELDS IN KATSINA STATE, NIGERIA

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ABSTRACT

The implications of climate variations are many and varied as it influences drought, rainfall pattern and agricultural productivity in a negative manner especially in northern Nigeria. Climate variability impacts on agricultural yields and livelihood is becoming increasingly adverse over time and potentially catastrophic especially in some areas of northern Nigeria. This study basically focuses on the assessment of climatic variations and the implication on crop yields in Katsina State. The study used climatic data (temperature and rainfall) and data on crop yields (millet, sorghum, cowpea, rice and maize). Climatic data on temperature and rainfall were collected for the period of twelve years (2004-2015). Similarly, crop yields data on millet, sorghum, cowpea, rice and maize were also collected for the same period. Descriptive statistics- mean, standard deviation and coefficient of variation were employed in data analysis. Multiple regression and trend analysis were also employed. The result of the analysis reveals that data on crop yield varies from one year to the other. Millet, rice and maize yields exhibits downward trend while cowpea exhibits upward trend. Similarly, the result of the analysis of the relationship between climatic parameters and the crop yields shows that temperature and rainfall have a weak relationship on the variations in the selected crop yields. The outcome of the result shows that variations in the yield of the selected crops could be credited to other factors outside the selected climatic elements. The paper therefore, suggests the adoption of modern farming system, application of fertilizer, soil and water conservation strategies as part of measures to improve soil fertility.

Keywords: Assessment, Climatic Variation, Trend and Crop yield.

INTRODUCTION

Climate variability impacts on agricultural yields and livelihood is becoming increasingly adverse over time and potentially catastrophic especially in some areas of northern Nigeria. It is when fluctuation between the normally experienced climate conditions and a different, but recurrent set of the climate conditions occurs over a given region of the world that the word 'climate variability' comes into play (IPCC, 1998). The occurrence of which is as a result of natural and/or human interference. According to Ayoade (2003), climate variability is defined as those secular fluctuations in climate occurring over an area. Example of such fluctuation can be seen in the change in inter-annual rainfall amount in Northern Nigeria experienced through the decrease in annual rainfall totals between 1963 and 1992 (Ati *et al*., 2009) and an apparent increase for the year 1992 up to 2008 (Abaje *et al*., 2012). This portrays typical climate variability over the region. Climatic variability is undoubtedly one of the critical factors that play a significant role in agricultural production especially in rainfedagricultural regimes. Despite technological advances, agricultural productivity is highly dependent on climate. Climate is so fundamental to agriculture because its affect virtually all aspect of crop production (Adeniyi, 2013). The impacts of climate variability are of serious concern especially in developing countries because of the alarming rate on agriculture and implication for food security. The implications of climate variability on agriculture is that it threatens all dimensions of food security including but not limited to higher volatile food price, reduction in crops, livestock and fisheries production as well as disruption in the livelihood of millions of rural people who depend on agriculture for their income (FAO, 2016). Although, the effect of climate on agriculture is well known to farmers (Enete, 2014), its influence on agriculture is associated to variation in local climate rather than in global climate pattern. Northern Nigeria region is known for its associated problems of climate variability. Notable climatic variability is occurring in the amount, intensity, frequency and type of precipitation. The region generally exhibits high inter-annual variability in rainfall of between 15 and 20% (Oladipo, 1993). The region has equally suffered decrease in rainfall in the range of about 3.4% per decade since the beginning of the 19^{th} century (FRN, 2003). Rainfall and temperature variability have a significant influence on crop growth, development and yield. The year to year variations in agricultural output in form of harvest are largely as a result of variations in climatic elements – temperature and precipitation (Enete, 2014). Rainfall regime has been identified as the most significant climatic factor influencing agricultural productivity in the tropics. This is because it determines the season of crop growth and farming system. The type of crop grown, time of planting, time of harvesting, growth, development and yield are equally climate determined. Available evidence on the nature of rainfall variability in northern Nigeria suggests that a single overall meanperiodicity is not observed. Rather, rainfall is primarily characterized by a multiple, non-symmetric cycle ofanomalies with varying magnitudes (Ati*et al.*, 2009 and Abaje*et al.*, 2012). With this, agricultural production is already being adversely affected by rising temperature, increased temperature variability, changes in level and frequency of precipitation, a greater frequency of dry spells and drought, and the increasing intensity of extreme weather condition.

