SCIENTIA
AGRICULTURAE
BOHEMICA

Article

Climate Change Adaptation Strategies by Smallholder Farmers in Nigeria: What Role Do Social Capital Formations Play in the Adoption Process?

Abiola Adeagbo[1], Ayodeji Kehinde[12*], and Adebayo Bamire[1]

[1]Department of Agricultural Economics, Faculty of Agriculture, Obafemi Awolowo University, P.M.B. 13, Ile-Ife, Osun State, 220282, Nigeria; bioladeagbo@gmail.com; asbamire@yahoo.co.uk; kehindeayodeji8@gmail.com

[2] Disaster Management Training and Education Centre for Africa, Agriculture Building Bloemfontein Campus, University of the Free State, Nelson Mandela Road, Bloemfontein, 9300, South Africa; kehindeayodeji8@gmail.com

*Correspondence: kehindeayodeji8@gmail.com (Nigeria)

Abstract: The concept of social capital formations has received much attention. However, its role in implementing climate change adaptation strategies is rarely discussed. This study investigated the effects of social capital formations on the adopting of climate change adaptation strategies among smallholder farmers in Osun State. A multi-stage sampling procedure was used to select respondents. Data were analysed using descriptive statistics and a multinomial logit model. The predominant climate adaptation methods are early and late planting (73.3%), fallowing (36.3), intercropping (10%), crop rotation (83.3 %), irrigation (60%), and crop residue/mulching (7.7%). The social capital formation strategies used by farmers in descending order of predominance were *Esusu* (90.3%), religious group (88.9%), farmers' group (86.23%), thrift and credit union (63.9%) and age group association (27.8%). The result of the multinomial logit model reveals that membership in social capital formations has positive and significant effects on the decision of farmers to practice climate change mitigation methods. This study contributes to understanding how social capital, through networks, trust, and shared norms, shapes the adoption of climate change adaptation strategies in Nigeria. It highlights the role of community ties in enhancing knowledge exchange, resource access, and collective action, promoting more effective adaptation to climate impacts.

Keywords: Social Capital Formations; Adoption; Climate Change Adaptation Strategies; Osun State

Received for publication on 06.03.2024

Accepted for publication on 13.02.2025

1. Introduction

Smallholder farming is a significant source of income and economic development for poor communities (Bolang et al., 2023; File and Nhamo, 2023). More than 80% of farms worldwide are managed by smallholder farmers (Ricciardi et al., 2018; Ayisi et al., 2022). Smallholder farmers have an average farm size of less than 2 hectares (Food and Agriculture Organization [FAO], 2019). Smallholder farms produce over 80% of the food in Asia and Sub-Saharan Africa (SSA) (Ayisi et al., 2022). Notably, many of the smallholder farmers are in Sub-Saharan Africa. Smallholder farmers, on the other hand, practice agriculture on rainfed land (Peprah et al., 2020). As a result, they are more vulnerable to the effects of climate change. Thus, smallholder farming is fundamentally more exposed to climate change hazards (Smit and Skinner, 2002), and it has suffered as a result (Di Falco et al., 2012; Wang et al., 2014). Many studies (Bandara and Cai, 2014; Das et al., 2020) have found that smallholder farmers are among the most vulnerable to climate change in poor nations. Climate change affects agricultural productivity and increases crop instability, affecting the global food supply and causing food and nutritional poverty. Climate change has a negative impact on food production due to water shortages, pest outbreaks, and soil degradation, resulting in major agricultural yield losses and posing serious challenges to global food security (Läderach et al., 2017; Arora, 2019; Zizinga et al., 2022; Mirón et al., 2023). To address the issues raised by climate change, a variety of mitigation measures have been proposed.

Smallholder farmers, the majority of whom are self-sufficient, are continually adapting their farm management practices to counteract the consequences of climate change. Farm management options include adjusting land size, crop sales, mulching, pesticide use, livestock rearing, mixed cropping, monocropping, and water and soil conservation practices, among others (Challinor et al., 2014; Asfaw et al., 2018). These strategies also include integrated crop systems, crop diversification, intercropping, improved pest, water, and nutrient management, improved grassland management, reduced tillage, and the use of diverse varieties and breeds, and land restoration (Zakaria et al., 2020; Khatri-Chhetri et al., 2020; Aryal et al., 2020; Waaswa et al., 2022; Vatsa et al., 2023). These agricultural management practices could greatly minimize risk and thereby mitigate the harmful effects of climate change. However, Yakubu et al. (2022) stressed the need for farmers to know and apply learned information to combat the threat of climate change. Adjusting planting dates, diversifying crops, implementing irrigation, using climate-tolerant varieties, varying sowing times, using improved crop varieties (e.g., stress-tolerant varieties), and transitioning to new crops may all be part of the knowledge (Stringer et al., 2020; Ojo and Baiyegunhi, 2020; Jallason, 2019). However, Yakubu et al. (2022) pointed out that different farmers may employ different farm management techniques, and that this varies depending on many circumstances. Given the availability of human and natural capital for agricultural production in Nigeria, it is important to recognize that smallholder farmers' ability to successfully adapt to the stressors of climate change is both directly and indirectly related to their access to a variety of capital, particularly financial, physical, and social capital (Bolang et al., 2023).

Researchers are interested in studying the role of social capital in climate change adaptation strategies; for example, Saptutyningsih et al. (2020) discovered that social capital increased farmers' readiness to make financial contributions to adaptation measures by 70%. People in European nations are more likely to have climate behaviour and intentions if they have more social capital (Hao et al., 2020). Furthermore, farmers' ability to use a variety of institutions is crucial for their ability to adapt to change (Alam et al., 2016). Formal and informal interactions among members of a society create social capital, which can be thought of as a non-monetary form of capital. It is generally accepted that social networks created by connections and effects between individuals are how social capital functions. Adepoju and Oni (2012) and Kehinde et al. (2021) also support this, arguing that social capital arises in relationships in a variety of contexts, including those involving friends and family, neighbourhoods, religious communities, school communities, ethnic and community groups, occupational groups, businesses, and other institutions. Like other types of capital, social capital is regarded as an asset. According to Craig et al. (2023), social capital serves as a stimulant for socioeconomic growth and development and is interconnected with all other capitals. According to Deressa et al. (2009), social capital affects loan lending, capacity building for climate change adaptation, and access to agricultural information. As a result, smallholder farmers who have access to social capital may be better able to handle and adjust to the stresses of climate unpredictability. According to Nyangena and Sterner (2009), this is because social networks encourage group behaviour and cooperative behaviour, particularly on individual farms, through risk sharing, labour exchange, and credit provision. Additionally, it maintains the connection with government institutions, offers group-based training in new methods led by farmers, and increases knowledge of new technologies. Consequently, social capital is crucial for risk management related to climate change.

Although the importance of social capital in climate change adaptation has been argued, several studies have focused on perceptions of climate change and the adoption of climate change adaptation strategies (Kibue et al., 2016; Mulwa et al., 2017; Diallo et al., 2020; Ojo and Baiyegunhi, 2020; Abid et al., 2023). The significance of social capital in influencing household decisions to adapt to climate change has not been thoroughly examined. Although the influence of social networks on the adoption of climate change adaptation strategies has been studied in Nigeria (Ogunleye et al., 2021), Vietnam (Phan et al., 2019), South Africa (Thamaga-Chitja and Tamaka, 2017), and Indonesia (Saptutyningsih et al., 2020), no study to our knowledge has looked at the impact of social capital formation on the adoption of climate change adaptation strategies. Furthermore, earlier research examined social capital in the form of a single dimension or aggregate measure (Ngigi et al., 2012; Ogunleye et al., 2021). This research failed to demonstrate how various components of social capital development, such as bonding, bridging, and linking, influence the adoption of climate change adaptation measures. To address this gap, this study investigated how social capital development, such as bonding, bridging, and linking, influences the adoption of climate change adaptation measures. The paper is led by two objectives: (1) to investigate the various types of social capital formations by farmers in Osun State, and (2) to investigate the impact of social capital formations on the adoption of climate change adaptation techniques.

The research adds two important additions to the literature on improving smallholder farmers' ability to adapt to climate change, particularly in Nigeria, by extending awareness of the importance of social capital in day-to-day agricultural activities and smallholder farmers' livelihoods. It identifies effective ways in which social capital can be leveraged to facilitate access to other assets, particularly financial and physical capital, for smallholder farmers. It provides insights into how social capital support mechanisms and institutions—governmental and non-governmental organizations, global and national policy formulation platforms—can become more interested in finding solutions to the challenges faced by rural farmers in Nigeria and other related geographies.

Overall, the report helps Nigeria achieve the United Nations Sustainable Development Goals (SDGs), notably SDG 2 (end hunger) and SDG 1 (end poverty) by 2030.

The rest of this work is organized as follows. The following part discusses the literature review. Section three discusses the study area, data-gathering methods, and estimating procedures. Section four provides detailed explanations of the results and debates. The conclusion and policy implications are addressed in the final section.

