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Geospatial assessment of the impact of climate variability on millet and yam yield in FCT, Abuja

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Abstract

The study assessed the adaptive capacity of millet/yam farmers in the six Area Councils of FCT using Geoinformatics. The objectives of the study were to analyze the variation of millet, yam and the climatic elements for the six-area council within the period of study (2000-2021), to analyse the trend of climate characteristics as regards millet and yam yield in Abuja and to establish the relationship between the crop yield and climatic variables under study. Socio-economic indicators were used to map the adaptive capacity of FCT farmers to climate variability from 2000-2021. The arable crops considered are: yam and millet. The selected climatic variables based on their importance to crop production are: rainfall, temperature and relative humidity. Simple computations of sums, annual averages were performed on the climate variables of rainfall, temperature and relative humidity. The result was summarized into annual mean for analysis. The regression result revealed that the variance in, millet and yam respectively be explained by the climatic elements under study. Similarly, of the variance in yam and millet respectively can also be explained by the climatic elements under study. Hence, there is no significant difference in impacts of changes in climatic elements between yam and millet yield. Therefore, it can be concluded that, the trend of climate features varied among the six area councils. The area's relative humidity would only marginally decrease by 2026, according to climate scenario forecast. It is recommended that steps should be taken using locally applied evidence-based technology to prevent uncertainties that might discourage the production of yam and millet by offering improved yam breeds and millet seedlings that are resilient to shocks from climate fluctuations.

keywords: Climate change; Millet/Yam; Geoinformatics; Socio-economic; Questionnaires; Cropland Coefficient of variance COV.

1. Introduction

Many people are aware of the phenomena of climate change since it has received a lot of attention in recent years due to its poisonous impacts on ecosystems. Up until recently, it was believed that human activity had little impact on climatic variability, and as a result, climate change was broadly accepted. Contrarily, it has been demonstrated that climate change is not a problem that should be treated lightly; it is already having a serious negative impact on the planet, particularly challenging agricultural productivity and food security globally, even in developed nations, and as a result, urgent action is needed. However, there is a possibility that the effects of climate change on agricultural output could be either positive or negative; a number of empirical research, however, indicate that the latter is more significant than the former [1]; [2]. The pattern of rainfall in Nigeria and all of Africa has already changed, delaying the start of planting season and lowering harvest yields. Since 2012, there has been an increase in the unpredictability of rainfall (changes in variance and seasons of rainfall); it is now very common for the south-western part of the country to

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experience rainfall that is insufficient for crop production (drought), while the northern part experiences excessive rainfall compared to the usual crop requirement, which causes floods. Both floods and droughts are bad for agricultural practices. Some areas of the east experience early or late seasons of rainfall that are different from the regular seasons. [3] claim that the severe shifts in Nigeria's rainfall patterns and rise in temperature will introduce unfavourable growth conditions into the cropping calendars, changing the growing seasons of crops and perhaps lowering crop output. Economic effects on farm profitability, agricultural supply and demand, trade, and price will result from a decrease in crop productivity. The backbone of the Nigerian economy continues to be agriculture, which includes agricultural production, animal production, and forestry.

According to the Federal Ministry of Agriculture and Water Resources (FMAWR), 2008, it is the primary sector responsible for supplying income and employment to rural residents, employing 90% of the rural poor and approximately 70% of the entire labour force. It also generates 90% of non-oil export revenues. According to a recent estimate of the nation's GDP, agriculture's contribution is declining. A sectorial analysis of the real GDP in 2006 revealed that the agricultural sector contributed to about 41.7 percent of the GDP compared to 41.2 percent in 2005, and an analysis of the real GDP performance in 2007 reveals that the agricultural sector contributed the largest share, 42.2%, compared to 41.7% in 2006 [4].

According to [5], climate variability has a major impact on how well agricultural production performs. Solar radiation, temperature, and water or rainfall are crucial climatic factors for crop development and yield [6], Because agricultural operations depend on the climatic variability of a region, the relationship between climate variability and agricultural activities has garnered considerable interest from scholars ([7]; [6]).

For their agricultural production activities, Nigerian farmers heavily rely on the resources that nature offers, such as the amount of rainfall, the intensity of the sun, and other climate features. For instance, the most common technique used by crop farmers, who mostly grow maize, rice, cassava, yam, and other crops, is rain-fed agriculture [8]. The yam (Dioscorea spp.) is one of the extensively grown, climate-sensitive food crops in Nigeria. This annual root tuber crop has at least 600 species, six of which are essential for society and the economy in terms of food, currency, and medicine. They are raised in tropical climates, particularly in the savannah of West Africa [9]. Nigeria is the world's leading producer of yams, contributing over 66% of the crop's total output, according to the Food and Agricultural Organisation [10]. The following five nations are Ghana, Côte d'Ivoire, Benin, Togo, and Cameroon. The tuber crop is also grown in Colombia, Brazil, Haiti, Cuba, and Jamaica, according to [10]. Yams are frequently marketed as fresh tubers by farmers and marketers [11]. Before being ingested, it can also take on other forms. Production of yams in Nigeria is vulnerable to the effects of climate change and fluctuation. This is demonstrated by the negative effects it has on agricultural growth and output [6]. In Nigeria, the yam crop thrives and produces well, but because the annual weather conditions change from year to year, it has displayed variable growth habits and variable yields [12]. In Nigeria, where over 14 million people experience food shortages and undernutrition, the phenomena of climate change or variability poses a challenge to food security [13]; [14]. The decrease in food crop production from almost 34% of the GDP in 2002 to 18.6% in 2016 [14], highlights the food shortage. Studies on the impact of climate variation on agricultural production in Nigeria have gotten little attention, despite the fact that over 60% of Nigerians who are in the labour force are farmers [15].

1.1. YAM

Yam is a monocot annual plant that is grown extensively in Nigeria as a food and cash crop. It is a member of the family Dioscoreacea and the genus Dioscorea. There are 600 different species of food plants, ten of which produce edible tubers, and only six of these are grown in Africa [16]. The majority of Nigerians eat a lot of yams, a root crop that is important to the diet of people in West Africa in general and Nigeria in particular. Despite the fact that yam output in Africa has decreased in comparison to cassava and rice, yam is such a popular staple food that demand will continue to grow despite population growth [17] (Srivastava and Gaiser, 2008).

