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Vulnerability Assessment of Food Crop Production and Climate Change: Implication for Agricultural Productivity and Development in Nigeria

Mojirayo Ayooluwa Ayodele [1], Abeeb Babatunde Omotoso [1,2,*], Ibrahim Opeyemi Sulaimon [1] and Saidat Adebola Daud [2]

[1] Department of Agricultural Technology, Oyo State College of Agriculture and Technology, P.M.B. 10, Igboora 201103, Nigeria; mojirayoayodele4@gmail.com (M.A.A.); ibroalhaji1@gmail.com (I.O.S.)

[2] Faculty of Natural and Agricultural Sciences, North-West University, Mafikeng 2790, South Africa; saidatdaud@gmail.com (S.A.D.)

* Corresponding author. E-mail: omotosoabeebtunde@yhoo.com or abomotoso@oyscatech.edu.ng (A.B.O.); Tel.: +234-8066643962 (A.B.O.)

Received: 3 April 2025; Accepted: 6 May 2025; Available online: 8 May 2025

ABSTRACT: Climate change poses significant challenges to agriculture, particularly in developing nations like Nigeria, where the sector is highly dependent on vulnerable rain-fed farming systems. Extreme weather events such as prolonged droughts, erratic rainfall, flooding, and rising temperatures threaten agricultural productivity, food security, and rural livelihoods. This study examines the vulnerability of food crops to climate change, focusing on smallholder farmers' perceptions and adaptation strategies. Using a multistage sampling technique, data were collected from 480 smallholder farmers across selected agro-ecological zones in Nigeria. The study employed descriptive statistics and a crop vulnerability scale to assess the susceptibility of key food crops—maize, cassava, sorghum, rice, millet, soybean, and yam—to climate extremes. Findings reveal that drought is the most critical climate-induced stressor affecting food crops, with maize and cassava exhibiting the highest vulnerability indices. Flooding also presents a substantial risk, particularly to maize, while temperature fluctuations have relatively less severe immediate impacts. The study highlights the importance of climate information dissemination, cooperative memberships, and extension services in enhancing farmers' resilience. However, limited access to climate information remains a significant barrier to adaptation. Given the observed variability in crop vulnerability, it is recommended to implement targeted climate adaptation strategies such as drought-resistant crop varieties, improved drainage systems, and early warning mechanisms. This study underscores the urgent need for climate-smart agricultural policies and resilience-building measures to safeguard food production and rural livelihoods in Nigeria amid escalating climate change threats.

Keywords: Extreme stress; Flooding; Rural Nigeria; Susceptibility; Sustainability

1. Introduction

Climate change remains one of the most pressing challenges facing global agriculture, with developing countries like Nigeria experiencing the most severe consequences [1]. Nigeria's agricultural sector is highly vulnerable to climate variability due to its dependence on rain-fed farming systems, making it susceptible to extreme weather events such as prolonged droughts, erratic rainfall, flooding, and rising temperatures [2,3]. These climate-related shocks not only reduce agricultural yields but also pose significant threats to food security, livelihoods, and economic stability [4]. The increasing unpredictability of weather patterns affects crop cycles, disrupts planting and harvesting schedules, and exacerbates pest and disease outbreaks, further worsening productivity losses [5]. Given that agriculture contributes significantly to Nigeria's gross domestic product (GDPs) and employs a large proportion of the rural population, addressing climate change impacts on the sector is critical for national development and poverty alleviation [6].

Noteworthy, climate change-related floods and droughts are becoming more common in Nigeria, posing a significant threat to agricultural households [1,7]. According to [8,9], rising average global temperatures lead to global

https://doi.org/10.70322/rrd.2025.10008

warming, affecting precipitation and negatively impacting agricultural activity and crop productivity. Nigeria's crop season is expected to shorten due to heavy reliance on rain-fed agriculture, which is particularly vulnerable to climate change [10,11]. Few studies [1,12] have assessed crop vulnerability at the household level, where livelihood activities are concentrated. Research on agricultural system vulnerability to climate change often focuses on cropping systems rather than identifying specific crop vulnerability to extreme weather. Consequently, assessing crop vulnerability to particular climatic extremes in sub-Saharan Africa, and Nigeria specifically, to inform climate change adaptation planning (CCAP) is limited.