2. Literature review

Social capital refers to the networks, norms, and trust that enable individuals and groups to work together for mutual benefit. In the context of climate change adaptation, social capital can play a significant role in facilitating collective action, knowledge sharing, and resource mobilization. This literature review explores the relationship between social capital formation and the adoption of climate change adaptation strategies in Nigeria, emphasizing its potential to influence both community resilience and sustainable development. Social capital's influence on climate change adaptation in developing countries, such as Nigeria, is an emerging area of research. According to Adger (2003), social capital contributes to the resilience of communities by enhancing collective problem-solving capacities, fostering cooperation, and facilitating access to critical resources. In the context of climate change, these elements are vital as communities face disruptions in agriculture, water resources, and infrastructure due to changing climatic patterns. Social networks, particularly within rural communities in Nigeria, can help share information about new adaptive practices, mobilize collective resources, and promote innovative solutions to mitigate climate-related risks.

In Nigeria, a country particularly vulnerable to climate change due to its dependence on agriculture, the formation of social capital is seen as an essential factor for successful adaptation. According to the study by Adeoye et al. (2019), communities with stronger social capital are more likely to implement sustainable agricultural practices and adopt resilient strategies in response to climate risks. These communities often leverage local networks to access support, resources, and information about climate change adaptation, thus increasing their adaptive capacity. One key aspect of social capital is trust, which has been shown to enhance cooperation among farmers and community members (Okoli, 2020). In Nigerian rural areas, trust is critical in fostering joint decision-making and collective action, especially in the context of scarce resources. Trust within social networks can enhance the willingness to share knowledge and resources, which is crucial for implementing successful adaptation strategies.

Social capital also aids in resource mobilization, which is central to the adoption of climate change adaptation strategies. In a study by Olusola et al. (2018), it was found that communities with stronger social ties are better able to pool resources for collective action, such as building irrigation systems or implementing soil conservation measures. This collaborative approach is particularly important in a context like Nigeria, where government support for climate change adaptation can be inconsistent and often lacks coordination. The role of social capital in accessing external support, such as funding from NGOs or government agencies, is also notable. Communities with robust networks of trust and cooperation are more likely to secure funding for adaptation projects. As noted by Nzeadibe (2015), community-based organizations in Nigeria often play a crucial role in linking rural populations with external development partners, thus enhancing the effectiveness of adaptation initiatives.

Despite its potential benefits, the formation of social capital in Nigeria faces several challenges. These include ethnic divisions, political instability, and socio-economic inequalities, which can hinder the development of trust and cooperation across different groups (Akinyemi & Adefolalu, 2020). Additionally, the erosion of traditional social structures due to modernization and urbanization may limit the extent to which rural communities can rely on social capital for adaptation. In conclusion, social capital formation plays a crucial role in the adoption of climate change adaptation strategies in Nigeria. By fostering trust, cooperation, and resource mobilization, social capital enhances communities' ability to respond to climate risks. However, for social capital to effectively facilitate adaptation, challenges related to ethnic divisions, political instability, and socio-economic inequalities need to be addressed. Further research is required to better understand the specific mechanisms through which social capital influences climate change adaptation in Nigerian communities.

3. Materials and Methods

3.1 Description of the study area

This study was carried out in Osun State, Nigeria. Osun State is selected due to the incidence of climate change in the state. The state has three agro-ecological zones (AEZs) namely rainforest (Ife/Ijesha), derived savannah (Osogbo as state capital) and savannah (Iwo) zones with thirty (30) local government and one (1) area office. The state lies between the 4^0 and 6° longitude east of the Greenwich meridian, and latitude 50 and 8° North of the equator. This means that the state lies entirely in the tropics. The state is bounded in the west by Oyo State, in the north by Kwara State, in the east by Ondo and Ekiti State, also in the south by Ogun State. The climate is tropical and characterized by a bi-modal rainfall pattern. The wet season, which is the cropping season, starts in late March and ends in October. This is followed by a short break of about three weeks and then the dry season starts from November to early March. The annual rainfall ranges from 800mm in the derived savannah zone to 1500mm in the rainforest zone while the mean annual temperature varies from 21.1°C and 31.10 C. The state's soil type is the highly ferruginous tropical red soil and the vegetation is mostly rainforest.

The people of the state are mostly farmers, traders and artisans with a larger percentage being farmers. The farmers cultivate permanent crops such as cocoa *(Theobroma cacao),* kola nut *(Cola nitida and C. acuminata),* plantain and bananas *(Musa spp),* Oil palm *(Elias guinensis)* and citrus *(Citrus spp.).* They also cultivate arable crops, especially maize *(Zea mays)* with different varieties widely cultivated. Other arable crops cultivated include yam *(Discoreaspp)*, cassava *(Manihotesculenta),* rice *(Oryza sativa)* and cocoyam *(Colocasia spp.).*

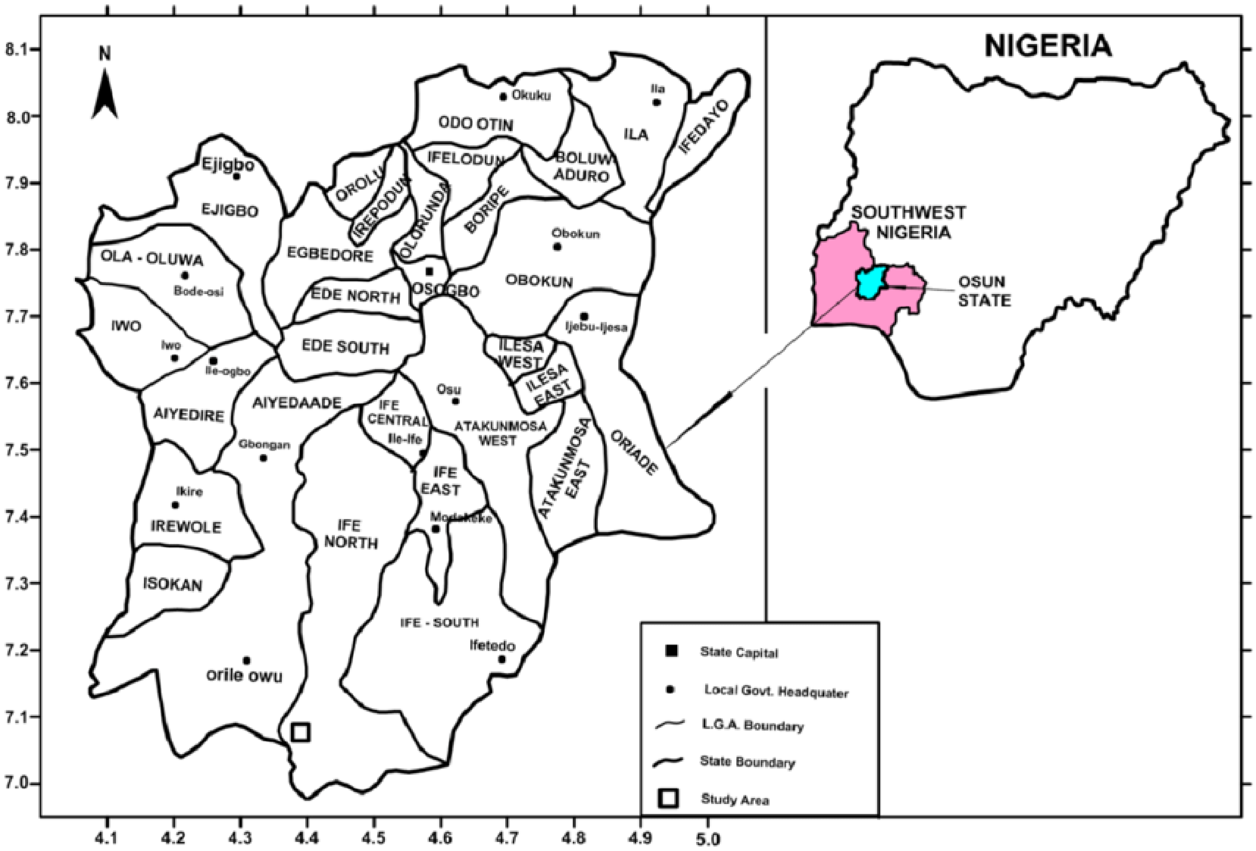

Figure 1. Map of Osun State showing the study areas.

Source: Google Map, 2024 Accessed from https://www.osunstate.gov.ng/map-of-osun-state-showing-the-local-government-areas-and-the-locality-png/

3.2. Sampling Procedure

A multi-stage sampling procedure was employed to select respondents for the study. The first stage involved the purposive selection of the three agroecological zones (AEZs) in Osun State as defined by ADP based on the predominance of smallholder farmers. There are three AEZs and thirty-one blocks (Agboola et al., 2021), based on information from the records of the Agricultural Development Programme (ADP). These are Osogbo (ten blocks), Ife /Ijesha (ten blocks) and Iwo (eleven blocks). The second stage involved the simple random selection of two blocks from each of the zones. Osogbo (12 villages) and Olorunda (18 villages) were selected in the Osogbo zone; Ede South (11 villages) and Ede North (15 villages) were selected in the Iwo zone while Ife Central (16 villages) and Ife East (13 villages) were also selected in the Ife/Ijesha zone. The third stage involved the simple random selection of two villages from each of the blocks using balloting methods. Using power calculation, a simple random sampling technique was used to select not least 360 farmers in the chosen villages in the final stage. The rationale behind the selection of the procedure is that it can reduce the possibility of systematic errors in the selection of respondents.

