Environment, Development and Sustainability
https://doi.org/10.1007/s10668-024-04681-8

Enhancing dietary diversity and food security through the adoption of climate-smart agricultural practices in Nigeria: a micro level evidence

Abeeb Babatunde Omotoso[1] · **Abiodun Olusola Omotayo**[1,2]

Received: 19 January 2023 / Accepted: 18 February 2024

Abstract

The paranoid belief that climate change will gradually reduce the ability of the world to meet the demand for food serves as the rationale for Nigerian smallholder farmers' advocacy of climate-smart agriculture (CSA) techniques. The study investigates the effects of CSA practice on the food security status of rural farming households in Nigeria. A multi-stage sampling technique was employed in selecting 480 rural farming households across three selected states from Southwest, Nigeria. Data were analyzed using descriptive and inferential statistics. Obtained results showed that 59.79% of the respondents were food insecure while severe and depth of food insecure among the farming households were 0.0711 and 0.1913 respectively. The result of the household dietary diversity score revealed the diverse consumption-ability of the respondents and the contributions of CSA practice in their farming system. This implies that households engaged in climate-smart farming are more likely to achieve higher levels of food consumption score, dietary diversity, and food security. The probit regression revealed that the food security status among rural farming households was significantly influenced by household heads' gender, farm size, and contact with extension agents as well as adopted CSA practices such as crop diversification, agroforestry, and use of Fadama land for agricultural activities. This research concludes that CSA lowered the probability of food insecurity among rural farming households in Nigeria. Accordingly, the study suggests that the government and the key players should encourage the use of CSA practices in order to ensure agricultural sustainability and food security in agrarian communities by reducing the impact of climate change.

Keywords Climate variability · Climate-smart agriculture · Crop diversification · Food security · Sustainability

✉ Abiodun Olusola Omotayo
abiodunomotayo@daad-alumni.de; omotayoabiodun777@gmail.com

[1] Department of Agricultural Economics and Extension, Faculty of Natural and Agricultural Science, North West University, Mafikeng, South Africa

[2] Food Security and Safety Focus Area Research Group, Faculty of Natural and Agricultural Sciences, North-West University, Mafikeng, South Africa

1 Introduction

Food provisions for homes are essential, with about 850 million people worldwide confronted with the problem of hunger, while more than two-thirds of the earth's population lacks essential food nutrients, thus, affecting their diet, standard of living, well-being, as well as life expectancy (Food and Agriculture Organization (FAO, 2019). As a result, the World Bank Food Project predicts that by 2030, more than a billion people would be facing food insecurity as a result of the impacts of climatic variability and change (FAO, 2020). Regrettably, climate change is a serious environmental concern affecting mankind that impacts cut across various sectors, ranging from health to agriculture (Omotoso et al., 2023; Shen et al., 2021). Climate variabilities and change have adversely affected agriculture globally, while its impact on households' food security is predicted to get more intense over time and to differ among regions and countries if not well tackled (FAO, 2022; Abegunde et al., 2022).

The agricultural industry is intrinsically sensitive to climatic conditions and has become highly vulnerable to the battered by the dangers and its impacts (Gebrehiwot, 2015; Omotoso & Omotayo, 2024). Despite the enormous contribution of the agricultural sector to the overall economy, this sector has been encountering several challenges, the most severe of which are climate-related events such as flooding and drought, and the situation is anticipated to deteriorate in the future (Abegunde et al., 2022; Ochieng, 2018; Alayande et al., 2017). More so, this has led to a paranoid belief that climate change impacts may hinder the abilities and capabilities of the agricultural sector to fulfill the food demands of the world's 10 billion people by the year 2050 (Omotayo et al., 2022; Omotoso & Omotayo, 2024). This is one of the reasons why researchers are advocating for climate-smart agriculture (CSA) (Dooley & Chapman, 2021; Anuga & Gordon, 2016). CSA could refute this unfortunate outcome through the integration of climate change adaptation practices with sustainable agricultural practices (Mutengwa et al., 2023; Wekesa et al., 2018).

Intriguingly, CSA is a unique form of farming technique that involves all the practices to ensure sustainably increment in agricultural productivity and food security through adapting to climate change by building resilience and reduction in greenhouse gas emissions related to agricultural practices in order to optimize farming output and ensure environmental sustainability (FAO, 2020; Onyeneke et al., 2020). This farming technique enhances food crop production and food security through efficiently utilizing scarce resources, thereby increasing farmers' revenue and their standard of living without compromising biodiversity, the environment, and farmers' well-being (Jiao et al., 2023; Shen et al., 2021). In addition, CSA balances the ecological and socio-economic components of humans in ensuring that current tense agricultural operations do not jeopardize future agricultural production capacity (Abegunde et al., 2022; Ochieng, 2018).

Contrary to conventional agricultural practices characterized by cultivating low-yield cultivars incorporated with excessive nitrogen fertilizer applications, are unsustainable since they contribute to the emissions of greenhouse gases and global warming (Luo et al., 2022; Omotayo et al., 2021; Omotoso & Omotayo, 2024). CSA practices embraces enhanced yielding varieties, such as droughts tolerant crops, pests and disease-tolerant plants, and genetically modified farm input that limit the use of costly nonrenewable, and environmentally-depleting agrochemicals (Bellia et al., 2022; Ofori et al., 2021; Omotoso & Omotayo, 2024). It also encourages the adoption of improved technology such as smart farming and efficient land-use management, which are implemented alongside integrated farming systems, such as integrated plant and pest management systems, to reduce GHG emissions and climate change (Omotoso & Omotayo, 2024; Rigolot et al., 2017). However, the adoption of CSA practices by farmers in developing nations, especially in Nigeria is quite low despite the numerous efforts directed toward the sensitization of farmers about its importance in mitigating climate change (Partey et al., 2019; Abegunde et al., 2022).

Based on this context, our research seeks to contribute to the body of knowledge on how to enhance household dietary diversity and food security in rural farming households through the adoption of CSA practices. The research aims to highlight various CSA practices adopted by farming households and evaluate their food security status as well as the effects of CSA on food security status using Nigeria as a case study. The findings given here are based on an evaluation and provide empirical evidence that supplements the literature to assist policy debates on CSA practices, implementation tactics, and decision-making about the household dietary diversity and food security situation of farming households in Nigeria.