Evidence abounds in literature that climatic variability undoubtedly has serious impacts on crop yields. For instance, while Adeniyi (2013) opined that rainfall is a significant factor affecting crop productivity, Ajadi and Adeniyi (2017) reported that variations in rainfall and temperature affects crop yield. Similarly, Patrick (2017) reported that rainfall patterns affects crop yield by either increasing or decreasing it depending on its intensity.Olaniran and Babatolu (1987) also emphasized that rainfall distribution and the occurrence of moisture stress condition during the vegetative period are important for maize yield at Kabba while temperature is important for maize yield during the grain filling and flowering period. Furthermore, Odjugo (2010) also observed that the numbers of rain days dropped by 53% in North-eastern Nigeria. The decreasing rainfall has led to shortening of the growing season thereby causing crop failure and food shortage. According to Webster and Wilson (1990), the length of the growing season and crop growth or increase in dry weight of crop per unit land area per unit time upon which the total dry weight yield of crop depends are been influenced by climate.Changes in the occurrence and severity of drought and floods due to variations in rainfall could pose great threat for farmers and threatens food safety (Ziska *et. al.* 2016). With all these, and going by IPCC (2007) projection, which was assigned "high confidence", climate variability and change, would severely affect agricultural production and access to food in Africa.

Crop production and rural livelihood in Katsina has been characterized over time by climate variability. In a study by Yahaya and Issa (2017), rainfall being the most critical aspect of Nigeria agriculture has its amount and pattern affected by climatic variability, the resultant effects of which are further noticed in recurrent drought, reduction in crop yield and increase in temperature among the populace of KatsinaState.The decreasing rainfall has led to shortening of the growing season thereby causing crop failure and food shortage. Abaje et al (2014) also emphasized in their study that climate change is having severe impacts on the local people's livelihoods in Katsina resulting in water shortage and decline in crop yields. Although climate change is a "catch-all" term, its manifestations will be complex and diverse. The binding constraints in terms of productivity vary considerably between farming systems and regions. Furthermore, there is no certainty whether variability or extremes in rainfall or temperature will have the greatest impacts on yields. Understanding the key climatic elements and the extent of variation they may cause in crop yields become imperative in determining the type of support to be accorded to smallholder's farmers. In view of this, the focus of this paper is to assess the implication of variation in climatic elements (notably, rainfall and temperature) on yields of some selected crops in Katsina State of Nigeria.

Geography of the Study Area

Katsina State is located on Latitude 11°30' N and 13°15'North of the Equator and Longitudes 6°52' E and 09°20' East of the Greenwich Meridian. The state shares boundaries with Niger Republic to the North, Kaduna State to the South, Zamfara State to the west, and Kano and Jigawa States tothe East (see Figure 1).Katsina State covers an area of 23,938 Km^2 which is about 2.7 percent of the total land area of Nigeria (Zayyana, 2010).