To ensure representativeness and due to the limited budget, a simplified formula Eq. (1), developed by Kothari (2004) was used to calculate the sample size of the respondents at the community level. A 95% confidence level, 5% estimated percentage, and P = 0.5 were assumed in the equations.

$$n = \frac{Z^2 X_p X_q X N}{e^2 X (N-1) + Z^2 X_p X_q} \quad (1)$$

where n is the sample size, N is the population size, e is the estimated proportion, p is the sample proportion, $q = 1 - p$, and z is the value of the standard variate at a given confidence level. Based on this formula, the respondents' sample size is approximately 360. The total number of farmers was selected from the ADP list using a simple random sampling technique using the balloting method.

The data for this study was primary which was obtained between November 2022 and Feb 2023 from across sectional survey, with the use of a pre-tested well-structured questionnaire designed to collect information on the socioeconomic characteristics of the respondents such as age, sex, marital status, family size, level of education, employment, information on climate change adaptation methods used by farmers such as mulching, early and late planting, irrigation, the choice of social capital formation strategies such as Esusu, cooperative society, religion society among others.

3.3. Analytical framework

Firstly, data were analysed using descriptive statistics to profile the climate change adaptation methods used by the farmers and the social capital formation by farmers in Osun state. Then, the Multinomial Logit Model (MNL) was used to analyze the data collected.

3.3.1. Multinomial logit model

Following Hassan and Nhemachena's (2007) and Otitoju's (2013) estimation approach, the MNL model was chosen because of its ability to handle multiple, unordered decisions and to accurately estimate the relationships between climate change adaptation strategies and explanatory variables. The distinguishing feature of multivariate choice models is the ability to simultaneously examine the relationships between each adaptation option and a common set of explanatory variables (Hassan and Nhemachena, 2007). Another advantage of using this approach is its ability to explicitly recognize and control potential correlations among climate change adaptation options. Therefore, the model provides more accurate estimates of relationships between each adaptation option and its explanatory variables (Hassan and Nhemachena, 2007). The model provides a convenient closed form for underlying choice probabilities, with no need for multivariate integration, making it simple to compute choice situations characterized by many alternatives. The Multinomial Logit model was employed to repackage climate change adaptation methods into a five-model scenario. The model was employed instead of the Tobit, Logit or Probit model because they assume that non-adopter climatic change adaptation methods do not adopt any other as they only allow zero or one dependent variable. This is because when there is more than one option to choose from, that the farmer does not pick one does not mean he is a non-adopter. Hence, the non-adoption of one method does not necessarily put the farmer in the non-adopter category. The model was also preferred because it permits the analysis of decisions across more than two categories in the dependent variable; hence it becomes possible to determine choice probabilities for the different climate change adaptation strategies. On the contrary, the binary Probit or Logit models are limited to a maximum of two choice categories (Maddala, 1983). The MNL was preferred for this study because it is simpler to compute than its counterpart, the Multinomial Probit model (Hassan and Nhemachena, 2008). The IIA assumption requires that the probability of combining climatic change adaptation methods by a given farmer must be independent of the probability of adopting another climatic change adaptation method (that is, *Pj/Pk* is independent of the remaining probabilities). This supports the model's appropriateness for the various categories.

The multinomial logit model deals with truly nominal and mutually exclusive categories. Suppose a dependent variable (DV), y, has m categories that are y = 1, 2 …m with P1, P2…Pm as associated probabilities, such that P1+P2+…+Pm = 1. The usual thing is to designate one as the reference category. The probability of membership in other categories is then compared to the probability of membership in the reference category. Consequently, for a DV with M categories, this requires the calculation of m-1 equations, one for each category relative to the reference category, to describe the relationship between the DV and the independent variables (IVs). The choice of the reference category is arbitrary but should be theoretically motivated.

Climate change adaptation strategies can be evaluated based on alternative adaptation strategies, which can be easily linked to utility. According to Greene (2000), the unordered choice model could be motivated by a random utility framework, where for the *i*th household faced with *j* technology choices, the utility of technology choice *j* is given by

$$U_{ij} = \beta_{ij} X_{ij} + \varepsilon_{ij} \qquad (2)$$

Where *Ui* is the utility of farmer *i* derived from land management and climate change adaptation strategy choice *j*, *Xij* is a vector of explanatory variables, and βj is a set of parameters that reflect the impact of changes in *Xij* on *Uij*. The disturbance terms *εi* are assumed to be independently and identically distributed. If farmers choose adaptation strategy *j*, then *Uij* is the maximum among all possible utilities. This means that

$$U_{ij} > U_{ik} \forall k \neq j \qquad (3)$$

Where *Uik* is the utility to the ith farmer from technology k. Equation (3) means that when each land management and climate change adaptation strategy is thought of as a possible adoption decision, farmers will be expected to choose the adaptation strategy that maximizes their utility given available alternatives (Dorfman, 1996). The choice of *j* depends on *Xij*, which includes aspects specific to the household and plot of the farm, among other factors. Following Greene (2000), *Y*i is a random variable that indicates the choice of land management and climate change adaptation measures of farmers. We assume that each farmer faces a set of discreet, mutually exclusive choices of adaptation strategies or measures. The MNL model specifies the following relationship between the probability of choosing land management and climate change adaptation and the set of explanatory variables (Greene, 2003).

$$\Pr(Y_i = j) = \frac{e\beta_{i_{ij}}}{\sum_{i=0}^{j} e^{b_i x_{ij}}}, \ j = 0,1,2,..., j \quad (4)$$

Estimating equation (3) provides a set of probabilities for j+1 technology choices for a decision maker with characteristics *Xij*. The equation can be normalized by assuming that βo= 0, in which case the probabilities can be estimated as

$$\Pr(Y_i = j) = \frac{e\beta_j x_{ij}}{1 + \sum_{m=1}^{5} e^{\beta_m x_{ij}}}, \ j = 0,1,2,..., j \quad (5)$$

$$\Pr(Y_i = j) = \frac{1}{1 + \sum_{m=1}^{j} e^{\beta_m x_{ij}}}, \ j = 0,1,2,..., j \quad (6)$$

Normalizing any other probabilities yields the following log-odds ratio:

$$\ln\left[\frac{P_{ij}}{P_{ik}}\right] = x_i(\beta j - \beta_m) \quad (7)$$

In this case, the dependent variable is the log of one alternative relative to the base/reference alternative. The coefficients in an MNL model are difficult to interpret, and associating the βj with the jth outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as in Greene (2000):

$$m_j = \frac{\partial P_j}{\partial x_i} = P_j\left[\beta_j - \sum_{k=0}^{j} P_k \beta_k\right] = P_j\left[\beta_j - \sum_{k=0}^{j} P_k P_k\right] = P_j\left[\beta_j - \overline{\beta}\right] \quad (8)$$

The marginal effects measure the expected change in the probability of a particular choice being made concerning a unit change in an explanatory variable (Long, 1997; Greene, 2000). The signs of the marginal effects and respective coefficients may be different, as the former depends on the sign and magnitude of all other coefficients.

The empirical model is specified as follows:

$$Yi = \beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3 + \beta 4 X4 + ei \quad (9)$$

The inclusion of these independent variables in the model was based on a previous expectation of the variable used and a review of the literature. These independent variables are expected to influence the dependent variable (Table 1). Data were gathered by the researchers and processed using the social science package software (SPSS) version 23 and STATA software (ver. 18, College Station, TX).

Table 1. Description of dependent and explanatory variables

Dependent variables		
Variables	**Description**	
Climate change adaptation strategies (Mulching or crop residues, Fallows, Intercropping, Early and late planting, Crop rotation)	Dummy, 1=if a farmer adopts climate change adaptation strategies, 0 = if otherwise	
Independent variables		
Variables	**Description**	**Signs**
Religion Group	Dummy; 1 = If a respondent participates in a Religion group and 0 if otherwise	+/-
Group farm cooperatives	Dummy; 1 = If a respondent participates in Group farm cooperatives and 0 if otherwise	+/-
Thrift and credit union	Dummy; 1 = If a respondent participates in a Thrift and credit union, and 0 if otherwise	+/-
Esusu	Dummy; 1 = If a respondent participates in Esusu, and 0 if otherwise	+/-

4. Results and discussion

4.1. Socioeconomic characteristics of smallholder farmers

Table 2 presents the socioeconomic characteristics of smallholder farmers in the study area.

Table 2. Socioeconomic characteristics of rural households

Socioeconomic characteristics	Percent	Mean	Std.
Male (%)	93		
Age (years)		47.5	19.6
Total household size (Number)		9.2	2.2
Farm size		3.7	1.3
Formal education (%)	64		
Access to credit (%)	53		
Years of farming experience		28.7	16.2
Extension visits (%)	56		

The majority of the respondents (93%) are male. This suggests that male farmers dominate smallholder farming. Male farmers in smallholder farming often play a central role in climate change adaptation strategies and decision-making. Their adoption of such practices is influenced by factors like access to resources, knowledge, and societal roles, with studies highlighting varying levels of engagement based on socioeconomic conditions and gender dynamics (Gbetibouo, 2009; Möller et al., 2021; Kehinde et al., 2022a). The mean age of smallholder farmers is 49.5 years. This finding indicates that farmers are still in their active years. Young farmers in smallholder farming play a crucial role in adopting climate change adaptation strategies, leveraging innovation and new technologies. Their willingness to embrace sustainable practices can enhance resilience to climate impacts, though challenges like limited resources and knowledge persist (FAO, 2020; Kivumbi et al., 2021; Ogunleye et al., 2020). The average household size is 9.15. The mean farm size of respondents is 3.7 hectares. This implies that the farmers are small-scale farmers. Small farm sizes in smallholder farming limit the adoption of climate change adaptation strategies due to restricted resources, low capital, and limited access to technology. This hampers the ability to invest in climate-resilient practices, leading to increased vulnerability (Kehinde et al., 2018; Alemu et al., 2022; Manda et al., 2024).

