

## Research Article

Funminiyi Peter Oyawole\*, Adewale Oladapo Dipeolu, Adebayo Musediku Shittu, Abiodun Elijah Obayelu, Thomas Oladeji Fabunmi

# Adoption of agricultural practices with climate smart agriculture potentials and food security among farm households in northern Nigeria

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**Abstract:** Despite the conceptual promise and attractiveness of Climate Smart Agriculture (CSA) in ensuring farmers' resilience and food security, empirical evidence of its success are observed to be scanty and mixed in terms of results, thus prompting further research. In this article, we analyzed the effect of adopting six Agricultural Practices with CSA Potentials (AP-CSAPs) on food security status using recent cross-sectional data on 238 maize farmers from Northern Nigeria. Data were analyzed using descriptive statistics and Probit regression. The results showed that 92.4% of the maize farmers were male, with a mean age and household size of 44 years and nine persons, respectively. We find that 37.0% of the farm households were food insecure, and adoption of the AP-CSAPs was generally low. However, while refuse retention and agroforestry influenced food security, the remaining four practices considered did not. In addition, we find that land fragmentation, off-farm income and age influence the likelihood of being food secure. We recommend further research on the medium- to long-term effects of AP-CSAPs and suggest that policies aimed at consolidating

landholdings to promote monocropping among rural farmers be discouraged.

**Keywords:** climate smart agriculture, food security, probit regression, adoption

## 1 Introduction

Food, along with oxygen and water, is a compulsory requirement for human sustenance. Food security exists when “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” (Perez-Escamilla and Segall-Correa 2008). While the achievement of food security for all has long been a global development target, as expressed in Sustainable Development Goal 2 “to end hunger, achieve food security and improved nutrition,” not much progress has been made in Africa compared to other regions (UNDP 2016). At least 25% of all the underfed people in the world live in Africa. Globally, only Africa has recorded a consistent decline in per capita agricultural production for the past three decades (Sasson 2012). Specifically, the percentage of food insecure people has been on the increase in Nigeria, increasing steadily from about 18% in 1986 to about 33.6% in 2004 and 41.0% in 2010 (NBS 2012).

Given that most of the poor and food insecure in SSA derive their livelihood from agriculture (Williams et al. 2015), climate change threatens to erode progress gained and undermine both present and future efforts to ensure food security. In Nigeria, about 69% of the poor engage in mostly rain-fed agriculture, thus exposing their livelihood to the vagaries of climatic fluctuations, with grave implications for food security (NBS 2012; Moyo 2016). For instance, it has been estimated that growing periods in West Africa may reduce by a quarter in the next 30 years as a result of climate change, leading to about one-third

\* **Corresponding author: Funminiyi Peter Oyawole**, Department of Agricultural Economics and Farm Management, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, e-mail: peteniy@gmail.com

**Adewale Oladapo Dipeolu, Abiodun Elijah Obayelu:** Department of Agricultural Economics and Farm Management, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

**Adebayo Musediku Shittu:** Department of Agricultural Economics and Farm Management, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria; Department of Agricultural Economics and Extension, Landmark University, Omu-Aran, Kwara State, Nigeria

**Thomas Oladeji Fabunmi:** Department of Plant Physiology and Crop Production, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

reduction in cereal yields (Lobell *et al.* 2011). This makes climate change adaptation imperative for agricultural production systems in SSA, hence the promotion of “Climate Smart Agriculture” (CSA) as a sustainable alternative (FAO 2010).

CSA is an approach that is based on principles of sustainable development, which promotes the adoption of Agricultural Practices with Climate Smart Agriculture Potentials (AP-CSAPs) at the farm level (Williams *et al.* 2015). It aims to “sustainably increase agricultural productivity and incomes, build resilience and capacity of agricultural and food systems to adapt to climate change, and reduce or remove greenhouse gases while enhancing national food security” (Neufeldt *et al.* 2013). However, despite the conceptual promise and attractiveness of CSA, empirical evidence of its success under Africa’s diverse agroecologies and socioeconomic conditions are observed to still be scanty and mixed in terms of results (Neate 2013; Shittu *et al.* 2018). For instance, while Brüßow *et al.* (2015) report that implementing a climate-smart approach contributes to improved food security in Tanzania, Asfaw *et al.* (2016) reported no significant impact of these practices on crop outcomes in Niger. Thus, there is a need for continued empirical studies into the effects of these AP-CSAPs on crop yield, revenue and consequent livelihood outcomes.

