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Climate Change Adaptation Strategies Used by Tomato Farmers in Gombe State, Nigeria

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Abstract

The study assessed adaptation strategies to mitigate the effects of climate change and production constraints among tomato farmers in Gombe State, Nigeria. A multistage sampling procedure was used to select 528 farmers. Descriptive statistics (mean and principal component analyses were used to analyse the data collected through a structured questionnaire. The findings reveal that farmers use different adaptation strategies to mitigate the effects of climate change, with a mean score of (3.551). The most used adaptation strategies by farmers to curb the effects of climate change include diversifying to non-farm activities, which have the highest mean score of ($\bar{x}$ = 3.69), ranked 1st. The farmers were confronted with other problems outside the elements of climate change; these comprise inadequate information about climate change ($\bar{x}$ =0.821), high temperature ($\bar{x}$ = 0.747), unstable and uncertain prices for tomato products ($\bar{x}$ = 0.773) and inadequate storage facilities ($\bar{x}$ = 0.842). Hence, the study recommends that horticultural research institutes and other relevant agencies should, as a matter of urgency, promote technologies such as smart agriculture that can mitigate the effects of climate change, improve post-harvest shelf life of tomato crops, and reduce losses farmers suffer because of climate severity.

Keywords: Climate change, adaptation strategies, constraints and tomato production

Introduction

Climate change and environmental destruction are interconnected threats to the future of our planet (Piguet, 2022). This is linked to a growing global population preoccupied with the current race for industrial and human development, which often overlooks drastic changes in natural systems and their consequences for the environment (Lubchenco et al., 2022). Industrial Revolution, natural resource extraction, urbanisation, and the use of fossil fuels have been driving forces for global economic advancement; also, the intensification of agricultural activities and the production of food and raw materials for industries, at the detriment of

afforestation, have led to a widespread increase in global warming and changes in elements of the climate. According to Adejuwon (2021), the effects of climate change are increasingly jeopardizing Nigeria's agricultural productivity. This affects agriculture and other sectors of the economy and threatens livelihoods. Farmers have demonstrated resilience by using adaptation strategies to remain productive.

Adaptation refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change (IPCC, 2023). Climate change adaptation refers to actions that help reduce vulnerability to the current or expected impacts of climate change, such as weather extremes and hazards, sea-level rise, biodiversity loss, or food and water insecurity. Adaptation measures include planting crop varieties more resistant to drought and practising regenerative agriculture, and improving water storage to cope with extreme weather such as floods and heat waves (Portia et al., 2018). Climate change is a menace to rural people who directly depend upon natural resources for their livelihood; farmers need to devise means for sustainable productivity through adaptation strategies (Abbass et al., 2022). Ogundeji and Okolie (2022) posited that farmers' responses to climate change can be categorised into two groups: coping and adaptation strategies. Coping strategies describe short-term mechanisms farmers adopt to ensure continuity in production enterprises, while adaptation strategies refer to longer-term shifts in practices, such as shifting cultivation and crop rotations, adopted by farmers to mitigate the effects of climate change. Despite growing awareness of the effects of climate change in the agricultural sector, tomato farmers face other issues beyond climate change. According to Ngbede et al. (2021), major constraints of tomato production included: high incidences of pests and diseases, perishability of produce, poor market structure, poor storage facilities, and high cost of agrochemicals, inadequate credit facilities, high cost of transportation, bad roads, and high cost of hiring labour. Several environmental changes in Gombe State, Nigeria include drought, flooding, irregular rainfall patterns, deforestation, desert encroachment, and increased rural-urban migration. According to Alalade et al. (2022), limited resources, poor infrastructure, and dependence on rain-fed agriculture further heighten the region's vulnerability. In addition, Ati (2023) and Tarfa et al. (2025) have examined the effects of climate change and adaptation. However, research on farmers' perceived adaptation strategies and constraints among tomato farmers in Gombe State, Nigeria remains limited.
The study;
i. assessed farmers' perceived adaptation strategies to the effects of climate change on tomato production; and
ii. ascertained the challenges faced by tomato farmers in Gombe State, Nigeria.