About 64% of the respondents are educated. This implies that many of the smallholder farmers had at least one form of education or the other. Literate farmers in smallholder farming are more likely to adopt climate change adaptation strategies due to their ability to understand new information, access resources, and implement innovative practices. Education enhances their decision-making capacity, improving resilience to climate impacts (Bhatta et al., 2017; Adhikari, 2021). Many of the respondents (53%) have access to credit. This suggests that credit is the primary source of money for operating crop production in the study area. Access to credit services enables smallholder farmers to invest in climate change adaptation strategies, such as improved irrigation, drought-resistant crops, and soil conservation techniques. This financial support reduces vulnerability, enhances productivity, and strengthens resilience to climate impacts (Diagne and Zeller, 2001; Dercon et al., 2014; Kehinde and Tijani, 2021). The mean years of farming experience is 28 years. This implies that farmers have many years of farming experience. This result supports the findings of Ayinde *et al.* (2018) and Kehinde and Adeyemo (2020). Long years of farming experience in smallholder farming often enhance farmers' resilience to climate change, fostering greater adaptability to new strategies. Experienced farmers can more effectively assess environmental changes and adopt sustainable practices like water conservation or crop diversification, improving productivity and sustainability (Mertz et al., 2009; Deressa et al., 2010; Adeyemo and Kehinde, 2019). About 56% of respondents had access to extension services. This result implies that most of the farmers had access to extension services. Extension services play a crucial role in supporting smallholder farmers by disseminating climate change adaptation strategies, enhancing knowledge of resilient agricultural practices, and promoting sustainable farming. Effective extension services facilitate the adoption of adaptive measures, improving productivity and resilience. (Davis, 2008; Franzel et al., 2014; Adeyemo and Kehinde, 2020).

4.2. Profile of Climate Change Adaptation Methods Used by Farmers

The climate change adaptation methods used by farmers is presented in Table 3.

Table 3. Climate Change Adaptation Methods Used by Farmers

Climate Change Adaptation Methods	Percentage (%)
Intercropping	10
Crop residue/mulching	7.7
Irrigation	60.
Fallowing	36.3
Early and late planting	73.3
Crop rotation	83.3

*Multiple responses

The predominant climate change adaptation methods are early and late planting (73.3%), fallowing (36.3%), intercropping (10%), crop rotation (83.3 %), irrigation (60%) and crop residue/mulching (7.7%). The major climate adaptation methods are early and late planting (92.2%), mulching (67.2%) and irrigation (63.6%). Many farmers are using crop rotation and early and late planting as their main methods of climate change adaptation practice. Crop rotation is widely used by farmers to adapt to climate change because it improves soil health, reduces pest and disease cycles, and increases biodiversity. By alternating crops, farmers can enhance soil fertility, reduce dependency on chemical fertilizers, and prevent soil erosion, all of which are crucial in changing climatic conditions. Additionally, crop rotation helps manage water use more efficiently by diversifying root systems, mitigating drought, and improving resilience to extreme weather. Studies have shown that this practice boosts long-term sustainability, making it an effective adaptation strategy in response to climate challenges (Lynch et al., 2021; Smith et al., 2019; Kehinde et al., 2022b). Also, farmers often use early and late planting as climate change adaptation strategies to manage shifting weather patterns. Early planting helps avoid drought periods, while late planting can mitigate risks associated with extreme rainfall or temperature fluctuations. These methods enable farmers to synchronize crop growth with more predictable weather windows, increasing yields and reducing losses. Research indicates that adjusting planting dates is a cost-effective and accessible strategy, particularly in regions facing unpredictable rainfall and temperature changes (Thornton et al., 2015; Lipper and Zilberman, 2018). These practices help maintain food security despite climate variability.

However, mulching is the least adopted climate change adaptation method among smallholder farmers (Table 3). Few farmers use mulching as their main climate change adaptation practice due to various constraints. High initial costs for materials like plastic or organic mulch deter many, especially small-scale farmers. Additionally, there is limited knowledge or awareness of mulching's benefits, such as moisture retention and temperature regulation. Inadequate access to extension services or training further exacerbates the issue. Also, in some regions, labour shortages or the availability of suitable mulching materials (e.g., organic matter) can hinder its widespread adoption. (Pretty, 2008; Mukhwana et al., 2016). These factors often make alternative practices more appealing.

4.3. Social capital formation strategies

The various social capital formation strategies used by the farmers are presented in Table 4.

Table 4. Social Capital Formation Strategies Used by Farmers

Climate Change Adaptation Methods	*Percentage (%)	rank
Esusu	90.30	1st
Religious cooperative groups	88.90	2nd
Farmers' group	86.23	3rd
Thrift and credit	63.90	4th
Age-group cooperative societies	27.80	5th

*Multiple responses

The major strategies used by the farmers in forming social capital are *Esusu* (90.3%) and religious cooperative groups (88.9%). Many farmers in Nigeria practice Esusu (a traditional savings and loan system) due to its accessibility and cultural significance. Esusu provides a means for farmers, particularly those with limited access to formal banking services, to save money and borrow funds when needed for agricultural activities. It fosters a sense of community, as members support each other in times of financial need. Additionally, it offers flexibility, allowing farmers to contribute small amounts regularly and access lump sums for seasonal expenses, such as planting or harvesting (Olayemi, 2019; Obasaju, 2022; Kehinde and Kehinde, 2020; Adeyemi et al., 2020).

In Nigeria, many farmers belong to religious cooperative groups due to shared beliefs, trust, and community support. These cooperatives often provide a platform for pooling resources, securing credit, and accessing agricultural inputs. Religious affiliation fosters a sense of belonging and mutual assistance, which is crucial in rural areas where formal institutions may be lacking. Furthermore, religious leaders often act as facilitators, guiding farmers towards effective practices. These groups enhance social capital, ensuring greater participation and success. According to Olayide (2021) and Kehinde et al. (2021), religious cooperatives empower farmers through solidarity and resource-sharing, enabling them to overcome challenges. Social structures, such as community gatherings, often align with religious groups, further consolidating the link between farming and religious identity in rural areas.

However, many of the farmers indicated that they were not members of any age group cooperative societies, but about 27% indicated they belonged to an age group cooperative societies. Age group association is not so common among the respondents; it is only common among the youths, who are not much represented in this survey. Few farmers in Nigeria belong to age group cooperative societies due to factors like limited awareness, lack of education, and financial constraints. Many farmers, especially older ones, are not aware of the benefits of these societies, while younger farmers may not have access to the necessary resources to join. Additionally, traditional systems and individualistic farming practices often prevent collective action. Age-related barriers, such as generational differences in understanding cooperative principles, further hinder participation. According to Akinyemi (2020), Oluponna et al. (2023), and Kehinde et al. (2025), social, economic, and educational challenges contribute significantly to low participation in such societies.

4.4. Effect of social capital formation on land management practices

The effect of social capital formation on land management practices is presented in Table 5.

Table 5. Effect of social capital formations on the Adoption of Climate Change Adaptation method

Variables	Intercropping	Mulching or crop residues	Fallows	Early and late planting	Crop rotation
Religious group	-0.2752(-0.39)	-0.9537(-0.80)	0.2584(0.60)	0.4146(0.91)	1.3693*(1.96)
Farmers' group	-1.0153*(-1.68)	-0.7773(-0.78)	-0.8253(-1.57)	1.9213***(3.60)	1.6540**(2.49)
Thrift and credit union	-0.1175(-0.19)	1.0821**(1.93)	1.160**(2.21)	0.9173***(1.73)	-0.7883(-0.92)
Esusu	-0.5428(-0.68)	14.7714**(2.02)	1.307**(1.99)	1.4068**(2.44)	1.8729**(2.57)
Constant	-0.5195*(-1.74)	-1.3138*(-1.79)	0.5723**(1.99)	1.8812***(3.33)	-1.1051(-1.31)
Log-likelihood	-286.419				
LR chi(20)	65.48				
Prob>chi(2)	0.0000				
Nagelkerke's Pseudo R^2	0.494				

Note: ***, **, and * p-values are significant at 1%, 5% and 10%, respectively. The base outcome or category is irrigation. The estimation includes a set of control variables, but these are not reported as they are not of direct interest

The model was statistically significant at a 1% probability level with an LR chi (20) of 65.48. Also, the log-likelihood is high and significant, indicating the model is the best fit. The results of the estimated equations are discussed in terms of the significance and signs of the parameters. The results show that the set of significant explanatory variables varies across the groups in terms of the levels of significance and signs of multinomial regression coefficients. The results showed that the coefficient of the farmers' group has a negative and significant influence on the farmers' probability of practising intercropping as a climate change adaptation strategy. This implies that the farmers' group reduced the effects of farmers' probability of practising intercropping as a climate change adaptation strategy. One plausible reason for the negative effect on farmers' probability of practising intercropping as a climate change adaptation strategy is the increased unpredictability of weather patterns. Climate change leads to more frequent droughts, floods, or irregular rainfall, making it difficult for farmers to plan and manage multiple crops. This uncertainty, coupled with limited access to resources such as water or seeds, can discourage intercropping (Rao et al., 2019; Kandel et al., 2023; Kehinde et al., 2024). Additionally, the lack of knowledge or expertise in managing intercropping systems can further hinder its adoption (Tsubo et al., 2009).