This study contributes to filling this knowledge gap in the literature by assessing the effect of adoption of AP-CSAPs on food security using recent cross-sectional data from Northern Nigeria. Specifically, we assessed the extent of adoption of six AP-CSAPs by maize farmers across six states in the region and determined the effect of such adoption on their food security status among other covariates. Second, to better determine the effect of AP-CSAPs’ adoption on food security, we modeled the adoption of each practice as the actual proportion of farmland on which each farmer actually utilized it on his/her farm. Traditionally, a farmer is considered an adopter of a technology if he/she uses the technology on any of the plots or fraction of land in his/her farm (Nata *et al.* 2014; Coulibaly *et al.* 2017). However, farmers’ decision-making process about technology adoption is often influenced by plot-specific characteristics, and as such, a farmer may adopt a practice on some plot(s) and not on the others in his farm. Thus, in measuring the effect of the adoption of the technology, we argue that it is more beneficial to utilize the actual proportion of the farmer’s farmland on which the technology was used. Section 2 discusses our data (study area, data and sampling procedure) and the method of data analysis. Section 3 discusses the descriptive and empirical results, respectively, and the last section concludes this article

## 2 Materials and methods

### 2.1 Study area

The study was conducted in northern Nigeria. Northern Nigeria consists of three geopolitical zones: the north-west (which consists of seven states), north-central (which consists of six states and the Federal Capital Territory) and Northeast (which consists of six states) geopolitical zones. Northern Nigeria lies between latitude 9°–14°N and longitude 3°–15°E and is bounded in the North by Niger republic, Chad and Cameroon in the East and in the West by Republic of Benin (AbdulKadir *et al.* 2013). It is a semi-arid region neighboring the Sahara Desert, with an annual mean precipitation of less than 600 mm. The region’s rainy season lasts for about 3–4 months, while temperature can vary between 13°C and 38°C, with an average of 29°C (Usman *et al.* 2013). Northern Nigeria is dominated by the Guinea, Sudan and Sahel savannahs, and the vegetation density decreases northward in response to climatic conditions. Although the region is geographically prone to drought, desertification, wind and water erosion, agriculture remains the most dominant economic activity in the region (AbdulKadir *et al.* 2013). Cereals (maize, rice, sorghum and millet) and cash crops (cotton and groundnut) are commonly grown in this region (Ugwu and Kanu 2012) (Figure 1).

### 2.2 Data and sampling procedure

This study utilized the data collected by FUNAAB-RAAF-PASANAO project, titled “Incentivizing Adoption of Climate Smart Practices in Cereals Production in Nigeria: Sociocultural and Economic Diagnosis,” which was funded by ECOWAS—Regional Agency for Agriculture and Food (RAAF). The sampling process was based on the nationwide Agricultural Development Program (ADP) structure that split each state into zones, blocks and cells for easy administration and extension outreach. As outlined by Shittu *et al.* (2018), cells are groups of close farming communities assigned to an Agricultural Extension Officer, while blocks are groups of five to eight cells under the supervision of a block extension supervisor. A number of blocks form a zone and each state in Nigeria has about three or four agricultural zones. A multistage sampling process was implemented in drawing respondents for this study. In stage 1, two states reputed for maize production were purposively selected from