Nigeria's agricultural sector has consistently showcased its significance, contributing about 30% to the GDP and sustaining the livelihoods of 60% of the population [1,7]. Nonetheless, prospects for expansion are jeopardized by climate change due to the population's heavy reliance on natural resources and rain-fed agriculture for sustenance. Projected alterations in precipitation patterns and rising temperatures are expected to impose significant additional problems on a sector already grappling with the severe consequences of climate change [13]. Climate change directly negatively impacts agriculture through crop failures, the emergence of novel pest and disease patterns, soil infertility, diminished water retention, and agricultural demand [6]. Furthermore, the stability of crop yields and food supplies will be adversely impacted by alterations in climatic factors, which will differentially influence physical, economic, and social access to food due to reductions in agricultural productivity, elevated food prices, and diminished purchasing power [5,9].

Nevertheless, there is a scarcity of empirical data regarding crop-specific vulnerability to climate extremes in Nigeria. Vulnerability is defined as the extent to which a system is prone to or incapable of managing the adverse effects of climate change [14]. This study defines vulnerability as the extent to which climate change negatively impacts food crop output [15]. Vulnerability has emerged as a significant theme in climate change literature in recent years. This is attributable to its function in supplying information for the comprehension, assessment, and evaluation of the circumstances of communities and individuals affected by climate-induced disasters [6,13]. The Intergovernmental Panel on Climate Change (IPCC) emphasizes the necessity for a thorough evaluation and comprehension of the vulnerability of regions to climate change to improve the development of adaptation strategies and resilience enhancement. In Nigeria, empirical evidence [1,16] indicates that agricultural systems are susceptible to climate change, particularly to stresses such as less rainfall, drought, arid periods, and elevated temperatures [17].

Research [13,18] has demonstrated communities' vulnerability to climate change and their adaptive tactics. Notwithstanding, the significance of these evaluations on the region's vulnerability to climate change, the degree to which staple food crops (maize, sorghum, rice, millet, soybean, and yam) are imperiled by climate change remains inadequately examined. This research examines smallholder farmers' perception of crop vulnerability to climate change to evaluate crop-specific vulnerability and its implications for adaptation strategy and resilience enhancement.

2. Method and Materials

2.1. Study Area

The study was conducted in some selected farming communities reputed for food crop production (maize, cassava, and vegetables) across the six geopolitical zones covering five (Southeast, Southwest, Northwest, Northeast, and Northcentral) of the six Agro-ecological zones (AEZs) of Nigeria. Nigeria is situated in the West African region and lies between longitudes 3° and 14° and latitudes 4° and 14° with a land mass of 923,768 km^2. Nigeria shares a land border with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast lies on the Gulf of Guinea in the south, bordering Lake Chad to the northeast. Agriculture is the mainstay of the economy and employs about 80% of the population [1]. Other crops cultivated include yams, cassava, rice, sorghum, beans, maize, and cotton. The Nation is marked by two distinct seasons: the wet season, which spans through the middle of April to October, and the dry season, which spans from November to March. For agricultural development, especially in the area of extension delivery systems, it was divided into four agricultural development program (ADP) zones.

2.2. Sampling Techniques and Data Analysis

The study employed a multistage sampling technique to select 480 food crop farmers from Nigeria's southwestern agro-ecological zones (AEZs). The first stage involved the purposive selection of two states—Oyo and Ogun—from the southwestern AEZ, recognized as leading producers of cassava and maize in Nigeria. The second stage involved a random selection of three (3) Agricultural Extension Blocks per state, which gives a total of 6 blocks, and the third stage is a random selection of two (2) Extension Cells per block—that is, 12 Cells across six Blocks. The final stage involved

the random selection of 40 members from the Cassava/Maize farmers' groups in each of the selected cells. This process yielded a total of 480 smallholder farmers interviewed for the study. Data were collected on the farmers' characteristics, such as household size, output/yields, and prices for the 2024 farming season. In addition, data were collected on farmers' perceptions of climate change and their vulnerability status.