Meanwhile, the results showed that the coefficients of the thrift and credit union and *Esusu* have a positive and significant influence on the farmers' probability of using mulching or crop residues as a climate change adaptation strategy. This implies that the thrift and credit union, and *Esusu*, increase the effects of farmers' probability of using mulching or crop residues as a climate change adaptation strategy. Thrift and credit unions can positively affect farmers' adoption of climate change adaptation strategies like mulching or using crop residues by providing financial support and enhancing access to credit. These financial institutions help reduce liquidity constraints, enabling farmers to invest in sustainable practices. Access to credit allows farmers to purchase necessary inputs (e.g., equipment and materials) for implementing soil conservation methods. Moreover, savings through thrift unions can increase farmers' financial security, encouraging risk-taking in adopting new practices (Olweny, 2016; Akinola et al., 2023). Such financial services foster adaptive capacity by lowering financial barriers and promoting long-term agricultural sustainability (Henderson et al., 2020; Bakare et al., 2023). Esusu, a traditional savings system, can positively impact farmers' use of mulching or crop residues as a climate change adaptation strategy by providing financial stability and access to capital. This enables farmers to invest in practices that improve soil health and water retention, essential for coping with climate change. By pooling resources, farmers can also access the necessary tools and knowledge to implement sustainable practices. Studies have shown that community-based savings programs increase agricultural resilience, including promoting soil conservation techniques such as mulching (Akinola et al., 2024; Kandel et al., 2023; Adekunle et al., 2023; Adeshina et al., 2020).

Also, the results showed that the coefficients of the thrift and credit union and *Esusu* have a positive and significant influence on the farmers' probability of using the fallowing as a climate change adaptation strategy. This implies that the thrift and credit union and *Esusu* increase the effects of farmers' probability of using fallowing as a climate change adaptation strategy. Thrift and credit unions can positively impact farmers' likelihood of using fallowing as a climate change adaptation strategy by improving their access to financial resources. These institutions provide affordable loans and savings opportunities, enabling farmers to manage income volatility and invest in land management practices like fallowing, which may require periodic land resting to preserve soil health. Access to credit can also buffer against the financial risks associated with extreme weather patterns, allowing farmers to implement such adaptive strategies when necessary. Studies, such as those by Di Falco et al. (2012) and Ogunleye et al. (2021), emphasize the role of financial services in promoting resilience to climate change. Esusu, a traditional savings and credit system, can positively influence farmers' likelihood of using the fallowing as a climate adaptation strategy by providing financial security. It allows farmers to save collectively, creating a safety net that enables them to afford the costs of fallowing, which often requires land to be left idle for soil restoration. By facilitating access to funds, Esusu mitigates the economic risks associated with fallowing, making it a more viable option. Studies suggest that such communal savings systems can enhance adaptive capacity in rural communities, supporting sustainable agricultural practices in the face of climate change (Akanbi et al., 2021; Kandel et al., 2023).

Also, the results showed that the coefficients of the thrift and credit union, farmers' group and *Esusu* have a positive and significant influence on the farmers' probability of using early and late planting as a climate change adaptation strategy. This implies that the thrift and credit union farmers' group and *Esusu* increase the effects of farmers' probability of using early and late planting as a climate change adaptation strategy. Thrift institutions and credit unions improve farmers' access to financial resources, which is crucial for adopting climate change adaptation strategies like early and late planting. By offering affordable loans and savings plans, they help farmers invest in seeds, equipment, and technology necessary for these practices. Access to credit also enables farmers to take risks and plan for unpredictable weather patterns. Studies show that financial access through these institutions promotes innovation in agricultural practices and enhances resilience (Hossain, 2012; Kehinde and Ogundeji, 2022; Bakare et al., 2023). These financial services thus empower farmers to adopt diverse planting strategies to cope with climate variability. Farmers' groups are likely to enhance the probability of using early and late planting as climate change adaptation strategies due to shared knowledge and resources. These groups provide a platform for farmers to exchange information on climate patterns, agronomic practices, and weather forecasting. Social networks can also facilitate access to seeds, tools, and credit, reducing individual risks. Additionally, collective action can strengthen bargaining power and increase access to training on climate-resilient practices (O'Brien et al., 2009; Kehinde, 2021). Studies show that collaborative decision-making among farmers leads to more effective adaptation strategies (Adger et al., 2005; Kolapo et al., 2021). Hence, social networks play a crucial role in adaptive behaviours. Esusu, a traditional savings and lending system, can positively impact farmers' likelihood of using early and late planting strategies as a climate change adaptation technique. This system allows farmers to access timely financial resources, enabling them to invest in the necessary inputs like seeds, fertilizers, and irrigation equipment. With Esusu, farmers can better plan their planting schedules to align with changing weather patterns, thus improving crop yield and reducing risk. Studies show that financial stability from community savings mechanisms increases adaptive capacity (Akinola et al., 2020; Kandel et al., 2023). This access to funds empowers farmers to adapt more effectively.

Table 5 further revealed that the coefficients of membership in religious groups, farmers' groups and *Esusu* have a positive and significant influence on the farmers' probability of practising crop rotations as a climate change adaptation strategy. This implies that membership in religious groups, farmers' groups and *Esusu* increase the effects of farmers' probability of practising crop rotations as a climate change adaptation strategy. Membership in religious groups can positively influence farmers' likelihood of practising crop rotations as a climate change adaptation strategy due to the social and community support these groups provide. Religious organizations often promote values of stewardship, sustainability, and care for the environment, which align with adaptive agricultural practices like crop rotation. Additionally, these groups foster strong social networks, encouraging knowledge exchange and cooperative behaviour. Research suggests that religious beliefs can motivate collective action toward environmental conservation (Anderson et al., 2014). The community aspect also reduces the risks associated with adopting new practices (Jha et al., 2023). Membership in farmers' groups can positively influence the likelihood of practising crop rotation as a climate change adaptation strategy by fostering knowledge exchange, access to resources, and collective problem-solving. These groups often facilitate the sharing of best practices, technical expertise, and innovative techniques, enabling farmers to adopt sustainable practices like crop rotation. Additionally, group members may benefit from collective bargaining for inputs like seeds or fertilizers, which can lower costs and encourage experimentation with crop rotation. Studies show that social networks within farmer groups improve adaptive capacity (Pretty, 2003; Armitage et al., 2009; Ayanwale et al., 2024). Membership in an Esusu (informal savings group) can positively affect farmers' likelihood of adopting crop rotation as a climate change adaptation strategy due to increased financial security and access to resources. By pooling savings, members can access funds for purchasing input, training, or improving farm infrastructure. This economic stability allows farmers to diversify crops, a key element of crop rotation. Additionally, Esusu fosters collective knowledge sharing, which can enhance farmers' awareness and adoption of sustainable agricultural practices (Adebayo et al., 2020; Oyekale, 2021; Kehinde and Ogundeji, 2022b; Kandel et al., 2023). This reduces financial barriers and empowers farmers to implement climate-smart practices.

5. Conclusions

This study investigated the effects of social capital formations on the adoption of climate change adaptation strategies among smallholder farmers in Osun State. A multi-stage sampling procedure was used to select two blocks from three agroecological zones (AEZs) in Osun State, two villages per block and thirty respondents per village to give a total of 360 respondents. Data were analysed using descriptive statistics and a multinomial logit model. A multinomial logit model handles multiple outcomes, is easy to interpret, and allows for flexible modelling of choice data. The descriptive statistics show average values of 49 years for age, 9 people for household size and 3.7 ha for farm size. Arising from the findings of this study, it could be concluded that predominant climate adaptation methods are early and late planting (73.3%), fallowing (36.3), intercropping (10%), crop rotation (83.3 %), irrigation (60%) and crop residue/mulching (7.7%). The major climate adaptation methods are: early and late planting (92.2%), mulching (67.2%) and irrigation (63.6%). The social capital formation strategies used by farmers in descending order of predominance were *Esusu* (90.3%), religious group (88.9%), farmers’ group (86.23%), thrift and credit union (63.9%) and age group association (27.8%). The result of the multinomial logit model reveals that membership in social capital formations has positive and significant effects on the decision of farmers to practice climate change mitigation methods. Hence, climate change adaptation strategies should be disseminated to farmers through social groups such as religious organizations, group farm cooperation, and Esusu society. Social capital networks can be mobilized by leveraging trusted community leaders, influencers, and local organizations to share climate adaptation knowledge. Peer-to-peer communication, collaborative partnerships, and building strong community ties enhance information dissemination, making it more accessible, culturally relevant, and actionable for diverse groups, thus fostering collective climate resilience.