Methodology

The study was conducted in Gombe State. The state is located between latitudes 9°30'and 12°30'N and longitudes 8°45'and 11 °45'E of the Greenwich Meridian. It lies in the centre of the North-east geopolitical zone of Nigeria and shares a common boundary with all the other states in the zone, namely, Adamawa, Bauchi, Borno, Taraba and Yobe. Gombe State occupies a total land area of about 20, 265 km2 and has a topography that is mountainous and undulating to

the south and a flat open plain to the north (www.gombestate.gov.ng). With an average annual rainfall of 850 mm, the state is endowed with rich agricultural land, and about 80% of the people are mainly peasant farmers producing food and cash crops such as tomato, vegetables, millet, sorghum, maize, cotton, and groundnut through rain-fed and limited irrigation. Some people are also engaged in livestock farming, fishing, and craft work (www.gombestate.gov.ng).

Gombe State is divided into three agricultural zones, namely Gombe North, Gombe Central, and Gombe South, and is dominated by smallholder farmers (Okorie et al., 2019). Tomato is among the major crops grown in the area. The state's favourable soil and climatic conditions, such as abundant rainfall, make it well-suited for tomato cultivation. The map below (Figure 1) shows the location of the study area, which includes Nafada and Kwami in the northern part of the state, Akko in the middle part of the state, and Kaltungo and Balanga in the South-Western part of the state.

The population of this study comprises all tomato farmers. A total of five hundred and twenty-eight (528) respondents were selected using multistage sampling procedure was used to select respondents for this study from the study area, in the three agricultural zones which are zone A, (Gombe north), zone B (Gombe central), and zone C (Gombe south) which made up of five (5) LGAs in zone A, two (2) LGAs in zone B and four (4) LGAs in zone C. The second stage involved purposive selection of three (3) villages that dominate tomato production from each zone, for a total of nine (9) villages. These constitute a population of 7540 tomato farmers, based on the sample frame of the selected villages. The last stage involved proportionate random sampling of five hundred and twenty-eight (528) tomato farmers, using 7% of the tomato farmer population in each village.

Table 1: Sample size selection

S/N	Agricultural zone	LGA	Settlement Area	Sample Frame of Farm Families	Sample Size Selection 7%
1	A(North)	Kwami	Jurara	512	36
			Mallari	369	26
			Malamsidi	298	21
		Nafada	Barwu	421	29
			Njankam	143	10
			Nafadageri	723	51
2	C(South)	Kaltungo	Dogonruwa	818	57
			Lakolin	103	7
			Kokde	197	14
		Balanga	Kolaku	1078	75
			Bambam	216	15
			Charm	362	25
3	B(Central)	Akko	Kembu	916	64
			Tukulma	829	58
			Kobuwa	553	39
	Sub-Total			7540	528

*GSADP, (2021)

Analysis was conducted using frequency counts, percentages, and descriptive statistics. Mean score was used to measure adaptation strategies used by

farmers to mitigate the effects of climate change, and factor analysis was used to assess constraints affecting tomato production.
The Likert scale was used. The options were Strongly Disagree = (SD < 1-1.49), Disagree = (DA 1.50 - 2.49), Undecided= (UD 2.5-3.49), Agree= (A, 3.5 - 4.47) and Strongly Agree = (SA,4.50 -> 5.00). All scores were summed and divided by five (5) to obtain a critical point used to decide whether to accept or reject a variable. Determination of cutoff point

$$\bar{} = \frac{\Sigma F}{n} = \frac{5+4+3+2+1}{5} = \frac{15}{5} = 3.0$$

Principal Component Analysis (PCA)

Principal component analysis was used to assess the constraints affecting tomato production. The FA model is organized in such a way that all variables within a particular group are highly correlated among themselves but have relatively small correlations with variables in another group. Factor analysis of the constraints faced by tomato farmers during tomato production was conducted using the principal factor model. The constraints were grouped using the principal factor method with Kaiser's varimax orthogonal rotation method. Model acceptance was based on two criteria: each variable, in order to be included in the variable cluster of a factor, must load on it by more than 0.4, and variables that load on more than one factor were discarded. The model is expressed mathematically as:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \ast\ast\ast + a_{1n}X_n \quad (2.13)$$

$$Y_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \ast\ast\ast + a_{2n}X_n \quad (2.14)$$

* * * * *

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$$Y_n = a_{n1}X_1 + a_{n2}X_2 + a_{n3}X_3 + \ast\ast\ast + a_{nm}X_n \quad (2.15)$$

Where:

$Y_1, \ _2, \ \ldots\ldots, Y_n$ = Observed constraints farmers encountered during tomato production

$a_1 - a_n$ = Constraint loading or correlation coefficients;

$X_1, \ _2, \ \ldots\ldots, X_n$ = Unobserved underlying factors constraining tomato production.