2.3. Analytical Technique and Vulnerability Specification

Descriptive statistics such as mean and standard deviation were used to analyze the quantitative data, and results were presented in tables and graphs. Additionally, a crop vulnerability scale was developed to assess the level of vulnerability of each crop to climate change extremes individually. To assess a crop's vulnerability to climate change, smallholder farmers in each of the selected communities were asked to identify the crops that were most susceptible to weather extremes such as drought, floods, intense sunshine, bushfires, and dry periods. To accomplish this, a pre-field survey conducted in March 2023 identified the main food crops—maize and cassava grown in the selected communities. A Likert scale was created for each crop, with the options being very high (4), high (3), moderate (2), low (1), and very low (0.5), to allow farmers to rate their sensitivity to each climate change extreme. The mean score for each crop under each climate extreme was calculated to estimate its corresponding vulnerability score. Vulnerability scores exceeding 0.5 for each crop under each climate extreme were viewed as extremely high according to the World Bank's (2012) interpretation of the vulnerability scale, and they may have an impact on the crop or crops' level of productivity.

3. Results and Discussion

3.1. Socioeconomic Characteristics of the Farming Households

Table 1 presents the descriptive statistics of the farming households surveyed in this study, highlighting key demographic, economic, and agricultural production variables. The results indicate that the average quantity of maize harvested per hectare was 11.6 tons, while cassava production averaged 15.8 tons per hectare. The variability in yields suggests differences in farm productivity, which may be influenced by factors such as farm size, soil fertility, access to inputs, and climate conditions. The average farm size of 8.3 hectares, with a wide range from 1 to 22 hectares, indicates that smallholder farmers with limited land resources coexist with relatively larger-scale producers. Additionally, the average age of household heads is 49.2 years, which suggests that most farmers are middle-aged or older, which aligns with studies indicating that the ageing farming population in Africa poses challenges to agricultural productivity and innovation [5,12].

As shown in Table 1, the gender distribution reveals that 62.9% of the household heads are male, which is consistent with [18,19], who reported that male farmers often have better access to resources such as land, credit, and agricultural extension services compared to their female counterparts. In terms of economic factors, 72.6% of the farmers reported having off-farm income sources, which is in line with studies indicating that livelihood diversification is a common coping strategy for smallholder farmers in response to climate shocks [20]. Membership in cooperative societies was high, with 77.2% of farmers participating, which suggests that social capital plays an important role in accessing credit, market information, and adaptation resources. Additionally, 82.2% of farmers had contact with extension agents, reflecting the potential for technology dissemination and climate-smart agricultural practices through extension services. However, access to climate information was relatively low at 42.3%, which could limit farmers' ability to make informed adaptation decisions.

The findings underscore the importance of climate information and extension services in enhancing farmers' resilience to climate change. Studies [3,21] have shown that access to climate information significantly improves farmers' adaptive capacity, enabling them to adjust planting dates, adopt drought-resistant crops, and implement soil conservation techniques. Limited access to climate information may account for the variability in farm productivity, as farmers without timely weather forecasts and climate projections often struggle to mitigate risks, thereby contributing to higher vulnerability indices. Figure 1 presents extreme climatic factors affecting respondents' crops. It is essential to understand how various climatic stressors influence smallholder agriculture in Nigeria. Extreme climate events such as droughts, floods, erratic rainfall, and temperature fluctuations can significantly impact crop productivity, leading to food insecurity and economic hardship for farming households [11]. Notably, rising temperature extremes, floods, and drought negatively impact crop growth, accelerating evapotranspiration, and increasing plant stress and vulnerability, which ultimately reduces yields [15,22].

Table 1. Variable description and descriptive statistics of the farming household (n = 480).

Variables	Description	Mean	Std. Dev.	Min	Max
Maize	Quantity of maize harvested (ton/ht)	11.6	4.9	3	21
Cassava	Quantity of cassava harvested (ton/ht)	15.8	7.7	2	16
Farm size	Area cultivated (hectares)	8.3	5.1	1	22
Age	Age of the HH in years	49.2	29.1	31	72
Sex	Gender of HH (1 = male, 0 = otherwise)	0.629	0.437	0	1
Marital status	Marital status of HH (1 = married, 0 = otherwise)	0.680	0.227	0	1
Off income	Off-farm income (1 = yes, 0 = otherwise)	0.726	0.331	0	1
Experience	Farming experience (years)	11.3	4.1	4	16
Cooperative	Membership of cooperative society (1 = yes, 0 = otherwise)	0.772	0.225	0	1
Hh size	Number of household members	7.2	3.1	1	12
Extension	Contact with extension agent (1 = yes, 0 = otherwise	0.822	0.401	0	1
Climate	Access to climate information (1 = yes, 0 = otherwise)	0.423	0.186	0	1