According to [18], yam provides more than 200 nutritional calories per person per day for more than 150 million people in West Africa. It also acts as a significant source of revenue for the population. Yam can also be used to make industrial starch and as animal feed, but Nigeria's yam crop appears to be the most at risk from the negative effects of climate change. Because production growth has not kept up with population growth and demand has surpassed supply, it is getting more expensive and relatively high-priced in metropolitan areas [6].
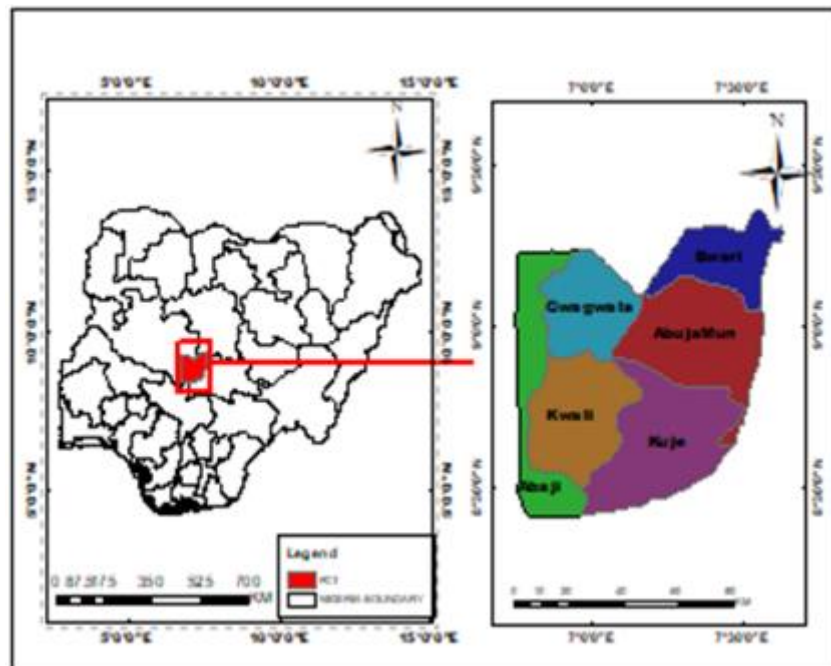
1.2. Millet

The most significant dry land food crop in West Africa is pearl millet (Pennisetum glaucum) [19]. According to [20], pearl millet is the most significant cereal in Nigeria's dry sub-humid and semi-arid zones. Nigeria (54%), Niger (20%), and Mali (9%), three of West Africa's major millet-producing nations, dominated the region in 2000. Pearl millet

dominates the agricultural production systems and is the principal stable food in Borno State. In the semi-tropical and tropical parts of Asia and Africa, the crop is yearly cultivated on more than 29 million hectares. With a drop in demand, some farmers stopped cultivating these traditional crops, even though they were much better suited to their arid environment.

As the most significant crop in Nigeria's dry sub-humid and semi-arid zones, millet feeds around 40 million people in northern Nigeria [21]. Pearl millet thrives in soils with high salinity and is well adapted to growing regions with drought, low soil fertility, and high temperatures [22]. Pearl millet reacts well to management inputs, therefore it has a strong potential to become a significant part of intensive agriculture, particularly in dry and semi-arid locations, according to [23] in [24]. In the semiarid tropical regions of Asia and Africa, particularly in India, Mali, Nigeria, and Niger, it is a significant crop. With an average yearly production of 5,000,000 tonnes during the years 1999 and 2010, Nigeria comes in second place behind India in terms of pearl millet production worldwide [25]. While output during the 2016–2017 agricultural season was around 1,468, 688 tonnes [26]. According to [27], the crop comes in third place among cereal food crops behind maize and sorghum. According to National Agricultural Extension and Research Liaison Services (NAERLS) and the Federal Ministry of Agriculture and Rural Development [28], millet, a traditional food crop of Gombe State, is grown on an area of about 108,680 Ha, producing about 102.66 million metric tonnes in 2016. In 2017, production increased to about 105.62 MT, a significant increase of 2.88%.

In Nigeria, some researchers have carried out crop specific studies that focused on yam production [29]; [11]; [30]; [31]; [9]; [32], while some have studied the impact of climate variability on yam production [33]; [34]. The effects of climate variability or change on the production of yam or millet in FCT Abuja have not been studied [6]. Yam farming is a major source of income and food security for the Federal Capital Territory (FCT), and Abuja is a significant yam market hub in North Central Nigeria. Yam farming is a climate-dependent activity that has a significant negative impact on the environment while providing food and fibre to the burgeoning Nigerian population.

The emerging world, particularly the dry plains of Northern Nigeria, will be severely impacted by the growing challenge of climatic change. This is due to the region's economy being primarily agrarian and rain-fed. Because of their extreme poverty and lack of technological advancement, the farmers in this region are not able to make ends meet [35]; [36]; [37]. According to predictions made by Jones and Thornton in 2002, crop yield in Africa could decrease by 10–20% or perhaps by 50% by 2050 as a result of climate change, while food demand is expected to rise by 70–90% [38].

Figure 1 Study area showing the six area councils

The study assessed the impact of climate variability on millet and yam yields in FCT with the objectives to: analyze the variation of millet, yam and the climatic elements for the six-area council within the period of study (2000-2021), analyse the trend of climate characteristics as regards millet and yam yield in Abuja and establish the relationship

between the crop yield and climatic variables under study. The hypothesis has it that there is no relationship between climate variability in yam and millet yield in FCT Abuja and there is no significant variation in the climatic conditions and this millet/yam yield across the six-area council.