Consequently, there has been little study on the synergy between CSA practice adoption, household dietary diversity and food security in Nigeria, whereas studies available are inconsistent, fragmented, or restricted in scope. Interestingly, Nigeria is currently facing two major environmental challenges, among others: (i) increasing agricultural output to meet the needs of an expanding population, which is expected to reach 320 million by 2050, without jeopardizing farming households' well-being, and (ii) increasing the resilience of the region's agri-food systems to the predicted climate change (Bazzana et al., 2022; Rigolot et al., 2017). As a result, research into the adoption of CSA impact on food security necessitates a broad proclamation by the government and other stakeholders to aid policy discussions on CSA, implementation techniques, and decision-making that will ensure agricultural sustainability and improve the welfare of rural families in Nigeria.

2 Context and related literature review

2.1 Climate Change's impact on agriculture production and food security in Nigeria

Climate change poses a significant threat to global food security by affecting crop yields, altering precipitation patterns, and increasing the frequency of extreme weather events (Omotoso et al., 2023). Research in climate-smart agriculture is essential to develop adaptive strategies that can mitigate these impacts and ensure sustainable agriculture production in Nigeria (Bazzana et al., 2022; Luo et al., 2022; Omotoso et al., 2022). Consequently, agricultural production contributes about 24% to Nigeria 's gross domestic product (GDP), where more than 72% of its population is directly involved in food crop production and the food supply chain (Abegunde et al., 2022).

Agriculture is sensitive to climate-related factors such as temperature changes, precipitations, and extreme weather events like floods and droughts which could lead to inefficiency in the agricultural sector (Pretty, 2017). There is a confirmation that agricultural yields are already being impacted by climate change in many developing nations (Abegunde et al., 2022; Partey et al., 2019; FAO, 2019). This is obvious in low-income nations like Nigeria, where inadequate adaptation capacities to climate change resulted in low agricultural productivity (Pretty, 2017). However, most rural farming households in Nigeria are into subsistence farming, thereby making the food industry highly susceptible to climate variabilities and change (Abegunde et al., 2022).

In Nigeria, the impact of climate change on food crop production is categorized as biophysical and socioeconomic impacts due to the poor institutional structure and adaptation measures which led to national food insecurity (Partey et al., 2019). Recently, Nigeria faced unpredictably high temperatures, droughts, floods, and heat stress, which hindered farm output and significantly raised food costs (Shiru et al., 2018). For example, the country's Northern region, which generates substantial bulk of the nation's food supply, has grown increasingly vulnerable to drought and flooding conditions over time (Pretty, 2017). This was complicated by the region's multiple conflicts as well as the exhausted water bodies, which has negative effects on the farmer's and fishermen's livelihoods (Onyeneke et al., 2020). It is expected that natural resource-based (such as farming and forestry and aquaculture) livelihoods will be severely depleted as a result of climate change impacts if not well managed (Pretty, 2017).

Numerous studies (Pretty, 2017; Abegunde et al., 2022; Shiru et al., 2018), highlighted the implications of rainfed agricultural practices in various ecological zones in Nigeria. Due to their reliance on conventional agricultural practices and available capital resources, the impact of climate change on crop production as well as food security is severe across the ecological zones in the country (Ofori et al., 2021; Omotayo et al., 2022). This impact will vary with adaption and mitigation strategies as well as the resources avail by rural farmers across the nations (Abegunde et al., 2022). Notably, (Onyeneke et al., 2020; Abegunde et al., 2022), displayed proof of the possible economic implications of unfavorable weather events on food crop production and food security most especially in southwestern, Nigeria. They reported poor harvests in arable crop production as a result of declined precipitation which discouraged farming households in the region from farming (Abegunde et al., 2022). Thereby, migrating to the country's cities in pursuit of white-collar employment which resultantly leads to a significant population surge in the cities and reduced food consumption score (Shiru et al., 2018; Abegunde et al., 2022).

Similarly, in rural areas of Ogun State, climate change has been a difficult experience for farmers, causing a diverse range of issues like low crop output, the emergence of new insects, disease outbreaks, constant migration, as well as river dryness, land salinity, and intense droughts leading to food insecurity (Abegunde et al., 2022). Furthermore, several studies (Pretty, 2017; Ologeh et al., 2021; Onyeneke et al., 2020; Tiamiyu et al.,2018), concluded that subsistence farmers with poor adaptation measures would be more vulnerable to climate change impacts than their commercial counterparts. Thus, leading to exacerbating income inequalities, poor agricultural output, dietary diversity, and food insecurity within the households and countries at large (Bellia et al., 2022; Hasan et al., 2018). Climate change's impact on agricultural production in Nigeria has a negative influence on its ability to feed its ever-growing population, thus without relying on food importations, this will leave over 85 million of her citizenry food insecure (Abegunde et al., 2022). This research is justified by its potential to address urgent global challenges, improve the livelihoods of farmers, contribute to sustainable development goals, and create a resilient and adaptable agricultural sector capable of mitigating and adapting to the impacts of climate change.

2.2 Empirical review of CSA practices in Nigeria

Challenges relating to climate change in agriculture necessitate the use of novel strategies capable of boosting resilience and minimizing impacts, while also sustaining productivity and ensuring food security (Dooley & Chapman, 2021). Until there is a drastic change in our approach towards planning and investment in the growth and development of agriculture in Nigeria, there might be the tendency of improper allocation of resources which will not only generate food production that is incapable of reducing food insecurity but will contribute to increase in climate change (Anuga & Gordon, 2016). Due to poor institutional structure and synergic linkage between climate change, food production, and security, farmers are responsible to plan ahead as well as implementing context-based adaptation strategies to climate change like CSA to ensure agricultural sustainability and food security (Onyeneke et al., 2020).

Nevertheless, Climate-smart agriculture (CSA) can help to avoid these negative outcomes by putting into consideration climate change in the planning and implementation of sustainable agricultural strategies (Atta-Aidoo et al., 2022). This involves building resilience to climate change through climate change adaptations strategies and the reduction in greenhouse gas emissions related to conventional practices in order to ensure sustainable agricultural productivity, food availability, and security for farming households (Ogundari & Bolarinwa, 2018; Abegunde et al., 2022). In addition, Ochieng (2018), reported that CSA practices like planting improved crop cultivars, agroforestry, soil mulching, changing planting dates, as well as crop diversification are the most effective and used climate change adaptation strategies in Nigeria.

Recent scholars' works (Abegunde et al., 2022; Ologeh et al., 2021), have shown that rural farmer's choices and usage of these CSA practices depend on their socioeconomic characteristics, institutional variables (access to extension training, climate information, and educational status) as well as the cost of implementation and the overall effectiveness on their farm output. Most farmers in rural communities of Nigeria are now involved in CSA practices in an attempt to ensure food security through climate change mitigation (Ologeh et al., 2021). For example, between 2013 and 2018, some pilot projects were executed by the Nigerian Environmental Study Action Team focusing on the adoption of CSA initiatives in agrarian communities across the country's ecological zones.

