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Research Article

Perceived Effects of Climate Change on Farm Income: Insights from Smallholder Arable Crops Farmers in South-west Nigeria

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Abstract: Climate change presents significant challenges for smallholder arable crop farmers whose major livelihood revolves around agriculture. This is further worsened by farmers' poor awareness and limited knowledge of mitigating the associated risks with debilitating consequences on Farm Income. Therefore, this study investigated the perceived effects of climate change on farm income in South-west Nigeria, using cross-sectional data elicited from randomly selected 389 arable crop farmers. The data were analyzed using descriptive statistics, principal component analysis (PCA), and ordinary least square regression (OLS) technique. The results indicated that the farming population skewed towards older individuals, with an average age of approximately 55 years. Farmers were predominantly male, comprising 78.1% of the sample, who primarily derived their livelihood from agriculture, with 77.4% engaging in farming as their main occupation. Additionally, a significant portion of the farmers, accounting for 67.6%, possess secondary or higher education qualifications. Widely adopted coping practices include varying planting dates, multiple cropping, zero bush burning, crop rotation, irrigation, manure mulching, and cultivating drought/flood-tolerant varieties. Also, the estimates from the fitted OLS regression model revealed that farmers' knowledge and perception of climate change had significant relationships with farm income. Factors such as education, years of farming experience, farm size, access to extension services, social networks, access to climate change information, challenges on climate change mitigation, and coping strategies employed by the farmers were indicated to significantly influence farm income among the smallholder farmers in the study area. Therefore, the promotion of sustainable agricultural practices and bridging the knowledge-practice gap can strengthen farmers' adaptive capacity against climate change effects.

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1. Introduction

Agriculture is closely linked to climate factors and is vulnerable to extreme events caused by climate variability (Shaffril et al., 2017). Changes in rainfall patterns and the frequency of extreme climatic events, such as droughts, significantly threaten crop yields and harvests. Conversely, sustainable agriculture practices have the tendency to mitigate the effects of climate extreme events, for instance, by enhancing the carbon-sequestering capacity of soils through proper management practices (Deutsch et al., 2008). Understanding the interplay between climate change and agricultural production, as well as agri-food systems more broadly, is critical and important. Climate change is defined as the alteration in the statistical properties of the climatic system over a decade, irrespective of the cause (Bamigboye, 2016). It is widely recognized that human activities and other development activities have resulted in the pollution of the atmosphere with substantial amounts of carbon dioxide and other greenhouse gases, thereby contributing to climate change impacts (Lesley and Lalevie, 2019). These changes are impacting the climate and consequently leading to adverse effects on human health, public welfare, and ecosystems. Climate plays a crucial role in all aspects of agriculture, which has a direct influence on food production output and farm income. Farmers face such significant challenges and uncertainties due to shifting rainfall patterns, rising temperatures, prolonged droughts, flooding, desertification, erosion, crop failures, pest infestations, diseases, and other extreme climate events (Bamigboye, 2016).

Climate change poses a major challenge for arable crop farmers whose major livelihood activity is agriculture and is even worsened by their poor awareness and limited knowledge of mitigating the risks associated with its effects (Khatibi et al., 2021). Since 2008, the impact of climate change has been felt by the arable crop farmers in terms of heavy flooding and erosion, crop failure, infestation of pests and disease outbreaks, harsh weather conditions, and prolonged periods of drought and this has contributed to the challenges facing the agricultural sector in general. In the recent past, there has been a drastic decrease in the yield of cassava and maize production in Nigeria because of extreme weather conditions which result in low yield and reduced income among the arable crop farmers. These deep-seated and unresolved challenges are also worsened by arable crop farmers' poor access to resources, inequality, and marginalization in terms of development policy implementation by the government (Peng et al., 2023). This has also created diverse attitudes among arable crop farmers. With this in mind, this research intends to contribute towards a further understanding of farmers' coping mechanisms in terms of mitigating and adapting practices towards effects of climate change among arable crop farmers in South-west, Nigeria. This study seeks to provide answers to the following research questions: What are the coping strategies employed by the arable crop farmers to mitigate the effects of climate change? Do farmers' knowledge, attitude, and perception of climate change have any effect on farm income? And, what are the constraints to the implementation of coping practices against the effects of climate change? Likewise, the study hypothesized that there exists no relationship between farmers' knowledge, attitude and perception, and farm income.

