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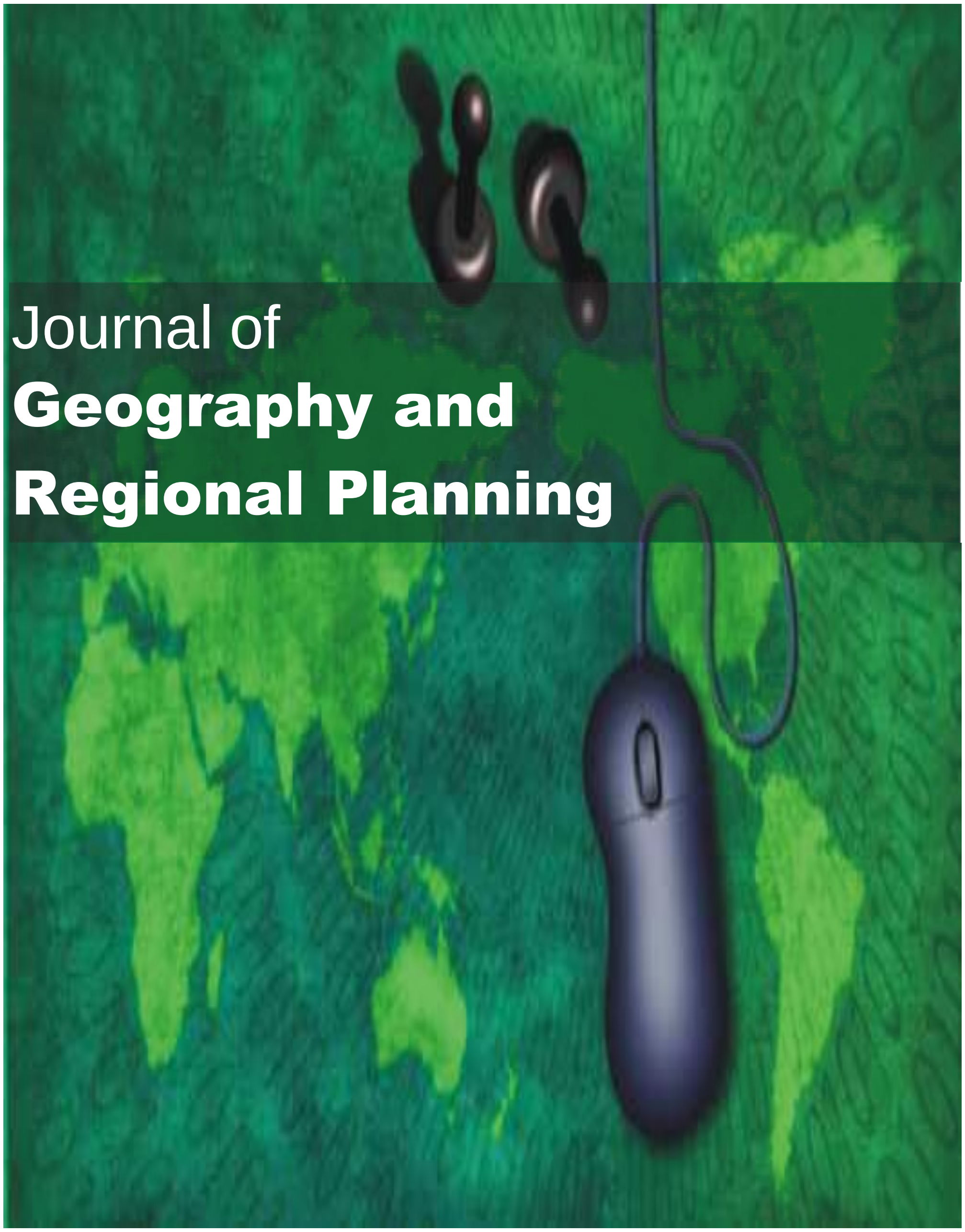

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Full Length Research Paper

Public perception of the risk of climate change issues in Zaria city and its environs in Kaduna State, Nigeria

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Many researchers, climatologist, engineers and environmentalists are expressing deep concerns about changes in the overall climate system of the earth. Does the public perceive climate change to have occurred already? What are their sources of information? This study analyzed the public perception of climate change issues in Zaria city and its environs, Kaduna State, Nigeria. The objective of this paper was to analyze the public's level of awareness and perception on climate change issues. Four hundred respondents were randomly sampled and administered questionnaire. Open-ended questions were used to ask the respondents whether they had noticed long-term changes in temperature and rainfall. The study revealed that the public perceptions of climatic change in the study area were in line with climatic data records. Eighty-two percent of the respondents are well aware of climate change issues. The electronic media (television and radio) was the major source of awareness on climate change issues followed by schools. The result further revealed that the inhabitants of the city are to a large extent aware of the dynamics of the local climate. Indeed, age, occupation and level of education affected the respondents' knowledge on climate change issues. Based on these findings, some recommendations were made, which include the need for a comprehensive environmental education, studies on climate change and other environmental issues should be integrated into the primary, secondary and tertiary school curriculum among others.

Key words: Awareness, climate change, climate variability, perception, Zaria city.

INTRODUCTION

The hazards caused by global warming are continuously causing major damage to the Earth's environment. Most people are still unaware of global warming and do not consider it to be a big problem in years to come. What most people do not understand is that global warming is currently happening, and we are already experiencing some of its withering effects. It is and will severely affect ecosystems and disturb ecological balance. Owing to the treacherous effects of global warming, some solutions must be devised (Shahzad, 2015). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) affirmed that climate

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change is no longer in doubt, it is now communally believed to be a foremost global problem. Although, extreme violent weather has occurred throughout history, recent upsurge in climate related hazards is confirming the argument for global warming and climate change (Odjugo and Ikhuoria, 2003; Nwafor, 2006). The evolving climate change coupled with increasing temperature has been observed to plunge some localities. The IPCC (2001) projected that climate change resulting from increased greenhouse gases concentrations has the potential to harm societies and ecosystems, agriculture and water resources among others.

Climate change is said to exist when the level of climatic deviation from the normal is very significant over a long period of time (preferably centuries) and such deviations have clear and permanent impacts on the ecosystem (Odjugo, 2009). IPCC (2007) defined climate change as a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties, which persists for an extended period typically decades or longer. Climate change, in the most general sense – encompasses all forms of climatic inconstancy (that is, any difference between the "long-term" statistics of the meteorological elements calculated for different periods but relating to the same area), regardless of their statistical nature or physical cause (Maunder, 1994). Climate change implies a new mean climatic state or climatic normal (Ayoade, 2002). The most crucial thing about the concept of climate change is not only the time periods involved but also the degree of variability that the change is subjected to as well as the duration and impact of such variability on man and the ecosystem.

According to Shahzad (2015), global warming begins when sunlight reaches the Earth surface. The clouds, atmospheric particles, reflective ground surfaces and surface of oceans then sends back about 30% of sunlight back into the space, whilst the remaining is absorbed by oceans, air and land. This consequently heats up the surface of the planet and atmosphere, making life feasible. As the Earth warms up, this solar energy is radiated by thermal radiation and infrared rays, propagating directly out to space thereby cooling the Earth. However, some of the outgoing radiation is re-absorbed by carbon dioxide, water vapours, ozone, methane and other gases in the atmosphere and is radiated back to the surface of Earth. These gases are commonly known as greenhouse gases due to their heat-trapping capacity. It must be noted that this re-absorption process is actually good as the Earth's average surface temperature would be very cold if there was no existence of greenhouse gases.