People within those communities were involved in a variety of CSA adaptation practices, like harvesting water, adopting improved seedlings, irrigation, early mature crops, agroforestry, tree planting, using simple weather forecasting tools, erosion control, planting drought-resistance plants, mulching, and agroforestry (Ologeh et al., 2021). It was discovered that agroforestry, irrigation, adopting improved seedlings, as well as planting early mature crops were the major CSA practices affecting their livelihood activities and food security status in the communities involved (Ologeh et al., 2021). Consistently, these CSA practices enhance the resilience of farming systems to climate variability (Luo et al., 2022; Wassmann et al., 2019). This is crucial for the livelihoods and food security of rural farmers who are often vulnerable to the impacts of climate change (Jiao et al., 2023; Mishra et al., 2021). The research aims to develop and promote practices that empower farmers to adapt and thrive in changing conditions. This calls for a wide proclamation by the government and all stakeholders on the incorporation of CSA practices in farming activities among the rural dwellers in the Nation to ensure improved productivity (Osuafor et al., 2020).

3 Methodology

3.1 Study area

The research was conducted in rural Southwest, Nigeria (Fig. 1), comprising the following states: Osun, Ogun, Ekiti, Ondo, Lagos, and Oyo. The area is bordered in the east by Delta State, the Republic of Benin in the west, in the north by Kogi States, as well as the Atlantic Ocean in the south (Akrong et al., 2023; Daud et al., 2018). Crop farming is the main source of livelihood activity in the geopolitical zone, with maize, cassava, yam, oil palm, cocoa, as well as lumber all being commercially produced (Elum et al., 2017). The majority of the households in this zone rely majorly on subsistence farming, with additional revenue from trading, hunting, food gathering, and handcrafting (Omotayo et al., 2022; Omotoso et al., 2022). As a result, rural households plunged into a more severe poverty category, necessitating them to rely on savings as well as aid from friends/relatives (Omotoso et al., 2022). The natural vegetation of the geopolitical zone comprises tropical rainforest in the south and guinea savannah in the north, with soil favorable for subsistence agriculture (Onyeneke et al., 2020).

3.2 Sampling procedures and data analysis

Primary data were employed for this research and acquired via well-structured questionnaires. The population of the study consists of rural farm families in the zone which pre-

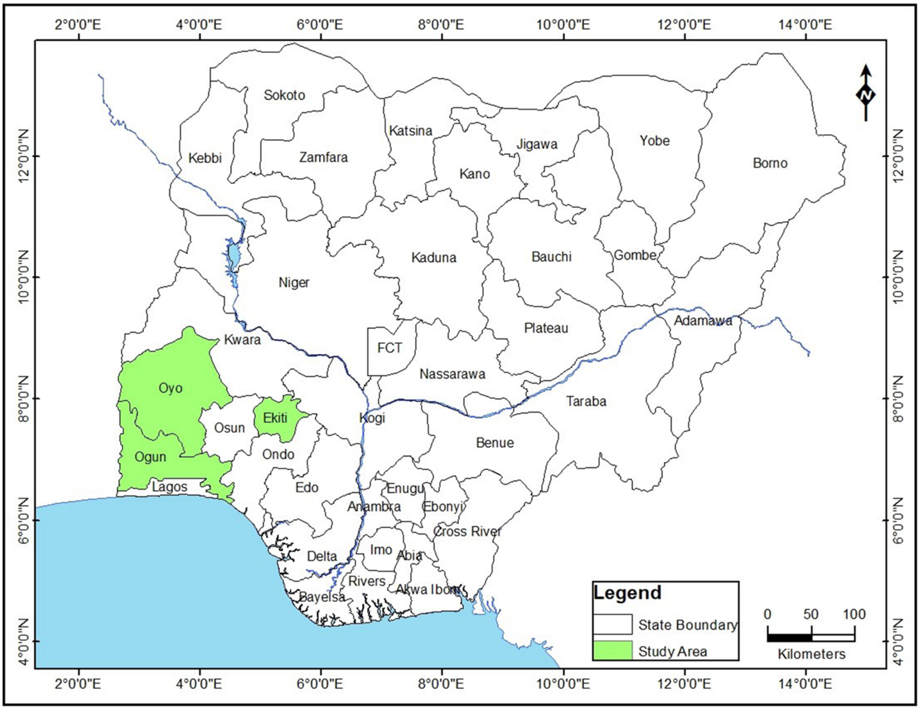

Fig. 1 The geographical location of Nigeria indicating the selected study area

dominantly practice subsistence farming. A multistage sampling procedure was adopted in selecting 480 farming households across six (6) states that made up Southwestern, Nigeria. The first stage involved the purposive selection of Ekiti, Ogun, and Oyo out of the states that made up the southwest geopolitical zone in Nigeria. The three selected states were purposefully chosen because they were popular with small-scale agricultural farming and are the food hub of the geopolitical zone. The second stage involves the selection of two zones from each state, (totaling 6 zones) based on the extent of rural farming households.

The third stage involves the random selection of two blocks each from six zones in the area, totaling 12 blocks. The fourth stage involves randomly selecting four cells from each of the 12 blocks (totaling 48 cells). The last stage involves randomly selecting 10 rural framing households from each of the 48 cells, totaling 480 farming households for the study. The collected data were analyzed through descriptive statistics, which includes means, frequencies, and standard deviations (SD). The Probit regression model was used to determine the effect of CSA practices on the food security status of rural farming households, while Households Dietary Diversity Scores were used to categorize the households into food secure and insecure.

3.3 Model specifications

3.3.1 Measurement of dependent variable

a). Household dietary diversity score (HDDS).

HDDS is determined through the addition of all the food groups consumes within a given time range (24 h) within the household (FAO, 2020). HDDS denotes a systematic free recall of food items consumed by households in the last 24 h (Huluka et al., 2019). Following FAO (2022), this research used HDDS as an indicator for household food security measures. This food security indicator assesses food diversity arising from dietary quality and adequacy as a result of output from farm and CSA practices adopted to improve farming operations.

