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## Impact of Climate Variability and Adaptation Strategies on Tomato Production Among Smallholder Farmers in Bauchi L.G.A., Nigeria

Auwal Garba<sup>1\*</sup>, Nasir Adamu Umar<sup>2</sup>, Mijinyawa Garba Abdullahi<sup>3</sup>

<sup>1,3</sup>Researcher, Department of Environmental Management Technology, Abubakar Tafawa Balewa University, Bauchi.

<sup>2</sup>Researcher, Department of Environmental Management, Federal University of Technology, Owerri.

\*Corresponding Author

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### Abstract

*This study evaluated the impact of climatic variability and adaptation tactics on smallholder farmers' tomato production in Bauchi L.G.A. The lack of consistency in the pattern of different climatic factors for one or more seasons was assessed by smallholder farmers in communities as a large or moderate influence of climate variability. According to the survey, farmers used a variety of adaptation measures. The majority of them favoured mixed cropping, the use of agrochemicals, and crop diversification. Numerous farmers believed the impacts to be the occurrence of tomato disease, which lowers crop yield and has negative effects on the net production of tomatoes. The study comes to the conclusion that one of the key elements influencing tomato yield in the study area is climate variability. The study suggests that tomato farmers' ability to receive meteorological information may improve their capacity for adaptation. This might lessen how negatively climate variability affects their activities and tomato output.*

**Keywords:** Variability; Climate; Adaptation; Tomato; Farmers

### INTRODUCTION

The amount and quality of agricultural production are directly influenced by climate fluctuation, frequently in a negative way (Garba and Abdullahi, 2026). The vegetation and, thus, the sort of crop that can be grown in a region are intimately associated with its climate. The key climatic factors that affect agricultural yield are temperature, precipitation, humidity, and sunshine (day length). For the short- and long-term planning of farm activities, the general predictability of these climatic factors is crucial (Ismaila, 2010). The varieties of plants that can thrive in a certain area are influenced by the climate, which is a key factor in agricultural output. The urgency of the adaptation techniques is increased by climate variability and its effects (FAO, 2010). In Nigeria, the production of tomatoes has decreased to fewer than 10 tons per hectare as a result of recent climate unpredictability (NIHORT, 2020). Unfortunately, the local government of Bauchi is one of those in the nation that is susceptible to climate change, and throughout the years, has seen a decrease in tomato yield as a result of the changing environment. Small-scale farmers in Bauchi State, who make up the majority of low-income earners, already struggle to make ends meet due to climate instability and variation, and

they have little access to resources or information to help them adjust to climatic changes (Arku, 2013). As a result, they are directly dependent on resources with a high sensitivity to climate change, including farms, forests, fisheries, and other resources. As a result, many places are experiencing a decrease in the reliability of their resources due to climate change, which makes it more difficult for many small-scale farmers to escape poverty. They create and put into practice a variety of coping mechanisms in reaction to the issue (Arku, 2013). The majority of agricultural properties are modest and dispersed. Around two-thirds of Nigeria's agricultural output is produced by traditional small-scale business owners who employ basic production methods and the bush-fallow system of farming. Nigeria can produce a wide range of food and cash crops thanks to its diverse climate. But as the population grew, food production could not keep up. As a result, food scarcity is related to climate change across time (Adefolalu, 2004). Agriculture's ability to function is primarily dependent on the climate, claims Ayoade (1983). So, precipitation, sun radiation, wind, temperature, relative humidity, and other climatic factors have a direct impact on and are the sole determinants of where crops and livestock are distributed globally and how

productive they are. Changes in temperature and precipitation directly affect crop production and can even change the distribution of agro-ecological zones, according to Kurukulasuriya and Rosenthal (2003). Increased CO<sub>2</sub> is anticipated to have a negative impact on agricultural production due to greater water use efficiency and higher rates of plant photosynthesis. Runoff or water availability is crucial in determining the impact of climate change.