The ozone layer is a layer in Earth's atmosphere which contains relatively high concentrations of ozone (O3). This layer absorbs 93 to 99% of the sun's high frequency ultraviolet light, which is potentially damaging to life on earth (Albritton, 1998). According to McMichael (1993), ozone depletion is a process that results from the accrual of greenhouse gases in the troposphere. Ozone depletion occurs when the natural balance between the production and destruction of stratospheric ozone is tipped in favour of destruction. Although natural phenomena can cause temporary ozone loss, chlorine and bromine released from man-made compounds such as CFCs are now accepted as the main cause of this depletion. In particular, most of the atmosphere's ozone resides within the stratosphere. The ozone layer absorbs much of the incoming solar ultraviolet radiation (UVR) and thus offers substantial protection from this radiation to all organisms living at, or near to, Earth's surface. Intriguingly, atmospheric ozone is not part of the planet's original system but a product of life on Earth.

Climate Change would directly or indirectly affect human health and settlements in Nigeria. According to Odjugo (2010a), about 15% of the country's population is presently affected by climatic variation and sea level changes. With climate change, between 50 and 60% of the population would be affected. The excessive heat, increasing water stress, air pollution and suppressed immune system occasioned by climate change will result in increasing incidence of excessive death due to heat exhaustion, famine, water related diseases (diarrhea, cholera and skin diseases), inflammatory and respiratory diseases (cough and asthma), depression, skin cancer and cataract (DeWeerdt, 2007).

One of the greatest impacts of climate change is the worsening condition of extreme weather events like drought, flood, rainstorms, windstorms, thunderstorms and landslides and among others (Odjugo, 2001). Odjugo (2009) noted that the frequency and magnitude of wind and rainstorms did not only increase, they also killed 199 people and destroyed property worth 85.03 billion naira in Nigeria between 1992 and 2007. Odjugo (2010b) showed that climate change has shortened the growing season which has led to a shift in crops cultivated in northern Nigeria. The sea incursion is reducing the arable land of the coastal plains, and desertification with its associated sand dunes is depriving farmers of their agricultural farmlands and grazing rangelands.

The term perception is generally understood to mean an attitude or understanding based on what is observed or thought. Perception is a process by which people interpret and organize sensation to produce a meaningful experience of the world. Perception is the process by which we receive information or stimuli from our environment and transform it into psychological awareness (UNFCCC, 2006). Doss and Morris (2000) opined that the perspectives of the people in an environment, the way they think and behave in relation to climate, as well as their values and aspirations have a significant role to play in addressing climate change.

Awareness is having a knowledge or understanding of a subject, issue or situation. It is instructive to note that individuals understand certain situations or phenomena in

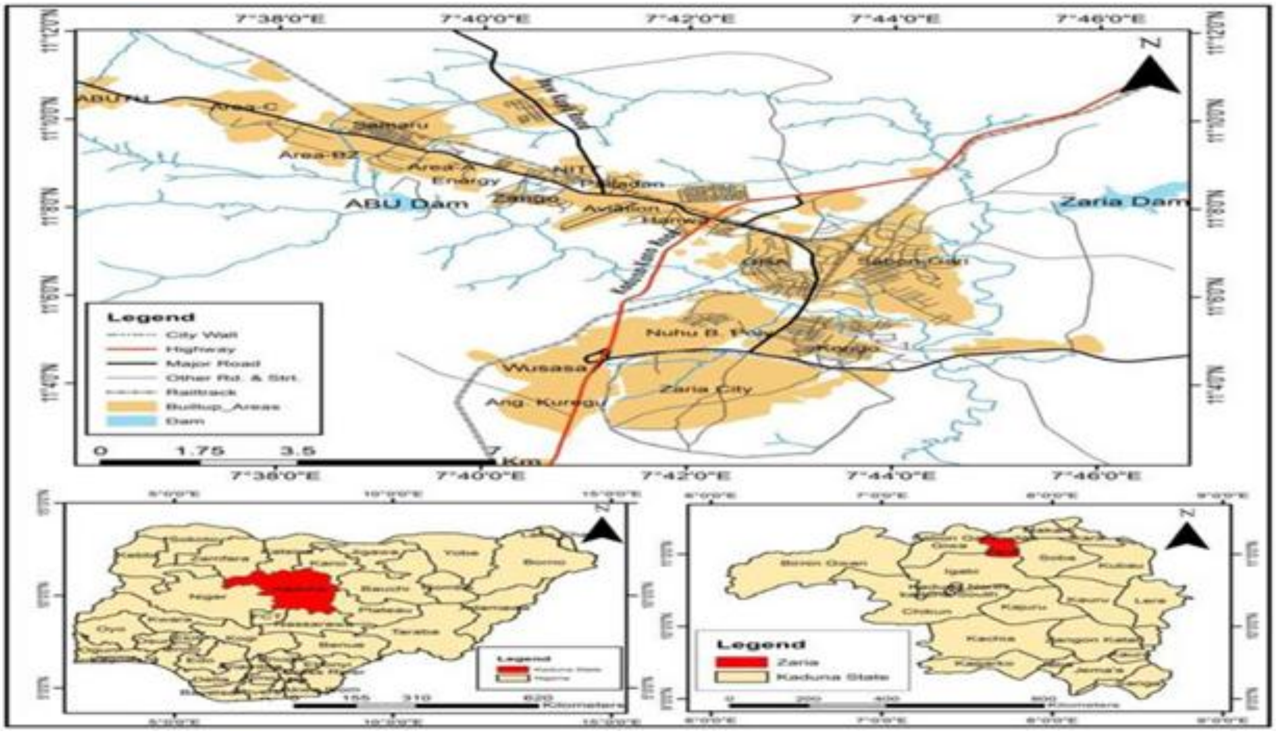

Figure 1. Map of Zaria City and its environs.
Source: Administrative map of Zaria, 2017.

different ways using very similar or dissimilar sets of information. Banjade (2003) opined that knowledge, interest, culture and many other social processes can shape the behaviour of an actor who uses information and attempts to influence that particular situation or phenomenon. Perception varies with the individuals' past experiences and present sets or attitudes acting through values, needs, memories, moods, social circumstances, and expectations.

In spite of this, traditional people are only rarely considered in academic, policy and public discourses on climate change, though the impact of impending changes of climate is greater on them (Adefolalu, 1986). Does the public perceive climate change to have occurred already? What are their sources of information? Does age, occupation and educational level of the respondents affect their knowledge of climate change? What, if any, is the role of government, individuals and Non-Governmental Organizations (NGOs) in addressing the impacts of climate change? These are the questions this paper aimed to address.

MATERIALS AND METHODS

The study area is located approximately within Latitude 11° 40'N and 11° 10' N of the Equator and Longitude 7° 38'E to 7° 46' 00'E of the Greenwich meridian (Yusuf, 2013). It is located in Zaria Local Government Area of Kaduna State. Zaria is the second largest town in Kaduna State after Kaduna town. Zaria has a total land mass of about 61Km^2 and it is located at an average height of about 600 meters above sea level which is characterized by the bedrock of metamorphic rocks of the basement complex. The soils of Zaria are basically leached ferruginous tropical soils (Mortimore, 1970). The river system of the study area is dendritic in nature and the major rivers found are Galma, Kubanni, Kamacha, Saye, Shika and Yashi (Figure 1). Zaria has a population of about 408,198 people (2006 Census). The settlement pattern of the study area is mainly nucleated. Most of the populations are engaged in agriculture, trading, civil service jobs etc. (Yusuf, 2013). Data on the public perception of climate change issues in the study area were collected through structured questionnaire. The questionnaire was randomly distributed to four hundred (400) sampled respondents in the study area. Results of the study were analyzed using chi-square and summarized and presented in charts and tables.