Signs of changing climate are evident worldwide, with observations showing increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising sea levels (IPCC, 2014). This phenomenon may result in more variable weather, prolonged and intense heat waves, more frequent heavy precipitation, and extreme weather events like flooding (Lesley and Lalevie, 2019). The impact of climate change on human health was acknowledged relatively late in the development of climate science and policy. The necessity for societies to adopt adaptive mechanisms to guard humans and the environment from the adverse consequences of climate extreme events was strongly emphasized in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (Kabir et al., 2016). To ensure food availability, strategic adaptation interventions will be crucial over the next 20-30 years in less developed countries, such as Nigeria (Kabir et al., 2016). Additionally, climate change has led to the spread of pests and diseases, further threatening crop production and food security, while changes in temperature and humidity levels have equally created favorable conditions for the spread of certain pests and pathogens, leading to crop losses and increased costs for pest management (Emmanuel et al., 2024). Furthermore, the increased frequency and intensity of extreme weather events, such as heavy rains and floods, have also caused crop damage and soil erosion, further exacerbating the challenges faced by arable crop farmers (Abid et al., 2019). In support of the above submission, Ajala and Chagwiza (2024) also emphasized that climate variability, particularly changes in rainfall distribution and temperature extremes, has been identified as a significant factor affecting arable crop farmers' output and welfare outcome in a related study conducted in Nigeria. Different kinds of literature globally and in Nigeria have argued and underscored the importance of farmers' knowledge, attitude, and perception of the changing conditions of the climate which help facilitate the adaptation process (Olajide, 2014; Heriansyah et al., 2022; Mba et al., 2022). Specifically, in a study conducted by Olajide (2014) on the impacts of climate change on crop output and farmers' adaptation strategies. The findings revealed that while most farmers had a good understanding of climate events and their consequences, their adaptation practices were limited due to factors such as lack of access to credit, inadequate extension services, and limited resources. All these multiplicity of factors have a significant impact on farm productivity, farmers' income, and general welfare status in Nigeria.

Theoretically, this study was guided by the "theory of planned behavior", as described by Ajzen (1991 and 2002). This theory suggests that an individual's behavior is influenced by three main factors: attitudes, subjective norms, and perceived behavioral control. It posits that the intention to act, coupled with objective situational factors, directly impacts pro-environmental behavior. The intention reflects the "interaction of cognitive variables, including knowledge of action strategies and issues, action skills, and personality traits such as locus of control, attitudes, and personal responsibility."

2. Material and Methods

The study involved human participants and was approved by the Research Ethics and the Postgraduate Research Committees, Faculty of Agricultural Production and Management, College of Agriculture, Osun State University, Nigeria, on May 17, 2023.

The study area is the South-west region of Nigeria which features a tropical climate and is ideal for cultivating both crops and livestock. However, agricultural systems in this area are also vulnerable to the negative consequences of climate extreme events (Elum et al., 2017). Covering about 114 271 km^2 and constituting approximately 12% of Nigeria's landmass, this region comprises six states: Oyo, Osun, Ogun, Ondo, Ekiti, and Lagos. This study concentrated on Oyo and Osun states where favorable agroecological conditions support crop production, playing a significant role in their economies. Oyo State, located between latitudes 7.8°N and 3.9°E, spans 27 249 km^2 and shares borders with Ogun, Kwara, Osun, and the Republic of Benin (Oyo State Government, 2022). Agriculture remains central to Oyo's sustenance, employment, raw material supply, and revenue generation. Similarly, Osun State, with an estimated population of 4 435 800 in 2022 and a 1.6% annual growth rate (NPC, 2022), lies entirely within the tropics, bordered by Oyo, Kwara, Ondo, and Ogun states (Osun State Government, 2022). With 30 Local Government Areas and its capital in Osogbo, agriculture serves as a primary economic activity in Osun. Despite climate change challenges, the tropical climate and fertile lands in both states support diverse crop and livestock production.