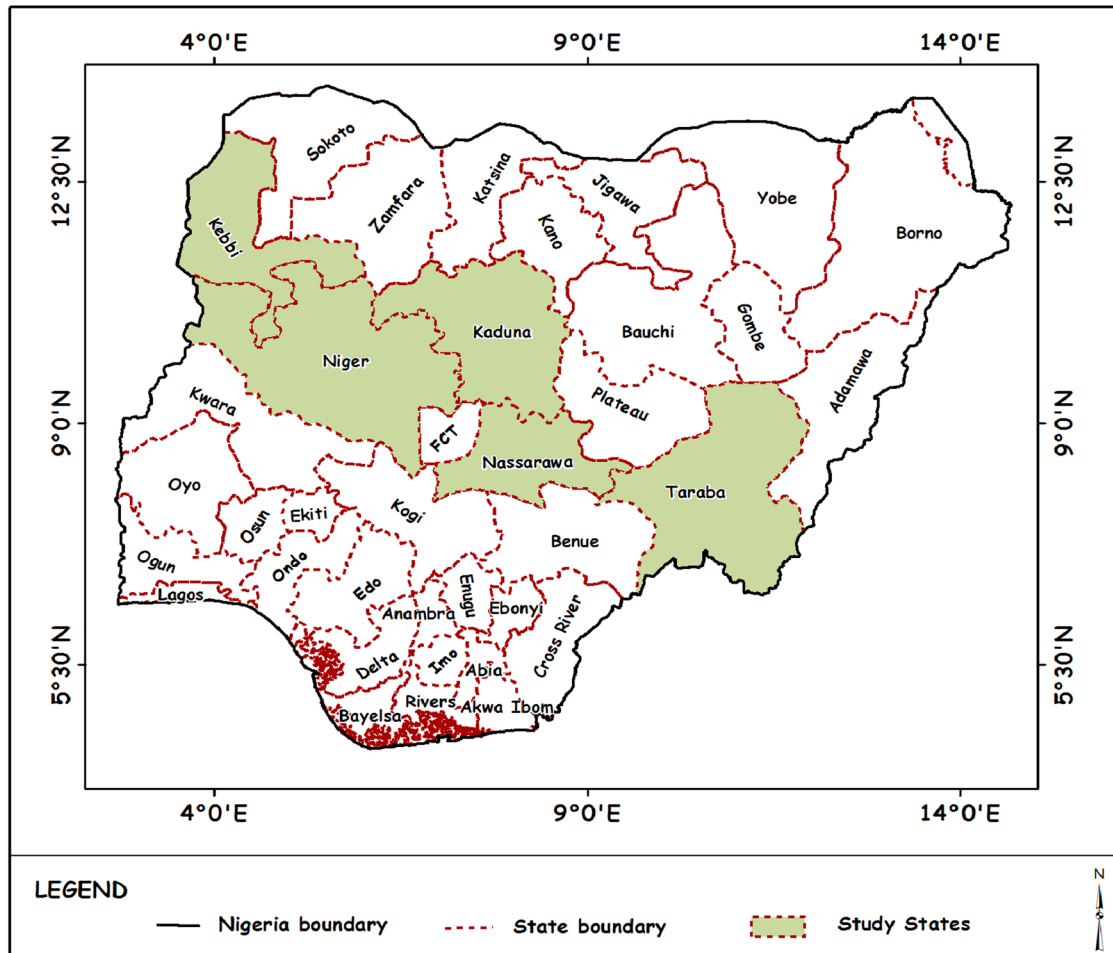


Figure 1: Map of Nigeria showing the study locations.

each of the three geopolitical zones of northern Nigeria (Knoema 2019). Kaduna and Kebbi were selected from the Northwest, while Niger and Nasarawa were selected from the North-central. However, only Taraba was selected from the Northeast because of the religious unrest in the zone. In stage 2, three blocks reputed for maize production were purposively chosen from each of the five states that had been selected. (This was done in consultation with the states' ADPs given the lack of production data per block within the states.) In stage 3, two cells were randomly selected from each block, while in the last stage, 10 maize farmers were randomly selected from each of the selected cells. After dropping households with incomplete information, this process yielded a total of 238 maize farming households that were used for the study. Data collected include farmers' social, economic and institutional variables, adoption of AP-CSAPs as well as their livelihood characteristics.

### 3 Analytical framework

#### 3.1 Descriptive statistics

Data from the household survey on key socioeconomic characteristics (sex, farm size, education, extension contact among others), adoption of AP-CSAPs and food security status were analyzed using descriptive statistics—frequencies, means and percentages.

#### 3.2 United states department of agriculture's food security survey module

Food security was measured using the United States Department of Agriculture's Food Security Survey Module. It is a tool that is used to generate a score that depicts the

**Table 1:** USDA food security classification

Status	Households with children (18 questions)	Households without children (10 questions)
High food security	Positive responses between 0 and 2	Positive responses between 0 and 2
Marginal food security	3–7	3–5
Low food security	8–12	6–8
Very low food security	13–18	9–10

Source: United States Department of Agriculture (USDA) 2016. Survey Tools. United States Department of Agriculture-Economic Research Service. <http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/survey-tools.aspx>, Accessed on 28th September, 2016.

level of household food insecurity and can be classified into four categories (Obayelu 2012). Data were collected using the “18-item household food security questionnaire.” The food security status was determined from respondents’ answers to a set of questions about their typical behavior when satisfying household food needs becomes difficult (Bickel *et al.* 2000). Each question asks whether the behavior occurred at any time during the last 30 days (Maitra and Rao 2015) and is as a result of funds or food insufficiency and not dieting or voluntary fasting. For each household, a score is generated using the total number of questions positively responded to, ranging from 0 to 18 in households with children and 0 to 10 in households without children. Based on this score, households are then classified into four categories, namely, “high food security,” “marginal food security,” “low food security” and “very low food security” (Table 1).

### 3.3 Land fragmentation: Simpson index

Land fragmentation occurs when an individual or farming household possesses several spatially separated plots of land that are usually scattered over a wide area (Demetriou 2014). However, whether land fragmentation is a problem is still a subject of multidisciplinary debate in the literature due to the contrasting reports of various studies (Shittu 2014). Following Shittu (2014) and Sundqvist and Andersson (2006), land fragmentation was measured using the Simpson index in this study. This index is the sum of the squares of the separate plot sizes divided by the square of the total farm size. It is calculated as follows:

$$SI = 1 - \frac{\sum_{i=1}^n a_i^2}{A^2}$$

where  $n$  is the number of plots an individual or household operates,  $a$  is the area of the  $i$ th plot or farm parcel (ha),  $A$  is the total area of all the plots (ha) and  $SI$  is the Simpson index, which is a value between 0 and 1.

A value of zero implies that the household farms a single, contiguous land fragment, i.e., the farm consists of only one parcel. However, a value of one means that the farm is very fragmented and operates multiple plots. This implies that the more the  $SI$  moves toward 1, the more fragmented the land holding of the household is.

### 3.4 Probit regression model: determinants of food security

The Probit regression model was used to determine the factors influencing food security among farming households in the study area. Although the USDA food security module has four classifications, the first two categories (“high food security” and “marginal food security”) were classified as food secure, while the last two (“low food security” and “very low food security”) were classified as food insecure following Maitra and Rao (2015) and Chinakali *et al.* (2014).