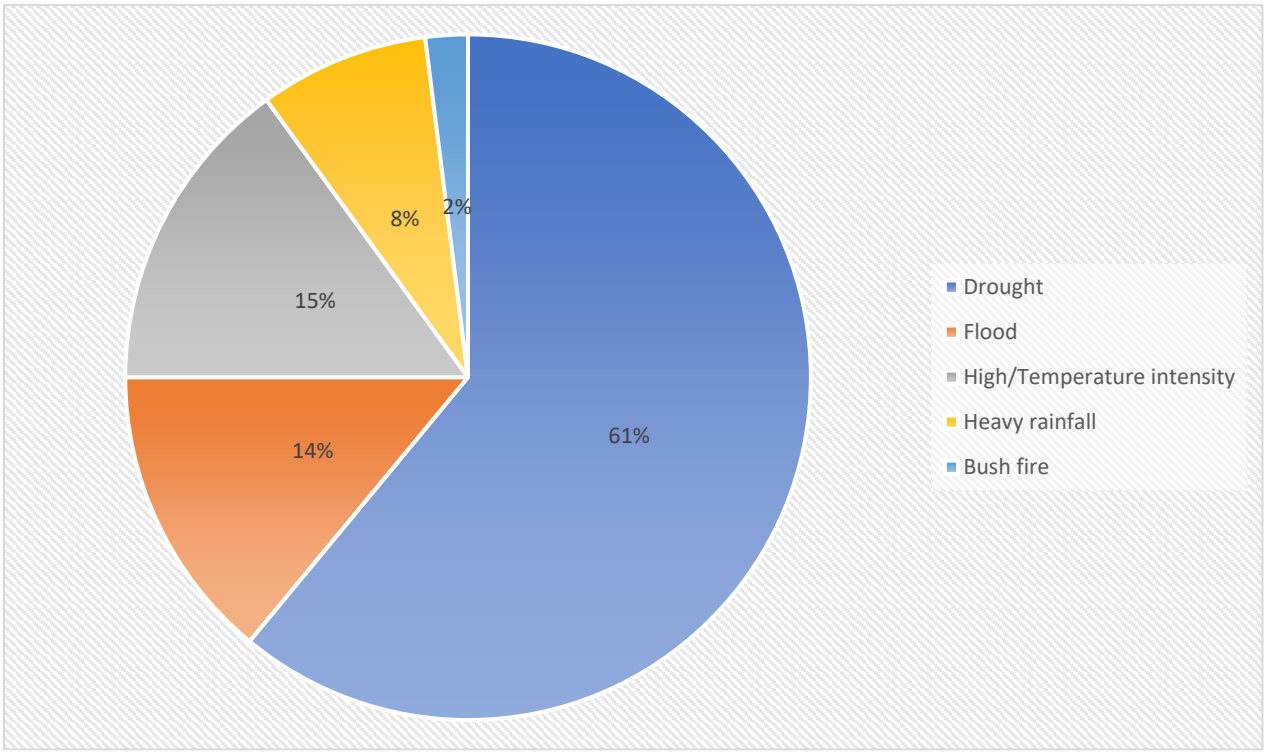

Figure 1. Extremes climatic factors affecting respondents' crops.

3.2. Extreme Climatic Factors and Crop Vulnerability

The study assessed the vulnerability of food crops to different climatic stressors—drought, flooding, and high-temperature intensity. As shown in Table 2, the results indicate that drought poses the most significant threat to food crop production, with maize (0.773), cassava (0.626), millet (0.577), and yam (0.601) showing high vulnerability indices. Flooding is also a critical concern, primarily affecting maize (0.622) and cassava (0.505), while millet and yam appear to be more flood-resilient. Conversely, high-temperature intensity has a comparatively lower impact on all crops, suggesting that temperature fluctuations alone are not a major determinant of vulnerability in the study area. The high vulnerability of food crops to drought is consistent with global climate studies, which emphasize water scarcity as a leading cause of food insecurity in sub-Saharan Africa [13,23]. Prolonged dry spells reduce soil moisture, lower yields, and threaten livelihoods [3,5].