Dietary diversity has an edge to confirm the degree of variation in dietary patterns of the households as well as households' economic capacity for consumption of a diverse range of food items (Mango et al., 2018). A 24-hour recall food intake was employed to obtain the dietary diversity data of the studied families. Following (Mutengwa et al., 2023; Wekesa et al., 2018), various food items consumed in the study locations were listed and the respondents were asked to choose which of them they consumed in the last 24 h. Following (FAO, 2022; Huluka et al., 2019), the list of household food items consumed was then classified into twelve conventional groups (Table 1). Yes = 1 and no = 0 were assigned to responses depending on dietary categories. Scores were assigned to each food category consumed, with the mean of the HDDS functioning as a criterion in categorizing the sampled homes as food secure or insecure (FAO, 2022). Furthermore, the food insecurity index of the farming households was later categorized into depth (P_1) and severity food insecurity (P_2) based on the headcount, which denotes the proportion of sampled households below the food security line.

b). Household food consumption score (HFCS)

HFCS is an extension of HDDS which is made of weighting frequency (Mango et al., 2018). Following (Bellia et al., 2022; Mishra et al., 2021; Mutengwa et al., 2023), this article made use of HFCS as supplementary to HDDS. This is calculated using records of food

Table 1 Food groups for dietary diversity estimation

	Food groups
1	Cereals include rice, wheat, maize, rice, sorghum, millet, or any other food derived from them
2	Tubers, roots food include potatoes, cassava, and other foods derived from them
3	Vegetables, lettuce, cabbages, and any other vegetables can be used.
4	Beef (from goat, lamb, cattle), pork, lamb, rabbit, game,
5	Fruit
6	Egg
7	Seafood or fishes
8	Pulses, nuts, or Legumes
9	Milk such as cheese, yogurt, milk
10	Oil and Fat
11	Honey and Sugar
12	Other food items such as condiments, tea, and coffee

Key Yes = 1, No = 0 to any of the food groups

items consumed (7 days recall) before data collection (Mango et al., 2018). The consumption frequencies of the food groups were summed up, then multiplied by their weighting, thus giving weighted food group scores (Mango et al., 2018). HFCS is calculated as the sum of the weighted food category scores. Following (Mango et al., 2018; FAO, 2022), HFCS obtained were then classified into poor (0–17), borderline (17.1–30), and acceptable (>30) threshold of consumption groups.

3.3.2 Probit Regression Model

Probit regression was adopted in determining the effects of CSA practices on the food security status of rural farming households. Following (Gebrehiwot, 2015; Mishra et al., 2021), the model calculated the effects of parameter estimates of the independent variables (see Table 2) on the food security status of rural farming households. Notably, household food security (HFS) is a dichotomous variable taking the value of 1 for food secure households and 0 otherwise, while independent variables are the respondents' selected socioeconomic characteristics and various CSA practices used in crop production in the study area.

Probit model is specified as follows.

$$\mathrm{P} = E(Yi = 1/Xi)\,\beta\,\mathrm{Xi} + \varepsilon\mathrm{i} \quad (1)$$

P = Probability of dependent variable Y (1 = food secure, 0 = food insecure).

X = Vectors of independent variables (such as age, income, household size, sex, marital, educational level, and CSA practices).

β = Coefficients;

εi = Random error.

Table 2 Variable descriptions used in the model

Variable	Description	Measurement
FoodSec	Food security status	1 if food secure, 0 if otherwise (Dummy)
Gender	Gender of the household head	1 if the house head is male and 0 if otherwise (Dummy)
Age	Age of the household head)	Number of years (Continuous)
Educ	Education level (household head)	Years of academic education (Continuous)
HH Size	People within the household	Number of household members (Continuous)
Farm size	Total land area cultivated for farming	Number in Hectares (Continuous)
Farm Exp	Years of experience in farming	Number of years (Continuous)
Farm income	Annual income from farm enterprise	Amount in $ (Continuous)
Ext Contact	Contact with extension agents	1 if contacted and 0 if otherwise (Dummy)
M Occup	Main occupation	1 if farming, 0 if otherwise (Dummy)
CSA 1	Planting cover crop	1 if yes, 0 if otherwise (Dummy)
CSA 2	Crop diversification	1 if yes, 0 if otherwise (Dummy)
CSA 3	Crop rotation	1 if yes, 0 if otherwise (Dummy)
CSA 4	Mulching	1 if yes, 0 if otherwise (Dummy)
CSA 5	Agroforestry	1 if yes, 0 if otherwise (Dummy)
CSA 6	Using organic manure	1 if yes, 0 if otherwise (Dummy)
CSA 7	Using Fadama land	1 if yes, 0 if otherwise (Dummy)
CSA 8	Planting drought-resistance varieties	1 if yes, 0 if otherwise (Dummy)
CSA 9	Planting crops with early maturity	1 if yes, 0 if otherwise (Dummy)

4 Result and discussions

4.1 Socioeconomic characteristics of the rural farming households

Table 3 presents the socioeconomic characteristics of the respondents, with over two-thirds (81.00%) of the farming households being male-headed, with the mean age estimated at 47 years, thus revealing that they are energetic and thus presumed to be productive with the resources available. This was in line with Rahman et al. (2021), who pinpointed that the average age of respondents in rural farming households in Nigeria was between the ages of 45–50 years. Omotoso et al. (2018) and Omotayo et al. (2022) also corroborated the claim that the majority of farming households in Nigeria are headed by males and are within the

Table 3 Summary statistics on the respondents' socioeconomic characteristics (n=480)

Variable	Mean	SD
Gender of the household head (1=male, female=0)	0.81	0.193
Age (1=adult; 0=youth)	47.1	0.201
Educational level of the household head (1=formal; 0=Non formal)	0.62	0.117
Household size (number)	5.31	0.410
Marital status (1=Married; 0=Otherwise)	0.76	0.291
Farm size (hectares)	3.77	1.321
Farming experience (years)	8.23	1.092
Contact with extension agent (1=yes)	0.81	0.018
Main source of income: (1=Farming, 0=Others)	0.78	0.512
Income from farming: <250 USD	0.72	0.221
251–500 USD	0.20	0.012
>500 USD	0.08	0.162

Table 4 Climate-smart agricultural practices (CSAP)

CSAP	WMS	SD
Crop diversification	4.723	1.004
Crop rotation	4.281	0.961
Mulching	2.104	0.452
Agroforestry	1.982	0.142
Uses of organic manure	3.441	0.811
Uses of Fadama land	2.981	0.051
Planting early-maturity crops	3.831	1.031
Planting drought-tolerant crop	4.016	1.441
Cover crop planting	1.052	1.113

Note WMS=Weighted Mean Score SD=Standard Deviation

age range of 45–50 years. Also, 76.00% of the respondents were married, likewise, 78.00% pinpointed farming as their main income-generating activity with mean household size and farm size of 6 persons and 3.77 hectares respectively. Majority (72.00%) of the rural farming households earned less than $250.00[1] while about two-thirds (81.0%) of them had contact with extension agents. Extension agent is very important in information dissemination and the adoption of new technology (Omotayo et al., 2022).