A multi-stage sampling approach was utilized in the selection of research subjects (farmers). Initially (first stage), two states, namely Osun and Oyo were randomly chosen from the six Southwestern states of Nigeria because of the predominant farming activities in these areas. Subsequently, in the second stage, two comparable agroecological zones or what is known as Agricultural Development Program zones (ADPs)- forest and derived savanna were purposively selected in each of the two selected states, making 4 ADP zones in all. That is, in Osun State, Oshogbo and Ife/Ijesa ADP zones were chosen and these belong to derived savannah and forest ecological zones, respectively. Similarly, in Oyo State, Ibadan/Ibarapa and Saki ADP zones were selected and these also belong to the rainforest and derived savannah ecological zone, respectively. In the third stage, two (2) Local Government Areas (LGAs) were randomly selected from each of the 4 ecological (ADP) zones, making eight (8) LGAs in all. These are Olorunsogo, Oorelope, Ido, and Lagelu LGAs from Oyo State, while Atakumosa West, Ilesha East, Osogbo, and Olorunda LGAs were chosen from Osun State. Finally, in the fourth and last stage, a proportionate-to-size sampling technique was employed to select a sample size of 400 smallholder farmers because of the variation in the population of people across the villages in the selected LGAs in each of the two States. However, responses from only 389 farmers were deemed sufficient for the final analyses. In line with the research aims, a structured research instrument was used to elicit relevant information on the study objectives from the smallholder farmers in the study area.

2.1. Data analytical technique

The study applied frequency counts, percentages, and mean values to explore and describe the dataset. In addition, separate questions on farmers' knowledge, attitude, and perception of climate change were developed, and responses to these questions were subjected to principal component analysis (PCA) to generate separate indexes for each of these concepts (knowledge, attitude, and perception) which were included in the subsequent estimation process. PCA was also used to generate an index for climate information sources, coping strategies, and challenges in climate mitigation. Furthermore, the Ordinary Least Square (OLS) regression model was fitted to investigate the effects of farmers' knowledge, attitude, and perception, as well as other influencing dynamics on farm income.

2.1.1. Model specification

The ordinary Least Square (OLS) regression model is an inferential statistical technique that allows a more sophisticated exploration of the interrelationships among a set of explanatory variables and a response variable. The analysis of this type reveals how well a set of variables were able to predict an outcome, and which variable in the set of explanatory variables appears as the best predictor. It also shows if a particular variable is still able to predict an outcome when the effects of other variables are controlled for. For this study, a semi-log function of the OLS model was fitted, and this is specified as:

$$L_nY = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \dots\dots\dots\dots\dots\dots\dots\dots \beta_nX_n + \varepsilon_i \quad (1)$$

Where:
LnY = Dependent variable (natural logarithm of farm income).
X_i = Explanatory variables (i = 1, 2, 3, 4, ………………..n), and these are:
X_i = Index of knowledge (continuous)
X_i = Index of attitude (continuous)
X_i = Index of perception (continuous)
X_i = Gender (Male = 1, *0*, Otherwise)
X_i = Marital status (Married = 1, *0*, otherwise)
X_i = Age (years-continuous)
X_i = Family size (Actual number-continuous)
X_i = Educational status (No formal = 0, Primary = 1, Secondary = 2, Tertiary = 3)
X_i = Years of farming experience (Years-continuous)
X_i = Farm size (ha-continuous)
X_i = Frequency of extension visit (Actual number-continuous)
X_i = Social organization membership (member = 1, *0*, otherwise)
X_i = Index of climate information sources (continuous)
X_i = Index of climate coping strategies (continuous)
X_i = Index of challenges on climate mitigation (continuous)
β = Regression coefficient
α = Error term

3. Results

3.1. Personal and socio-economic characteristics of farmers

The results in Table 1 provide an exploration into the age distribution of arable crop farmers in the study area, shedding light on key socio-economic attributes vital for adapting to climate change in the agricultural sector. Findings revealed that the average age of farmers, recorded was 55 years, indicating an aging farming population, which aligns with Alao et al. (2014) who also reported the predominance of older individuals in arable crop farming in their related study conducted in Osun State, Nigeria. This suggests that older individuals are prominently involved in agricultural activities compared to younger counterparts, which is likely to be influenced by factors such as intergenerational land inheritance, economic constraints limiting youth involvement in agriculture, and cultural norms favoring older generations' participation in farming. Furthermore, technological barriers and limited educational access may deter younger individuals from pursuing agricultural endeavors, contributing to the observed demographic imbalance.