The model is explicitly stated; thus,

$$Y^* = \mathbf{X}\beta + \alpha\mathbf{A} + \varepsilon \quad (1)$$

$$Y_i = \begin{cases} 1 & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \leq 0 \end{cases}$$

where  $Y^*$  is the underlying response variable;  $Y_i$  is 1 if household is food insecure and 0 if otherwise;  $\mathbf{X}$  is a vector of socioeconomic and farm characteristics; and  $\mathbf{A}$  is a vector of AP-CSAPs’ adoption, which is measured as follows:  $A_1$  represents use of green manure (proportion of farmland on which practice has been adopted),  $A_2$  represents agroforestry (proportion of farmland on which practice has been adopted),  $A_3$  represents the use of organic manure (proportion of farmland on which practice has been adopted),  $A_4$  represents crop rotation (proportion of farmland on which practice has been adopted),  $A_5$  represents refuse retention (proportion of farmland on which practice has been adopted) and  $A_6$  represents zero or minimum tillage (proportion of farmland on

which practice has been adopted);  $\beta$  and  $\alpha$  are parameter estimates; and  $\varepsilon$  is the error term.

## 4 Results and discussion

### 4.1 Socioeconomic characteristics of the maize farmers

Table 2 presents the results of the socioeconomic characteristics of the respondent households. Most (92.4%) of respondents were male, and 94.1% of them were married. The average age of a maize farmer was 44 years, having a mean household size of nine persons. This suggests that the typical maize farmer was still in his economically active age and has access to family labor, which forms a significant part of farm labor (Idrisa et al. 2012; Adegboye 2016). Over half (56.3%) of the respondents had at least primary education although the average years of formal education obtained was about seven years. Most (74.0%) of them had access to extension services in the previous season, indicating a robust presence of agricultural extension services in the study area. Most (66.4%) of the respondents claimed that they had access to credit in the last cropping season, while 45.8% of them were involved in at least one off-farm activity. Furthermore, Table 2 presents that 48.7% of the respondents cultivated two or more spatially separated plots of maize. This gives credence to the fact that farmers often cultivate more than one plot of land that have inherently different characteristics (e.g., trekking distance, land type, ownership status, and size), which may influence their decision on which technology to adopt on such plots.

### 4.2 Description of adoption of AP-CSAPs by the maize farmers

The results presented in Table 3 reveal that the adoption of the AP-CSAPs was generally low. This corresponds to the findings of McCarthy and Brubaker (2014) and Teklewold et al. (2013), who reported that CSA practices' adoption remains generally low in sub-Saharan Africa. Green manure (17.0%) and crop rotation (29.0%) were the least adopted practices, while zero/minimum tillage was adopted on about a third (37.0%) of the respondents' maize farms on the average. Furthermore, refuse retention was

**Table 2:** Distribution of respondents by their socioeconomic characteristics

Variable	Frequency	Percentage	Mean
<b>Sex</b>			
Male	220	92.4	
Female	18	7.6	
Total	238	100	
<b>Age</b>			44 (12.11)
≤20	7	2.9	
21–30	35	14.7	
31–40	50	21.0	
41–50	82	34.5	
51–60	45	18.9	
>60	19	8.0	
Total	238	100	
<b>Marital status</b>			
Married	224	94.1	
Single	9	3.8	
Divorced	5	2.1	
Total	238	100	
<b>Educational status</b>			6.9 (6.4)
None	88	37.0	
Arabic	16	6.7	
Primary	31	13.0	
Secondary	44	18.5	
Tertiary	59	24.8	
Total	238	100	
<b>Household size range</b>			9.0 (6.3)
≤4	46	19.3	
5–8	95	39.9	
9–12	48	20.2	
13–16	26	10.9	
>16	23	9.7	
Total	238	100	
<b>Access to credit</b>			
No	141	59.2	
Yes	97	40.8	
Total	238	100	
<b>Extension contact</b>			
No	62	26.0	
Yes	176	74.0	
Total	238	100	
<b>Off-farm activities</b>			
No	129	54.2	
Yes	109	45.8	
Total	238	100	
<b>Number of farm plots</b>			
1	122	51.3	
2	71	29.8	
>2	45	18.9	

Source: authors' computation.

adopted on 45.0% of the maize farms on the average, while organic manure use and agroforestry were adopted on 43.0% and 42.0% of the maize farms, respectively.