Results and Discussion

Perceived Adaptation Strategies Used by Farmers to Mitigate the Effects of Climate Change on Tomato Production

Ten variables were stated as indices to assess perceived adaptation strategies used by farmers to mitigate the effects of climate change on tomato production, and farmers were requested to indicate if they strongly agreed, agreed, undecided, disagreed, or strongly disagreed with these statements as presented in Table 2. Strongly agree and agree were treated as agreed; undecided, disagreed, and strongly disagree were treated as strongly disagreed. The grand mean score (M.S) of the study was 3.543. From the results, 10 of the identified adaptation strategies had mean values ranging from 3.11 to 3.69, which were greater than the cut-off point value of 3.00 on a 5-point rating scale. This showed that respondents in the study area agree with the ten (10) listed adaptation

strategies as a means of mitigating the effects of climate change on tomato production.

A greater number (74%) of farmers agreed that diversifying into non-farm activities was a means to curb the effects of climate change, with a mean score (3.574), ranking 1st. Respondents sought other livelihoods outside tomato production to avert the effects of climate change on tomato production. This also aligns with the findings of Idoma et al. (2017) that livelihood diversification is a common adaptation strategy to mitigate climate change risk management in Africa and Asia. Moreover, the results show that a large proportion (74%) of tomato farmers agreed that mixed cropping mitigates the effects of climate change, with a mean score of 3.680, ranking 2nd. The mixed cropping system helps reduce the risk and uncertainty associated with sole cropping, especially in an era when weather conditions are unpredictable. The mixed cropping system was found to be practised and adopted by vegetable farmers to boost production in the Western Cape, South Africa (Baba, Abdullahi and Garba, 2024). Also, a large proportion (73%) of tomato farmers, who ranked 3rd with a mean score of 3.649, agreed that using pest- and disease-resistant tomato varieties is the strategy adopted to mitigate the effects of climate change on their production for maximum output. Strategies include using varieties resistant to pests and diseases, altering the timing or location of cropping activities, using different planting dates, and shortening the growing period. The majority (70%) of respondents said that soil moisture conservation technologies are a strategy for mitigating the effects of climate change on tomato production, with a mean score of 3.495, ranking 4th.

Soil and water conservation techniques help retain moisture in the soil for efficient plant use; this also reduces the negative effects of evaporation and soil degradation. This is commensurate with the findings of Driedonks Rieu and Vriezen (2022), that farmers resort to technical and management adjustments, like: mulching, Farm Yard Manure (FYM) application, advanced irrigation technology and sustainable crop management systems as adaptation mechanism engaged by farmers to increase tomato plants' ability to cope with changes in climatic indices. Furthermore, most (73%) respondents in the study area resorted to early-maturing tomato varieties to address the effects of climate change, with a mean score of 3.633, ranking 5th. To remain productive, farmers plant improved tomato varieties with short-maturing potential to mitigate the adverse effects of climate change on their production. The result further revealed that a greater proportion(74%) of the respondents adopt recommended practices as a means to mitigate the effects of climate change, with a mean score (3.688), which ranked 6th. This implies that farmers agree that the use of recommended practices by research institutes mitigates the effects of climate change on their production. Crop diversification is another strategy engage by tomato farmers to mitigate the effect of climate change, with a mean score (3.634) and ranked (7th) cultivation of non-vegetable crops enable farmers to avoid income and livelihood loss associated with sole cropping system liable to be affected by adverse effects of climate change, farmers practice diversification in agriculture with a view to minimize risk and uncertainty due to climate change and biological vagaries (Obi & Nwafor, 2021). Similarly, the majority (74%) of the respondents, with a mean score of (3.690), ranked 8th. Adapt synthetic pesticides as a means of mitigating the effects of climate change. Incidences of pests and diseases are increasing