The result of the CSA adopted by the respondents (see Table 4) revealed that crop diversification is the form of CSA mostly adopted in the study area followed by crop rotation and intercropping. Furthermore, 23.13% of the respondents are low users while 61.25% and 15.63% of the respondents are medium and high users respectively (see Fig. 2). The finding was in conformity with Partey et al. (2019), who positioned that CSAP in rural areas are being silent and the importance is not well pronounced which could be the reason for its moderate usage as indicated from the study (see Fig. 2).

[1] Note: $1 = ₦720 at the time of carrying out this research.

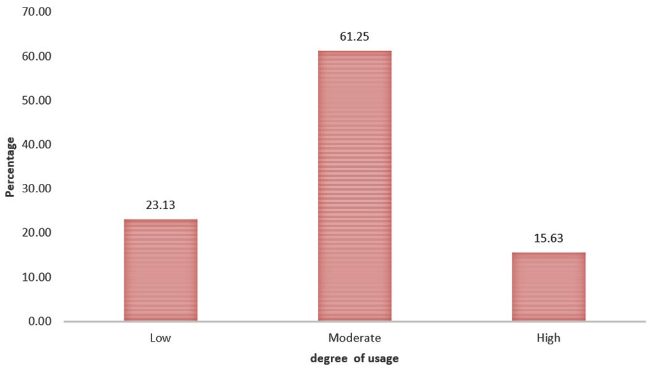

Fig. 2 Degree of usage of CSAP by the respondents

Table 5 Categorization of rural farming households based on dietary diversity

Categories of DD	Pooled		Male-headed		Female-headed	
	Frequency	%	Frequency	%	Frequency	%
Low Dietary Diversity	120	25.00	105	26.99	33	36.36
Medium Dietary	292	60.83	235	60.41	47	51.65
High Dietary	68	14.17	49	12.60	11	12.09
Total	480	100.00	389	100.00	91	100.0
Mean Score of Dietary Diversity	5.12	SD = 1.97				

Table 6 Food security status of the rural farming households (μ = 5.12)

Food security status	Frequency	%
Food Secure	193	40.21
Food Insecure	287	59.79
Total	480	100.00

4.2 Household food security

4.2.1 Household dietary diversity (HDD)

Table 5 revealed the categorization of sampled rural farming households according to their HDDS threshold (μ = 5.12). Following (Abegunde et al., 2022; Omotayo et al., 2022), on the importance of dietary diversity (DD) ratings in determining food security, households with DD scores of 3 were classified as low DD; those with scores of 4–6 were defined as having medium dietary diversity; and those with scores of 7 were classified as having high dietary diversity. Furthermore, result in Table 6 itemized household groups based on food security categories. Following FAO (2022), the mean HDDS threshold is used to group the households into food secure and insecure categories. Rural households with HDDS above the threshold (μ = 5.12, SD = 1.97) were considered food secure, whereas those with HDDS below the threshold were classified as food insecure. The result revealed that about 60.00% of rural farming households were food insecure while about 40.00% of them were food secure.

Dietary diversity is positively associated with household per capita consumption, and household per capita calories (Omotayo et al., 2022). The findings clearly demonstrated that HDDS is a good predictor of food security status in rural farming households. This was supported by (Partey et al., 2019; Omotayo et al., 2022; FAO, 2022), who stated that agricultural output has a direct impact on food availability. This suggests that greater agricultural production and output as a result of climate-smart farming contribute to a bigger food supply, guaranteeing that enough food is available to fulfill the demands of the growing population, thereby enhancing the food security status (Huluka et al., 2019).

4.2.2 Household food insecurity indices

Following Omotayo et al. (2021), P_0 (food insecurity incidence/headcount), P_1 (depth food insecurity), and P_2 (severity food insecurity) were food insecurity parameters used. Headcount denotes the proportion of sampled households below the food security line (Omotayo, 2016; Omotayo et al., 2022). The results in Table 7 showed that P_0 within the households was 0.4205, indicating 42.05% of the farming households were food insecure (unable to achieve the recommended daily food security threshold), while 57.95% were food secure. Following (Bellia et al., 2022; Omotayo et al., 2022). The food insecurity gap was also estimated to assess the degree to which food insecure household falls below the recommended food security threshold. This gap depicts the many categories of food insecurity situations faced by agrarian households in Nigeria.

Furthermore, P_1 of the sampled rural households was 0.1913 (see Table 7). This indicates that, theoretically, food insecurity may indeed be abolished if resources were deployed to fulfill 19.13% of the calorie requirements of all food insecure households. The P_2 value was 0.0711, signifying that respondents' food insecurity severity was 7.11%. This implies that an average core food insecure home would require around 7.11% of the food insecurity line to the households' food budget in order to move out of their severe food insecurity state. Based on the findings of this study, food insecurity exists among rural households in the study area. This is in line with the findings of Babalola (2018) and Omotayo et al. (2022), who reported that the majority of farming households in Nigeria are food insecure.

4.2.3 Households food consumption score (HFSC)

Table 8 revealed the distribution of rural farming households according to food consumption scores. HFSC was employed to supplement the food security status of the households as revealed by the HDDS. Majority (73.95%) of the rural farming households had acceptable food consumption scores while 20.42% and 5.63% of them had borderline and inadequate food consumption scores respectively. This result showcases the diverse consumption-ability of the respondents across the study area. Following (Mutengwa et al., 2023; Omotayo et al., 2022), HFSC metrics track the food consumption diversity of the farming households as a result of farm output and the CSA practices adopted to improve farming operations. This study emphasizes the significance of CSA techniques in their agricultural operation since

Table 7 Food insecurity indices among the rural farming households

Food Insecurity Status	Value
Incidence of Food Insecurity (P_0)	0.4205
Depth food insecure (P_1)	0.1913
Severe food insecure (P_2)	0.0711

Table 8 Distribution of respondents based on households' food consumption scores

Categorization of households based on food consumption score	Frequency	%
0–17 (Poor)	27	5.63
17.1–30 (Borderline)	98	20.42
Above 30 (Acceptable)	355	73.95
Total	480	100.00

it will raise farm production and yield, hence improving food availability for consumption in households.

Climate-smart farming strategies adopted by farming households, such as diverse cropping systems, agroforestry, and conservation agriculture, will increase crop yield and output for the varieties of crops cultivated (Babalola, 2018). These practices would boost the availability of a variety of food alternatives, such as fruits, vegetables, and grains, resulting in a more balanced and healthy diet (Sikka et al., 2018). As a result of improved access to a broader choice of nutritious foods, households adopting climate-smart farming are more likely to achieve a higher food consumption score (Mutengwa et al., 2023). Intriguingly, a rise in the households' food consumption score would positively contribute to their food security status (Huluka et al., 2019).

