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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

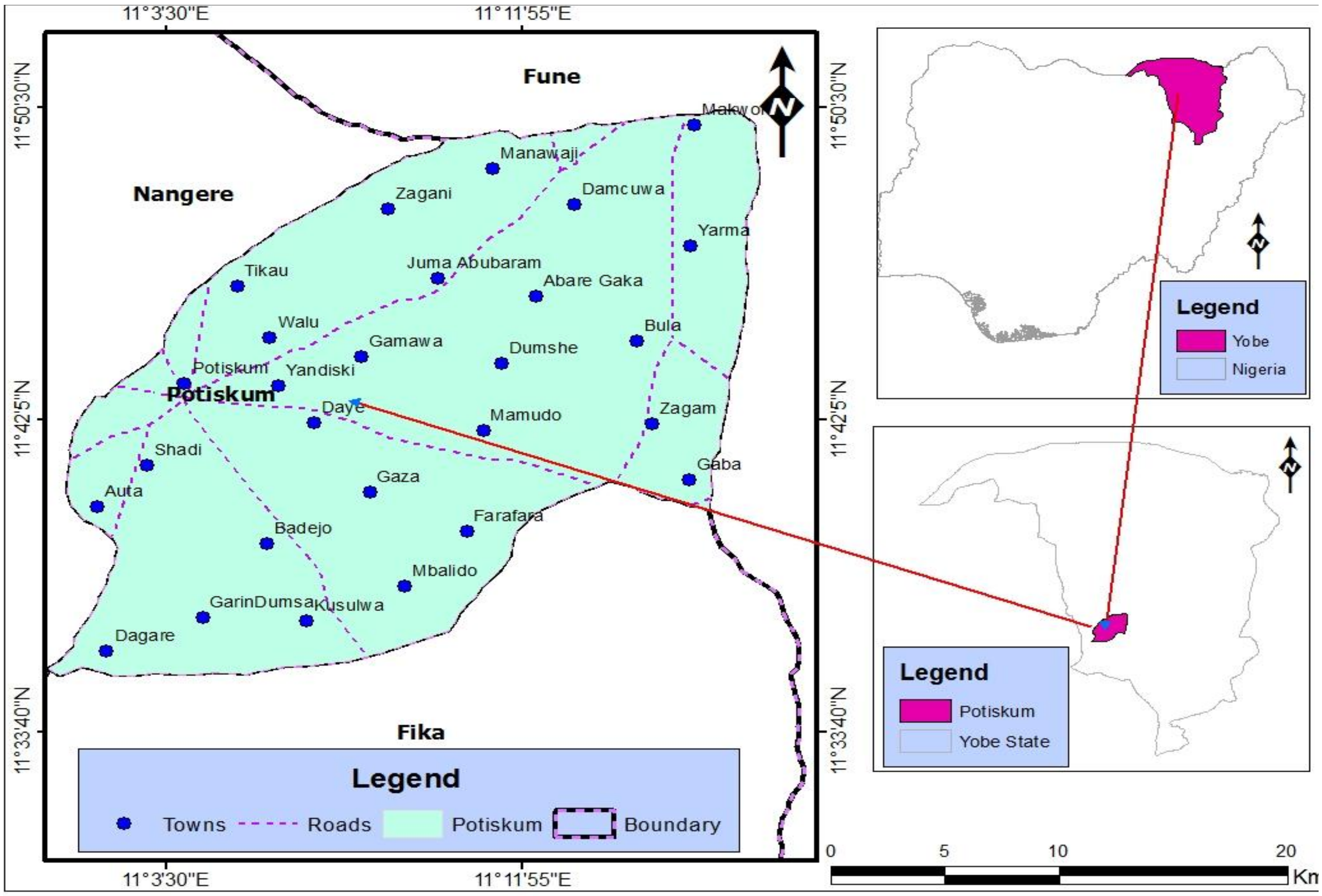

Figure 1. Map of the Study Area.
Source: GIS and Remote Sensing Lab., ABU, Zaria (2020).

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).