because temperature changes create a conducive environment for insects and diseases to breed. Pests such as red spider mites cause severe flower drop during the reproductive stage of the tomato crop; as an adaptation strategy, many tomato farmers use synthetic pesticides to control insect pests. The result, however, showed that about 70% of tomato farmers in the study area engage in manipulating the planting date of the tomato crop in the field to ameliorate the effects of climate change, with a mean score of 3.495, which ranked 9th. This result implies that farmers use planting time and date to mitigate the effects of climate change, such as flooding, heavy rainfall, and high temperatures. The results support the findings of Sigmund, Ågerstr, and Antonelli (2023), who reported that farmers adjusted planting dates from early planting to late planting, or from late planting to early planting, to ameliorate the effects of climate change. The majority (74%) of the respondents adopted the use of improved seed as their adaptive measure to mitigate the effects of climate change on tomato production, with a mean score of (3.511), which ranked 10th. Improved tomato seeds are developed with inherent characteristics that can withstand the current changing climatic conditions compared with seeds obtained from previous planting seasons; this is a common practice among rural farmers. Planting improved tomato seedlings that are resistant to the effects of climate change helps in improving tomato yield despite changes in climate variables (Guo, Zhang and Yu, 2023)

.**Table2: Perceived adaptation strategies employed by farmers to mitigate the effects of climate change**

Statements	SA	A	UN	DA	SDA	WS	MS	%	Ranked	Decision
Adopting soil moisture conservation technologies	146	195	75	78	34	1925	3.646***	73	4	A
Diversification to non-farm activities	166	176	82	66	38	1950	3.693***	74	1	A
Changing time of planting	113	216	100	69	30	1897	3.592***	71	9	A
Crop diversification	124	218	79	83	24	1919	3.634***	73	7	A
Planting improved tomato seedlings	158	204	125	62	47	1854	3.511***	70	10	UD
Use of early maturing varieties	132	162	75	78	34	1925	3.645***	73	5	A
Mixed cropping system	156	183	84	74	31	1943	3.670***	74	2	A
Adopting recommended practices	150	184	73	91	30	1917	3.644***	73	6	A
Use of pesticide for insect control	151	199	68	77	33	1942	3.630***	74	8	A
Planting pest and disease resistant tomato	146	207	51	100	24	1935	3.664***	73	3	A
Grand mean							3.587***			

WS (Weighted Score) and MS (Mean Score), Strongly Disagree = (SD < 1-1.49), Disagree = (DA 1.50 - 2.49), Undecided= (UD 2.5-3.49), Agree= (A, 3.5 - 4.47) and Strongly Agree = (SA, 4.50 -> 5.00

Constraint Associated with Tomato Production

The results in Table 3 examined the constraint variables using the factorability technique and show that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.724, which is adequate and acceptable based on the KMO classification. Bartlett's test of sphericity (χ 2 = 352.899) was significant at p < 0.01; this indicates that the matrix differs significantly from zero (0), meaning it differs from the identity matrix. This implied that there was sufficient factor

analysis; more specifically, variables that had factor loadings of less than ±0.346 were not used, while variables that loaded in more than one constraint were also discarded (Oladimeji, 2024). Constraints were listed according to the proportion of variance associated with them and were classified under four factors. These factors are Factor 1 (institutional), Factor 2 (economical), Factor 3 (environmental), and Factor 4 (infrastructure), and were discussed as follows.