The study was conducted in the Federal Capital Territory (FCT), Abuja, Nigeria. It lies within latitudes 9° 4' N and 9° 06' N of the equator and within longitudes 7° 29' E and 7° 483' E. The Federal Capital Territory is bordered to the north by Kaduna State, to the east by Nasarawa State, to the south-west by Kogi State and to the west by Niger State. Abuja has an estimated population of 5 million (National Population Commission, 2006) the projected population growth rate for 2015 at 35 % growth rate is 2,238,800 (Central Bank of Nigeria (CBN), 2015). Abuja has an approximately land area of 8,000 square kilometers. The rainy season begins from April and ends in October while the mean annual temperature is 25.7oC with about 1389 mm of precipitation annually. Federal Capital Territory has a warm, humid rainy season and a blistering dry season. In addition, it has six area councils which include Bwari, Kuje, Abuja Municipal, Gwagwalada, Abaji and Kwali Area Council. The inhabitants of the Abuja countryside are predominantly farmers and the major crops grown are Rice, Yam, Soybeans, Mellon, Guinea Corn, Beans, Maize, Sorghum, Cassava, Millets, Groundnut, Cowpea and Sesame.

2. Research methodology

This research utilized both secondary and primary data and adopted quantitative research methods, relying on the climate characteristics, yam, and millet yield data; analyzed the data to describe, explain, predict, and control variables and phenomena of interest [39]. Statistical inference will be drawn from the relationship between both variables in the area.

2.1. Secondary Data Collection

Climatic data such as maximum and minimum temperatures, rainfall, potential evapotranspiration, and relative humidity between 2000 and 2021, a span of 21 years was obtained from the Nigeria Meteorological Agency (NIMET) station at Nnamdi Azikiwe International Airport provided meteorological data for the Federal Capital Territory (FCT). Simple sum and yearly average calculations were made for the climatic data variability.

2.2. Primary Data Collection

Primary data from twenty copies of questionnaires were distributed and was gathered during the 2000–2021 production season by utilizing Computer-Aided Personal Interviews (CAPI) to administer structured questionnaires to a sample of yam and millet farmers in the Federal Capital Territory of Abuja. The questionnaire was used to determine the farmers' characteristics, including their educational background, farming experience, agricultural skill, land ownership, cultivation area, type of yam and millet field, distance from water resources, input costs, output price, land size, and number of household farmers. Frequency counts and percentages were used as descriptive statistics to examine the data that was gathered from the respondents. The data was analysed using inferential statistics such as Analysis of Variance (ANOVA), Pearson Product Moment Correlation, and Chi-square (X2). Utilising adaptive capacity questionnaires, pertinent data regarding the socioeconomic attributes of the farmers was gathered.

2.3. Data Analysis

For analysis, the result was condensed into an annual mean. Time series analysis was used to evaluate a phenomenon's frequency or trend over a predetermined amount of time [40]. The climate and yam/millet yield statistics in this instance are from 1990 to 2016 and 2017 to 2021, respectively, and make up the trend data. The forecasting was accomplished using the Time Series Modeller. Forecasts are generated by estimating exponential smoothing, multivariate ARIMA (or transfer function models), and univariate Autoregressive Integrated Moving Average (ARIMA) models for time series [41]. The method of [42], was used to simulate how agricultural output is sensitive to climatic fluctuation, through multiple regression analysis. The effects of the independent **variables (x1–x5)** on a single dependent variable **(y)** were assessed using multiple regression analysis. The regression model was specified as: $Y= a +b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 + b_n x_n$ .... (1)

Where: Y = the dependent variable (yam yield and millet yield); b1, b2, b3, b4, b5 = regression coefficients; x1, x2, x3, x4, x5 = the independent variables (mean sunshine intensity, mean temperature, mean relative humidity, mean rainfall volume, total number of rain days); a=y intercept; e= error term.

Table 1 Data Type, Data Source and Year

S/N	Data type	Data source	Year
1	Rainfall	NiMeT	2000 to 2021
2	Temperature (Min. & Max.)	NiMeT	2000 to 2021
3	Relative Humidity (RH)	NiMeT	2000 to 2021
4	Questionnaire	Farmer's (from FCT)	2000 to 2021

3. Result and discussion

### 3.1. Millet, yam and the climatic elements for the six area councils within the period of study (2000-2021)

Table 2 Descriptive analysis of the climatic variables and crop yield

	STAT	Millet	Yam	Tempt	Rainfall	RH
AMAC	Sum	3536	28094	748.6	35483.9	1070.3
	Mean	160.7	1277	34.0	1612.9	48.6
	STD	40.6	160.6	1.05	361.2	3.07
	COV	25.3	12.6	3.09	22.4	6.32
	Remark	Moderate	Low	Low	Moderate	Low
ABAJI	Sum	3470	23019	791.6	30117.1	1015.0
	Mean	157.7	1046.3	36.0	1369.0	46.1
	STD	8.87	426.0	1.23	388.4	10.0
	COV	5.62	40.7	3.43	28.4	21.7
BWARI	Sum	7537	44266	731.1	39963.7	1048.58
	Mean	342.6	2012.1	33.2	1816.5	47.7
	STD	173.4	1798.0	0.98	458.8	14.1
	COV	50.6	89.4	2.96	25.3	29.5
	Remark	High	High	Low	Moderate	Moderate
G/LADA	Sum	6680	26802	806.7	25777.87	1055.1
	Mean	303.6	1218.3	36.7	1171.7	48
	STD	201.7	813.1	1.01	345.3	11.4
	COV	66.4	66.7	2.75	29.5	23.8
	Remark	High	High	Low	Moderate	Moderate
KUJE	Sum	6216	62396	781.7	31104.9	1070.5
	Mean	282.5	2836.2	35.5	1413.9	48.7
	STD	224.9	2767.2	1.11	306.2	13.1
	COV	79.6	97.6	3.12	21.7	26.9
	Remark	High	High	Low	Moderate	Moderate
KWALI	Sum	8278	66206	809.7	26994.7	1051.0
	Mean	376.3	3009.4	36.8	1227.0	48.2

	STD	275.6	2058.9	1.10	283.8	11.4
	COV	73.2	68.4	0.0	23.1	23.7
	Remark	High	High	Low	Moderate	Moderate

Table 1 displays the AMAC coefficient of variation (COV), which indicates that with low temperatures, moderate rainfall, and low relative humidity, the millet yield was moderate and the yam yield was low. Abaji COV demonstrates that with low temperature, moderate rainfall, and relative humidity, millet yield was low and yam yield was moderate. According to Bwari COV, there was a high yield of millet and yam at low temperatures, moderate rainfall, and relative humidity. According to Gwagwalada COV, there was a high yield of millet and yam at low temperatures, moderate rainfall, and relative humidity.