Consistently, flooding poses a crop-specific challenge, impacting maize and cassava more severely than millet and yam. While high-temperature stress appears to be less severe, its long-term effects on crop physiology and pest outbreaks require continued monitoring and adaptation strategies [19]. This highlights the need for crop diversification, flood-resistant seed varieties, and improved drainage systems to mitigate the adverse impacts of extreme rainfall events. Furthermore, early warning systems and land-use planning policies must be strengthened to reduce farmers' exposure to flood-related risks.

Table 2. Perceived effects of climatic factor on food crop production and vulnerability index.

Climatic Factors	Food Crop	Mean
Drought	Maize	0.773
	Cassava	0.626
	Millet	0.577
	Yam	0.601
	Vulnerability Index	**0.619**
Flood	Maize	0.622
	Cassava	0.505
	Millet	0.102
	Yam	0.117
	Vulnerability Index	**0.201**
High/Temperature intensity	Maize	0.212
	Cassava	0.129
	Millet	0.137
	Yam	0.185
	Vulnerability Index	**0.122**

NB: Crops with mean values less than 0.5 (50%) are less vulnerable to climate extremes, while those with mean score more than 0.5 are more sensitive to climate extremes.

4. Conclusions and Recommendations

This study assessed the vulnerability of food crop farming to climate change impacts in Nigeria. The findings reveal that drought (61%) is the most severe climatic threat, significantly affecting major food crops such as maize, cassava, millet, and yam. Flooding (14%) also poses challenges, particularly for maize and cassava, whereas high-temperature intensity has a relatively lower impact on all crops. The vulnerability index (0.122) underscores that different crops respond differently to climate stressors, highlighting the need for targeted adaptation strategies. The study reinforces the importance of climate-smart agriculture in mitigating the negative effects of extreme weather conditions on food security and rural livelihoods. Farmers' adaptive capacity depends on access to climate information, extension services, and membership in cooperative societies. The study emphasizes that proactive adaptation measures such as drought-resistant crop varieties, efficient water management, improved drainage systems, and early warning systems are essential for reducing climate risks. Strengthening institutional support and promoting farmer education programs will further enhance resilience to climate variability. Addressing these vulnerabilities is critical for ensuring sustainable agricultural productivity and food security in the face of increasing climate change threats.

Acknowledgements

The authors acknowledge and appreciate the Tertiary Education Trust Fund (TetFund) Institutional Based Research (IBR) with grant number OYSCATECH/RG/2023/09 and OYSCATECH/RG/2023/14 for the financial support towards the success of this research. Additionally, the conducive environment support by Oyo State College of Agriculture and Technology, Igboora, Nigeria, for the successful completion of this research work is appreciated and recognized. Opinions and conclusions herewith are those of the authors and are not necessarily to be attributed to the bodies.

Author Contributions

Conceptualization A.B.O., M.A.A.; Methodology, Writing (original draft preparation) and Writing—Reviewing and Editing: A.B.O., I.O.S. and S.A.D. The authors have read and approved the published version of the manuscript.

Ethics Statement

The Ethics Committee of the Faculty of Plant and Environmental Sciences, OYSCATECH, Igboora, Nigeria approved the research's ethical clearance (OYSCATECH/EC/001), 2024. While the Department of Agricultural Technology, OYSCATECH, Igboora, Nigeria, granted the researchers permission to visit the study area.

Informed Consent Statement

Informed consent was obtained from the participants involved in the study.

Data Availability Statement

The data underlying this article will be shared on reasonable request from the corresponding author.