4.3 4.3 Maximum Likelihood Estimate of Probit Regression of Effects of Socioeconomic Characteristics and CSA Practices on the Food Security Status

The result of Probit regression showed the effect of selected socioeconomic characteristics of the respondents and CSA practices on food security status of the rural farming households (as shown in Table 9). In addition, gender differential of socioeconomic characteristics and CSA practices' effects on farming households' food security status were also assessed. The statistically significant variables influencing farming households' food security status were the gender of the household head ($p<0.1$), contact with an extension agent ($p<0.05$), household size ($p<0.01$), years of educational attainment of household head ($p<0.01$), farm size ($p<0.01$), as well as various CSA practices adopted such as crop diversification, agroforestry, using organic manure, uses of Fadama and planting crop with early maturity at $p<0.01$. The gender of the household's head was negative and significant, indicating that households headed by males have a lower probability of being food insecure than female-headed households, which might be attributed to males having more income-generating activities than females. The result was buttressed by (Rahman et al., 2021; Omotayo et al., 2022), indicating that there are more food secure male-headed families in Nigeria than female-headed ones.

Additionally, the farm size coefficient was negative and significantly influenced the probability of a household being food insecure. Similar findings were observed in all three contexts examined (pooled, female-headed, and male-headed households). This denotes that the higher a household's farm size, the lower the probability of being food insecure. The parameter estimate of years of education of the household head was negative, this will have a considerable impact on the household's food security status which is similar across the three-context considered. This implies that educational attainment had a higher probability of leading to a food secure status and households become less vulnerable with an increase in educational attainment.

Table 9 Probit regression result of effects of socioeconomic characteristics and CSA practices on food security status

	Pooled households			Male-headed households			Female-headed households		
Variables	Coefficient	Robust Std error	Marginal effect	Coefficient	Robust Std error	Marginal effect	Coefficient	Robust Std error	Marginal effect
Constant	0.2491***	0.0973		0.3812***	0.0107		0.2081**	0.0779	
Gender	-0.3981*	0.1318	-0.0051						
Age of the respondents	0.1041	0.2503	0.1591	-0.2017	0.1918	-0.1091	0.0809	0.1741	0.0612
Educational level	-0.5203***	0.1007	-0.0470	-0.1868**	0.0311	-0.0762	-0.1702*	0.0665	-0.0049
Household size	0.3374***	0.0849	-0.1041	0.1671**	0.0519	0.0087	0.0938**	0.0592	0.0611
Farm size	-0.5419***	0.1125	-0.0061	-0.3701***	0.0710	-0.0071	0.1276*	0.0806	0.0048
Farming experience	0.0852	0.1841	-0.0760	-0.2961**	0.1007	-0.1174	-0.7418	0.6103	-0.1017
Farm income	0.0186	0.1905	0.0120	0.0231	0.1172	0.1031	-0.0081	0.0324	-0.0149
Contact with Extension agent	-0.5521**	0.2131	-0.0492	-1.0085***	0.2626	-0.0503	-0.1896	0.0973	-0.0076
Main occupation	0.0872	0.0951	0.1084	-0.4491	0.5093	-0.1005	-0.2205	0.1748	-0.0307
Planting cover crop	1.3913	0.9973	0.0651	-0.7619	0.6915	-0.0021	0.0613	0.1047	0.1138
Crop diversification	-0.1457**	0.0427	-0.0151	-0.2814*	0.1117	-0.0037	0.0175	0.0537	0.0053
Crop rotation	0.0613	0.1671	0.0481	-0.0771	0.1061	-0.0015	0.3914	0.5453	0.0915
Mulching	-0.1153	0.2096	0.0752	0.1164	0.2015	0.0491	-0.0719	0.1153	-0.0381
Agroforestry	-1.0651*	0.0513	-0.0043	0.0882	0.1741	0.0526	-0.0958**	0.0417	-0.0014
Use of organic manure	-0.7741**	0.2503	-0.0117	-0.3861***	0.0850	-0.0074	0.1306	0.2151	0.0375
Use of Fadama land	-0.3450***	0.0261	-0.1004	-0.0609	0.1039	-0.0013	-0.1407**	0.0912	-0.0091
Planting drought-resistance	0.8711	0.9226	0.1103	-0.0993***	0.0117	-0.0401	-0.0159	0.1055	-0.1062
Planting crop with early maturity	-0.5512***	0.1713	0.0713	-0.0471*	0.0178	-0.0074	-0.2051***	0.0697	-0.0412
Likelihood	-152.106			-113.513			-127.091		
Pseudo R^2	0.6278			0.6057			0.6735		
Chi Square	23.17***			31.81***			28.71***		
Number of observations	480			389			91		

Note ***, **, and * represent 1%, 5%, and 10% significance level, respectively

Farmers' capacity to acquire, process, and apply knowledge related to the adoption and management of efficient farming techniques is expected to improve with education (Onyeneke et al., 2020; Omotayo et al., 2022). Onyeneke et al. (2020), contend that educated farmers would decline CSA strategies that did not include risk-mitigation strategies which could safeguard their investments from uncertainties of climate variabilities and change. The coefficient of contact with agricultural extension agents was negative and statistically affected the probability of a household being food insecure, meaning that increasing access to extension services lowered the probability of being food insecure. Extension services in agriculture provide information and knowledge on improved agricultural methodologies as well as adaptation to climate change (Ogundare & Bolarinwa, 2018; Onyeneke et al., 2020).

Furthermore, the coefficient of some selected CSAP such as crop diversification, agroforestry, uses of organic mature, uses of Fadama, and planting early maturity crops were negative and significantly influenced the rural households' food security status. The result revealed that implementing additional CSA practices would reduce the probability of farming households becoming food insecure. According to the findings, CSA adaptation would increase the probability of farming households becoming food secure. This finding is consistent with Onyeneke et al. (2020), in their research on CSA practices on smallholders' food security status in SSA, who reported that farmers who embraced CSA methods are more food secure than non-adopters. Partey et al. (2019), also indicated that agrarian households will profit from CSA adoption because it incorporates adaptation and mitigation advantages to food security. The Adjusted R^2 (0.6278) indicates that explanatory variables account for about 62.78% of the variance in the Probit regression model assessing the effects of CSA practices on food security.