3.2. Trend analysis of climate characteristics, millet and yam production in Abuja
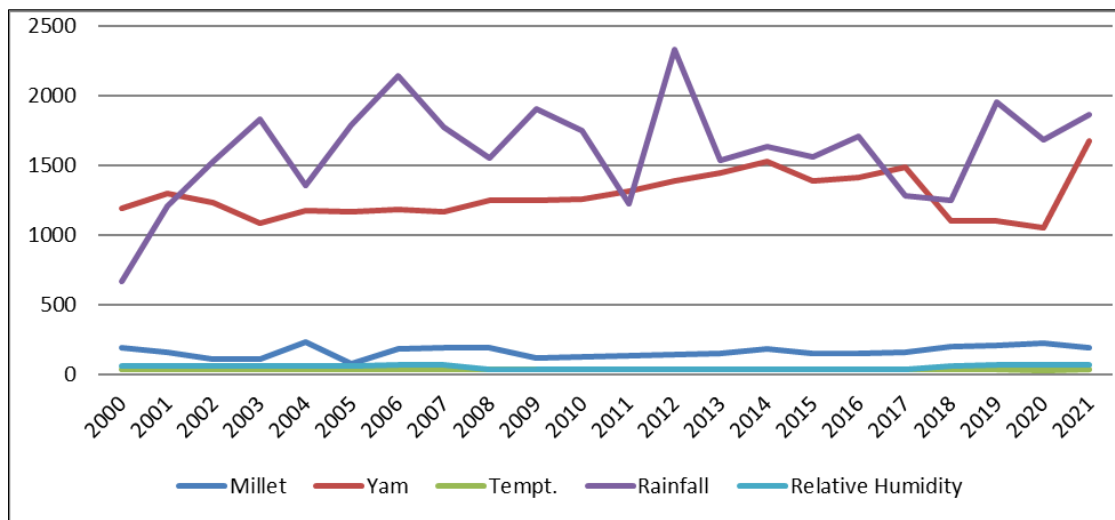

Figure 2 Millet and Yam yield/ha for AMAC (2000-2021)

The increase in rainfall was at its peak in the years 2011 and 2013 and it contributed to the increase in yam yield. Millet yield was low due to the increase in rainfall.

Figure 3 below shows an increase in yam yield from the year 2013-2016. Rainfall also contributes to the increase of yam yield and decrease in millet yield.
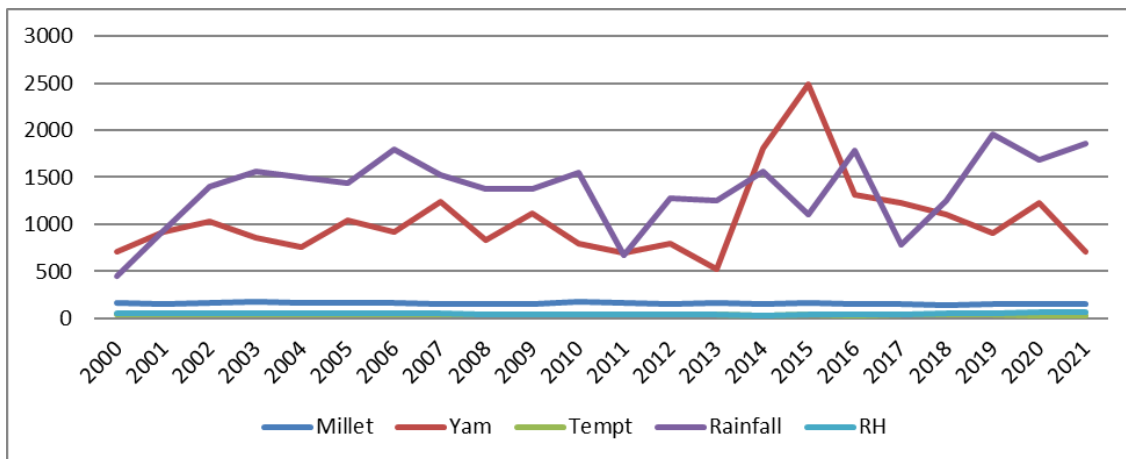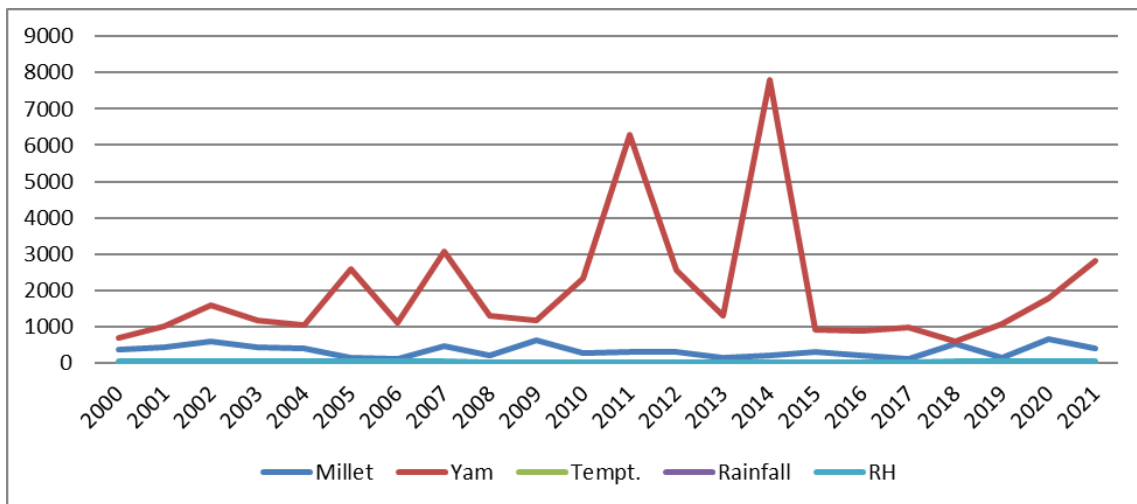