Climatic characteristics of Zaria

Figure 2 shows the total annual rainfall pattern of the study area. The trend line equation Y= 6.7883x + 914.83 indicates an increasing total annual rainfall amount in the study area. Figure 3 shows the maximum temperature of the study area. The trend line equation Y (0.0338X + 33.395 shows an increasing temperature in the study area.

RESULTS AND DISCUSSION

Public awareness of climate change

The results of the awareness of climate change issues

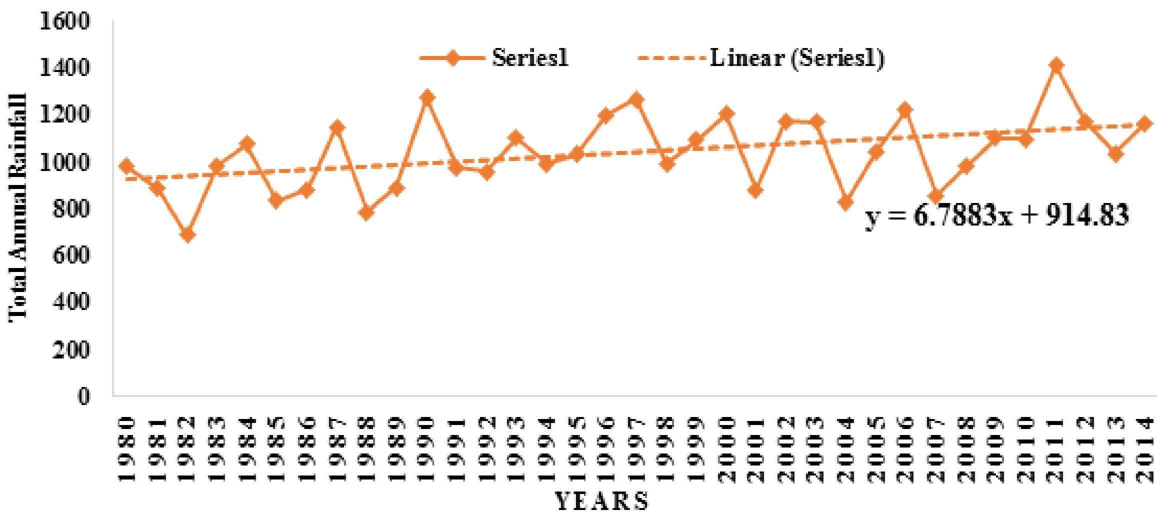

Figure 2. Total annual rainfall of Zaria.

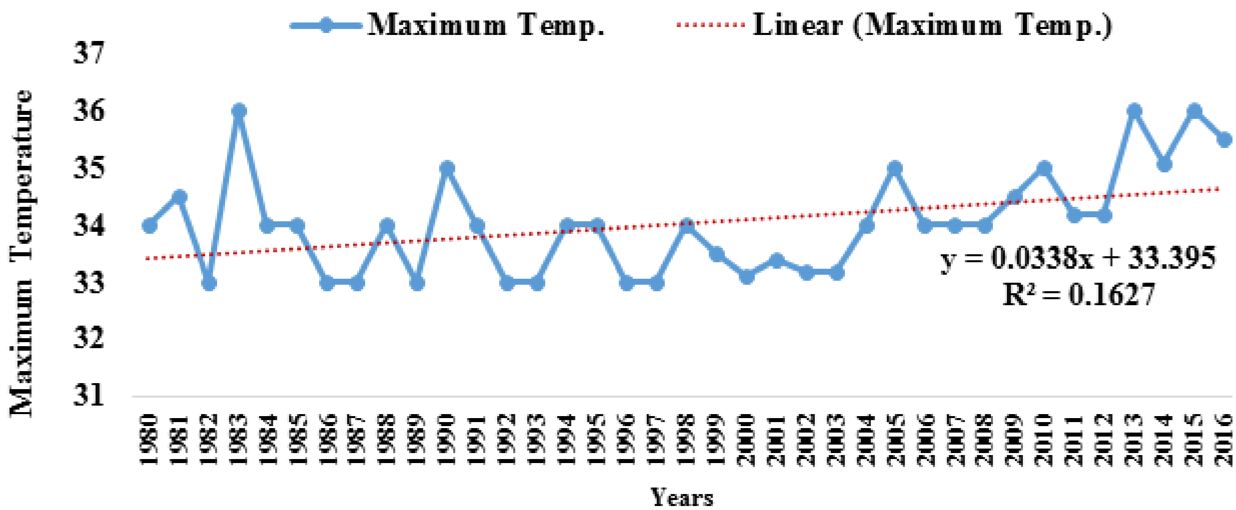

Figure 3. Maximum temperature of Zaria.

are presented in Table 1. The result shows that 82% of the respondents are aware of climate change issues in the study area, while 18% are not aware. According to Maddison (2006), respondent's awareness of change in climate attributes (temperature and precipitation) is important to adaptation decision making. The awareness of climate problems and the potential benefits of taking action is an important determinant of adoption of agricultural technologies (Hassan and Nhemachena, 2008). Araya and Adjaye (2001) reported that respondents' awareness and perceptions of climate change in an environment positively and significantly affect their decisions to adopt viable adaptation measures. This result agrees with the findings of Agboola and Emmanuel (2016) which indicated that 97% of undergraduates in Southwest Nigeria are aware of climate change. There is tendency of the years of awareness of climate change to have positive effect on the adaptation strategies used by the respondents, that is, the higher the number of years of awareness the more experienced the respondents in coping with the change in climate (Otitoju, 2013).

Table 2 presents the age of the respondents and their knowledge on global climate issues. The result of the age and knowledge of global climate change issues indicate that age of the respondents affects their knowledge of climate change issues. Respondents who are between 20 years and 40 years are better informed about global climate change issues as shown in Table 2. This could be as a result of their active mind in education and exposure

Table 1. Public awareness of climate change issues in Zaria and its environs.

Awareness	Respondents	Percentage
Yes	328	82
No	72	18
Total	**400**	**100**
How long have you heard about climate change?		
1 - 5 Years	146	36.5
6 - 10 years	102	25.5
11 - 15 years	62	15.5
16 - 20 years	36	9
21 - 25 years	24	6
26 - 30 years	18	4.5
≥31 years	12	3
Total	**400**	**100**

Source: Field Survey 2016.

Table 2. Age and knowledge of global climate change issues in Zaria and its environs.

Age (years)	Global climate change (%)	Global warming (%)	Ozone depletion (%)	Greenhouse gases (%)
Less than 20	75	62.5	43.8	62.5
20 - 29	92	92.8	88	88.8
30 - 40	82	78.6	78.6	75
41 - 50	69.5	78.3	69.6	73.9
≥51	75	75	62.5	62.5
Chi square test	0.000*	0.000*	0.000*	0.000*

*Significant at 0.05.

Table 3. Education and knowledge of global climate change issues in Zaria and environs.

Education	Global climate change (%)	Global warming (%)	Ozone depletion (%)	Green house gases (%)
None	40	40	46.6	26.6
Primary	63.3	60	70	66.6
Secondary	71.8	68.8	78.1	75
Tertiary	94.2	94.2	93.1	94.2
Traditional	83.3	80.5	72.2	75
Chi square test	0.000*	0.000*	0.000*	0.000*

*Significant at 0.05.

to the social media. The result agrees with the study of Hassan and Nhemachena (2008) reported that the experience and ability of the respondent to observe climatic changes in the environment matters more than merely the age of the respondent when it comes to adaptation to climate change. They argued that a keen personal observation of the physical environment increases the probability of a respondent's awareness and knowledge of climate change. This result disagrees with the study of Deressa et al. (2008) who argued that the older the respondents, the more his awareness and experience in knowledge of climate change and the more exposed to past and present climatic conditions over a longer horizon of his lifespan. This disagreement is on the perspective that the age of the farmers is related to his years of experience in farming activities.