5 Conclusion, recommendation and policy implication

There are visible changes in atmospheric and climatic conditions, and thus have a severe implication on food security, as seen in most regions of the countries especially the southwest region which are suffering from total dryness and the impact of climate change. Invariably, farming households are now faced with the choice of either falling casualty to the impact of climate change on their productivity and food security or adapting to the impact through various CSA practices available. From the study, CSA practices enhanced the food security status of the farming households with a larger percentage of the farming households signified that crop diversification, crop rotation, planting of drought-resistance crops, intercropping, and using organic manure were the major CSA practices adopted in their farming system. HDDS revealed the dietary quality and adequacy as a result of the correlation between farming out and the CSA practice adopted in farming operations. Consequently, households practicing climate-smart farming would have a higher likelihood of achieving a better food consumption score, dietary diversity, and improved food security status. The results of this study complement the goals of CSA, which is to reduce food insecurity by fostering sustainable agriculture as well as building resilience to climate change. In order to enhance Nigeria's current food system and assure a more food secure country, the study recommends that government and the major stakeholders should promote and encourage the adoption of CSA that will ensure agricultural sustainability in agrarian communities, this will help the farmers to resist to climate-related threats and enhance their households' food security status. Likewise, policymakers should incorporate more productive extension services methods for information dissemination about the importance of CSA in more appealing ways which will enhance effective decision-making and wide acceptability of CSAP.

Acknowledgements The authors would like to acknowledge North-West University for making this research possible. The Editor and the anonymous reviewers of this work are appreciated for their insightful observations and ideas that greatly improved the manuscript. The usual disclaimer applies.

Author contributions Both authors collaborated on this study's design, conceptualization, collection of data, analysis, and manuscript write-up. Before submission, the writers read and approved the final text copy.

Funding There was no funding for this research from any institution or organization.
Open access funding provided by North-West University.

Data availability Data that supports the study's outcomes is accessible from the authors upon a reasonable request.

Declarations

Ethics approval and consent to participate The North West Universities Research Ethics Committee granted the approval. Respondent's participation was entirely voluntary and the participants provided informed consent.

Consent for publication Not applicable.

Competing interests Authors claim that they don't have any competing interests.

References

Abegunde, V. O., Sibanda, M., & Obi, A. (2022). Effect of climate-smart agriculture on household food security in small-scale production systems: A micro-level analysis from West Africa. *Journal of Environment*. https://doi.org/10.1080/23311886.2022.2086343.

Akrong, R., Akorsu, A. D., Jha, P., & Agyenim (2023). J.B. Towards environmental sustainability: The role of certification in the adoption of climate-smart agricultural practices among Ghanaian mango farmers. *Cogent Food & Agriculture*, 9(1):2174482.

Anuga, S. W., & Gordon, C. (2016). Adoption of climate-smart weather practices among smallholder food crop farmers in the Techiman municipal: Implication for crop yield. *Research Journal of Agriculture and Environmental Management*, *5*(9), 279–286.

Atta-Aidoo, J., Antwi-Agyei, P., Dougill, A. J., Ogbanje, C. E., Akoto-Danso, E. K., & Eze, S. (2022). Adoption of climate-smart agricultural practices by smallholder farmers in rural Ghana: An application of the theory of planned behavior. *PLoS Climate*, *1*(10), e0000082.

Babalola, D. (2018). Analysis of the determinants of food expenditure patterns among urban households in Nigeria: Evidence from Lagos State. *IOSR Journal of Agriculture and Veterinary Science*, *7*, 71–75.

Bazzana, D., Foltz, J., & Zhang, Y. (2022). Impact of climate smart agriculture on food security: An agent-based analysis. *Food Policy*, 111:102304.

Bellia, C., Bacarella, S., & Ingrassia, M. (2022). Interactions between street food and food safety topics in the Scientific literature—a bibliometric analysis with science mapping. *Foods*, 11(6):789.

Daud, S. A., Omotayo, A. O., Aremu, A. O., & Omotoso, A. B. (2018). Rural infrastructure and profitability of crop production in Oyo State, Nigeria. *Applied Ecology and Environmental Research*, *16*(4), 4655–4665. https://doi.org/10.15666/aeer/1604_46554665.

Dooley, E., & Chapman, S. (2021). Climate-smart agriculture and REDD+implementation in Kenya. Cambridge Centre for Climate Change Mitigation Research. *University of Cambridge. Baker and McKenzie*

Elum, Z. A., Modise, D. M., & Nhamo, G. (2017). Climate change mitigation: The potential of agriculture as a renewable energy source in Nigeria. *Environmental Science and Pollution Research*, *24*, 3260–3273.

Food and Agriculture Organization (FAO). (2019). Climate-smart agriculture in Nigeria. CSA country profiles for Africa series. International Center for Tropical Agriculture (CIAT). *International Crops Research Institute for the Semi-arid tropics* (pp. 23–41). ICRISAT).

FAO (2020). Food security. Food and agriculture organization of the United Nations. 1–330. ISBN 92-5-103858-9FAO. (2010). Guidelines for measuring household and individual dietary diversity. *Food and Agriculture Organization of the United Nations*. 1–53. ISBN 978-92-5-106749-9.

FAO (2022). Climate-smart agriculture sourcebook. Food and Agriculture Organization of the United Nations. 1–557. ISBN 978-92-5-107720-7.

Gebrehiwot, K. G. (2015). The impact of agricultural extension on households' welfare in Ethiopia. *International Journal of Social Economics*, *42*(8), 733–748.

Hasan, M. K., Desiere, S., D'Haese, M., & Kumar, L. (2018). Impact of climate-smart agriculture adoption on the food security of coastal farmers in Bangladesh. *Food Security*, *10*, 1073–1088.

Huluka, A. T., Wondimagegnhu, B. A., & Yildiz, F. (2019). Determinants of household dietary diversity in Africa: An empirical analysis using sustainable livelihood framework. *Cogent Food & Agriculture*, *5*(1), 1–29. https://doi.org/10.1080/23311932.2019.1690.

Jiao, Y., Zhu, G., Meng, G., Lu, S., Qiu, D., Lin, X., & Zhao, L. (2023). Estimating non-productive water loss in irrigated farmland in arid oasis regions: Based on stable isotope data. *Agricultural Water Management*, *289*, 108515.

Luo, J., Zhao, C., Chen, Q., & Li, G. (2022). Using deep belief network to construct the agricultural information system based on internet of things. *The Journal of Supercomputing*, *78*(1), 379–405.

Mango, N., Makate, C., Mapemba, L., & Sopo, M. (2018). The role of crop diversification in improving household food security in central Malawi. *Agriculture & Food Security*, *7*(1), 1–10. https://doi.org/10.1186/s40066-018-0160.

Mishra, A., Ketelaar, J. W., Uphoff, N., & Whitten, M. (2021). 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. *International Journal of Agricultural Sustainability*, *19*(2), 152–174.