Under institutional factors, these were dominated by problems of inadequate information about climate change from relevant authorities (0.825), inadequate government policies on climate change adaptation strategies (0.853), loaded very high, indicating that there is limited useful information about climate change from weather experts addressing meaningful agronomic practices in order to aid tomato farmers farm decision-making processes so as to offset the risk associated with climate change in the study area. Lack of government policies that support inclusive and sustainable adaptive strategies to improve tomato production is one of the stumbling blocks to tomato production. Smallholder farmers face inadequate information on the threats climate change poses to agricultural activities. Climate change poses a growing threat to agricultural productivity, especially in developing countries like Nigeria. Agriculture, a cornerstone of Nigeria's economy, contributes approximately 24% to the GDP and employs about 70% of the population (FAO, 2021). Access to and availability of information on climate change is a serious challenge confronting tomato producers. The constraints that load highly on factor two comprise high input costs. These include the price of improved seeds and seedlings (0.991) and low and uncertain market prices for tomato products (0.773). High input costs are a major constraint in tomato production; subsistence farmers can hardly cope with the high price tag on inputs required for improved crop productivity. Low and unattractive market prices for farm output limit the profit-maximisation margin, discouraging farmers from intensifying production. This lends credence to Kassa and Merkine (2020), who argue that unaffordable farm input prices deterred farmers from using improved seeds, even though improved seeds offer better productivity and disease and pest resistance than local seeds. Environmental factors have high loadings, indicating a high incidence of pests and diseases (0.852), impoverished farmland (0.747), and drought (0.707). A reasonable number of farmers may be using seeds that are not pest- and disease-resistant. Together, these problems pose a major threat to tomato yield and farmers' productivity in the study area. This also suggests that tomato crops are vulnerable to insect pests and diseases, which can occur when water loss through evapotranspiration in a hot, dry climate creates salty deposits around the crop's root system. This prevents the crop from absorbing water, thus lowering the plant's immune system. Environmental factors such as drought, erosion, and high temperatures significantly affect tomato yield; tomato temperatures are between 25°C and 30°C during the day and 20°C at night. However, temperatures beyond these thresholds are detrimental to the crop, with effects including decreased pollen quality, flower abscission, abnormal growth, and reduced fruit bearing in the tomato crop (Fadairo, Williams, and Nalwanga, 2020; Vijayakumar & Beena, 2020). Under infrastructural factors, poor road network (0.695) and inadequate storage facilities (0.842) were highly loaded. The perishable nature of tomato fruit makes it necessary for farmers to dispose of their product at a giveaway price before it loses quality and value in the eyes of the buyer. However, storing

tomatoes in large quantities is a challenge for tomato farmers. Farmers cannot smoothly transport their farm produce from the field or preserve it for long. This can cause post-harvest losses, which reduce farmers' income. Poor road network and inadequate storage facilities are major problems confronting rural farmers (Haruna *et al*., 2020).

Table 3: Constraints associated with tomato production

Constraints	Mean	SD	Component Factor 1	Factor 2	Factor 3	Factor 4
Inadequate information about climate change	3.61	1.309	**0.821**			
Inadequate extension contacts about climate change	3.66	1.197	**0.656**			
Inadequate access to credit facilities	3.83	1.141	**0.692**			
Inadequate government policies on climate change adaptation and mitigation	3.85	1.185	**0.853**			
Complexity of climate change information	3.87	1.249	**0.693**			
Inadequate access to weather forecast	3.79	1.199	**0.869**			
Unstable and uncertain price for tomato products	3.77	1.181		**0.773**		
Use of local seeds and seedlings	3.84	2.412		**0.991**		
Low farm gate price	3.69	1.232		**0.692**		
High cost of fertilizer	3.85	1.182		**0.704**		
High rainfall	3.76	1.151			**0.747**	
Emergence of a new pest of tomato	3.71	1.195			**0.852**	
Drought	3.71	1.233			**0.707**	
Poor road access and transport facilities	3.85	1.171				**0.695**
Inadequate storage system	3.79	1.152				**0.842**
Diagnostic Analysis						
KMO Measure of Sampling Adequacy	0.724					
Bartlett's Test of Sphericity	352.899***					
Df	171					
Sig.	0.000					

:** p ≤ 0.05. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Factor loading of ±0.346 was used at 1% overlapping variance;
Variables with factor loadings of less than ±0.346 were not used

Conclusion and Recommendations

The study concludes that climate change threatens tomato crops, and farmers are using multiple adaptation strategies to mitigate its effects on production. The constraints associated with tomato production were factored and loaded as institutional factors (inadequate information about climate change), environmental factors (high temperature), economic factors (unstable and uncertain prices for tomato products) and infrastructural factors (inadequate storage facilities). Hence, the study recommends that horticultural research institutes and other relevant agencies should, as a matter of urgency, make technologies such as smart agriculture and infrastructure available that can mitigate the effects of climate

change, improve post-harvest shelf-life of tomato crops, and reduce losses farmers suffer as a result of climate severity in the study area.

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