**Table 3:** Adoption of AP-CSAPs on the farmers' plots

Variable	Mean	Standard deviation
Green manure	0.17	0.34
Agroforestry	0.42	0.44
Organic manure	0.43	0.42
Refuse retention	0.45	0.43
Crop rotation	0.29	0.41
Zero/minimum tillage	0.37	0.41

### 4.3 Analysis of farm households' food security status

Table 4 presents the result of the analysis of households' food security using the USDA food security assessment. Households were classified into four food security classes ("high food security, marginal food security, low food security and very low food security") based on 18 food security items for households with children and 10 adult referenced items for households without children. As presented in Table 4, 50% of the households without children were highly food secure, with another 18.8% classified as marginally food secure. In comparison, 34.7% of households with children were highly food secure, while 27.9% of them were marginally food secure. This gives credence to the findings of Obayelu (2010) who reported that households with fewer members are more food secure, perhaps as a result of having less people to feed. Pooling the households, 35.7% of the households were highly food secure, while 27.3% of them were marginally food secure. In addition, 16.0% and 21.0% of the households had "low food security" and "very low food security," respectively. Combining the four USDA food security classes into two broad classes of food security ("high food security and marginal food security") and food insecurity ("low food security and very low food security"), 63.0% of the sampled households were food secure, while 37.0% of them were food insecure.

This represents an improvement on the food security status (35.0%) reported by Davies (2009) but is less than

the 70% food security situation reported by FAO (2016) in northern Nigeria using the food consumption score.

### 4.4 Determinants of food security among the farming households

Table 5 presents the results of the Probit regression, which was used to analyze the factors influencing the food security status of the farming households. The Wald chi-square test statistics shows that the hypothesis that all regression coefficients in the model are jointly equal to zero is rejected at 1%, indicating the fitness of the model and the relevance of the chosen independent variables. The results reveal that only two of the six AP-CSAPs evaluated significantly influenced food insecurity as presented in Table 5.

Specifically, retention of refuse negatively influenced food insecurity, suggesting that households that practice bush burning on their farms have a greater likelihood of being food insecure. This may be due to the net negative impact of bush burning on soil properties, which leads to the loss of productivity. As reported by Nigussie and Kissi (2011) and Pantami *et al.* (2010), although bush burning saves time and adds ash, which reduces soil acidity to the soil, its positive effect is short lived. This is because it simultaneously causes the loss of 80% nitrogen, 25% phosphorus and 21% potassium, and thus results in low yield, own food production and farm income. However, agroforestry positively influenced food insecurity at 5%, implying that households that adopted agroforestry are more likely to be food insecure. While this is against *a priori* expectation, it is likely due to the reduction in effective crop area available for cultivation necessitated by adopting agroforestry, which may lead to a decrease in the crop output and productivity initially before the tree species begin to yield benefits to the farmers (Peralta and Swindon 2016).

However, other household and farm characteristics significantly influenced food security in the study area.

**Table 4:** Classification of respondents' household according to food security status

Food security categories	Households without children	Percent	Households with children	Percent	Pooled households	Percent
High food security	8	50.0	77	34.7	85	35.7
Marginal food security	3	18.8	62	27.9	65	27.3
Low food security	3	18.8	35	15.8	38	16.0
Very low food security	2	12.4	48	21.6	50	21.0
Total	16	100	222	100	238	100

**Table 5:** Probit regression estimates of factors influencing food insecurity

Variables	Coefficient	Std error	Z-Value	Marginal effect
Age of household head	-0.073*	0.042	-1.73	-0.007
Age squared of household head	0.001	$4.74 \times 10^{-04}$	1.33	$6.35 \times 10^{-05}$
Sex	-0.458	0.405	-1.13	-0.034
Years of education of household head	0.021	0.016	1.30	0.002
Household size	0.019	0.016	1.19	0.002
Monthly expenditure	$9.73 \times 10^{-07}$	$1.03 \times 10^{-06}$	0.95	$9.82 \times 10^{-08}$
Land ownership	-0.171	0.240	-0.71	-0.017
Access to extension contact	0.061	0.221	0.28	0.006
Land dispute	0.563	0.415	1.36	0.057
Off-farm income	$-3.56 \times 10^{-07}$ *	$2.03 \times 10^{-07}$	-1.75	$-3.59 \times 10^{-08}$
Farm size (Ha)	0.006	0.007	0.88	0.001
Farmers' association membership	0.036	0.062	0.58	0.004
Cooperative society's membership	-0.072	0.053	-1.36	-0.007
Land fragmentation (Simpson index)	-0.864**	0.391	-2.21	-0.087
Tropical livestock unit	-0.091	0.348	-0.26	-0.009
Green manure	-0.172	0.316	-0.55	-0.017
Agroforestry	0.519**	0.232	2.23	0.052
Organic fertilizer/compost	0.062	0.234	0.27	0.006
Retain refuse	-0.546**	0.248	-2.20	-0.055
Crop rotation	-0.128	0.226	-0.57	-0.013
Zero/minimum tillage	-0.155	0.232	-0.67	-0.016
Northern Guinea	0.434	0.329	1.32	0.055
Derived Savannah	0.796**	0.320	2.49	0.123
Southern Guinea	1.066***	0.292	3.65	0.133
Constant	0.947	1.001	0.95	
Pseudo $R^2 = 0.182$				
Wald $\chi^2 (25) = 56.09$				
Prob > $\chi^2 = 0.000$				
Log pseudolikelihood = -128.279				

\*, \*\*, \*\*\* represent 10%, 5% and 1% level of significance respectively.