Mutengwa, C. S., Mnkeni, P., & Kondwakwenda, A. (2023). Climate-Smart Agriculture and Food Security in Southern Africa: A review of the vulnerability of Smallholder Agriculture and Food Security to Climate Change. *Sustainability*, *15*(4), 2882.

Ochieng, C. M. (2018). Climate change and guidance for preventing and managing land and natural resources conflict: Conflict prevention in resource-rich economies. Retrieved from http://works.bepress.com/cosmas_ochieng/11/ on Friday 24th June, 2018.

Ofori, S. A., Cobbina, S. J., & Obiri, S. (2021). Climate change, land, water, and food security: Perspectives from Sub-saharan Africa. *Frontiers in Sustainable Food Systems*, *5*, 680924.

Ogundare, A., & Bolarinwa, A. (2018). Soil Organic Carbon Management for Sustainable Land Use in Sudano- Sahelian West Africa. *Nutrient Cycling in Agroecosystems*, *61*, 131–142.

Ologeh, I., Adesina, F., & Sobanke, V. (2021). Assessment of farmers' indigenous technology adoptions for climate change adaptation in Nigeria. African handbook of climate change adaptation. *Environment and Climate*. https://doi.org/10.1007/978-3-030-42091-8_28-1.

Omotayo, A. O. (2016). Farming households' environment, nutrition and health interplay in Southwest, Nigeria. *International Journal of Scientific Research in Agricultural Sciences*, *3*, 84–98.

Omotayo, A. O., Olagunju, K. O., Omotoso, A. B., Ogunniyi, A. I., Otekunrin, O. A., & Daud, A. S. (2021). Clean water, sanitation and under-five children diarrhea incidence: Empirical evidence from the South Africa's General Household Survey. *Environmental Science and Pollution Research*, *28*, 63150–63162.

Omotayo, A. O., Omotoso, A. B., Daud, S. A., Omotayo, O. P., & Adeniyi, B. A. (2022). Rising Food Prices and Farming Households Food Insecurity during the COVID-19 pandemic: Policy implications from SouthWest Nigeria. *Agriculture*, *12*, 363. https://doi.org/10.3390/agriculture12030363.

Omotoso, A. B., & Omotayo, A. O. (2024). The interplay between agriculture, greenhouse gases, and climate change in Sub-saharan Africa. *Regional Environmental Change*, *24*(1), 1.

Omotoso, A. B., Daud, A. S., Adebayo, R. A., & Omotayo, A. O. (2018). Socioeconomic determinants of rural households' food crop production in Ogun State, Nigeria. *Applied Ecology and Environmental Research*, *16*(3), 3627–3635.

Omotoso, A. B., Daud, S. A., Okojie, L., & Omotayo, A. O. (2022). Rural infrastructure and production efficiency of food crop farmers: Implication for rural development in Nigeria. *African Journal of Science Technology Innovation and Development*, *14*(1), 197–203.

Omotoso, A. B., Letsoalo, S., Olagunju, K. O., Tshwene, C. S., & Omotayo, A. O. (2023). Climate change and variability in sub-saharan Africa: A systematic review of trends and impacts on agriculture. *Journal of Cleaner Production*:137487.

Onyeneke, R. U., Igberi, C. O., Uwadoka, C. O., & Aligbe, J. O. (2020). Status of climate-smart agriculture in southeast Nigeria. *Geojournal*, *83*(2), 333–346. https://doi.org/10.1007/s10708-017-9773.

Osuafor, A. M., Fredy, H. Y., & Nnorom, N. R. (2020). Impact of climate change on food security in Nigeria. *International Journal of Science and Technology*, *3*(1), 208–219.

Partey, S. T., Zougmoré, R. B., Ouédraogo, M., & Campbell, B. M. (2019). Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. *Journal of Cleaner Production*, *187*, 285–295.

Pretty, J. (2017). Agricultural sustainability: Concepts, principles and evidence. *Philos Trans R Soc B Biol Sci*, *363*(1491), 447–465.

Rahman, T., Hasnain, M. G., & Islam, A. (2021). Food insecurity and mental health of women during COVID-19: Evidence from a developing country. *PloS One*, 16, e0255392.

Rigolot, C., De Voil, P., Douxchamps, S., Prestwidge, D., Van Wijk, M., Thornton, P. K., & Herrero, M. (2017). Interactions between intervention packages, climatic risk, climate change and food security in mixed crop–livestock systems in Burkina Faso. *Agricultural Systems*, *151*, 217–224.

Shen, C., Wei, M., & Sheng, Y. (2021). A bibliometric analysis of food safety governance research from 1999 to 2019. *Food Science & Nutrition*, *9*(4), 2316–2334.

Shiru, M. S., Shahid, S., Alias, N., & Chung, E. S. (2018). Trend analysis of droughts during crop growing seasons of Nigeria. *Sustainability*, *10*(3), 871. https://doi.org/10.3390/su10030871.

Sikka, A. K., Islam, A., & Rao, K. (2018). Climate-smart land and water management for sustainable agriculture. *Irrigation and Drainage*, *67*(1), 72–81.

Tiamiyu, S. A., Ugalahi, U. B., Eze, J. N., & Shittu, M. A. (2018). Adoption of climate smart agricultural practices and farmers' willingness to accept incentives in Nigeria. *International Journal of Agric Environment Research*, *4*(4), 198–205.

United States Agency for International Development (2018). A thematic roundup of research, decision-making support and capitalization extension of endogenous and scientific knowledge for the CSA in the ECOWAS/UEMOA/ CILSS region. Paper prepared for the high-level forum of climate-smart agriculture (CSA) stakeholders in West Africa, Bamako (Mali), June 15–18, 2018.

Wassmann, R., Villanueva, J., Khounthavong, M., Okumu, B. O., Vo, T. B. T., & Sander, B. O. (2019). Adaptation, mitigation and food security: Multi-criteria ranking system for climate- smart agriculture technologies illustrated for rainfed rice in Laos. *Global Food Security*, *23*, 33–40.

Wekesa, B. M., Ayuya, O. I., & Lagat, J. K. (2018). Effect of climate-smart agricultural practices on household food security in smallholder production systems: Micro-level evidence from Kenya. *Agriculture & Food Security*, *7*(1), 1–14. https://doi.org/10.1186/s40066-018-13.

WORLD BANK. Climate-smart agriculture: successes in Africa (2019). Available at: https://documents1.worldbank.org/curated/en/622181504179504144/pdf/119228- WPPUBLIC-CSA-in-Africa. pdf. Access on: Dec. 15, 2020.