Table 3 presents the level of education of the respondents and their knowledge on global climate

Table 4. Occupation and knowledge of global climate change issues in Zaria and environs.

Occupation	Global climate change (%)	Global warming (%)	Ozone depletion (%)	Green house gases (%)
Farmers	82.6	60.8	60.8	56.2
Traders	76	80	68	44
Students	78.9	84.2	78.9	84.2
Professionals	77.7	77.7	77.7	66.6
Civil servants	92.5	87.5	90	87.5
Other Professionals	94.4	88.8	83.3	88.8

Table 5. Gender and knowledge of global climate change issues in Zaria and environs.

Gender	Global climate change (%)	Global warming (%)	Ozone depletion (%)	Green house gases (%)
Male	83.9	76.9	75.5	69.9
Female	82.4	66.6	64.9	61.4
Chi square test	0.000*	0.000*	0.000*	0.000*

change issues in the study area. Higher level of education is often hypothesized to increase the knowledge and awareness of climate change and the probability of adopting new strategies (Adesina and Forson, 1995). Indeed, education is expected to increase one's ability to receive, decode, and understand information relevant to making innovative decisions (Wozniak, 1984). According to Enete et al. (2011), education has a positive and highly significant relationship between the farmers' level of education with the level of investment in indigenous and emerging climate change adaptation practices. This is to be expected as educated farmers may better understand and process information provided by different sources regarding new farm technologies, thereby increasing their allocation and technical efficiency. Table 3 showed that the respondents with tertiary education are better informed about climate change issues in the study area. This result agrees with the findings of Nkonya et al. (2008) who acknowledged that education increases one's ability to perceive climate change. Similarly, Gbegeh and Akubuilo (2013) have found that education empowers a respondent to access and conceptualize information relevant to making innovative decision. However, it disagrees with the study of Constable (2016) which observed that education does not influence one's knowledge of climate change. This disagreement was predicated on the fact that most of the farmers based in the rural areas are not well educated, yet they do well in farming activities.

Table 4 shows the relationship between occupation and knowledge of global climate change issues in the study area. The result shows that occupation affects ones' knowledge of climate change. The result revealed that farmers, students and Civil servants are better informed about climate change issues. The students must have read or taught about climate change issues in school. Researchers, environmentalists and policymakers are now advocating that climate change be integrated into the Nigerian curriculum system. The civil servants have access to different sources of information (print and media) on climate change issues, while the farmers through their experience and personal observation on farming activities have information on climate change.

The relationship between the knowledge of global climate change issues and gender is presented in Table 5. Table 5 indicates that gender affects one's knowledge on global climate change issues as males are better informed about climate change issues than the females as shown in Table 5. This result agrees with the findings of Umar et al. (2015) which reported that males dominate the agricultural workforce in Sokoto State with 99.1%, while female were about 0.9%. The results further agree with the observation of Adedoyin et al. (2005) who reported that women are restricted from actively participating in farming and other outdoor activities as a result of the socio-religious belief in northern Nigeria which affect their empirical knowledge on climate change issues.

Sources of awareness on climate change issues in Zaria and its environs

Among the many sources of information available to respondents on climate change related issues in the study area, electronic media is the most important source, followed by the school, printed materials and personal

Table 6. Sources of information on climate change issues in Zaria and its environs.

Sources	Respondents	Percentage (%)
Interacting with friends	30	7.5
School	50	12.5
Printed materials	40	10
Electronic media	112	28
Personal observation	40	10
All of the above	128	32
Total	**400**	**100**

Table 7. Public perception on weather and climate indices in Zaria and its environs.

Perception	Agreed (%)	Disagreed (%)	Undecided (%)
Total annual rainfall amount is increasing	77	18	5
Temperature is increasing	70	21	9
Number of rainy days have reduced compared to the past 5 years	67	22	11
Rain episodes are stormier now compared to the past 5 years	63	21	17
Floods after rain are more common now that 5 years ago	74	21	5
Harmattan period is now short compared to the past 5 years	47	38	13

observation (Table 6). That the majority stated that they got information on climate change from the electronic media disagrees with the study of Umar (2015) which reported that 96% of respondents in his study at Katsina identified friends and extension workers as important source of information on climate change which implies that information on climate change is majorly disseminated informally in his study area. The results further agree with the findings of Ejeh (2014) which stated that the respondents in Kano State received information on climate change majorly from Radio and Television as agreed by 73.1% of his respondents. The results further disagree with the findings of Ikpe (2021) which reported that grain farmers in Sokoto State, Nigeria got their information on climate change from personal observation and from interacting with friends. Personal observations and interaction with friends and researchers are viable sources of information on climate change issues. As earlier discussed, the students are well informed about climate change issues compared to traders.

This finding is in agreement with the findings of IPCC (2007) that media plays an important role in improving the "disaster reduction consciousness" of the general population and disseminating early warnings. In many cases, the media is the primary means of communication between policy makers, practitioners, and the public. In this regard, the media carries a great responsibility to serve the needs of their audiences, and policy makers and practitioners are tasked with improving ways to formulate messages that are "newsworthy" and attract the media.

The public perceptions on weather and climate change indices are presented in Table 7. The public perception on weather and climate change indices was analyzed; 77% of the respondents agreed that rainfall amount is increasing in the study area; 18% disagreed and 5% were undecided that rainfall amount is increasing in the study area. There is also a general consensus among households in the study area that temperatures have increased over the years. Trend analysis of the climatic data used for this study period (1970 - 2016) also revealed that recent trend in rainfall is increasing and temperature is getting warmer in recent years. The result that the number of rainy days is decreasing in study area as indicated by 67% of the respondents agrees with the study of Odjugo (2010b) who observed that rainfall amount and duration is decreasing as rainfall amount was reduced by 178mm within the 70 years reviewed (1940 - 2010) in the Northwest States of Sokoto and Zamfara.

Seventy-four percent of the respondents agreed that floods after rain are more common in recent years compared to the past five years; 21% disagreed, while 5% were undecided. Vincent and Afokoghene (2014) in their study: Natural hazard and crop yield in south-south Nigeria reported that the farmlands of Oleh community (South-south of Nigeria) have been subjected to seasonal flood events during and after every rain throughout the period of 2011 and 2012. The study further revealed that all the food crops cultivated by the inhabitants of Odah, Iwhreotah and Erorin quarters are affected by flooding. The results of the analyzed data showed satisfactory impact of flooding on crop yield in the area. Forty-seven percent of the respondents agreed that Harmattan period is now shorter compare to the past 5 years. This result agrees with the study of Umar et al. (2015) who reported a shortening Harmattan season in Sokoto State.

CONCLUSION AND RECOMMENDATIONS

The findings of the study revealed that majority (82%) of the public are well aware of climate change issues. Public perceptions of climatic variability are in line with the reviewed climatic data records. Also, age affects knowledge on global climate change issues as those from 20 years to 40 years have better knowledge and practical experience of climate change issues. Education and occupation are major determinant of the level of awareness of global climate change issues as those with tertiary education, civil servants and students are better informed about climate change issues in the study area. Moreso, electronic media is the main source of awareness on climate change issues.