Moreover, the study underscores a notable gender gap, with 78.1% of respondents being male farmers, mirroring national trends where women make up only 24% of the agricultural labor force (Alo et al., 2017). Ensuring greater gender inclusivity in agriculture is crucial, especially considering the heightened vulnerability of female farmers to climate impacts and their pivotal role in securing household food supply (Adzawla et al., 2019). The majority of farmers (83.8%) were married and predominantly belonged to the Yoruba ethnic group (95.1%). The average family size of 8 members suggests the availability of family labor, a common feature in smallholder farming systems in Nigeria; this is in tandem with Danso-Abbeam et al. (2019) who also reported similar results in a related study conducted in Ghana. Conversely, larger household sizes may also increase susceptibility to climate shocks as also emphasized in a related study by Wan et al. (2016). Additionally, 67.6% of farmers have attained secondary education or higher; a significant finding as education levels are linked to understanding climate information, adopting adaptative strategies, and scaling up resilient practices (Kibue et al., 2016; Eneji et al., 2020). Consistent with the findings of Yaqoob et al. (2022), farming was indicated to be the primary occupation for about 77.4% of the sampled respondents, while the results also showed an average of 27.4 years of farming experience among the respondents. This suggests that farmers possess a substantial indigenous agricultural knowledge crucial for climate adaptation, which was also emphasized in Nyong et al. (2007). Overall, these socio-economic features mirror the personal and demographic composition and adaptive capacity of farmers within the study area.

Table 1. Farmers' selected personal characteristics (n=389)

Variables	Frequency	Percentage
Age of the farmers (years)		
≤ 35	3	0.77
36-45	56	14.40
46-55	157	40.36
56-65	118	30.33
Above 65	55	14.14
Mean = 55.1		
Gender of the farmers		
Female	85	21.9
Male	304	78.1
Marital status		
Single	10	2.6
Married	326	83.8
Divorced	16	4.1
Separated	14	3.6
Widowed	23	5.9
Religion		
Christianity	226	58.1
Islam	150	38.6
African Traditional believe	13	3.3
Ethnicity		
Igbo	7	1.8
Hausa	11	2.8
Yoruba	370	95.1
Others	1	0.3
Family size (persons)		
<5	69	17.7
6-10	282	72.5
11-15	34	8.7
Above 15	4	1.0
Mean = 8		
Educational status		
No formal education	38	9.8
Primary education	88	22.6
Secondary Education	146	37.5
Tertiary education	117	30.1
Primary occupation		
Farming	301	77.4
Non-farming	88	22.6

Source: Data analysis, 2024.

3.2. Farmers' adaptive response (coping) strategies ın relation to climate change effects

Table 2 provides a comprehensive overview of the various coping strategies adopted by arable crop farmers in Southwest Nigeria to mitigate the effects of climate change.

Table 2. Climate change coping strategies

Climate Change Coping Strategies	*Never (0)	*Rarely (1)	*Often (2)	*Always (3)
Varying the planting dates and period	2 (0.5)	56 (14.4)	68 (17.5)	263 (67.6)
Multiple cropping	1 (0.3)	46 (11.8)	81 (20.8)	261 (67.1)
Crop rotation	2 (0.5)	44 (11.3)	188 (48.3)	155 (39.9)
Shifting cultivation	2 (0.5)	52 (13.4)	215 (55.3)	120 (30.8)
Irrigation	2 (0.5)	32 (8.2)	227 (58.4)	128 (32.9)
Manure mulching	2 (0.5)	28 (7.2)	228 (58.6)	131 (33.7)
Nylon mulching	4 (1.0)	195 (50.1)	116 (29.8)	74 (19.0)
Digging Cut-off drainages	17 (4.4)	112 (28.8)	205 (52.7)	55 (14.1)
Cover cropping	3 (0.8)	98 (25.2)	190 (48.8)	98 (25.2)
Plough/ridge across the slope	8 (2.2)	149 (40.2)	128 (34.5)	86 (23.2)
Cultivate drought resistance varieties	1 (0.3)	109 (28.0)	200 (51.4)	79 (20.3)
Cultivate early maturing varieties	4 (1.0)	195 (50.1)	116 (29.8)	74 (19.0)
Cultivate windbreaker crops	3 (0.8)	176 (45.2)	100 (25.7)	110 (28.3)
Farm crop insurance	3 (0.8)	137 (35.2)	167 (43.0)	82 (21.0)
Flood tolerant varieties	15 (3.9)	60 (15.2)	256 (65.8)	58 (14.9)
Stop bush burning	20 (5.1)	64 (16.5)	265 (68.1)	40 (10.2)
Others	51 (13.1)	28 (7.2)	188 (48.3)	122 (31.4)

* - Multiple responses, Figures in parentheses are percentage values. Source: Data analysis, 2024.