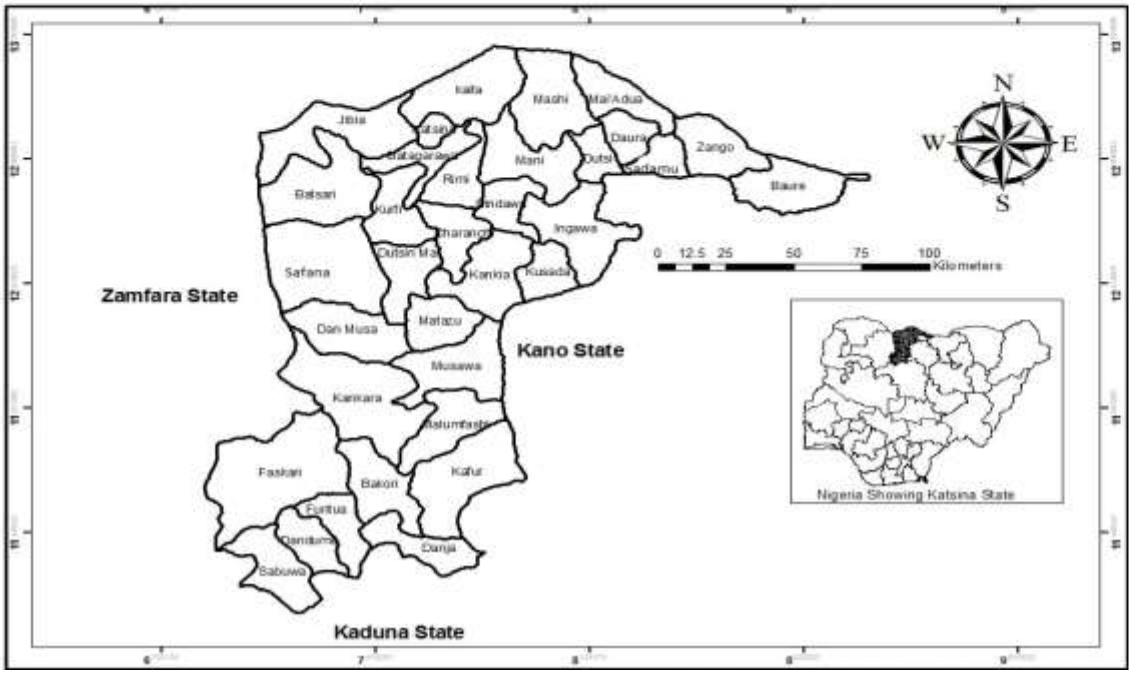

Fig. 1: Katsina State showing the LGAs
Source: Department of Geography and Regional Planning, FUDMA (2018)

Katsina state has tropical continental type of climate dominated by the activities of tropical maritime air mass (MT) and the tropical continental air mass (CT). The movements of tropical maritime air mass (MT) that has its origin from Atlantic ocean, and the tropical continental air mass (CT) originating from the Sahara desert causes seasonality in the climate of the area.The tropical maritime air mass is hot and humid while the tropical continental air mass is hot and dry.

The two major seasons in the area are wet and dry seasons. The wet season which normally lasts for 7 months (April-September) has an annual average of 1100mm in the southern part of the state and 650mm in the northern areas. The dry season varies from 5 to 6 month of the year (November-March). Temperatures are generally high in the state, especially during the peak of dry season reaching about 38^0C-40^0C. Average annual temperature is 30°C. Generally, the climate varies significantly accordingly to month and seasons. From December to February; a cool dry (harmattan) season is experienced, March to May; a hot dry season; June to September; a warm wet season and a less marked season after rains during the months of October to November, characterized by decreasing rainfall and gradual lowering of temperature (Adamu, 2000). The geological formation of the state comprises of basement complex and sedimentary formation. The basement complex accounts for over 80% of the total area.

The soil of Katsina State is generally sandy 'drift' deposits with two distinct types - clay and sandy. In the southern part of the state, the covering material is largely clayed soil; reddish black or dark-brown colour and very fine in texture. It is about 5 metres in depth and of medium fertility. The soils are difficult to work, tending to become water-logged with heavy rains and to dry out and crack during the dry season (Adamu, 2000). The soil of the southern part is suitable for the production of crops like maize, cotton, sorghum and guinea corn. In the northern part of the state, the drift deposits are coarse; resulting in light sandy soils of buff or reddish colours of low fertility and are slightly acidic (ph 5.5 to 6.5) and less leached with high base saturation, that are derived from basement complex rocks and Aeolian drifts (Abubakar, 1994). The soils of the northern part are marginal for efficient arable crop production. Millet and sorghum are the main food crops grown in the northern part while the predominant crop mixtures are sorghum/millet/cowpea or groundnut.The major rivers in the area are the Koza, Sabke, Tagwai and Gadarivers in the northern part of the state and the Karaduwa, Bunsuru, Gagare, Turami, Sokoto, Tubo, Chalawa and Galma rivers in the southern part. Most of these rivers only flow during the rainy season and have little or no water during the dry season.