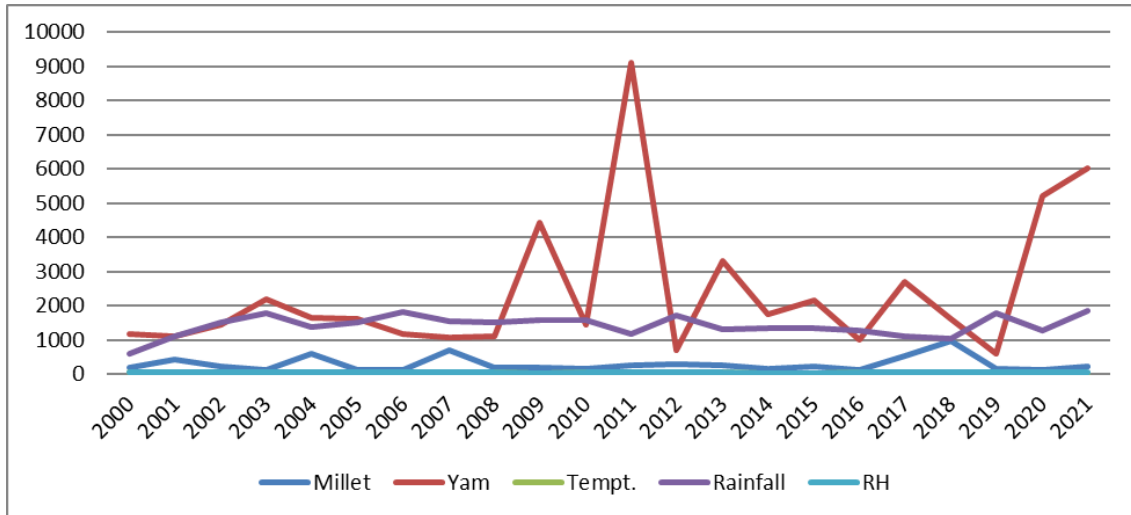**Figure 3** Millet/Yam yield of Abaji from 2000-2021
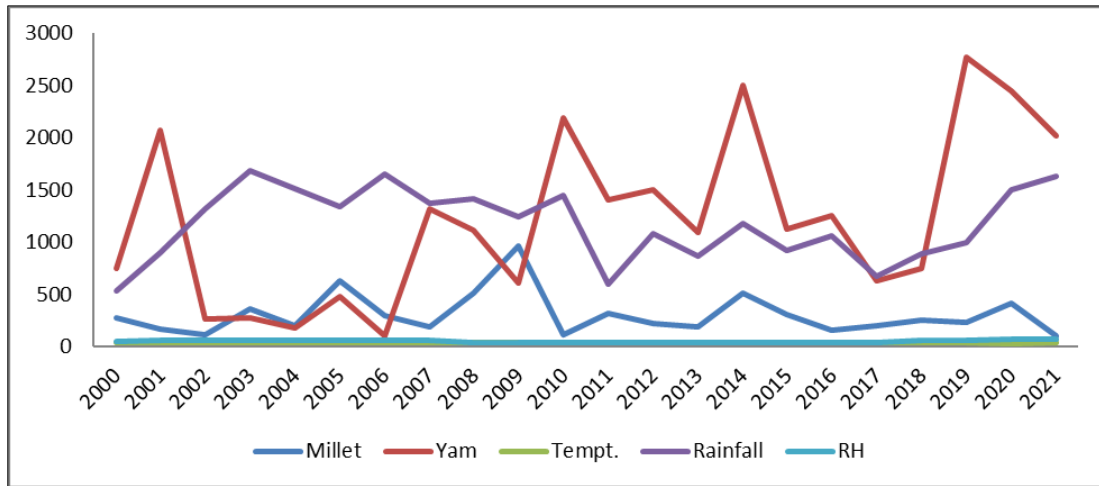
Figure 4 Millet/Yam yield of Gwagwalada from 2000-2021

Yield increases of yam, range between 2000mt in the year 2002, 2200mt in the year 2009, 2500mt in the year 2013 and 2700mt in the year 2018. Millet yield was also increased in the year 2007 with 1000 tons.

Figure 5 below shows that, Yam yield was at the increase between the years 2009-2013 with 620mt and 800mt in the year 2015. Millet yield was very low due to a decrease in rainfall.
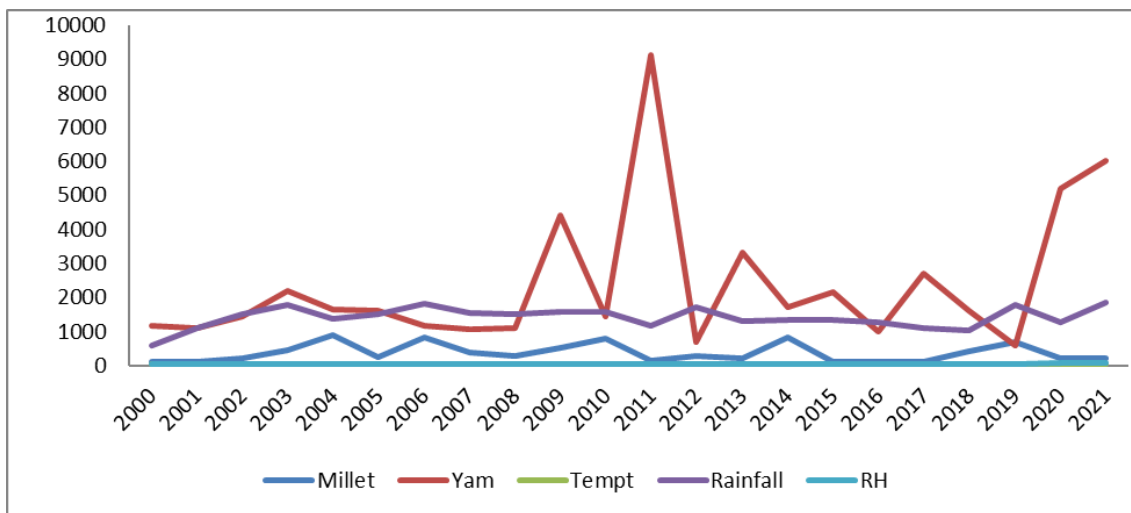