The data reveals a diverse range of strategies employed by the farmers against climate extreme events, thereby reflecting the complexity and multidimensional nature of such adaptation mechanisms in agricultural systems. One of the most widely adopted strategies is varying planting dates and periods, with a substantial majority (67.6%) of arable crop farmers reporting that they "always" practice this approach. This finding aligns with the observations of Ojo and Baiyegunhi (2020), who noted that adjusting planting dates and periods is a common adaptation strategy among arable crop farmers in Southwest Nigeria to align their crop cycles with changing weather patterns and precipitation regimes. By carefully timing their planting activities, farmers can potentially optimize crop yields and minimize the impacts of extreme events. Similarly, multiple cropping emerged as another highly adopted strategy, with 67.1 percent of arable crop farmers indicating that they "always" engage in this practice. Multiple cropping, which involves cultivating two or more crops simultaneously or in sequence on the same piece of land, is widely recognized as an effective climate change adaptation measure in agricultural systems (Waha et al., 2020). This strategy not only enhances resilience by diversifying crop portfolios but also optimizes resource utilization and potentially increases overall productivity. Interestingly, a significant proportion (68.1%) of the arable crop farmers reported that they "always" practice zero bush burning, a strategy that contributes to reducing greenhouse gas emissions and mitigating climate change. This finding suggests a growing awareness among arable crop farmers in Southwest Nigeria about the negative impacts of bush burning on the environment and the need to adopt more sustainable agricultural practices (Ibrahim et al., 2015).

Furthermore, a substantial proportion of farmers "often" engaged in strategies such as crop rotation (48.3%), shifting cultivation (55.3%), irrigation (58.4%), manure mulching (58.6%), and cover cropping (48.8%). These practices are well-established as effective climate change adaptation measures, as they enhance soil health, water management, and crop productivity, thereby improving the overall resilience of agricultural systems to climate change impacts. Additionally, cultivating drought-resistant varieties (51.4%) and flood-tolerant varieties (65.8%) were commonly adopted strategies, reflecting the farmers' efforts in adapting to the changing conditions by selecting crop varieties that are better suited to withstand extreme weather events and environmental stresses. However, some strategies were less frequently adopted, with a substantial percentage of farmers "rarely" or "never" practicing nylon mulching (50.1% and 1.0%, respectively), cultivating early maturing varieties (50.1% and 1.0%, respectively), and cultivating windbreaker crops (45.2% and 0.8%, respectively). These strategies may face adoption barriers such as limited access to resources, lack of information, or perceived effectiveness in the local context (Akinnagbe and Anugwa, 2015). Notably, a considerable proportion of farmers "rarely" or "never" engaged in digging cut-off drainages (28.8% and 4.4%, respectively), plowing/ridging across the slope (40.2% and 2.2%, respectively), and farm crop insurance (35.2% and 0.8%, respectively). These strategies, which are often recommended for soil and water conservation, erosion control, and risk management, may face challenges to adoption such as labor availability, resource constraints, or limited awareness (Adel et al., 2015).

3.3. Effects of farmers' knowledge, attitude, and perception of climate change on farm income

Table 3 below presents the results of the fitted model to examine the effects of farmers' knowledge, attitude, and perception on farm income.

Table 3. Effects of farmers' knowledge, attitude, and perception of climate change on farm income

Variables	**Coefficient**	**Std. Error**	**t-value**	**P>|t|**
Index of knowledge	-0.0206***	0.0078	-2.63	0.009
Index of attitude	-0.0187	0.0135	-1.39	0.166
Index of perception	-0.0458***	0.0126	-3.63	0.000
Gender	0.0593	0.0629	0.94	0.346
Marital status	0.1209*	0.0719	1.68	0.094
Age	0.0026	0.0044	0.60	0.551
Family size	0.0079	0.0127	0.62	0.534
Educational status				
Primary	0.0912	0.0980	0.93	0.353
Post-primary (Secondary)	0.1918**	0.0925	2.07	0.039
Post-secondary (Tertiary)	0.0473	0.0981	0.48	0.630
Years of farming experience	0.0050	0.0039	1.28	0.203
Farm size	0.1824***	0.0187	9.71	0.000
Frequency of extension visit	-0.0111	0.0311	-0.36	0.720
Social organization membership	0.1311*	0.0678	1.93	0.054
Index of climate information sources	-0.0570***	0.0137	-4.16	0.000
Index of climate coping strategies	0.0317*	0.0181	1.74	0.082
Index of challenges on climate mitigation	-0.0480***	0.0138	-3.48	0.001
Constant	12.2989***	0.2369	51.92	0.000

R-squared = 0.6853; Adjusted R-squared = 0.6572.
* - 10%, ** - 5%, and *** - 1%.
Source: Data analysis, 2024.