The vegetation of the study area falls under the Sudan and Sahelian type of classification with presence of grasses and short trees. The grasses are usually tall during rainy season and straw-like or tufted during the dry season. The trees are scattered and shed their leaves during the dry season. Examples of plant species found in the area include *Butyrospermumparkii, parkiabiglobosa, Entada Africana, prosopis Africana and AndropogonsGayanus.* This vegetation has been subjected to intense human activities, which has turned it to arable parkland savanna. The plant density decreases from south to north. The vegetation in the south is mixed up with fine-leaved species of thorny tree with steady short and feathery grass cover (Adamu, 2000).

The 2006 population census put the population of Katsina State at 5,792,578 and annual growth rate of 2.2%. Katsina is predominantly Hausa-Fulani State and most people speak only Huasa. A great majority of the people are settled cultivators and traders. A sizeable number of migrants from southern Nigeria, especially the Yoruba and Igbo, are found and dwell mostly in towns (Mortimore, 1989). Agriculture is the main economic activity of the state with little animal husbandry and food processing. Farming system in the state is based on rain fed subsistence production of annual crops, and the nomadic Fulanis rear livestock and hawk locally prepared fermented milk. About 95% of the population is into subsistence agriculture. A wide range of crops are grown which include maize, millet, cowpea, rice, sorghum, sugarcane and groundnut. Livestock production is also widespread in the state. These include cattle, goats, sheep, horses, donkeys, camel, poultry and pigeons. Urban and nodal villages are known for trading, business activities, artisan and craft work (Katsina State Ministry of Environment, 2002).

MATERIAL AND METHODS

The data for this study was mainly secondary data which include climatic data and data on crop yields. Climatic data on rainfall and temperature were collected from the Nigerian Meteorological Agency (NIMET) for period of 12 years (2004-2015). Data on crop yields for the same period of 12 years (2004-2015) were also collected from the Department of Planning Monitoring and Evaluation, Agricultural Development Project, and Katsina State Agricultural and Rural Development Authority (KATARDA). The selected crops are millet, sorghum, cowpea, rice and maize. These crops are purposefully selected because they are the major cereal and food crops cultivated in the state.

Descriptive and inferential statistics were used in data analysis. Mean, standard deviation and coefficient of variation were used to describe the variation in the characteristics of rainfall and temperature over the years of study. Semi-average method was employed in the trend analysis (upward/downward trend) in crop yields over the years. Mann- Kendull statistics was used to show the trend and variation in crop yield. Correlation and multiple regressions were engaged in estimating the relationship between the identified climatic parameters (rainfall and temperature) and crop yield.

RESULTS AND DISCUSSIONS

Variation in Rainfall and Temperature (2004-2015)

The results of the analysis of temperature and rainfall data collected for the year 2004 up to 2015 are presented in Table 1. From the table, temperature and rainfall have the highest mean values in 2011 and 2012 respectively. This reveals thatthe hottest year during the period under review is 2011 while the wettest year is 2012. The highest standard deviation value of temperature is in 2012 while that of rainfall is in 2006. This suggests that the value of temperature and rainfall in 2012 and 2006 respectively, vary significantly from the mean. This can be attributed to the apparent increase in rainfall witnessed in the study area from the year 1992 up to 2012 as pointed out by Abaje et al. (2012). On the other hand, the lowest deviation of temperature and rainfall was in 2010 and 2009 respectively. The coefficient of variation shows that temperature was homogeneous with values less than 33% while rainfall was heterogeneous with values greater than 33%. Generally, the result of the analysis shows that temperature almost maintains the same rate throughout the period under review while rainfall exhibits considerably variation over the years. Although, katsina is known for inherent extreme variability of climate, rainfall variability is more pronounced than that of temperature and with this, variation in crop yields will be greatly accounted for by rainfall than temperature.

Table 1: Variation in Temperature and Rainfall in Katsina State (2004-2015)

	Temperature			**Rainfall**		
Year	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Mean**	**Standard Deviation**	**Coefficient of Variation**
2004	34.02	3.27	9.61	58.2	89.36	153.54
2005	34.03	3.59	10.55	60.5	84.58	139.80
2006	34.26	3.14	9.17	60.5	98.63	163.02
2007	33.83	3.49	10.48	58.7	94.98	161.81
2008	33.09	3.19	9.64	46.4	75.23	162.13
2009	32.48	3.34	10.25	36.7	45.79	124.77
2010	34.04	3.10	9.11	71.1	97.43	137.03
2011	34.83	3.16	9.07	46.0	66.71	145.02
2012	33.12	4.02	12.14	61.1	85.76	140.36
2013	34.40	3.21	9.33	57.0	84.72	148.63
2014	34.40	3.11	9.04	42.7	63.44	148.57
2015	33.80	4.10	12.13	48.5	83.18	171.51

Source: Author's Computation, 2019.