The majority of farmers in the study region rely heavily on the production of tomato crops for their livelihood and income, which enables them to take care of the social obligations of their families. According to Khanal (2009), one of the main issues affecting agricultural production globally is climate variables, including unpredictable rainfall patterns and high temperatures. Because tomato farming depends on rain, the region's unpredictable weather patterns and high temperatures could endanger the farmers' ability to make a living. A thorough investigation is required to determine the extent of the impact of climate variability on tomato production in the Bauchi local government area because the decline in tomato production poses a threat to food security, particularly for those living in the study area and has the potential to increase the risk of famine. Although it appears that there has been much research on the effects of climate variability and change on agriculture (Adefolalu, 2004), there is very little information on the relationship between climate variability and vegetable production, particularly tomato in Nigeria and the study area in particular, which is known for its extensive tomato crop production. The topics covered thus far generate the following queries:

The majority of farmers in the study region rely heavily on the production of tomato crops for their livelihood and income, which enables them to take care of the social obligations of their families. Climate factors, such as unpredictable rainfall patterns and high temperatures, are some of the main issues influencing agricultural production globally (Codjoe and Owusu, 2011; Bitá and Gerats, 2013). Because tomato farming depends on rain, the region's unpredictable weather patterns and high temperatures could endanger the farmers' ability to make a living.

## LITERATURE REVIEW

The process of adjusting to the present or anticipated climate and its effects is referred to as adaptation to climate change, according to the IPCC (2007). It goes on to say that adaptation in human systems aims to lessen harm or take advantage of advantageous chances. Human intervention may help some natural systems adapt to expected warming and its impacts. According to Codjoe and Owusu (2011), who describe climate adaptation as the modification of natural or human systems in response to present or anticipated climatic stimuli or their impacts, which mitigates harm or takes advantage of advantageous chances, we can put these definitions on the same page. In a similar vein, the IPCC (2007) defines climate adaptation as programs and tactics to lessen the susceptibility of natural and human systems to the effects of climate change, whether they are present or anticipated.

Khanal (2009), on the other hand, took a different stance when they said that climate adaptation refers to all systemic modifications that mitigate the negative effects of climate change. Therefore, adaptation can be defined as a system's capacity to react to climate change (including climate variability and extremes), in order to reduce potential harm, seize opportunities, or cope with the effects. This indicates that a person has a variety of chances and options to adjust to a situation, particularly an environmental situation. In order to minimize the effects on people, communities, and the economy, climate adaptation can be defined as the collection of actions, strategies, procedures, and policies that are implemented in response to existing or anticipated climate change. Operationally, climate adaptation refers to the several tactics employed to cope with challenging climatic conditions (Arku, 2013). The most significant issue affecting rain-fed rice yields, which make up roughly 80% of the rice farmed in South and Southeast Asia and Africa, is variability in the amount and distribution of rainfall (Nguyen, 2006; Wassmann *et al.*, 2007). The coefficient of variability of the rainfall is larger in the tropics than in temperate regions for a given amount of precipitation. Regardless of latitude, variability is substantial in places with limited rainfall (Tao *et al.*, 2004). The main factor influencing how climate affects crop growth and yield is temperature. The temperature of the air or soil affects how quickly several growth and development processes occur in crop plants. The scientific community has recently become more interested in how crops react to temperature changes as a result of mounting evidence that human activity is raising the world's mean temperatures (FAO 2010). For some plants, nighttime high humidity is advantageous. The population is left with the option of overusing forests, wildlife, and other natural resources due to the regular increase in rainfall differential, which makes agriculture a dangerous, poorly rewarded, and low-paying vocation (Bhalme, 1998).

According to Awotoye and Matthew (2010), Nigeria now ranks second in Africa for the production of fresh tomatoes. Nigerian tomato production trend analysis from 2010 to 2014, generating 10.8% of the area's fresh tomatoes with 2.3 million tons produced in 2016, the nation ranked as the 14<sup>th</sup> largest tomato grower worldwide (FAO 2010). According to Sahel Research (SR, 2017), tomato production in 2016 contributed only a meager 1.2% to the global output. Nigeria's production of fresh tomatoes has increased by 25% in the last ten years, rising from 1.8 million tons to an estimated 2.3 million tons. But this growth has mostly been made possible by the ongoing expansion of the tomato harvesting area, which increased from 265,000 hectares to 668,292 hectares within the same time period (Codjoe and Owusu, 2011). In contrast to the global average yield of 38.1 tons/ha, tomato yields between 2006 and 2016 remained incredibly low at an average of 5.47 tons/ha. Low tomato output has been attributed to the use of outdated seedling kinds, rising temperatures, prolonged droughts that produce ideal conditions for pest and disease growth, weed invasion, and low soil fertility (Ayoade, 1983; Olaoye, 1999; SR, 2017). With a consumption rate of 22 kg per person, Nigeria is one of Sub-Saharan Africa's top vegetable consumers (Awotoye and Matthew, 2010). Particularly, Nigerians

consumed 12 kg of tomatoes per capita in 2016, with an estimated 2.3 9 million tons of tomatoes consumed annually.