The coefficients indicate the direction and strength of the relationships between the fitted independent variables, and the dependent variable, which is the farm income expressed in logarithm form. The results produced an adjusted R-squared value of 0.6572 which suggests that approximately 65.7% of the variation in the response (dependent) variable is explained by the explanatory (independent) variables, while the rest is accounted for by the noise (error) term. Considering the variables' estimates in the fitted model, except for the index of farmers' attitude towards climate change, the findings revealed that indexes of farmers' knowledge and perception about climate change have inverse and statistically significant relationships (both at a 1% probability level) with the farm income, suggesting that increase in these variables induces a decrease in farm income. Similarly, the negative and statistically significant coefficients (both at 1% probability level) associated with the indexes of climate information sources and challenges on climate change mitigation respectively suggest that facing greater difficulties in accessing information channels on climate change and implementing climate change mitigation strategies by farmers will induce a decrease in farm income, which is in line with Shikuku et al. (2017). These challenges include a lack of resources, limited access to information, or inadequate support systems, which can exacerbate the perceived impacts of climate change. In the same vein, the frequency of extension visits had an inverse but insignificant relationship with farm income, suggesting that any increase in the number of visits by the extension agents induces a lower farm income, which is unexpected. In line with a-priori expectations, frequent interaction with extension agents is expected to facilitate knowledge exchange and learning of new and improved arming systems, but the reason for this deviation could be attributed to the likely inefficient extension service delivery in the study area.

Conversely, the results indicated that being a male and married farmer (statistically significant at a 10% probability level) induces a higher farm income, while an increase in the age of the farmers and the family size also leads to an increase in farm income. Likewise, farmers having moderately higher levels of education, particularly post-primary (secondary) education (which is statistically significant at a 5% probability level) are inclined to have increased farm income. This could be attributed to their proper understanding of climate change and its potential consequences. Similarly, the positive coefficients of years of farming experience and farm size (which is statistically significant at a 1% probability level) imply that farmers with more years of farming experience and cultivated land hectarage are positioned to induce an increase in farm income, all things being equal. This result is in line with a similar study conducted by Burnham and Ma (2018). Furthermore, the positive coefficients for the social organization membership highlight the importance of access to information and social networks in shaping farmers' perceptions of climate change impacts which by extension can lead to increased farm income. In the real sense, participation in social organizations and/or local-level institutions can facilitate the exchange of knowledge and experiences related to climate change and induce a positive effect on agricultural production output and farm income.

Given all the findings, the implication is that several dynamics such as farmers' knowledge and perception about climate change, marital status, farm size, education (human capital), and social organization membership (social capital) have a significant influence on farm income.

3.3.1. Post estimation tests

The results of the post-estimation tests on multicollinearity were presented in Table 4, while the Ramsey regression specification-error test result (also known as Ramsey RESET test) which is another post-estimation test designed to investigate if there are omitted variables or not, was also indicated below. Here, the null hypothesis is that the model has no omitted variables, and from the result, it is clear that the model has no omitted variables, given the significant status of the *F*-statistics.

Table 4. Test of multicollinearity

Variable	Variance Inflation Factor (VIF)	Tolerance (1/VIF)
Index of knowledge	1.77	0.5633
Index of attitude	1.79	0.5599
Index of perception	1.69	0.5919
Gender	1.09	0.9168
Marital status	1.13	0.8833
Age	2.30	0.4343
Family size	1.45	0.6874
Primary	2.71	0.3689
Post-primary (Secondary)	3.24	0.3091
Post-secondary (Tertiary)	3.26	0.3063
Years of farming experience	2.44	0.4102
Farm size	1.27	0.7879
Frequency of extension visit	1.24	0.8085
Social organization membership	1.12	0.8967
Index of climate information sources	1.31	0.7629
Index of climate coping strategies	1.88	0.5325
Index of challenges on climate mitigation	1.27	0.7851
Mean VIF	1.82	

Source: Data analysis, 2024.

Ramsey regression specification-error test for omitted variables: Ramsey RESET test using powers of the fitted values of the natural logarithm of farm income.