Figure 5 Millet/Yam yield of Bwari from 2000-2021

Figure 6 Millet/Yam yield of Kuje from 2000-2021

Figure 6 above shows that, Yam yield was at the increase from the year 2010-2012 with 9000mm and millet yield was low with 1500tons in the year 2003 and 2006. In the year 2003 and 2006 increases with 1900mm contributing to the increase in yam yield.


Figure 7 Millet/Yam yield of Kwali from 2000-2021

Figure 7 shows that between the years 2010-2012, yam yield was at increased to 9000mt while millet yield was low. In the year 2020, there was a slight increase in rainfall which also contributed to the increase in yam yield.
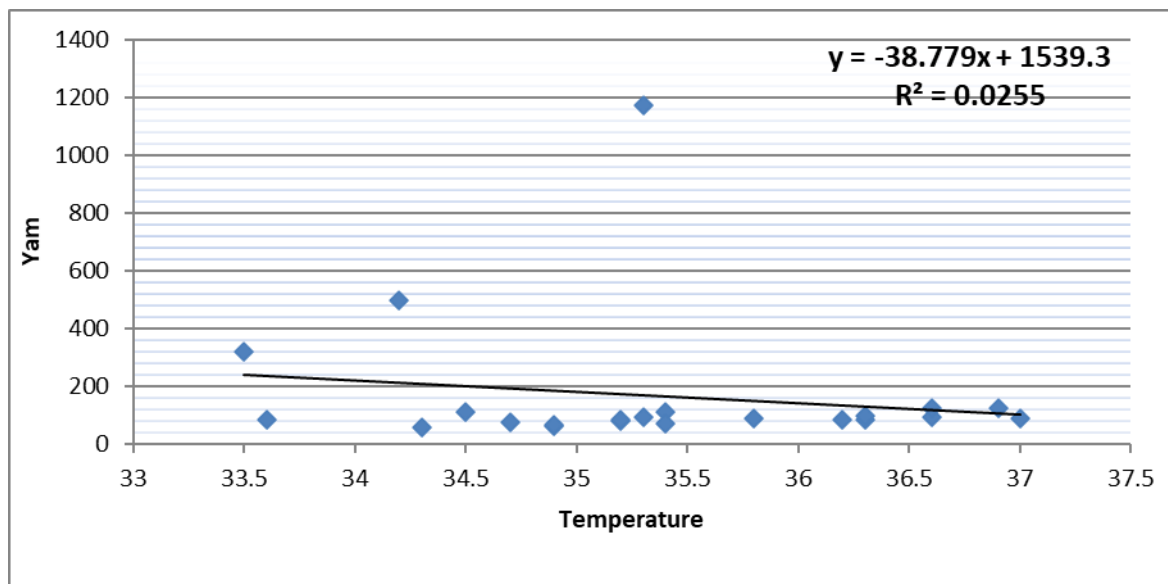
3.3. Relationship between crop yield and climatic variables under study

Figure 8 below shows that temperature contributes about a 4.5% increase in millet yield. There is a positive relationship between temperature and millet yield. As temperature increases, millet yield also increases.
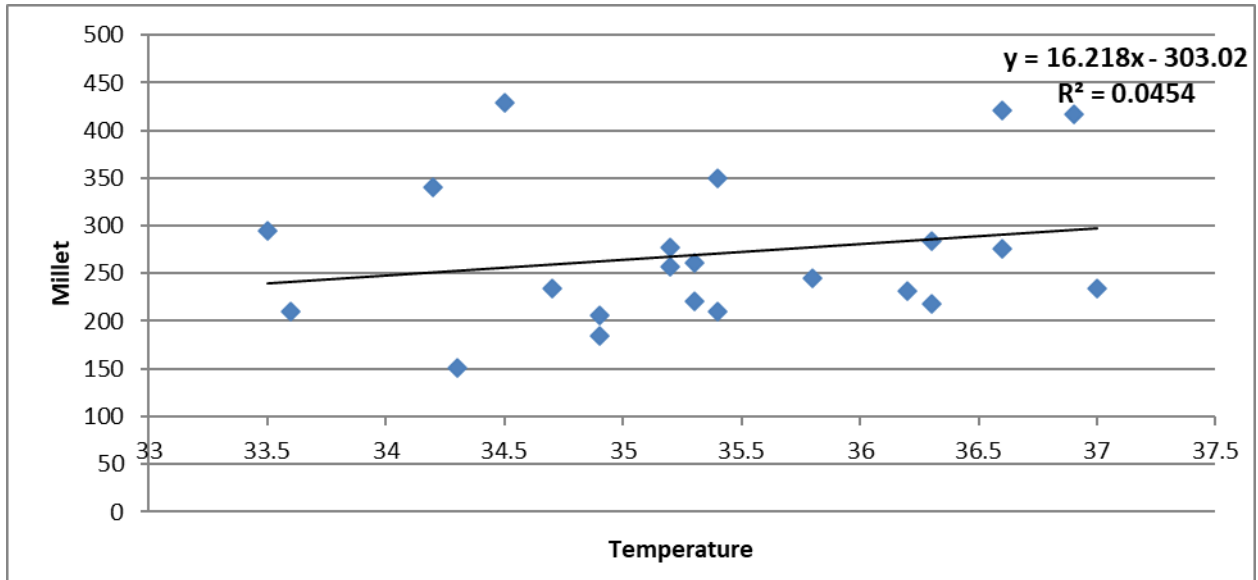
**Figure 8** Relationship Between Temperature and Millet Yield

Figure 9 The Yield of Yams Rises with Temperature Increase

Figure 9 above illustrates the factors that raise the yield of yams. The yield of yams is positively correlated with temperature.