The formation of social capital can significantly enhance the adoption of climate change adaptation strategies among smallholder farmers. Policies should focus on fostering community-based networks that facilitate knowledge sharing, collective action, and access to resources. Strengthening farmer organizations, promoting cooperative learning, and improving social ties can empower farmers to adopt more sustainable practices. Additionally, governments should provide platforms for social capital development and ensure that marginalized groups are included in decision-making processes. The government should further promote a more diverse set of social networks to achieve this objective. By integrating social capital into climate policy, farmers can better adapt to climate challenges, leading to more resilient agricultural systems. For policymakers, fostering community networks and trust can enhance information sharing and collaborative action, leading to more effective adaptation practices. Agricultural extension services can leverage social capital by engaging with farmer groups, facilitating peer learning, and promoting collective decision-making. By understanding the role of social ties and networks, policymakers and extension services can tailor interventions that strengthen community-based adaptation efforts, improve resource access, and encourage the widespread adoption of climate-resilient practices, ultimately enhancing agricultural sustainability and farmer resilience. Strong networks enable farmers to access vital resources such as information, financial support, and collective action opportunities. Studies, like those by Pretty and Smith (2004), highlight how social capital enhances resilience and resource-sharing, particularly in climate-sensitive regions. Compared to similar studies, such as those by Moser and Ekstrom (2010), the role of local social networks in fostering adaptive capacities is consistently emphasized, though variation exists depending on cultural and regional contexts.

Future research could explore how different forms of social capital (e.g., bonding, bridging) influence community-level climate adaptation strategies. Investigating the role of trust, networks, and shared norms in facilitating resource-sharing, collective action, and resilience-building could help develop more effective, context-specific adaptation policies for vulnerable populations.

Author Contributions: Conceptualization, A. Adeagbo and A.D. Kehinde; methodology, A. Kehinde and A.S. Bamire; software, A. Kehinde; validation, A.S. Bamire; formal analysis, A.D. Kehinde; investigation A. Adeagbo, A.D. Kehinde; resources, A.S. Bamire; writing—original draft preparation, A.D. Kehinde; writing—review and editing, A. D. Kehinde; visualization, A.D. Kehinde; supervision, A.S. Bamire; project administration, A.S. Bamire; funding acquisition, A. Adeagbo. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgements: We owe a debt of gratitude to the farmers who sat quietly for hours answering the questionnaire. We also thank the anonymous reviewers for their insightful remarks, which helped us improve the work.

Conflicts of Interest: The authors declare no conflict of interest

Data availability statement: The data supporting this study's findings can be obtained from the authors upon.

6. References

1. Abid N, Ahmad F, Aftab J, Razzaq A (2023): A blessing or a burden? Assessing the impact of climate change mitigation efforts in Europe using quantile regression models. *Energy Policy*, *178*, 113589.
2. Adebayo WG, Silberberger M (2020): Poverty reduction, sustainable agricultural development, and the cassava value chain in Nigeria. *The Palgrave Handbook of Agricultural and Rural Development in Africa*, 525-551.
3. Adekunle A, Ayanwale A, Kehinde AD (2023): Determinants of Participation in Innovation Platforms and Its Sustainability: A Case Study of Sub-Saharan Africa. *Tropical and Subtropical Agroecosystems*, 26(2): #051
4. Adeoye DO, Akintoye IA, Adedeji AO (2019): Social capital and climate change adaptation: A case study of rural communities in Nigeria. *Environmental Science & Policy, 101*, 67-74.
5. Adepoju AA, Oni OA (2012): Investigating endogeneity effects of social capital on household welfare in Nigeria: A control function approach. *Quarterly Journal of International Agriculture*, *51*(1), 73-96.
6. Adeshina KF, Tomiwa OY, Eniola OM (2020): Agricultural financing and economic performance in Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, *38*(7), 61-74.
7. Adeyemi EB, Adeyemo R, Kehinde AD, Famuyini CA (2020): Effects of Fadama III User Group Participation on Food Security of Rural Households in Benue State, Nigeria. *Ife Journal of Agriculture*, 32(3), 85-97.
8. Adeyemo R, Kehinde AD (2019): Community-Based Organisation and Land Management Practices in Cassava-Based Small Holder Farming System in Osun State. *Agricultura* 111-112 (3-4), 270-281.
9. Adeyemo R, Kehinde AD (2020): Membership in association, Gender and Adoption of Land-enhancing Technologies among Arable Farmers in Ogun State, Nigeria. *Agricultural Science and Technology*, 12 (2), 189-201.
10. Adeyemo R, Kehinde AD (2021): Community Driven Development: The case of FADAMA II Cooperatives in Alleviating Poverty in a Developing Country. *Contemporary Agriculture*, 70 (1-2), 46-53.
11. Adger WN (2003): Social capital, collective action, and adaptation to climate change. *Economic Geography, 79*(4), 387-404.
12. Adger WN, Arnell NW, Tompkins EL (2005): Successful adaptation to climate change across scales. *Global environmental change*, *15*(2), 77-86.
13. Adhikari D (2021): Climate change impacts and adaptation strategies in the Trans-Himalaya region of Nepal. *Journal of Forest and Livelihood*, *20*(1), 16-30.
14. Agboola TO, Akintunde OK, Adedire AO, Jimoh LO (2021): Evaluation of the relationship between participation in agricultural insurance scheme and income of poultry farmers in Osogbo ADP zone, Osun State. *Nigerian Journal of Animal Science*, *23*(1), 108-115.
15. Akanbi RT, Davis N, Ndarana T (2021): Climate change and maize production in the Vaal catchment of South Africa: assessment of farmers' awareness, perceptions and adaptation strategies. *Climate Research*, *82*, 191-209.

16. Akinola A, Kehinde AD, Tijani A, Ayanwale A, Adesiyan F, Tanimonure V, Ogunleye A, Ojo T (2023): Impact of Membership in Agricultural Cooperatives on Yield of Smallholder Tomato Farmers in Nigeria. *Environmental and Sustainability Indicators*, 20, 100313.
17. Akinola FF, Fasinmirin JT, Olorunfemi IE (2024): Effects of different tillage and cropping systems on water repellency and hydraulic properties in a tropical Alfisol of southwestern Nigeria. *Geoderma Regional*, *37*, e00815.
18. Akinola R, Pereira LM, Mabhaudhi T, De Bruin FM, Rusch L (2020): A review of indigenous food crops in Africa and the implications for more sustainable and healthy food systems. *Sustainability*, *12*(8), 3493.
19. Akinyemi SA (2020): Understanding Factors that Increase Citizens' Participation in Community Development Projects in Lagos, Nigeria (Doctoral dissertation, The Florida State University).
20. Akinyemi SO, Adefolalu DO (2020): Social capital and its implications for climate change adaptation in sub-Saharan Africa: A review of challenges in Nigeria. *Sustainable Development*, *28*(2), 157-169.
21. Alam GM, Alam K, Mushtaq S. (2016): Influence of institutional access and social capital on adaptation decision: Empirical evidence from hazard-prone rural households in Bangladesh. *Ecological Economics*, *130*, 243-251.
22. Alemu MG, Wubneh MA, Worku TA (2022): Impact of climate change on the hydrological response of Mojo river catchment, Awash river basin, Ethiopia. *Geocarto International*, 2152497.
23. Anderson TR, Goodale CL, Groffman PM, Walter MT (2014): Assessing denitrification from seasonally saturated soils in an agricultural landscape: A farm-scale mass-balance approach. *Agriculture, ecosystems & environment*, *189*, 60-69.
24. Armitage DR, Plummer R, Berkes F, Arthur RI, Charles AT, Davidson-Hunt IJ, Wollenberg EK (2009): Adaptive co-management for social-ecological complexity. *Frontiers in Ecology and the Environment*, *7*(2), 95-102.
25. Arora NK (2019): Impact of climate change on agriculture production and its sustainable solutions. *Environmental sustainability*, *2*(2), 95-96.
26. Aryal JP, Sapkota TB, Rahut DB, Krupnik TJ, Shahrin S, Jat ML, Stirling CM (2020): Major climate risks and adaptation strategies of smallholder farmers in coastal Bangladesh. *Environmental Management*, *66*(1), 105-120.
27. Asfaw A. Simane B, Hassen A, Bantider A (2018): Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. *Weather and climate extremes*, *19*, 29-41.
28. Ayanwale AB, Adekunle AA, Kehinde AD, Fatunbi OA (2024): Networking and Training for Improvement of Farm Income: A Case of Lifelong Learning (L3F) Approach in West Africa. *Heliyon*, 10, e23263.
29. Ayinde OE, Ajewole OO, Adeyemi UT, Salami MF (2018): Vulnerability analysis of maize farmers to climate risk in Kwara State, Nigeria. *Agrosearch*, *18*(1), 25-39.
30. Ayisi DN, Kozári J, Krisztina T (2022): Do smallholder farmers belong to the same adopter category? An assessment of smallholder farmers innovation adopter categories in Ghana. *Heliyon*, *8*(8).
31. Bakare AY, Ogunleye AS, Kehinde AD (2023): Impacts of Microcredit Access on Climate Change Adaptation Strategies Adoption and Rice Yield in Kwara State, Nigeria. *World Development Sustainability*, 2, 100047.
32. Bandara JS, Cai Y (2014): The impact of climate change on food crop productivity, food prices and food security in South Asia. *Economic Analysis and Policy*, *44*(4), 451-465.
33. Bhatta GD, Ojha HR, Aggarwal PK, Sulaiman VR, Sultana P, Thapa D, Ghimire L. (2017): Agricultural innovation and adaptation to climate change: empirical evidence from diverse agroecologies in South Asia. *Environment, Development and Sustainability*, *19*(2), 497-525.
34. Bolang PD, Sanyare FN, Gyader GN (2023): Achieving greater participation in agricultural production: A study of government workers in the Upper West region of Ghana. *Heliyon*, *9*(11).
35. Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N (2014): A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, *4*(4), 287-291.
36. Craig A, Hutton C, Musa FB, Sheffield J. (2023): Bonding, bridging and linking social capital combinations for food access; A gendered case study exploring temporal differences in southern Malawi. *Journal of Rural Studies*, *101*, 103039.
37. Das M, Das A, Momin S, Pandey R (2020): Mapping the effect of climate change on community livelihood vulnerability in the riparian region of Gangatic Plain, India. *Ecological Indicators*, *119*, 106815.