Null hypothesis (H_o): There are no omitted variables in the model

F (3, 368) = 5.32

$Prob > F$ = 0.0013

Furthermore, to ascertain the reliability of the OLS model, the degree of multicollinearity among the fitted explanatory variables was tested using the variance inflation factors (VIF) test, as a post-estimation. In agreement with the guideline provided in Marquardt (1970) on the usage of variance inflation factors vis-à-vis tolerance level for a diagnostic measure, which was further expatiated by Midi and Bagheri (2010), the post-estimation result presented in Table 4.30 indicated that the values of variance inflation factor (which range between 1.09 and 3.26), and the overall mean VIF were significantly below 10. This suggests that there is no significant evidence of multicollinearity problems. Since the diagnostic tests on the explanatory variables revealed no evidence of multicollinearity, and there is no issue concerning the model, it is, therefore, safe to infer that the fitted regression model is reliable and robust.

3.3.2. Test of hypothesis

The findings from Pearson's product-moment correlation fitted to investigate if there is an association between farmers' knowledge, attitude, and perception as well as farm income indicated a weak negative correlation between farmers' knowledge, attitudes, and perception of climate change and farm income. The associations between these three concepts and farm income were statistically significant (r = -0.1485, $p<0.01$; r = -0.2032, $p<0.01$; and r = 0.1340; $p<0.01$) in that sequence, respectively. This means that the knowledge acquired by the farmers, the attitude developed towards climate change events, as well as their perception of climate change significantly influence farmers' income. Although the associations appeared weak, this further indicates that with adequate knowledge acquired by farmers on climate change, having strong and positive attitudes towards climate change, and developing strong perception about climate change extreme events, there is an opportunity to change the narrative by increasing the production output and farm income, all things have been equal.

Table 5. Association between farmers' perceived effect of climate change and production output

	Knowledge	Attitude	Perception	Log of total income
Knowledge	1.0000	-	-	-
Attitude	0.5134*	1.0000	-	-
Perception	0.2431*	0.2009*	1.0000	-
Log of total income	-0.1485*	-0.2032*	-0.1340*	1.0000

* - 10%, ** - 5%, and *** - 1% .
Source: Data analysis, 2024.

4. Discussion

The relationship between farmers' personal and socio-economic factors, as well as how farmers' knowledge, attitude, and perception of climate change impact farm income and farmers' ability to cope with climate change extreme events is complex and multidimensional in nature. In agreement with Alao et al. (2014), younger farmers tend to be more adaptable, innovative, and willing to adopt new technologies, which can lead to higher farm productivity and income. Older farmers, on the other hand, may rely on traditional farming methods and be more risk-averse, potentially resulting in lower income. Younger farmers may be more responsive to adopting climate-resilient practices, such as crop diversification, conservation agriculture, and improved water management. Older farmers might even have more experience but could be less likely to change long-established practices, which might limit their ability to cope with climate extreme events. Gender also plays a significant role in farm income, as women farmers often have limited access to resources, credit, land, and technology compared to their male counterparts. Such disparity can potentially result in lower productivity and income for female farmers. This observation appears to agree with what Alo et al. (2017) and Adzawla et al. (2019) reported in their separate but related studies conducted in Nigeria and Ghana respectively. Gender-based factors can also influence access to information, decision-making power, and participation in community-based climate adaptation programs. Women may face greater challenges in coping with climate change due to cultural norms, lower access to resources, and higher vulnerability to climate impacts.

Likewise, married farmers may benefit from shared responsibilities, labor, and resources, which can enhance farm productivity and income. Single or widowed farmers might face labor constraints and have less access to capital, leading to lower income. Importantly, marital status can also affect a farmer's social support network. Married farmers may have stronger support systems, which can provide resilience during extreme events. Single farmers might lack such support, making it harder to cope with climate challenges. In terms of family size, larger family sizes can provide more labor, potentially leading to higher farm productivity and income, as also highlighted by Danso-Abbeam et al. (2019) in a study conducted in Ghana. However, they can also increase the household's dependency ratio, which might strain resources and reduce overall income per capita. Larger families may have more hands to help in implementing climate adaptation strategies, such as constructing water harvesting systems or diversifying crops. Conversely, larger households may also have higher food and resource needs, making them more vulnerable during climate-induced food shortages which was equally emphasized by Danso-Abbeam et al. (2019). Education is an important human capital and plays a crucial role in enhancing farm income. Educated farmers are more likely to adopt modern agricultural practices, use improved inputs, and access information on market trends, leading to higher productivity and income. In addition, education enhances a farmer’s ability to understand and implement climate-resilient practices. Educated farmers are more likely to access climate-related information, engage in sustainable farming practices, and participate in training programs, which strengthens their ability to cope with climate change. This observation is also consistent with what Kibue et al. (2016) and Eneji et al. (2020) discussed in their separate but related studies in China and Nigeria, respectively.