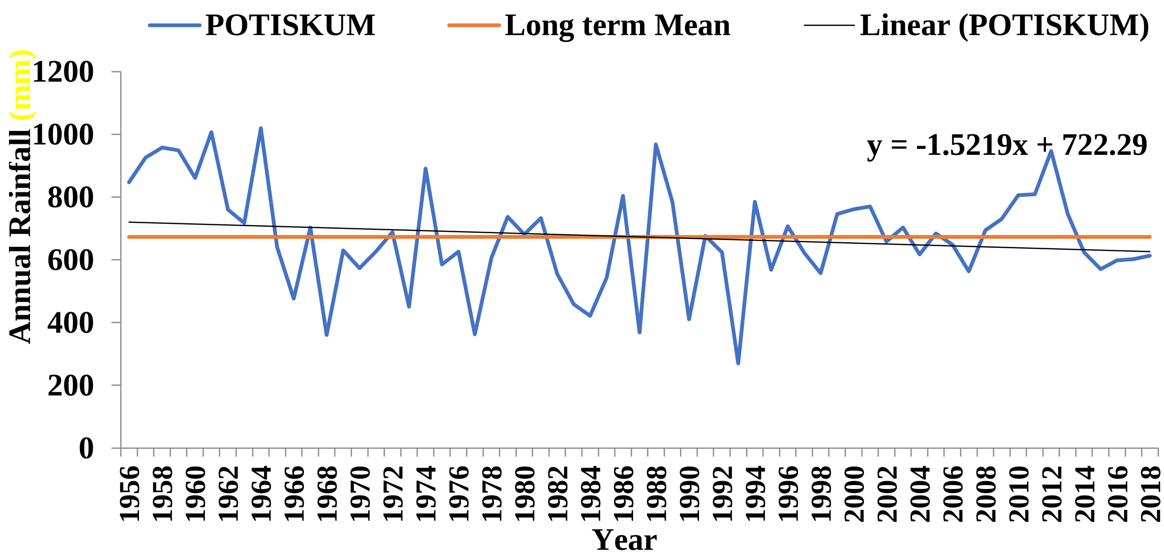

Figure 2. Trend in annual rainfall for Potiskum, Yobe State (1956-2018).

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

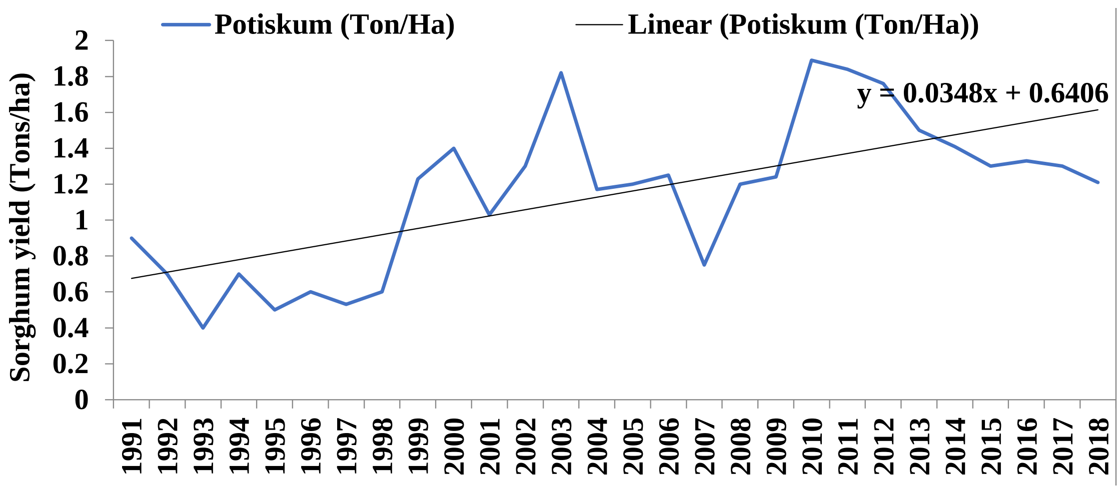

Figure 3. Trend in sorghum yield pattern for Potiskum (1956-2018).
Source: Field work analysis (2020).

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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