Following the findings of the study, the following recommendations are made:

1. Since the electronic media is the main source of awareness on climate change issues, the government and relevant organizations should utilize the advantage of the public media to educate more and inform the general public on climate change issues.
2. Studies on climate change and other environmental issues should be integrated into the primary, secondary and tertiary curriculum. Further studies of the science of climate change and its potential impacts in Nigeria are important in creating awareness and providing the background information for targeting policies adequately.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Relationship between rainfall variability and sorghum yield in Potiskum Local Government Area of Yobe State, Nigeria

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Researchers have shown that rainfall variability has significantly impacted on crop production with manifestations in frequent poor yield in Sub–Saharan African. This study examined the relationship between rainfall variability and sorghum yield in Potiskum Local Government Area of Yobe State, Nigeria. Rainfall data for 62 years (1956 – 2018) and yield data for sorghum were both analyzed. The standardized coefficients of skewness and kurtosis statistics were used to test for normality of the rainfall series. Pearson's moment product correlation coefficient was used to show the relationship between the trend in rainfall distribution and its impacts on the yield of sorghum. The results were presented in tables and graphs. The results showed that rainfall series was negatively skewed and had no significant deviation from the normal curve (1.96) at 95% confidence level showing normal distribution of data. The analyzed data showed an anomaly and decline in rainfall. The Pearson's Coefficient of Determination (R) calculated for sorghum yield (R^2=0.364) indicated a negative correlation between rainfall variability and sorghum yield. 36.4% of the variation in sorghum yield was associated with the rainfall variation during the study period. The findings further showed that sorghum is a drought resistant crop in the study area; despite the decline in annual rainfall, sorghum yield was increasing as a result of other factors. The study thus, recommended the provision of early warning weather information to farmers; use of climate-resilient varieties, high and early maturing cultivars and fertilizer management which will play a major role in improving the productivity of sorghum in the study area.

Key words: Climate change**,** productivity, rainfall variability, temperature.

INTRODUCTION

Rainfall is considered the primary input for crop yield in Sub-Saharan Africa, any significant variability in the amount of annual rainfall could have an equally significant impact on agricultural production (Ati et al., 2009). Rainfall shows a more complex structure over time and space. The rainfall is highly variable both in amount and distribution across regions and seasons (Mersha, 1999). The Intergovernmental Panel on Climate Change

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(IPCC, 2001) pointed out that rainfall in Sub-Saharan Africa exhibits high interdecadal variability, a pattern of continuous aridity since the late 1960s. The degree to which rainfall amounts vary across an area or through time is an important characteristic of the climate of an area. This subject area in meteorology/climatology is called rainfall variability (Nouaceur and Murarescu, 2016).

Impacts of rainfall variability are felt among farmers in many regions and developing countries including Nigeria. Rainfall variability constitutes a serious adverse socio-economic and environmental problem in Northeastern Nigeria. It has resulted into seasonal drought, flood, soil erosion, climate change, biodiversity loss among others (Adejuwon and Odekunle, 2006). The natural resources base on which farmers depend on are altered, traditional socio-economic livelihoods stressed and the potential for future agricultural development are affected by rainfall variability (Jost et al. 2016).

Moreover, over the past years concerns have grown on increased rainfall variability across seasons resulting in large yield variability and thus becoming an apparent determinant on the performance and adaptation of sorghum varieties (Traore et al., 2016). Meteorological data have shown that rainfall pattern in Nigeria has changed in the past decades. Oladipo (1995) reported that decline in the rainfall in Nigeria started in the beginning of the 1960s when a decade of relatively wet years ended. Fluctuations in rainfall and other manifestations of the impacts of climate change are direct threats to the livelihoods of Nigerians, and indeed a direct threat to farmers. As rainfall variability increases, its impact on livelihoods of indigenous farmers bites harder. Some of the consequences of this are that farmers are forced to cultivate more lands to marginally increase yield to make up for the shortfall (Agwu and Okhimamhe, 2009).

Total annual rainfall at a location is influenced by several variables including the frequency of rainfall events, the duration of the rainy period and the intensity of rainfall of individual events. Inhomogeneities in the annual rainfall therefore reflect changes in these contributory variables. Adejuwon et al. (1990) fitted linear trends to the annual rainfall series of several locations in Nigeria for the entire period of available data which, in some cases, began in 1922. Olaniran (1991) analyzed the fluctuations in the series of rain days of three rainfall categories (low, moderate and heavy intensity). On the other hand, Dammo et al. (2015) examined quantitative analysis of rainfall variations in north-eastern region of Nigeria based on the standard climatic normal periods. Apart from this, assessment of the trends and changes in different categories of rainfall variability and its effects on the yield of sorghum in Potiskum Local Government Area (LGA), Yobe State, Nigeria appears in the literature.

Sorghum (*Sorghum bicolor L. Moench*) is a local grain cultivated predominantly in the semiarid savannah and grassland areas of Northern Nigeria and other parts of the world. Sorghum is viewed as a possible replacement crop for corn cultivated for grain and silage, in part due to sorghum's lower input requirements and costs, and its drought tolerance. It is nutritionally rich and serves as a staple food in most parts of Northern Nigeria. The grain has assumed commercial relevance lately, especially in the food and beverage industry. It has been found to be a valuable ingredient next to malted barley used in the beverage industry. Sorghum is an annual grass, 5–7 feet tall, similar in appearance to maize (corn). Through breeding efforts, newer varieties now have 2-3 dwarf genes, resulting in a plant 2-4 feet tall and easier to harvest. The most extensively grown and best-known sorghum species in Nigeria is *vulgare* and *S. bicolor* (L.) Moench., locally called guinea corn,. Both varieties can be white or yellow (FAO, 2012).

Sorghum requires rainfall of about 600-1,000 mm for a duration of at least five months spread over eighty rainy days (Odjugo, 2009). That means where rainfall totals fall below 600 mm, effective sorghum production will be affected. It also implies that sorghum production will also be affected where the amount of rainfall exceeds the required maximum. The development of the crop takes 110 to 170 days, and is frequently considered to have 3 stages: emergence, floral initiation to flowering, and flowering to physiological maturity. The crop thrives better under dry and cool conditions. Sorghum is a thermophilic (26ºC-40ºC), drought-resistant plant, which grows slowly at 16-20ºC, and stops growing under 14ºC. Its productivity is dependent on quantity of rains during pre-sowing season and water holding capacity of soil (Iren, 2004).

Sorghum is widely grown both for food and as a feed grain. It plays a significant role in food security in northern Nigeria. The stems are used for fuel and building fences and local huts, hence, the reason for its wide cultivation in northern Nigeria. Nigeria must double its production capacity and equally address the challenges facing the agricultural sector, particularly those associated with rainfall variability in order to meet the high demand of sorghum. According to Schaefer (2001), crop yields are affected by climatic variables, uneven rainfall distribution and prolonged arid period which lead to further development of soil erosion and loss of fertile soil. Thus, this study succinctly assesses the relationship between rainfall variability and the yield of sorghum in Potiskum LGA of Yobe State, Nigeria. Results from previous studies/experiments on the production of sorghum show that sorghum yields vary among varieties and across locations and season.