The Federal Government unveiled a new tomato policy in 2017 with the aim of strengthening and increasing local output, enhancing value, and drawing in more investment. The program raises tariffs on tomato concentrate from 5% to 50% and imposes a USD1,500 penalty per ton in order to deter importation. Several large-scale industrial tomato processors left the sector before the policy was introduced. The main cause of this was the difficulty in finding fresh local tomatoes, which is mostly due to the effects of climate fluctuation on tomato crop productivity (FAO 2010). Climate variability is increasing as a result of climate change today (IPCC, 2007). In Least Developed Countries (LDCs), where most agricultural production systems are rain-fed and where people have minimal resources to deal with and adjust to these changes, the effects of increased climate variability are particularly obvious (Tao *et al.*, 2004). Climate variability, which has negative effects on agriculture, the environment, economic growth, and natural resources, is quickly becoming one of the major global issues affecting many different industries, according to IPCC reports from 2007.

Many suggested techniques for limiting the detrimental effects of climatic variability center on adaptation. A change to a human, ecological, or physical system is undertaken in reaction to a perceived vulnerability, according to Ozor (2009). According to Kurukulasuriya and Rosenthal (2003), adaptation is the process of making an effort to cope with current and future effects of climate change. Initiatives to lessen the susceptibility of natural climate change effects are included in the category of adaptation to climate change as well (IPCC, 2007). Climate change adaptation techniques, or the measures performed for and by people to get ready and make changes to protect themselves against climate change, have not received enough attention. As more individuals are forced to directly deal with the effects of climate change without a way of ameliorating or dealing with changes, this has increasingly led to greater vulnerability (Khanal, 2009). Because of this, adaptation and adaptive measures are essential (Ozor, 2009). Adaptive measures are steps made to lessen the risks that climate change poses to the availability of food, human health and well-being, and economic security (Ozor, 2009).

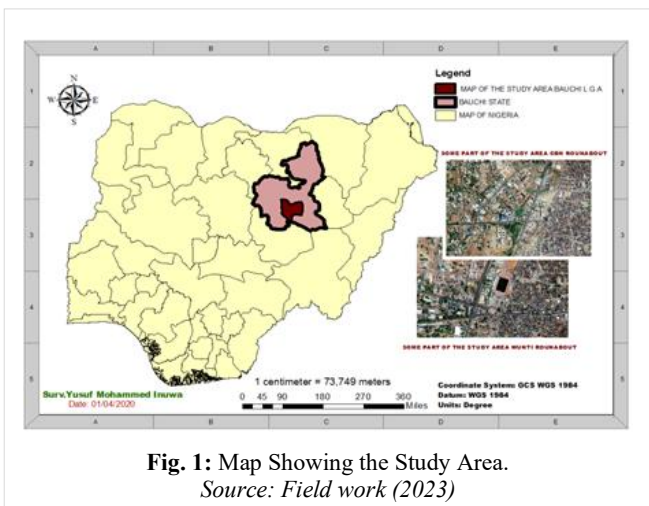


Fig. 1: Map Showing the Study Area. Source: Field work (2023)

## MATERIALS AND METHODS

The study area (Fig. 1) included the entire 881,600-population of Bauchi Local Government. The region has a total size of 14.85 km<sup>2</sup> and is located between latitudes 58°74"55" and 11°56"02" north of the equator and longitudes 52°32"34" and 11°14"34" east of the green witch meridian. From around 12% in February to about 68% in August, the relative humidity varies. May through September are the rainy months, with humidity levels ranging from 37% to 68%. In July, there are 343mm of rain, compared to 0.0mm in December and January. Rain usually starts in April and ends almost completely by October (NPC, 2006). Climate change has, however, had an impact on the timing of rainfall's beginning and ending as well as its distribution. Bauchi's vegetation is of the Sudan Savanna variety. In the direction to the south, the vegetation becomes increasingly rich. Sand and loam make up the Bauchi soil type. Due to the region's nature, Bauchi is classified as an agricultural area.