38. Davis K (2008): Intersectionality as buzzword: A sociology of science perspective on what makes a feminist theory successful. *Feminist theory*, *9*(1), 67-85.
39. Dercon G, Gerardo-Abaya J, Mavlyudov B (2014): Assessing the Impact of Climate Change on Land-Water-Ecosystem Quality in Polar and Mountainous Regions: A New Interregional Project (INT5153).
40. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M (2009): Determinants of farmers" choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global environmental change*, *19*(2), 248-255.
41. Deressa TT, Ringler C, Hassan RM (2010): Factors affecting the choices of coping strategies for climate extremes. *The case of farmers in the Nile Basin of Ethiopia IFPRI Discussion Paper*, *1032*.
42. Di Falco S, Yesuf M, Kohlin G, Ringler C (2012): Estimating the impact of climate change on agriculture in low-income countries: Household level evidence from the Nile Basin, Ethiopia. *Environmental and Resource Economics*, *52*, 457-478.
43. Diagne A (2001): Access to credit and its impact on welfare in Malawi. Research report No.116. Washington D.C. International Food Policy Research Institute.
44. Diallo A, Donkor E, Owusu V (2020): Climate change adaptation strategies, productivity and sustainable food security in southern Mali. *Climatic Change*, *159*(3), 309-327.
45. Dorfman JH (1996): Modeling multiple adoption decisions in a joint framework. *American journal of agricultural economics*, *78*(3), 547-557.
46. FAO (2019): Farms, family farms, farmland distribution an farm labour: What do we know today?. FAO Agriculture Development Economics Working Paper 19-08.
47. FAO (2020): FAOSTAT Database. UN Food and Agriculture Organization (FAO). https://www.fao.org/faostat
48. File DJMB, Nhamo G (2023): Farmers' choice for indigenous practices and implications for climate-smart agriculture in northern Ghana. *Heliyon*, *9*(11).
49. Franzel S, Carsan S, Lukuyu B, Sinja J, Wambugu C (2014): Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. *Current opinion in environmental sustainability*, *6*, 98-103.
50. Gbetibouo GA (2009): Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. Intl Food Policy Res Inst.
51. Greene WH (2000): Econometric analysis (4th ed). Prentice Hall, New Jersey.
52. Greene WH (2003): *Econometric Analysis*. 5th Edition. Upper Saddle River, New Jersey: Pearson Education,Inc.,
53. Hao F, Shao W, Huang W (2021): Understanding the influence of contextual factors and individual social capital on American public mask wearing in response to COVID–19. *Health & place*, *68*, 102537.
54. Hassan RM, Nhemachena C (2008): Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(1), 83-104.
55. Henderson GE, Beach P, Sun L, McConnel J (2020): Does the content of financial literacy education resources vary based on who made or paid for them?. *Citizenship, Social and Economics Education*, *19*(3), 192-210.
56. Hossain ST (2012): Organic farming in populated area: Bangladesh–an example of case study. *Organic farming in populated area: Bangladesh–an example of case study*, 105-113.
57. Jallason NP (2019): Climate change perceptions and attitudes of smallholder adaption in Northwestern, Nigeria Drylands. Social Science, 8(31) http://app.dimension.ai/details/publiction/pub.1111649369
58. Jha P, Chinngaihlian S, Upreti P, Handa A (2023): A machine learning approach to assess implications of Climate Risk Factors on Agriculture: The Indian case. *Climate Risk Management*, *41*, 100523.
59. Kandel GP, Bavorova M, Ullah A, Kaechele H, Pradhan P (2023): Building resilience to climate change: Examining the impact of agro-ecological zones and social groups on sustainable development. Sustainable Development, 31(5), 3796–3810. https://doi.org/10.1002/sd.2626.
60. Kehinde AD, Adeyemo R (2020): Effects of social capital dimensions on output and gross margin of cassava farmers in Osun State. *Nigerian Journal of Rural Sociology Vol*, *20*(1).
61. Kehinde AD, Adesiyan TF, Hassan SO, Familusi IG (2025): Leveraging on Membership in Agricultural Cooperatives to Alleviate Abject Poverty among Smallholder Farming Households in Nigeria. *Sustainable Futures*, 9, 100399.
62. Kehinde AD, Adeyemo R, Ogundeji AA (2021): Does social capital improve farm productivity and food security? Evidence from cocoa-based farming households in Southwestern Nigeria. *Heliyon*, *7*(3).

63. Kehinde AD (2021): Agricultural cooperatives and improved technologies adoption among smallholder farmers in cocoa-based farming systems of Southwestern Nigeria. *International Journal of Agricultural Management and Development*, 11(4), 467-483.
64. Kehinde AD, Kehinde MA (2020): The Impact of Credit Access and Cooperative Membership on Food Security of Rural Households in South-Western Nigeria. *Journal of Agribusiness and Rural Development*, 57(3), 255-268.
65. Kehinde AD, Ogundeji AA (2022a): The simultaneous impact of access to credit and cooperative services on cocoa productivity in South-western Nigeria. *Agriculture and Food Security*, 11, 1-17.
66. Kehinde AD, Ogundeji AA (2022b): Social Capital Networks (SCNs) Reducing the Poverty in Cocoa Producing Households: Evidence from Osun and Ondo States of Southwestern Nigeria. *Tropical and Subtropical Agroecosystems* 25: #082.
67. Kehinde AD Ojo TO, Ogundeji AA (2024): Impact of participation in social capital networks on the technical efficiency of maize producers in Southwest Nigeria. *Agriculture and Food Security*, 13(1), 1-19
68. Kehinde AD, Adeyemo R, Ogundeji AA (2021): Does Social Capital improve Farm Productivity and Food Security? Evidence from Cocoa-based farming Households in South-western Nigeria. *Heliyon*, 7(3), e06592.
69. Kehinde AD, Adeyemo R, Oke JTO, Ogunleye AS (2018): Effects of Access to credit and Membership in Farmers' Cooperatives on Improved Technologies Adoption Categories in Cocoa-based farming Systems of Southwestern Nigeria, *International Journal of Cooperatives Studies*, 7(2), 22- 29.
70. Kehinde AD, Tijani AA (2021): Effect of Cooperatives Membership on Farmers' Preference for Improved Maize Variety Attributes in Oyo State, Nigeria. *Acta Sci. Pol. Agricultura*, 20(1), 3–15.
71. Kehinde AD, Tijani AA, Ogundeji A (2022a): The Effects of Farmers' Organization and Access to Credit on Farmers' Preference for Attributes of Improved Rice Varieties in Ekiti State, Nigeria. *Tropical and Subtropical Agroecosystems* 25: #014.
72. Kehinde MA, Akinola A, Kehinde AD, and Ogundeji AA (2022b): Agricultural Organisations and Adoption of Soil Conservation Practices among Smallholder Farmers in Oyo State, Nigeria. *Tropical and Subtropical Agroecosystems* 25: #125.
73. Khatri-Chhetri A, Regmi PP, Chanana N, Aggarwal P K (2020): Potential of climate-smart agriculture in reducing women farmers' drudgery in high climatic risk areas. *Climatic Change*, *158*(1), 29-42.
74. Kibue GW, Liu X, Zheng J, Zhang X, Pan G, Li L, Han X (2016): Farmers' perceptions of climate variability and factors influencing adaptation: evidence from Anhui and Jiangsu, China. *Environmental management*, *57*, 976-986.
75. Kivumbi CC, Yona C, Hakizimana JN, Misinzo G (2021): An assessment of the epidemiology and socioeconomic impact of the 2019 African swine fever outbreak in Ngara district, western Tanzania. *Veterinary and Animal Science*, *14*, 100198.
76. Kolapo A, Ogunleye AS, Kehinde AD, Adebanke AA (2021): Determinants of farmers' access to microcredit from cooperative societies in Ondo state, Nigeria. *International Journal of Agricultural Research, Innovation and Technology,* 11(2), 103-107.
77. Läderach P, Ramirez–Villegas J, Navarro-Racines C, Zelaya C, Martinez–Valle A, Jarvis A (2017): Climate change adaptation of coffee production in space and time. *Climatic change*, *141*(1), 47-62.
78. Lipper L, Zilberman D (2018): A short history of the evolution of the climate smart agriculture approach and its links to climate change and sustainable agriculture debates. *Climate smart agriculture: Building resilience to climate change*, 13-30.
79. Long JS (1997): Regression Models for Categorical and Limited Dependent Variables. Thousand Oaks, CA: Sage Press.
80. Lynch J, Cain M, Frame D, Pierrehumbert R (2021): Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO2-emitting sectors. *Frontiers in sustainable food systems*, *4*, 518039.
81. Maddala GS (1983): *Limited-dependent and qualitative variables in econometrics* (Vol. 149). Cambridge University Press.
82. Manda S, Matenga C, Mdee A, Smith R, Nkiaka E (2024): Challenges for expanding inventories of climate possibilities through indigenous and local knowledges in rural Zambia. *Journal of the British Academy*, *12*(3).
83. Mertz O, Halsnæs K, Olesen JE, Rasmussen K (2009): Adaptation to climate change in developing countries. *Environmental management*, *43*, 743-752.