First, while the literature is replete with polarized reports on the relationship between land fragmentation and food security, the results show that land fragmentation negatively influences food insecurity and a marginal increase in the Simpson index reduces the likelihood of being food insecure by 8.7%. This could be because the cultivation of multiple plots allows farmers to exploit the variation in soil and environmental quality, cultivate diverse crops across seasons and thus minimize their production risk (Ali et al. 2015; Kadigi et al. 2017). This is consistent with the recent findings across SSA (Di Falco 2014; Knippenberg et al. 2018; Cholo et al. 2019). For instance, Cholo et al. (2019) report that farmers who produced crops on distinct plots of land have a higher likelihood of being food secure relative to farmers who produced crops in a single plot. They argue that while land fragmentation could be a form of insurance against total crop loss in the event of any shock or stress, growing different crops (which is engendered by fragmentation) that mature at different periods

within a year enhances the food availability and access for farmers' households all year round.

Consistent with other works (Reardon et al. 2007; Babatunde and Qaim 2010; Sani et al. 2014; Rahman and Mishra 2019), the result shows that off-farm income reduces the likelihood of being food insecure. Off-farm income generation is important for easing capital constraints and smoothening consumption, especially as household income is typically tied down in farm investment.

Given the seasonality of agricultural production due to rainfall (particularly in SSA where 96% of agricultural production is rain fed) and the increasing production risk due to possible climatic shocks, off-farm income is becoming increasingly important to faming households' wellbeing (Eshetu and Mekonnen 2016; Ibrahim et al. 2019).

In addition, the results of the age of the household head negatively influences food insecurity, implying that as the farmer gets older, the less likely he is to be food

insecure. This could be as a result of the fact that, as a farmer gets older, his/her work experience, social network and asset base often increases, thus giving him/her leverage to produce more and thus become more food secure (Mango *et al.* 2014). This is especially important in a rural farm environment, where allocation of land and other productive resources are still influenced by traditional culture of respect for older people. This finding is supported in the literature by Bogale and Shimelis (2009), Arene and Anyaeji (2010) and Zhou *et al.* (2019) who reported similar findings in Ethiopia, Nigeria and Pakistan, respectively.

## 5 Conclusion

This study was carried out to determine the effect of adoption of AP-CSAPs on food security among maize farmers in northern Nigeria. We found that the proportion of farmland on which AP-CSAPs were adopted was generally low, while 37.0% of the farm households were food insecure. However, four of the six AP-CSAPs considered did not have any significant influence on food security. We attribute this to three possible reasons; first, the benefits of CSA practices may not be immediately obvious compared to the use of modern inputs (such as inorganic fertilizers), which tend to have short-term returns. However, due to the unavailability of panel data on this practices and farmers' livelihood, we could not model the effect of AP-CSAPs' adoption over time. Second, these practices may not always lead to increased production, but rather help farmers adapt to climate change by maintaining their production level while conserving the environment. Finally, since there is no evidence of coordinated training of farmers on these practices by extension agencies, farmers may not be applying these practices correctly to get optimum results. However, land fragmentation, off-farm income and age negatively influenced the likelihood of food insecurity. First, we recommend that further research be carried out to probe the possible effect of AP-CSAPs in the medium to long term, when the benefits it confers on farmers are expected to be evident. In addition, we recommend that off-farm activities should be encouraged among farmers to improve their likelihood of being food secure. Second, we recommend that government policies to consolidate farmland holdings to promote monocropping should be carefully considered before being introduced to rural farmers (and perhaps limited to corporate farm entities), as land fragmentation has been shown to positively influence food security and limit the possibility of total crop loss.