Pattern and Variation in Crop Yield (2004-2015)

Table 2 shows the results of the analysis of crop yields in the study area between 2004 and 2015. Millet, sorghum, cowpea, rice and maize yields were analyzed. Out of the selected crops, millet has the highest mean value (1.44) while cowpea has the lowest mean value (0.60). This indicates that millet has the highest yields value while cowpea has the lowest yields value during the period under review. By implication, millet has the suitability to thrive well in the study area.

This could be the reason why Yahaya (2017) in his study affirmed that grains are majorly grown by farmers in the study area and millet is grown by almost every household and therefore becomes the most important crop grown in the study area. Similarly, Katsina State Community and Social Development Project (KSCSDP, 2012) report affirmed that in katsina where this study is conducted, the cultivation of millet has the highest land usage in hectares. Furthermore, as contained in Table 2, the highest standard deviation was obtained in millet production (i.e. 0.43) which indicates that millet greatly varies from the mean. This implies that there is significant disparity in the crop yields among the selected crops in which the yield of millet has a considerable variation from other crops. The result of the coefficient of variation shows that the value for all the crops is less than 33%. This indicates that all the selected crops were homogeneous i.e. they belong to the same class of cereal crop. Going by this, grain or cereal crops are majorly grown in the area.

Table 2: Pattern and Variation in Crop Yield in Katsina State (2004-2015)

Crop	Mean	Standard Deviation	Coefficient of Variation
Millet	1.44	0.43	29.86
Sorghum	1.20	0.17	14.17
Cowpea	0.60	0.06	10.00
Rice	1.42	0.40	28.17
Maize	1.39	0.17	12.23

Source: Author's Computation, 2019.

Relationship between Climatic Variable and Crop Yield

Table 3 shows the result of regression analysis. The correlation co-efficient (r) as shown in the table for millet, sorghum, cowpea, rice and maize are 0.471, 0.130, 0.374, 0.456, and 0.207 respectively while they have co-efficient of determination (r^2) of 0.222, 0.107, 0.140, 0.208, and 0.043 respectively. This indicates that about 22.2% variance in millet yields can be explained by rainfall and temperature while 10.7%, 14.0%, 20.8% and 4.3% variance in sorghum, cowpea, rice and maize yields can be attributed to the said climatic elements respectively. Going by the result, rainfall and temperature account for a much higher variation in millet (22.2%) and rice (20.8%) production than other crops. The least variation (4.3%) is found in maize. This indicates that impact of temperature and rainfall on crop yields during the study period is much felt on millet and rice. This could possibly be because the two crops are at the extreme of rainfall requirement. While millet is a drought resistant crop that requires less water, little nutrients and gets matured within 3-4 months, rice on the other side requires much water and is even grown in swampy areas or by irrigation. The inherent extreme climatic variation in Katsina state resulting in persistence decrease in rainfall amount and increase in temperatureis favorable for millet to be widely grown and make rice production to have limitation. In general, the percentage of variance in the entire selected crop is less than 50% and so therefore, the contributory effect of rainfall and temperature to variation in crop yields for the period under review is absolutely low. This suggests that variation in crop yield in the area during the period of study could be attributed to other climatic factors such as poor physical conditions in terms of soils, vegetation, and topography, faulty agricultural practices, and soil management techniques amongst others.

Table 3: Regression Analysis of Relationship between Climatic Variable and Crop Yield

Crops	R	R^2	Regression Coefficient	Standard Error	F	Significant
Millet	0.471	0.222	11.558	0.41571	1.281	0.324
Sorghum	0.130	0.107	1.660	0.18402	0.077	0.927
Cowpea	0.374	0.140	0.103	0.5992	0.732	0.508
Rice	0.456	0.208	-3.013	0.39569	1.184	0.349
Maize	0.207	0.043	2.710	0.17917	0.202	0.821

Source: Author's Computation, 2019.