Funding

This research received funding from Tertiary Education Trust Fund (TetFund) inform of Institutional Based Research (IBR) with grant numbers OYSCATECH/RG/2023/09 and OYSCATECH/RG/2023/14.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Omotoso AB, Omotayo AO. Enhancing dietary diversity and food security through the adoption of climate-smart agricultural practices in Nigeria: a micro level evidence. *Environ. Dev. Sustain.* **2024**, 1–18, doi:10.1007/s10668-024-04681-8.
2. Olutumise AI, Oparinde LO. Climate information and health variables as determinants of technical efficiency: insight from food crop farmers. *Sustainability* **2022**, *13*, 28–44.
3. Sabasi D, Shumway CR. Climate change, health care access and regional influence on components of US agricultural productivity. *Appl. Econ.* **2018**, *50*, 6149–6164.
4. Omotoso AB, Letsoalo S, Olagunju KO, Tshwene CS, Omotayo AO. Climate change and variability in sub-Saharan Africa: A systematic review of trends and impacts on agriculture. *J. Clean. Prod.* **2023**, *414*, 137487.
5. Omotayo AO, Omotoso AB. Climate-smart agricultural technology and gender-differentiated food, and water security: Evidence from smallholder sunflower (*Helianthus annuus* L.) Farmers. *Agric. Water Manag.* **2025**, *308*, 109276.
6. Dumenu WK, Obeng EA. Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. *Environ. Sci. Policy* **2016**, *55*, 208–217.
7. Olutumise AI, Ajibefun IA, Omonijo AG. Effect of climate variability on healthcare expenditure of food crop farmers in Southwest, Nigeria. *Int. J. Biometeorol.* **2021**, *65*, 951–961.
8. Mishra A, Ketelaar JW, Uphoff N, Whitten M. Food security and climate-smart agriculture in the lower Mekong basin of Southeast Asia: Evaluating impacts of system of rice intensification with special reference to rainfed agriculture. *Int. J. Agric. Sustain.* **2021**, *19*, 152–174.
9. Omotoso AB, Letsoalo SS, Daud SA, Tshwene C, Omotayo AO. Climate-smart agricultural practices, productivity, and food-nutrition security in rural South Africa: A dataset of smallholder maize farmers. *Data Brief* **2024**, *55*, 110725.
10. Fadare O, Srinivasan C, Zanello G. Livestock diversification mitigates the impact of farmer-herder conflicts on animal-source foods consumption in Nigeria. *Food Policy* **2024**, *122*, 102586.
11. Omotoso AB, Omotayo AO. The interplay between agriculture, greenhouse gases, and climate change in Sub-Saharan Africa. *Reg. Environ. Chang.* **2024**, *24*, 1.
12. Sikka AK, Islam A, Rao K. Climate-smart land and water management for sustainable agriculture. *Irrig. Drain.* **2018**, *67*, 72–81.
13. Bazzana D, Foltz J, Zhang Y. Impact of climate smart agriculture on food security: An agent-based analysis. *Food Policy* **2022**, *111*, 102304.
14. Rigolot C, De Voil P, Douxchamps S, Prestwidge D, Van Wijk M, Thornton PK, et al. Interactions between intervention packages, climatic risk, climate change and food security in mixed crop–livestock systems in Burkina Faso. *Agric. Syst.* **2017**, *151*, 217–224.
15. Danso-Abbeam G, Ehiakpor DS, Aidoo R. Agricultural extension and its effects on farm productivity and income: insight from Northern Ghana. *Agric. Food Secur.* **2018**, *7*, 1–10.
16. Wassmann R, Villanueva J, Khounthavong M, Okumu BO, Vo TBT, Sander BO. Adaptation, mitigation and food security: Multi-criteria ranking system for climate-smart agriculture technologies illustrated for rainfed rice in Laos. *Glob. Food Secur.* **2019**, *23*, 33–40.
17. Muriuki J, Hudson D, Fuad S. The impact of conflict on food security: evidence from household data in Ethiopia and Malawi. *Agric. Food Secur.* **2023**, *12*, 41.
18. Kogo BK, Kumar L, Koech R. Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environ. Dev. Sustain.* **2021**, *23*, 23–43.
19. Mutengwa CS, Mnkeni P, Kondwakwenda A. Climate-Smart Agriculture and Food Security in Southern Africa: A Review of the Vulnerability of Smallholder Agriculture and Food Security to Climate Change. *Sustainability* **2023**, *15*, 2882.
20. Gebrehiwot KG. The impact of agricultural extension on households' welfare in Ethiopia. *Int. J. Soc. Econ.* **2015**, *42*, 733–748.

21. Omotoso AB, Omotayo AO. Impact of behavioural intention to adopt climate-smart agricultural practices on the food and nutrition security of farming households: A microeconomic level evidence. *Clim. Chang.* **2024**, *177*, 117.
22. Fadare O, Zanello G, Srinivasan C. Stressor or succour? Examining the association between conflict, livestock assets, and farmers' mental health in Nigeria. *Econ. Hum. Biol.* **2023**, *49*, 101234.
23. Omotoso AB, Omotayo AO. Benefits of manure and drought-resistant maize varieties on farmers' welfare status in South Africa. *Agric. Biosci.* **2025**, *6*, 0021.