**Conflict of interest:** The authors declare no conflict of interest.

## References

- [1] AbdulKadir A, Usman MT, Shaba AH, Saidu S. An appraisal of the eco-climatic characteristics in northern Nigeria. *Afr J Environ Sci Technol.* 2013;7(8):748–57.
- [2] Adegboye MA. Socio-economic status categories of rural dwellers in Northern Nigeria. *Adv Res.* 2016;7(2):1–10.
- [3] Ali DA, Deininger K, Ronchi L. Costs and benefits of land fragmentation: evidence from Rwanda. Policy Research Working Paper 7290. Development Research Group, Agriculture and Rural Development Team-World Bank, 2015.
- [4] Arene CJ, Anyaeji J. Determinants of food security among households in Nsukka metropolis of Enugu State, Nigeria, Pakistan. *J Soc Stud.* 2010;30(1):9–16.
- [5] Asfaw S, Battista F, Lipper L. Agricultural technology adoption under climate change in the Sahel: micro-evidence from Niger. *J Afr Econ.* 2016;25(5):637–69. doi: 10.1093/jae/ejw005.
- [6] Babatunde RO, Qaim M. Impact of off-farm income on food security and nutrition in Nigeria. *Food Policy.* 2010;35(4):303–11.
- [7] Bickel G, Nord M, Price C, Hamilton WL, Cook JT. Guide to Measuring Household Food Security, Revised 2000. USDA, Food and Nutrition Service. <https://www.fns.usda.gov/fsec/files/fsguide.pdf/>.
- [8] Bogale A, Shimelis A. Household-level determinants of food insecurity in rural areas of Dire and Dawa, Eastern Ethiopia. *Afr J Food Agric Nutr Dev.* 2009;9(9):1914–26.
- [9] Brüssow K, Faëa A, Grote U. Adopting Climate-Smart Strategies and their Implications for Food Security in Tanzania. Tropentag Conference on International Research on Food Security, Natural Resource Management and Rural Development organised by the Humboldt-Universität zu Berlin and the Leibniz Centre for Agricultural Landscape Research (ZALF) September 15–18, 2015.
- [10] Chinnakali P, Upadhyay RP, Shokeen D, Singh K, Kaur M, Singh AK, *et al.* Prevalence of household-level food insecurity and its determinants in an urban resettlement colony in north India. *J Health Popul Nutr.* 2014;32(2):227–36.
- [11] Cholo TC, Fleskens L, Sietz D, Peerlings J. Land fragmentation, climate change adaptation, and food security in the Gamo Highlands of Ethiopia. *Agric Econ.* 2019;50(1):39–49.
- [12] Coulbaly JY, Chiputwa B, Nakelse T, Kundhlande G. Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agric Syst.* 2017;155:52–69.
- [13] Davies AE. Food security initiatives in Nigeria: prospects and challenges. *J Sustainable Dev Afr.* 2009;11(1):186–202.
- [14] Demetriou D. The development of an integrated planning and decision support system (IPDSS) for land consolidation [Springer Theses]. 2014. doi: 10.1007/978-3-319-02347-2\_2.
- [15] Di Falco S. Adaptation to climate change in sub-Saharan agriculture: assessing the evidence and rethinking the drivers. *Eur Rev Agric Econ.* 2014;41:405–30.
- [16] Eshetu F, Mekonnen E. Determinants of off farm income diversification and its effect on rural household poverty in