Primary sources were employed to gather the data for the study. Farmers were interviewed utilizing structured interview guides. The majority of the respondents in the study communities were found suitable for the structured interview. In light of this, the questions were read aloud in their native tongue to aid in better comprehension and proper response. The IBM SPSS Statistics Software, version 26, was used to handle and analyze the study's data using descriptive statistics. The inferential statistics used cross-tabulation and the Chi-square test of independence, while the descriptive statistics were displayed as tables, graphs, frequencies, and percentages.

Table 1: Demographic Information. Source: Field work (2023)

		Frequency	Percentage
Gender	Male	176	66.2
	Female	90	33.8
Age	10-20years	25	9.4
	21-30years	60	22.6
	31-40years	145	54.5
	41-50years	30	11.3
	>50years	6	2.3
Marital Status	Single	173	65.0
	Married	64	24.1
	Widow	19	7.1
	Divorced	10	3.8
Number of years lived in the community	5 to 10years	28	10.5
	11 to 20years	52	19.5
	21 and above	186	69.9
Number of years in tomato cultivation	1 to 10years	128	48.1
	11 to 20years	107	40.2
	21 and above	31	11.7
Size of your Farmland in hectare	1 to 3 hectares	63	23.7
	4 to 7 hectares	121	45.5
	8 and above	82	30.8

**Table 2:** Farmers’ knowledge on climate variability. *Source: Field work (2023)*

	SD	D	N	A	SA
Change in temperature	29	35	17	34	151
	10.9%	13.2%	6.4%	12.8%	56.8%
Change in rainfall pattern	22	35	18	35	156
	8.3%	13.2%	6.8%	13.2%	58.6%
Change in solar radiation	21	32	14	47	152
	7.9%	12.0%	5.3	17.7	57.1
Frequency of flooding	16	21	41	73	115
	6.0%	7.9%	15.4%	27.4%	43.2%
Frequency of drought	27	42	33	56	108
	10.2%	15.8%	12.4%	21.1%	40.6%

**RESULTS AND DISCUSSION**

Out of the total respondents (266), 176 of them (66.2%) were males, while 90 (33.8%) were females. The majority of the farmers (145 or 54.5%) were between the ages of 31 and 40 (Table 1). This was followed by those between the ages of 21 and 30, with a frequency of 60 (22.6%) of the total respondents, followed by 30 respondents (11.3%) aged 41 to 50. Again, 25 respondents (9.4%) were aged between 10 and 20, and 6 respondents (2.3%) were at the age of 50years and above.

Based on the findings of the study on farmers’ knowledge on climate variability, the indicators are represented in their highest values as follows: change in temperature recorded the highest with 56.8%, change in rainfall pattern 58.6%, change in solar radiation 57.1%, frequency of flooding 43.2%, and frequency of drought 40.6% (Table 2).

**The Cross-tabulation**

The cross-tabulation was used to establish the linkage between the sex of the farmers and their perception of climate variability effect on tomato production (Table 3 and Table 4).

The overall results show that out of the total of 266 valid cases, the majority of the respondents (99 or 36.3%) perceived the effects of climate variability on tomato to be the incidence of tomato disease, followed by 60 respondents (23%) who perceived the effects to be poor tomato yield (Table 4). Also, 58 respondents (22.7%) perceived the effect of climate variability on tomato to be inadequate tomato

**Table 3:** Farmers’ perception of the effects of climate variability. *Source: Field work (2023)*

	SD	D	N	A	SA
Inadequate food supply	9	8	19	41	189
	3.4	3	7.1	15.4	71.1
Poor crop yield	3	6	13	29	215
	1.1	2.3	4.9	10.9	80.8
Incidence of crop diseases	5	4	12	27	218
	1.9	1.5	4.5	10.2	82.0
Effect on livelihood	13	6	9	31	207
	4.9	2.3	3.4	11.7	77.8

supply, with the least respondents (51 or 17.7%) who perceived climate variability to affect the livelihood of farmers. The above results imply that the majority of the farmers perceived that climate variability could have some degree of impact on tomato yield, with the overall effect on its sustainable supply.

The Chi-square test result with a 5% level of significance and a 95% level of confidence revealed a significant relationship (P0.05) between the sex of farmers and their perception of the effects of climate variability on tomato production, demonstrating that the relationship was not the result of chance (Table 5).

**Table 5:** Chi-Square tests.

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.474 <sup>a</sup>	3	.009
Likelihood Ratio	11.676	3	.009
Linear-by-Linear Association	1.382	1	.240
N of Valid Cases	300		

*a.* 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.08.