Study area

Potiskum Local Government Area (LGA) is one of the seventeen LGA of Yobe State, Nigeria. It is located on the A3 highway and geographically referenced

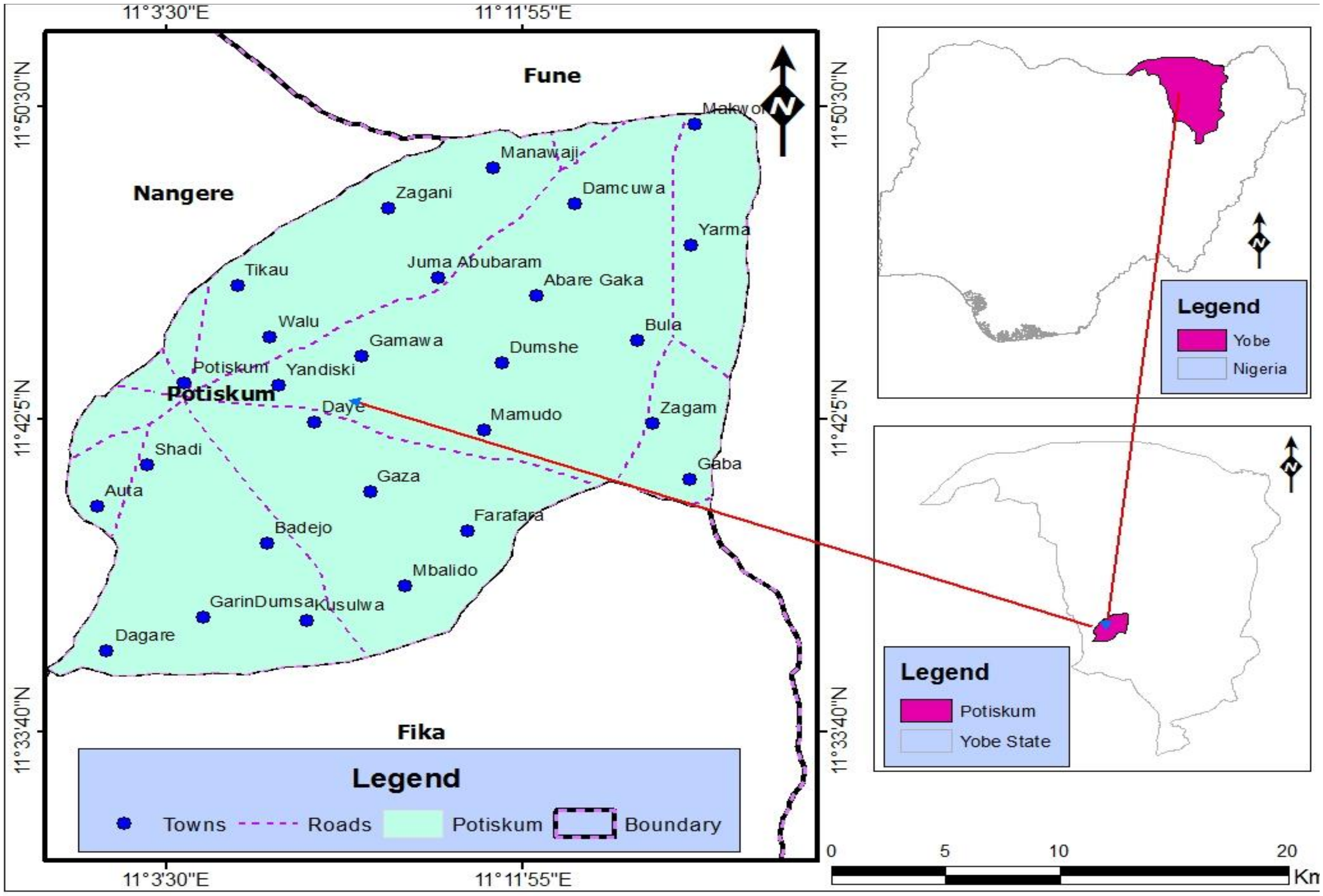

Figure 1. Map of the Study Area.
Source: GIS and Remote Sensing Lab., ABU, Zaria (2020).

approximately on 11°33’40"N to 11°50'30"N of the equator and 11°3'30"E to 11°11'55'E of the Greenwich meridian. It has an approximate total area of 559 Km^2. According to National Population Census (2009), Potiskum LGA has a total population of 244,050 people with a population density of about 436.6 people per km^2 (National Bureau of Statistics, 2019). Potiskum LGA shares boundaries with Fune LGA to the East, Fika LGA to the South, Nangere LGA to the North-West (Figure 1). The ethnical composition of Potiskum is heterogeneous which includes both indigenous and settlers. The indigenous ethnic groups include the Ngizim, Kare-Kare and Bolewa, whereas the settlers’ ethnic groups include the Hausa, Fulani, Babur, Kanuri, Igbos, Yoruba and Shuwa-Arabs. Agriculture is the predominant occupation among the people (NBS, 2019).

Generally, Yobe State is described as a major wetland in the semi-arid corridor, supporting over one million people in food production (FAO 2006). The study area falls within the extensive landscape of Borno plains. The vegetation is mostly light foliage and thorns (Nigerian Bureau of Statistics, 2019). Grasses are short, discontinuous, wiry and tussocks. They are much used by cattle and sheep. There is no real gallery or fringing forests but only riparian woodland of certain acacias, tamarind and baobab. The basic agriculture of the area is upland rainfed cultivation with crops such as maize, sorghum, cowpea, groundnut, rice and recently soybean (Amaza et al*.,* 2009). In most areas, cereal cropping systems are being intensified, replacing old ones. The agricultural sector is highly sensitive to rainfall patterns since rain-fed agriculture is mainly practiced (NOAA, 2008).

MATERIALS AND METHODS

Source and type of data

The study design involved the collection and analysis of rainfall data (1956 -2018) for Potiskum, Yobe State from the Nigerian Meteorological Agency (NiMET), Lagos. Yield data of the study area for sorghum in tons/ha (1991–2018) were sourced from the Yobe State Ministry of Agriculture archives. Available literature such as journals, textbooks, conference proceedings, seminar papers, thesis and reports were also used and properly referenced.

Test for normality

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were calculated and used to test for normality of the annual rainfall series (1956-2018). Nnachi (2014) also used this method in his research to test for rainfall normality in Gusau station, Zamfara State from 1971 to 2010. His results showed that the Gusau station received over 85% of its annual rainfall totals in these years which became a parameter for testing rainfall normality.

The standardized coefficient of skewness (Z_1) was calculated as;

$$Z_1 = [(\sum_{i-1}^{n} (x_i - x)^{3/N}) / [(\sum_{i-1}^{n} (x_i - x)^{2/N})^{3/2}] / (^6/_N)^{1/2} \quad (1)$$

The standardized coefficient of Kurtosis (Z_2) was determined as;

$$Z_2 = [(\sum_{i-1}^{n} (x_i - x)^{4/N}) / [(\sum_{i-1}^{n} (x_i - x)^{2/N})^2] - 3 / (^{24}/_N)^{1/2} \quad (2)$$

where:
x is the long term mean of x_i values and N is the number of years in the sample.

These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. Thus, if the computed absolute value of Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at 95% confidence level. Generally, the annual rainfall data showed a great tendency of normality. As a result, the data were used without any transformation.

Rainfall characteristics

The rainfall data obtained from NiMET for sixty-two years (1956–2018) was added for each of the years beginning from January to December to give the total annual rainfall (TAR) received in the study area. The long-term mean was determined by summing all annual rainfall records and dividing by the number of years. Standard deviation, long term mean and coefficient of variation were used in analyzing seasonal and annual rainfall over the study area. Scientifically, it is computed using the following formula:

$$CV = {}^{SD}/_{x}$$

where: CV is coefficient of variation, SD is the standard deviation and x mean for rainfall.

According to Hare and National Mission for Sustainable Agriculture (NMSA, 1983), magnitude of coefficient of variability is classified as follows: <20%; less variable, 20-30%; moderately variable, and >30%; highly variable and vulnerable to drought.