Figure 10 below illustrates a favourable correlation between rainfall and millet, as well as how rainfall increases millet yield.
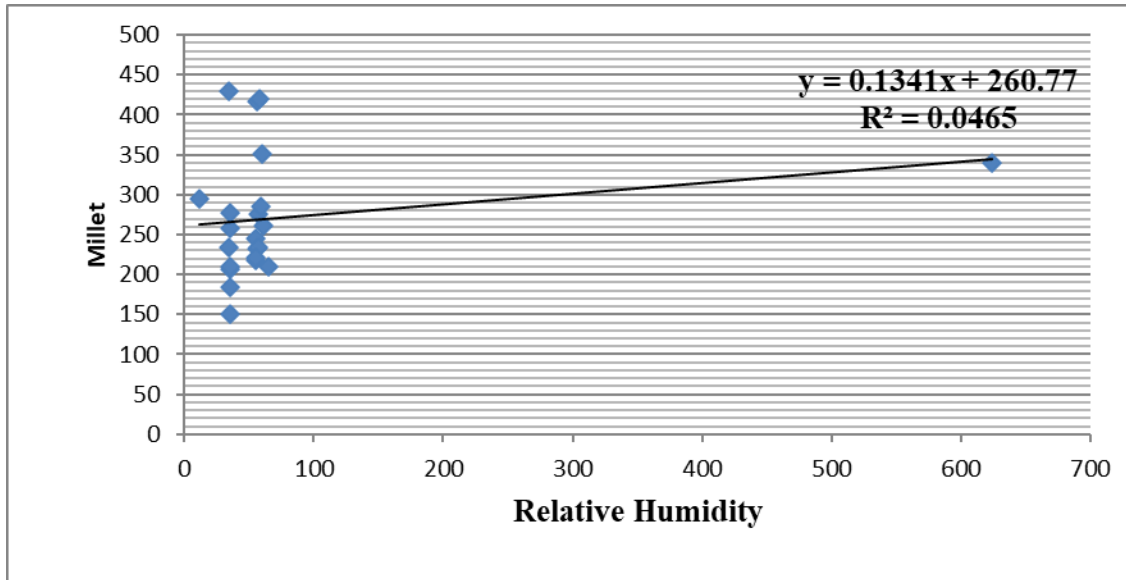
$$y = -1.1046x + 283.28$$
$$R^2 = 0.0087$$
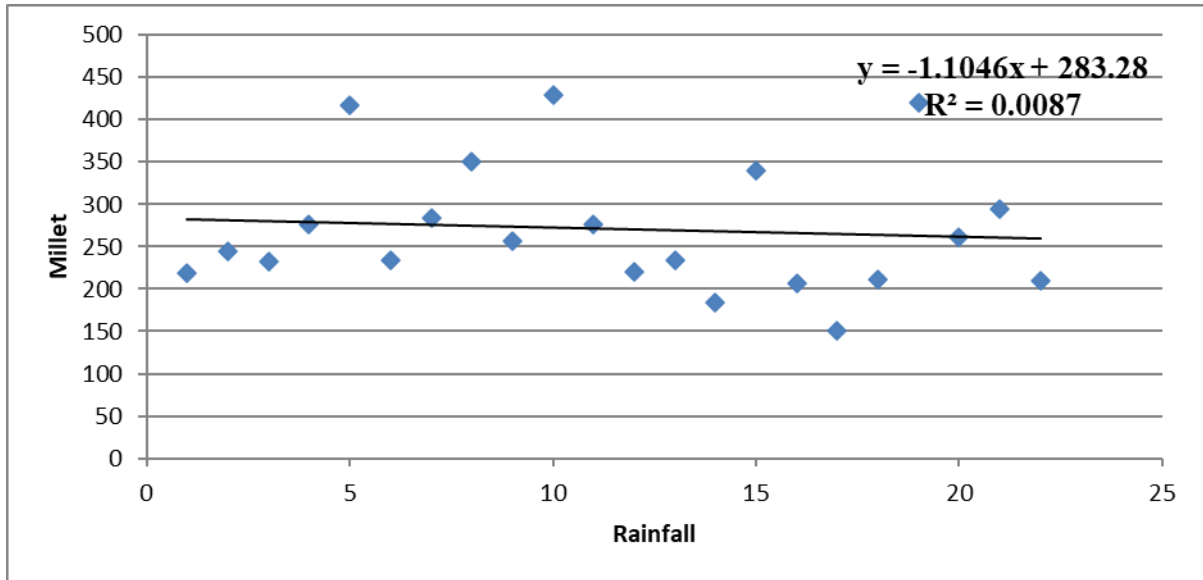
Figure 10 The Increased in Millet Yield with an Increase in Rainfall