Trends in Crop Yields between 2004 and 2015

The yield per hectare of major cereal crops in Katsina State for the period of 12 years (2004-20015) were analyzed for trends using the semi- average method as shown in Table 4(a) and Mann-Kendull statistics as presented in Table 4(b). From Table 4(a), millet, rice and maize yields exhibits a decrease in production from the first part average to the second part average. For Example, millet decreases from 2.21 yields per hectare in the first part average to 1.25 yields per hectare in the second part average. Sorghum is the only crop that does not shows any change in yields over the years while cowpea shows an increase in yields from 0.67 to 0.78 between the first part average and the second part average. This indicates that while millet, rice, and maize show a downward trend; cowpea shows an upward trend; and sorghum exhibits no trend. This therefore means that production of millet; rice and maize have been decreasing over the years. This may likely be that some farmers may have withdrawn from their production because they do not have an appreciable increase in market prices. On the other hand, cowpea yields have been increasing which means that many farmers may have intensified efforts at cowpea production in the area. This corroborates the finding of Yahaya (2018) that farmers in Katsina State have for long realized the importance of planting a particular short-period black-eye cowpea known in Hausa as "Dan-llamai hula makkakusa" especially among the people of Mashi, mai'adua and kaita local government areas. Because of the relatively short period of cultivation and harvest, they have been able to sell it and make good money from it.

Table 4(a): Trends in Crop Yields Using Semi- Average Method (2004-2015)

Crops	First Part Average	Second Part Average	Trend
Millet	2.21	1.25	Downward Trend
Sorghum	1.44	1.44	No Trend
Cowpea	0.67	0.78	Upward Trend
Rice	1.97	1.43	Downward Trend
Maize	1.75	1.59	Downward Trend

Source: Author's Computation, 2019.

Table 4(b): Trends in Crop Yield Using Mann- Kendull Statistics

Crops	R
Millet	-0.24
Sorghum	-0.03
Cowpea	0.94
Rice	-0.21
Maize	-0.30

Source: Author's Computation, 2019.

The result of the trend analysis using Mann- Kendull statistics as presented in Table 4(b)also shows that the millet, sorghum, rice and maize has a negative value which shows a decrease in their trends of production. In the same vein as that of the semi-average method, cowpea shows a positive value which is an indication that it exhibits an increase in the trend of production. The two methods (semi-average and Mann-Kendull statistics) used in determination of trend in crop yields give similar results. Although, sorghum shows a no trend in semi-average method, while it has a decrease in trend in Mann-Kendull statistics, the value of the decrease (-0.03) in Mann-Kendull statistics is so insignificant that it may have no effects in crop yields and hence, resulting in no tangible variation.

CONCLUSION AND RECOMMENDATIONS

The inter-annual variations in the spatial patterns and characteristics of dryness/wetness condition in Northern Nigeria indicate a tendency towards a generally drier than normal moisture condition. Besides, the implications of climate variability for the dry/arid regions are seriously reflected in longer periods of drought and scarcity of water for agriculture and/or irrigation practices and domestic uses. Since Katsina is located in climate sensitive region in which rainfall exhibits considerable variability on multiple time scales, the focus of the study is on the assessment of temperature and rainfall variations and the implication on the yields of millet, sorghum, cowpea, rice and maize from 2004 -2015.The result shows that rainfall and temperature have weak relationship on crop yields which is in contrary to the popular opinion that climatic variability undoubtedly has serious impacts on crop yields. The result therefore, implies that variation in crop yields of the study area could be as a result of other non- climatic factors such as soil fertility, faulty agricultural practices or farming system.

In view of this, the study therefore recommends that local and regional development policies that would recognize soil and water conservation strategies should be developed for sustainable livelihood and agricultural production. There is also the need for economically viable and sustainable farming practices. For example, nitrogen-efficient crop varieties can help boost crop production when planted in area of low soil fertility. In the same vein, there is need for reorientation of agricultural and rural development policies and incorporation of social protection programmes that will help in improving crop production. If these are done, productivity declines that would have serious implication for food security will in the long run become a mirage.

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