Relationship between rainfall and sorghum yield

The Pearson's product moment correlation coefficient (***r***) was computed to show if there was any significant relationship between rainfall (independent variables) and sorghum yield (dependent variable) from 1991–2018. It is a form of linear correlation analysis used to ascertain the strength or index of crop-climate relationship. Pearson's product moment correlation coefficient was suitable because the distribution is bivariate, continuous and normal. Both sorghum yield and rainfall data were harmonized by dividing by 100. The value ***r*** must fall within the ranges of -1≤ 0 ≤ +1. If the values tend towards +1, it indicates a perfect positive relationship but if it tends to -1, a perfect negative relationship has been established. If it is 0, there is no relationship established.

The Coefficient of determinism (R) was also used to ascertain the extent or degree of percentage or proportion to which independent variables (X_1 and X_2) influenced the outcome of dependent variables (Y). An R-value of ≥65% depicts greater or very significant influence; 45–64% shows moderate influence, while 0–44% depicts an insignificant or poor influence. The results of the study were presented in tables and charts for better clarity using Microsoft Excel.

RESULTS AND DISCUSSION

The annual rainfall series for Potiskum was subjected to the normality test using the coefficients of Skewness (Z_1) and Kurtosis (Z_2) as illustrated in Table 1.

Both results showed that the series was negatively skewed and had no significant deviation from the normal curve (1.96) at 95% confidence level showing normal distribution of data since the results were below 1.96. The Coefficient of variation showed that rainfall was moderately variable at 24.66%. The annual range of rainfall was lengthier for 29 years at 751.38 mm which raises serious concerns of rainfall irregularity and variability.

The trend in annual rainfall series from 1956 to 2018 as presented in Figure 2 generally showed that rainfall was oscillating and declining. The linear equation is:

$$y = -1.5219x + 722.29$$

This shows a negative trend line which signifies a below normal scenario. There were notable increases in TAR above the mean from 1956-1964, 1979-1981, 1999-2001 and from 2008-2013. Other yearly increases were short-lived especially in 1967, 1972, 1974, 1986, 1988 to 1989, 1991, 1994, 1996, 2003 and 2005. According to Ati et al. (2009), 5-year running mean show annual rainfall at Potiskum of above the long term mean from 1953–1960. The results further showed that rainfall amount was above the long-term mean from the late 1960s to the early 1990s. Declining total annual rainfall at Potiskum LGA contradicts findings by Mamman et al. (2008) who reported an upward trend in mean annual rainfall in similar ecological zones of Bauchi, Maiduguri, Nguru and Yelwa. FAO (2019) further observed an increasing average rainfall trend (1999–2016) for Potiskum (Figure 2). This finding also disagrees with findings by Audu (2016) who reported an upward trend in annual rainfall in Yobe State with an increasing rainfall of an approximately 74.6 mm at the rate of 1.86 mm annually.

However, in other years, TAR greatly dropped below normal condition especially in the mid-1960s to the mid-1970s, early- to late-1990s and from 2014 to 2018.

Table 1. Summarized rainfall statistics for Potiskum (1956-2018).

TAR	Long term mean	SD (mm)	CV (%)	Max (year)	Min (year)	Range (years)	Z_1	Z_2
42435.74 (mm)	673.58 (mm)	166.07	24.66	1020.58 mm (1964)	269.2 mm (1993)	751.38 mm (29 yrs)	-0.040	-0.041

Source: NiMET, Lagos office and Author's Field work analysis (2020).

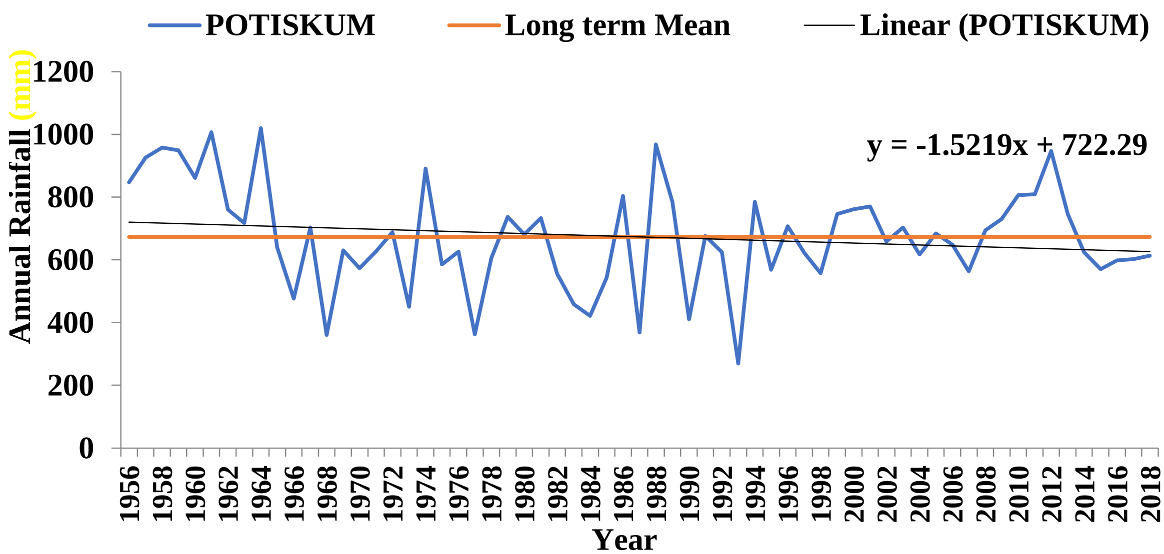

Figure 2. Trend in annual rainfall for Potiskum, Yobe State (1956-2018).

Generally, these findings depict that Potiskum suffered the great northern Nigerian drought years and rainfall decrease as reported by Oladipo (1995), Ati (2006), Sawa (2010) and Nnachi (2014). These studies showed that declining rainfall in northern Nigeria started in the early 1960s when a decade of relatively wet years ended. Of no doubt, this decline in TAR has a significant impact on crop production with manifestation in frequent crop failures and poor yields in the study area.

Figure 3 indicates an increasing trend in sorghum yield (ton/ha) in the study area with the trend line equation:

$$y = 0.0348x + 0.6406.$$

The graph shows a positive trend in the sorghum yield. The highest yields (tons/hectare) were recorded in 2003, 2010 and 2011, while the lowest yield was in 1993. With the decline in rainfall amounts in the study area, farmers would have expected a decline in the sorghum yield; rather the result shows that sorghum yields increased. Several factors could have resulted in this outcome. According to the Kano Agricultural and Rural Development Agency (KNARDA, 2008), there has been appreciable increase in the land area and output of sorghum in Nigeria which could be attributed to advanced agricultural technology and use of viable adaptation strategies such as the introduction of high yielding/ climate resilient crop varieties, application of fertilizers, irrigation, improved agronomic practices and provision of services such as seminars and workshop to rural farmers coupled with the provision of agricultural facilities and seeds. Moreover, the changing climate pattern must have given rise to the need to adopt improved agronomic practices as agriculture is more susceptible to climate change. Seydou et al. (2022) reported that farmers that have access to credit, highly resilient crop varieties, climate information and contact with extension services are likely to have increased crop yield despite the effect of climate change on crop production. Today, sorghum is a staple food for millions of Nigerians.

However, Saleh (2014) reported an increasing trend in annual rainfall and sorghum yield in Potiskum between 1981 and 2010. This result further corroborates the findings of Ikpe (2014) who reported an increase in sorghum yield in Goronyo LGA, Sokoto State, Nigeria.