$$y = 4.178x + 119.69$$
$$R^2 = 0.0122$$
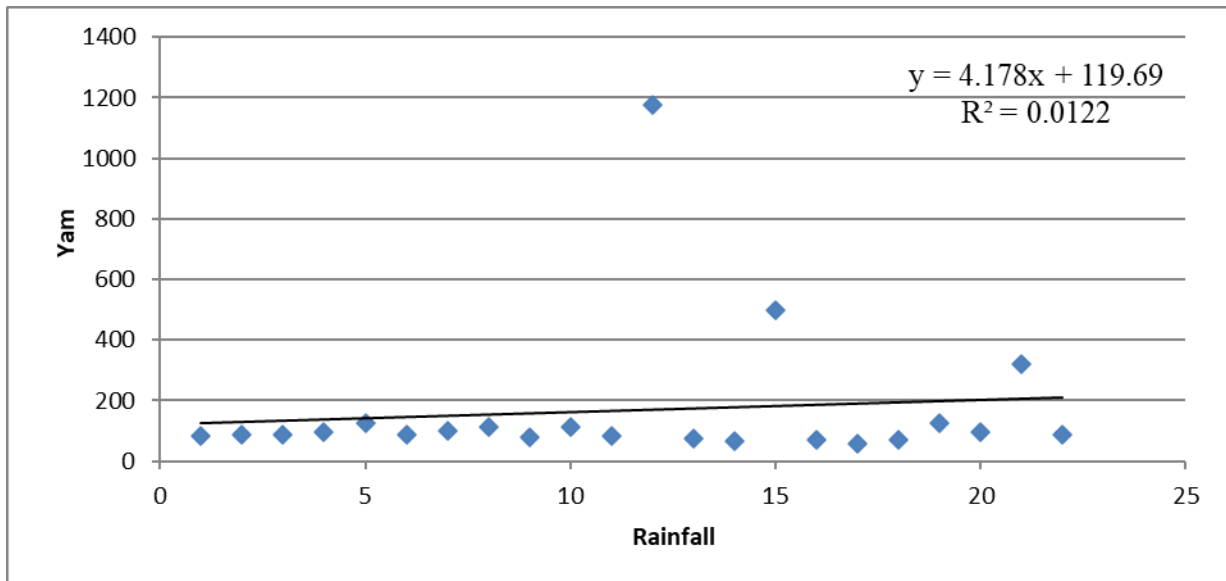
Figure 11 Relationship Between Yam Production and Rainfall

The relationship between yam production and rainfall is represented in Figure 11 which shows a positive correlation between yam yield and rainfall increase.

Figure 12 The millet yield increases with increase in relative humidity

Figure 12 illustrates how millet yield increases with relative humidity. Relative humidity and millet yield have a positive association. As relative humidity rises, millet yield rises as well.
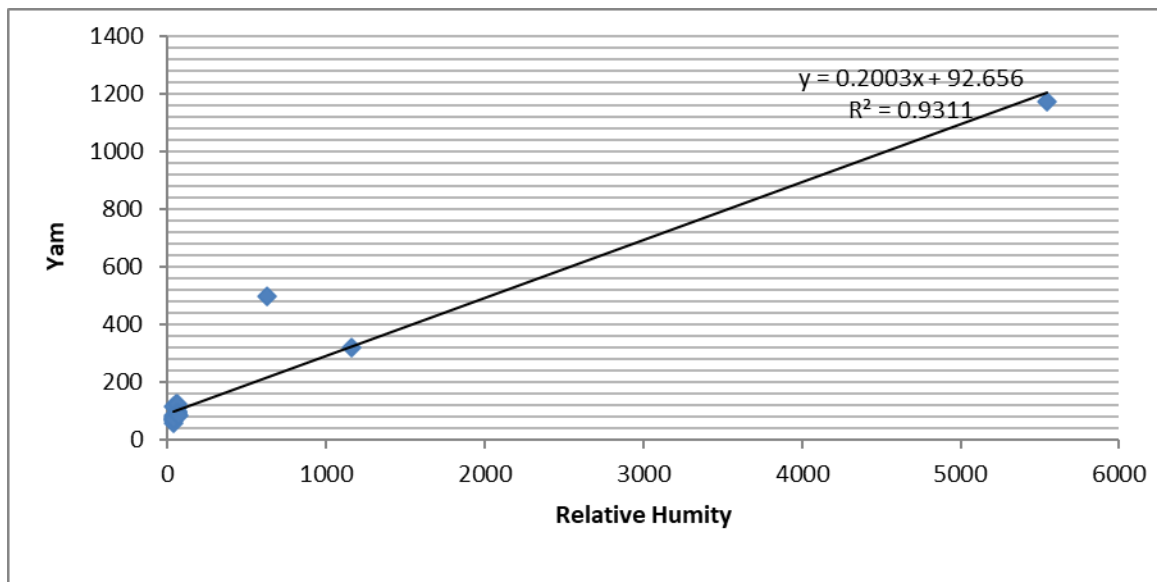
Figure 13 Positive correlation between an increase in relative humidity and an increase in yam yield

Figure 13 illustrates a positive correlation between relative humidity and yam yield as well as how relative humidity increases yam yield. As relative humidity increases, yam yield also increases.

4. Conclusion

Previous research has emphasized how crop productivity is impacted by climate variability. However, it has been demonstrated that the impact varies according to the crop variety and location. This study evaluated the effects of climatic variability on the yield of millet and yam in the six area councils in the Federal Capital Territory of Abuja. Yam and millet are widely grown food crops and staple foods. The study found that across the study period (2000–2021), the trend of climate features varied among the six area councils. The area's relative humidity would only marginally decrease by 2026, according to climate scenario forecasts. However, due to the high temperatures in the area, the yield of yams and millet grew marginally over time, albeit with oscillations. This was especially true in Bwari, Gwagwalada,

Kuje, and Kwali. The results also demonstrate how temperature, relative humidity, and rainfall affect the production of yams and millet in the six area councils in the Federal Capital Territory.

Yam production, like that of all other crops, is influenced by a variety of factors, including the climate. The most important factor affecting the types of crops that may be produced, the qualities of the soils, and the types of farming that can be done in every location is the climate. As a result, the ability to meet future demand may depend on an accurate evaluation of the susceptibility of medium- and long-term yam production to climate change and the adaptation measures done by the relevant stakeholder groups.

The results also demonstrate how temperature, relative humidity, and rainfall affect the production of yams and millet in the six area councils in the Federal Capital Territory.

Recommendation

For context-specific climate risk mitigation with respect to yam/millet yield, relevant government bodies including the Ministry of Agriculture and the Nigerian Meteorological Agency in the Federal Capital Territory should take into account the forecast of climatic variables in this study. Because of the known variations and fluctuations in the climate in the six area councils in the Federal Capital Territory, steps should be taken using locally applied evidence-based technology to prevent uncertainties that might discourage the production of yams and millet by offering improved yam breeds and millet seedlings that are resilient to shocks from climate fluctuations.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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