84. Mirón IJ, Linares C, Díaz J (2023): The influence of climate change on food production and food safety. *Environmental Research*, *216*, 114674.
85. Møller AB, Mulder VL, Heuvelink GB, Jacobsen NM, Greve MH (2021): Can we use machine learning for agricultural land suitability assessment?. *Agronomy*, *11*(4), 703.
86. Moser SC, Ekstrom JA (2010): A framework to diagnose barriers to climate change adaptation. *Proceedings of the national academy of sciences*, *107*(51), 22026-22031.
87. Mukhwana LV, Luke Q, Delmas E, Otoi K, Hamerlynck O, Vandepitte L, Adkins B (2016): Carbon stocks of the terraces of the Lower Tana River floodplain and delta, Kenya, prior to conversion for biofuel production. *African Journal of Aquatic Science*, *41*(1), 119-125.
88. Mulwa C, Marenya P, Kassie M (2017): Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate risk management*, *16*, 208-221.
89. Ngigi MW, Bryan E, Claudia R, Birner R, Mureithi D (2012): Climate Change Adaptation in Kenyan Agriculture: Could Social Capital help. In *The 8 th AFMA Congress Theme:"Repositioning African Agriculture by Enhancing Productivity, Market Access, Policy Dialogue and Adapting to Climate Change* (pp. 35-48).
90. Nhemachena C, Hassan R (2007): Micro-level analysis of farmers adaption to climate change in Southern Africa. Intl Food Policy Res Inst.
91. Nyangena W, Sterner T (2009): Social capital and rural institutions in Kenya-Is Machakos unique?. *Chinese Business Review*, *8*(10), 1.
92. Nzeadibe TC (2015): Climate change adaptation in Nigeria: The role of community-based organizations. *Climate and Development*, *7*(3), 302-312.
93. Obasaju RU (2022): Financial Deepening and Agricultural Labour Productivity in Economic Community of West African States (2000–2017) (Master's thesis, Kwara State University (Nigeria)).
94. O'Brien K, Hayward B, Berkes F (2009): Rethinking social contracts: building resilience in a changing climate. *Ecology and society*, *14*(2).
95. Ogunleye AS, Kehinde AD, Kolapo A. (2020): Effects of Social Capital on Income of Cocoa Farming Households in Osun State. *Tanzania Journal of Agricultural Science*, 19(2), 131-137.
96. Ogunleye AS, Kehinde AD, Mishra A, Ogundeji A (2021): Impacts of Farmers' Participation in Social Capital Networks on Climate Change Adaptation Strategies Adoption in Nigeria. *Heliyon*, e08624
97. Ojo TO, Baiyegunhi LJS (2020): Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. *Land Use Policy*, *95*, 103946.
98. Okoli FN (2020): Trust and collective action: An analysis of social capital in climate change adaptation in rural Nigeria. *Climate and Development*, *12*(5), 412-421.
99. Olawuyi SO (2019): Building resilience against food insecurity through social networks: The case of rural farmers in Oyo State, Nigeria. *International Journal of Social Economics*, *46*(7), 874-886.
100. Olayide O (2021): Nigeria-Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
101. Olupona OT, Kehinde AD (2022): Economics of Bio-fortified Cassava Varieties (BCVs) adoption and its Gender Implication among Farmers in Oyo States. *Ghana Journal of Agricultural Science*. 57(1), 55-71.
102. Olupona OT Kehinde AD, Bamire AS (2023): Agricultural Cooperative Membership, Gender Gap, and Adoption of Biofortified Cassava Varieties in Nigeria. Scientia Agriculturae Bohemica, 54, 63-79. DOI:10.7160/sab.2023.540307.
103. Olusola JM, Adebayo AF, Aladejana MA (2018): The role of social capital in sustainable climate change adaptation practices in Nigeria. *Environmental Development*, *29*, 1-12.
104. Olweny PO (2016) A comparative study of financial condition and performance of islamic and non-islamic banks in Kenya (Doctoral dissertation, University of Nairobi).
105. Otitoju MA (2013): The effects of climate change adaptation strategies on food crop production efficiency in southwestern Nigeria. Publised Ph.D thesis submitted to the Department of Agricultural Economics, University of Nigeria, Nsukka.
106. Oyekale AS (2021): Climate change adaptation and cocoa farm rehabilitation behaviour in Ahafo Ano North District of Ashanti region, Ghana. *Open Agriculture*, *6*(1), 263-275.
107. Peprah JA, Afoakwah C, Koomson I (2020): Analysis of Crop Yield Volatility Among Smallholder Farmers in Ghana. In *Inclusive Green Growth: Challenges and Opportunities for Green Business in Rural Africa* (pp. 69-89). Cham: Springer International Publishing.

108. Phan LT, Jou SC, Lin JH (2019): Gender inequality and adaptive capacity: The role of social capital on the impacts of climate change in Vietnam. *Sustainability*, *11*(5), 1257.
109. Pretty J (2008): Agricultural sustainability: concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 447-465.
110. Pretty J, Smith D (2004): Social capital in biodiversity conservation and management. *Conservation biology*, *18*(3), 631-638.
111. Rao CS, Kareemulla K, Krishnan P, Murthy GRK, Ramesh P, Ananthan PS, Joshi PK (2019): Agro-ecosystem based sustainability indicators for climate resilient agriculture in India: A conceptual framework. *Ecological Indicators*, *105*, 621-633.
112. Saptutyningsih E, Diswandi D, Jaung W (2020): Does social capital matter in climate change adaptation? A lesson from agricultural sector in Yogyakarta, Indonesia. *Land use policy*, *95*, 104189.
113. Smit B, Skinner MW (2002): Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change*, *7*(1), 85-114.
114. Smith DM, Eade R, Scaife AA, Caron LP, Danabasoglu G, DelSole TM, Yang X (2019): Robust skill of decadal climate predictions. *Npj Climate and Atmospheric Science*, *2*(1), 13.
115. Stringer LC, Fraser ED, Harris D, Lyon C, Pereira L, Ward CF, Simelton E (2020): Adaptation and development pathways for different types of farmers. *Environmental Science & Policy*, *104*, 174-189.
116. Thamaga-Chitja JM, Tamako N (2017): Does social capital play a role in climate change adaptation among smallholder farmers for improving food security and livelihoods? J. Consum. Sci., 16–27.
117. Thornton PK, Herrero M (2015): Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. *Nature Climate Change*, *5*(9), 830-836.
118. Tsubo M, Fukai S, Basnayake J, Ouk M (2009): Frequency of occurrence of various drought types and its impact on performance of photoperiod-sensitive and insensitive rice genotypes in rainfed lowland conditions in Cambodia. *Field Crops Research*, *113*(3), 287-296.
119. Vatsa P, Ma W, Zheng H, Li J (2023): Climate-smart agricultural practices for promoting sustainable agrifood production: yield impacts and implications for food security. *Food Policy*, *121*, 102551.
120. Waaswa A, Oywaya NA, Mwangi KA, Ngeno KJ (2022): Climate-Smart agriculture and potato production in Kenya: review of the determinants of practice. *Climate and Development*, *14*(1), 75-90.
121. Wang C, Zhang L, Lee SK, Wu L, Mechoso CR (2014): A global perspective on CMIP5 climate model biases. *Nature Climate Change*, *4*(3), 201-205.
122. Yakubu DH, Shetima DA, Lawal MLMM, Abubakar HN, Ali MB (2022): Factors Affecting Use of Indigenous Climate Change Adaptation Strategies by Farmers in Wurno and Tambuwal Local Government Areas of Sokoto State, Nigeria. *Journal of Agricultural Extension*, *27*(1), 4-16.
123. Zakaria A, Alhassan SI, Kuwornu JK, Azumah SB, Derkyi MA (2020): Factors influencing the adoption of climate-smart agricultural technologies among rice farmers in northern Ghana. *Earth Systems and Environment*, *4*, 257-271.
124. Zizinga A, Mwanjalolo JGM, Tietjen B, Martins MA, Bedadi B (2024): Maize yield under a changing climate in Uganda: long-term impacts for climate smart agriculture. *Regional Environmental Change*, *24*(1), 34.