Crop diversification came in first on the list of adaptive strategies with 24.7%, followed by the application of agrochemicals (21.0%), mixed cropping (20.0%), altering crop types (12.0%), moving the farm (6.7%), diversifying into non-agricultural pursuits (5.3%), and migration (4.7%)

**Table 4:** Cross tabulation. *Source: Field work (2023)*

Perceived effect of climate variability on tomato across gender					
		Sex			Total
		Female	Male		
How do you perceive the effect of climate variability on tomato	Poor tomato yield	Count	14	46	60
		% within Sex	20.9%	24.4%	23.3%
	Incidence of tomato disease	Count	40	59	99
		% within Sex	49.5%	30.6%	36.3%
	Effects on livelihood	Count	8	43	51
		% within Sex	9.9%	21.1%	17.7%
	Inadequate tomato supply	Count	13	45	58
		% within Sex	19.8%	23.9%	22.7%
Total	Count	90	176	266	
	% within Sex	100.0%	100.0%	100.0%	

**Table 6:** Farmers’ adaptation strategies in response to climate variability risk. *Source: Field work (2023)*

Which of the following on-farm / off-farm adaptation options do you practice/ adopt?		Parameter	Responses		
			YES	NO	Total
Farmers' adaptation strategies	Crop diversification	Count	57	17	74
		% within responses	24.7%	24.6%	24.7%
	Application of agrochemicals	Count	52	11	63
		% within responses	22.5%	15.9%	21.0%
	Mixed cropping	Count	49	11	60
		% within responses	21.2%	15.9%	20.0%
	Irrigation farming	Count	14	3	17
		% within responses	6.1%	4.3%	5.7%
	Change in farm location	Count	16	4	20
		% within responses	6.9%	5.8%	6.7%
	Changing crop varieties	Count	24	12	36
		% within responses	10.4%	17.4%	12.0%
	Migration	Count	7	7	14
		% within responses	3.0%	10.1%	4.7%
	Diversification to non-farming activities	Count	12	4	16
		% within responses	5.2%	5.8%	5.3%
<b>Total</b>		Count	211	55	266
		% within responses	100.0%	100.0%	100.0%

(Table 6). According to the survey, there were 230 (76.67%) male farmers, with 171 (57%) of them being between the ages of 31 and 40. The farmers' assessments of the consequences of climate variability varied. However, the majority of farmers believed the consequences to be the occurrence of tomato disease, which lowers crop output and has negative effects on the food supply. Additionally, it was discovered that the majority of farmers chose mixed cropping, the use of agrochemicals, and crop diversification as adaptive measures. Due to the low level of education of the farmers in the research area, experience was shown to be the main element determining their adaptation techniques. The study comes to the conclusion that one of the key elements influencing tomato yield in the study area is climate variance. The study area's smallholder farmers' most successful adapting techniques include mixed cropping and crop treatment. It is recommended that tomato producers' use of adaptive methods could be improved by their access to weather information. By doing this, the negative consequences of climate variability on their operations might be lessened. The optimum amount and timing of economical, efficient agro-allied chemicals should be available to farmers.

**SUMMARY, CONCLUSIONS AND RECOMMENDATIONS**

The survey found that farmers used a variety of adaptation techniques; the majority of them chose crop diversification, the use of agrochemicals, and mixed cropping. The incidence of tomato disease, which lowers crop yields and has negative consequences on tomato net production, was seen by many farmers as the main influence. The study discovered several perceptions of the farmers' sex traits that were similar. Reduced crop yield, crop disease incidence, and an impact on social and economic livelihoods are the main parallels amongst the sex groups' findings on the consequences of climate variability on tomato production. The study comes to

the conclusion that one of the key elements influencing tomato yield in the study area is climate variance. The study area's smallholder farmers' most successful adapting practices include mixed cropping and the use of agrochemicals. The study suggests that tomato farmers' ability to receive meteorological information may improve their capacity for adaptation. This might lessen how negatively climate variability affects their activity and tomato output. It has been discovered that difficulties including the high cost of agro-chemicals (such as fertilizer, ammonia, pesticides, and insecticides) and other farming inputs faced by both male and female tomato growers, considerably affect how responsive they are to hazards associated with climate variability.

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**Conflict of Interest**

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

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