- Gamo Gofa Zone, Southern Ethiopia. *J Dev Agric Econ.* 2016;8(10):215–27.
- [17] FAO. Climate Smart Agriculture: Policies, Practices and Financing For Food Security, Adaptation and Mitigation, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 2010.
- [18] FAO. Nigeria Food Security and Vulnerability Survey 2016 Report, FAO Representation in Nigeria. 2016. [http://fscluster.org/sites/default/files/documents/food\\_security\\_livelihoods\\_and\\_vulnerability\\_assessment-final\\_draft\\_report\\_of\\_2016\\_fsvs\\_fao\\_nbs\\_dec\\_1.pdf](http://fscluster.org/sites/default/files/documents/food_security_livelihoods_and_vulnerability_assessment-final_draft_report_of_2016_fsvs_fao_nbs_dec_1.pdf).
- [19] Ibrahim SB, Akerele D, Oyawole FP, Uthman OJ, Aminu RO. Effect of non-farm income on poverty status of farm households in Ogun State, Nigeria. *Nigerian J Agric Food Environ.* 2019;15(2):40–9.
- [20] Idrisa YL, Ogunbameru BO, Shehu H. Effects of adoption of improved maize seed on household food security in Gwoza Local Government Area of Borno state, Nigeria. *Agric Sci Res J.* 2012;2(2):70–6.
- [21] Kadigi RMJ, Kashaigili JJ, Sirima A, Kamau F, Sikira A, Mbungu W. Land fragmentation, agricultural productivity and implications for agricultural investments in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) region, Tanzania. *J Dev Agric Econ.* 2017;9(2):26–36.
- [22] Knippenberg E, Jolliffe D, Hoddinott J. Land fragmentation and food insecurity in Ethiopia. Policy Research Working Paper 8559, 2018, The World Bank..
- [23] Knoema Database. Production of Maize by States in Nigeria. <https://knoema.com/atlas/Nigeria/maps/Production-of-Maize>. 2019, last accessed on January 26, 2020.
- [24] Lobell DB, Bänziger M, Magorokosho C, Vivek B. Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nat Climate Change.* 2011;1:42–5.
- [25] Maitra C, Rao DSP. Poverty–food security nexus: evidence from a survey of urban slum dwellers in Kolkata. *World Dev.* 2015;72:308–25.
- [26] Mango N, Zamasiya B, Makate C, Nyikahadzoi K, Siziba S. Factors influencing household food security among smallholder farmers in the Mudzi district of Zimbabwe. *Dev Southern Africa.* 2014;31(4):625–40.
- [27] McCarthy N, Brubaker J. Climate-Smart Agriculture and resource tenure in Sub-Saharan Africa: A conceptual framework, Food and Agriculture Organization, Rome; 2014.
- [28] Moyo S. Family farming in sub-Saharan Africa: its contribution to agriculture, food security and rural development, International Policy Centre for Inclusive Growth (IPC-IG) Working Paper No. 150, 2016.
- [29] Nata JT, Mjelde JW, Boadu FO. Household adoption of soil-improving practices and food insecurity in Ghana. *Agric Food Security.* 2014;3(1):1–17, <https://agricultureandfoodsecurity.biomedcentral.com/track/pdf/10.1186/2048-7010-3-17>.
- [30] NBS, Nigeria Poverty Profile. 2012. Nigerian Bureau of Statistics.
- [31] Neate P. Climate-smart agriculture success stories from farming communities around the world. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Technical Centre for Agricultural and Rural Cooperation (CTA); 2013.
- [32] Neufeldt H, Jahn M, Campbell BM, Beddington JR, DeClerck F, De Pinto A, et al. Beyond climate-smart agriculture: toward safe operating spaces for global food systems. *Agric Food Security.* 2013;2(12):1–6.
- [33] Nigussie A, Kissi E. Impact of biomass burning on selected physicochemical properties of Nitisol in Jimma zone, southwestern Ethiopia. *Int Res J Agric Sci Soil Sci.* 2011;1(9):394–401.
- [34] Obayelu AE. Classification of households into food security status in the North-Central Nigeria: an application of Rasch Measurement Model. *J Agric Biol Sci.* 2010;5(3):26–41.
- [35] Obayelu AE. Comparative analysis of households' socioeconomic and demographic characteristics and food security status in Urban and rural areas of Kwara and Kogi States of North-Central Nigeria. *Afr J Food Agric Nutr Dev.* 2012;12(3):6027–54.
- [36] Pantami SA, Vongir N, Babaji GA, Mustapha S. Effect of burning on soil chemical properties in the dry sub-humid savanna zone of Nigeria. *Researcher.* 2010;2(7):78–83.
- [37] Peralta A, Swinton SM. Food vs. wood: dynamic choices for Kenyan smallholders. *Sustainable Agric Res.* 2016;5(1):97–108.
- [38] Perez-Escamilla R, Segall-Correa A. Food insecurity measurement and indicators. *Rev Nutrição.* 2008;21:15–26. doi: 10.1590/s1415-52732008000500003.
- [39] Rahman A, Mishra S. Does non-farm income affect food security? Evidence from India. *J Dev Stud.* 2019;56:1–20. doi: 10.1080/00220388.2019.1640871.
- [40] Reardon T, Stamoulis K, Pingali P. Rural nonfarm employment in developing countries in an era of globalization. *Agric Econ.* 2007;37:173–83.
- [41] Sani JM, Mansor IM, Nasir SM, Mahir AA. The impact of non-farm income generating activities on the food security status of rural households in Nigeria. *Int J Agric Sci Vet Med.* 2014;2(4):121–31.
- [42] Sasson A. Food security for Africa: an urgent global challenge. *Agric Food Security.* 2012;1(2):1–16.
- [43] Shittu AM. Off-farm labour supply and production efficiency of farm household in rural Southwest Nigeria. *Agric Food Econ.* 2014;2(1):8.
- [44] Shittu AM, Kehinde MO, Ogunnaike MG, Oyawole FP. Effects of land tenure and property rights on farm households' willingness to accept incentives to invest in measures to combat land degradation in Nigeria. *Agric Resour Econ Rev.* 2018;47(2):357–87.
- [45] Sundqvist P, Andersson L. A study of the impacts of land fragmentation on agricultural productivity in Northern Vietnam [A Thesis submitted to Department of Economics]. Uppsala University; 2006.
- [46] Teklewold H, Kassie M, Shiferaw B. Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia. *J Agric Econ.* 2013;64(3):597–623. doi: 10.1111/1477-9552.12011.
- [47] Ugwu DS, Kanu IO. Effects of agricultural reforms on the agricultural sector in Nigeria. *J Afr Stud Dev.* 2012;4(2):51–9.
- [48] UNDP. Sustainable development goals, 2016. [http://www.undp.org/content/dam/undp/library/corporate/brochure/SDGs\\_Booklet\\_Web\\_En.pdf](http://www.undp.org/content/dam/undp/library/corporate/brochure/SDGs_Booklet_Web_En.pdf).

- [49] Usman U, Yelwa SA, Gulumbe SU, Danbaba A. An assessment of the changing climate in Northern Nigeria using Cokriging. *Am J Appl Math Stat.* 2013;1(5):90–8.
- [50] Williams TO, Mul M, Cofie OO, Kinyangi J, Zougmore RB, Wamukoya G, et al. Climate smart agriculture in the African context. Background paper at the feeding Africa: an action plan for African agricultural transformation conference 21–23 October 2015. [https://cgspace.cgiar.org/bitstream/handle/10568/68944/Climate\\_Smart\\_Agriculture\\_in\\_the\\_African\\_Context%255b1%255d.pdf?sequence=1&isAllowed=y](https://cgspace.cgiar.org/bitstream/handle/10568/68944/Climate_Smart_Agriculture_in_the_African_Context%255b1%255d.pdf?sequence=1&isAllowed=y).
- [51] Zhou D, Shah T, Ali S, Ahmad W, Din IU, Ilyas A. Factors affecting household food security in rural northern hinterland of Pakistan. *J Saudi Soc Agric Sci.* 2019;18(2):201–10.