Furthermore, farmers’ knowledge, attitude, and perception of climate change significantly influence both farm income and their ability to cope with extreme weather events. In agreement with Kabir et al. (2016) and Elum et al. (2017), these factors play a critical role in shaping how farmers respond to the challenges posed by climate change, including their willingness to adopt adaptive strategies, invest in resilient farming practices, and engage with information and technology that can help mitigate risks. For instance, farmers who are knowledgeable about climate change and its impacts are more likely to implement adaptive strategies, such as selecting drought-resistant crops or altering planting schedules, which can protect and enhance farm income. Positive attitudes toward innovation and change are also crucial for sustaining income levels in a changing climate. Apparently, knowledge of climate change equips farmers with the ability to anticipate and prepare for extreme events. Farmers with a positive attitude and perception of climate change are more likely to participate in community adaptation programs, adopt sustainable practices, and seek information and resources to build resilience.

These three important factors (knowledge, attitude, and perception) are deeply interconnected in the sense that farmers’ knowledge of climate change shapes their attitude towards it, which in turn influences their perception of the risks and opportunities presented by climate change. Together, these factors determine how farmers approach decision-making, risk management, and adaptation strategies, all of which have direct and indirect impacts on farm income and resilience to extreme weather events. As stressed by Peng et al. (2023), a well-informed farmer with a positive attitude and a strong perception of climate change risks is more likely to invest in sustainable practices that protect both their income and their long-term viability. Conversely, a farmer with limited knowledge, a negative attitude, and a weak perception of climate risks may be less inclined to take necessary actions, leaving them more vulnerable to income loss and less capable of coping with extreme events.

In all, this is to say that farmers’ knowledge, attitude, and perception of climate change are critical determinants of both their economic outcomes and their resilience to extreme weather and unexpected events. Therefore, enhancing farmers’ understanding of climate change, fostering positive attitudes towards adaptation, and strengthening the perception of climate risks can significantly improve farm income and build the capacity of farming communities to withstand and recover from climate-induced challenges. Addressing these factors through education, extension services, and community engagement is essential for promoting sustainable agriculture in the face of climate change.

Conclusion and Recommendations

This study investigated the perceived effects of climate change on farm income among arable crop farmers in South-west Nigeria. Findings revealed that farmers with higher levels of knowledge and informed perceptions about climate change tend to have lower incomes, which invariably suggests low production outputs. This is contrary to expectations, and a plausible reason for this could be a result of a lack of seamless interoperability among the stakeholders in disseminating timely information to the smallholder farmers. This finding suggests a potential disconnect between farmers’ theoretical understanding and their practical implementation of adaptation strategies. More so, farmers’ knowledge, and perception, as well as marital status, formal education status, farm size, social organization membership, sources of climate information, coping strategies, and challenges confronting climate mitigation efforts were identified as key and significant drivers of of farm income in the study area. These findings underscore the need for targeted interventions to enhance farmers' adaptive capacity and resilience. Therefore, smallholder arable crop farmers should be encouraged to promote sustainable agricultural practices that enhance resilience to climate change impacts through mass enlightenment.

Ethical Statement

The dataset used in this research titled: "Perceived Effects of Climate Change on Farm Income: Insights from Smallholder Arable Crops Farmers in South-west Nigeria" was elicited from the research participants in line with standard ethical practices, and as highlighted in the Helsinki's declaration on research guidelines, which are: "anonymity, informed consent, privacy, confidentiality, and professionalism". The study was also approved by the Research Ethics and the Postgraduate Research Committees, Faculty of Agricultural Production and Management, College of Agriculture, Osun State University, Nigeria.

Conflict of Interest

The authors declared that there are no conflicts of interest.

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Author Contributions

Ayinla Rasheed Ayodele: Conceptualization, methodology, data analysis, and writing of original draft; Alao Oluwagbenga Titus: Conceptualization, methodology, supervision; Adesoji Solomon Adedapo: Conceptualization, methodology, supervision; Ayinla Rachael Ajibola: Data collection, data curation, and writing - review and editing; Olawuyi Seyi Olalekan: Methodology, data curation, data analysis and writing- review and editing.

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