Table 2 shows the computation of the Pearson's product moment correlation coefficient (***r***) calculated for both TAR and sorghum yield. The results (r=0.364) indicated that there was a negative correlation between rainfall and sorghum yield. Although there was a negative

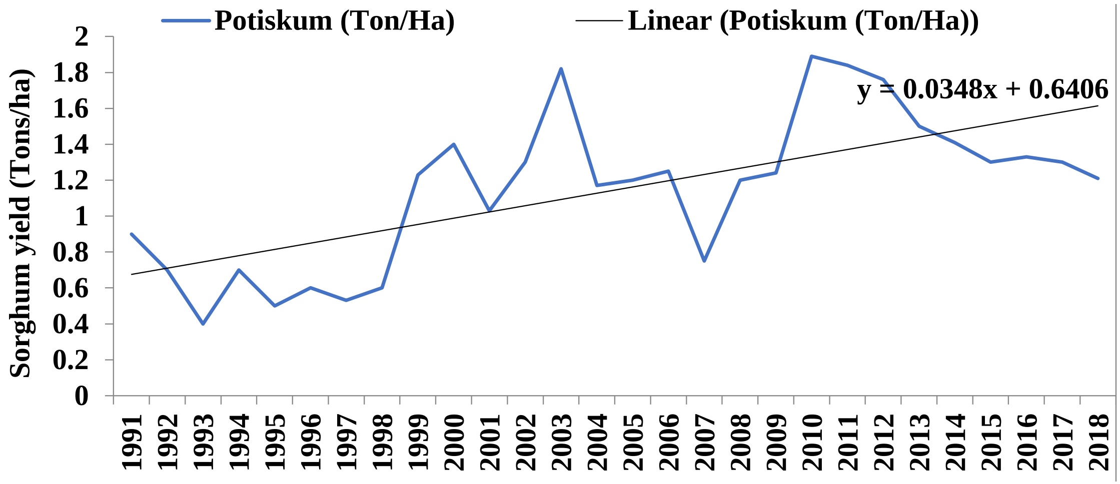

Figure 3. Trend in sorghum yield pattern for Potiskum (1956-2018).
Source: Field work analysis (2020).

Table 2. Computation of relationship between rainfall and sorghum yield data.

Year	TAR (X) (mm)	Sorghum Yield (Y) (tons/ha)	X – x	Y – y	(X – x) (Y – y)	$(X - x)^2$	$(Y- y)^2$
1991	676.2	0.9	0.83	-0.25	-0.21	0.69	0.06
1992	624.6	0.7	-4.33	-0.45	1.95	18.75	0.20
1993	269.2	0.4	-39.87	-0.75	29.90	1589.62	0.56
1994	785.2	0.7	11.73	-0.45	-5.28	137.59	0.20
1995	568.5	0.5	-9.94	-0.65	6.46	98.80	0.42
1996	706.8	0.6	3.89	-0.55	-2.14	15.13	0.30
1997	625	0.53	-4.59	-0.62	2.85	21.07	0.38
1998	557.5	0.6	-11.04	-0.55	6.07	121.88	0.30
1999	746.5	1.23	7.86	0.08	0.63	61.78	0.01
2000	760.8	1.4	9.29	0.25	2.32	86.30	0.06
2001	770	1.03	10.21	-0.12	-1.23	104.24	0.01
2002	658.4	1.3	-0.95	0.15	-0.14	0.90	0.02
2003	703.2	1.82	3.53	0.67	2.37	12.46	0.45
2004	616.9	1.17	-5.1	0.02	-0.10	26.01	0.00
2005	683.9	1.2	1.6	0.05	0.08	2.56	0.00
2006	648.5	1.25	-1.94	0.1	-0.19	3.76	0.01
2007	563	0.75	-10.49	-0.4	4.20	110.04	0.16
2008	694.1	1.2	2.62	0.05	0.13	6.86	0.00
2009	730.1	1.24	6.22	0.09	0.56	38.69	0.01
2010	806.1	1.89	13.82	0.74	10.23	190.99	0.55
2011	809.1	1.84	14.12	0.69	9.74	199.37	0.48
2012	946.8	1.76	27.89	0.61	17.01	777.85	0.37
2013	746.6	1.5	7.87	0.35	2.76	61.94	0.12
2014	624.5	1.41	-4.34	0.26	-1.13	18.84	0.07
2015	569.9	1.3	-9.8	0.15	-1.47	96.04	0.02
2016	598	1.33	-6.99	0.18	-1.26	48.86	0.03
2017	602.2	1.3	-6.57	0.15	-0.99	43.17	0.02
2018	613.4	1.21	-5.45	0.06	-0.33	29.70	0.00
Total	18,702	32.06			82.79	3923.89	4.81

* Significant at alpha = 95% confidence level, $\sum \mathbf{X} = 1870.2$, $\sum \mathbf{Y} = 32.06$, $x = {}^{\Sigma X_1}/_{n} = {}^{1870.2}/_{28} = 66.79$, $y = {}^{\Sigma Y}/_{n} = {}^{32.06}/_{28} = 1.15$, $\sum (\mathbf{X} - x)(Y - y) = 82.79$, $\sum (\mathbf{X} - x)^2 = 3923.89$, $\sum (\mathbf{Y} - y)^2 = 4.81$, $\boldsymbol{r} = {}^{82.79}/_{\sqrt{3923.89 \times 4.81}}$, $\boldsymbol{r} = {}^{82.79}/_{137.38}$, $r = 0.364$.

trend line in annual rainfall, sorghum yield was positive implying an increase. This is the reason why researchers like Sawa (2002) described sorghum as a drought resistant economic crop which thrives even when there is decline in rainfall.

The coefficient of determination (R) indicated that 36.4% of the variation in sorghum yield was associated with rainfall variation during the study period. This means that sorghum yield was boosted with declining annual rainfall amounts. More so, a negative correlation between rainfall and sorghum yield was recorded. This result disagrees with the findings of Saleh (2014), who reported that sorghum yield was significantly and negatively correlated with annual rainfall at 0.01 level of significance in the same location (Potiskum).

According to the Food and Agricultural Organization (FAO, 2012), sorghum is one of the few resilient crops that can adapt well to future climate change conditions, particularly increasing drought, soil salinity and high temperatures. In the study area, sorghum is one of the farmers' favourite and used in foods, such as porridge, bread, pastries, couscous, and beverages. Sorghum is mainly consumed as tuwo (local paste) and local beverages. Around the world, it is also used in the production of malt drinks, beer, other beverages and confectioneries as well as in livestock feed industry.

Conclusion

As meteorologists predict more frequent and longer droughts in Sub-Saharan Africa, it is believed that sorghum could be a better forage crop option for growers. Based on the relationship between rainfall and sorghum yield, analyses show that sorghum yield is not tightly dependent on water availability/rainfall. It is safe to conclude that there is a decreasing and oscillating trend in annual total rainfall over a long period (1956–2018). Evidence from the yield data analyzed shows that there is a significant increase in sorghum yield irrespective of the decline in annual rainfall amounts which portrayed sorghum as a drought resistant crop. Sorghum is a highly adaptable crop which can grow on about 80 percent of the world's arable land. This research has reported that other factors such as the use of viable adaptation strategies and other agronomic practices are factors that have promoted the yield of sorghum in the study area.

RECOMMENDATION

Based on the findings of the study, the following recommendations are made:

Qualitative climatic data should be made available and accessible to sectors that are sensitive to climate such as agriculture and water resources; efforts should be made to provide early warning weather information to farmers; policies should be formulated to ensure unlimited access to seed varieties and credit facilities by farmers. More so, soil moisture conservation, use of high yielding cultivars and fertilizer management will play a major role in improving the productivity of Sorghum in the study area. In addition, land use must continue to be monitored to determine their effects on changes in rainfall amounts and distribution. The establishment of agro-climatological research institutes in the study area should be considered for academic research and development planning purposes.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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