

Climate Smart Agricultural Practices Adoption and Its Impacts on Female Farmers in South West, Nigeria

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Abstract This research investigates the adoption of Climate-Smart Agricultural Practices (CSAPs) and its effects on female farmers in South West Nigeria. This research examines the extent of Climate-Smart Agricultural Practices (CSAP) adoption in a region susceptible to climate variability. It focuses on the determinants influencing adoption decisions and the resulting impacts on productivity and income, giving particular attention to the pivotal role of women in food production. Primary data were collected from 480 randomly chosen female farmers across the study area utilizing a multistage sampling method. Descriptive statistics, Probit regression, and the Endogenous Treatment Effect Model (ETEM) were employed to analyze the data. Findings revealed that access to extension services, education, and land ownership substantially affect adoption decisions. Moreover, individuals who adopted CSAPs exhibited increased productivity and income levels in comparison to those who did not adopt them. The study found that improving women's access to agricultural training, credit resources, and technology is essential for increasing the adoption of CSAP. Policy implications suggest that focused initiatives advocating for gender-sensitive climate resilience techniques can enhance food security and mitigate rural poverty.

Keywords: Climate-Smart Agriculture, Female Farmers, Adoption, Treatment Effect, South West Nigeria

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1. Introduction

Agriculture is a fundamental component of Nigeria's economy, accounting for about one-third of the gross domestic product (GDP) and providing employment for over 70% of the rural labor force [1]. The sector is confronted with escalating threats from climate variability and change, evident in irregular rainfall patterns, extended dry periods, flooding, and increasing temperatures. Environmental shocks negatively impact agricultural productivity, food security, and rural livelihoods [2,3]. Female farmers, constituting a significant portion of Nigeria's smallholder population, face heightened vulnerability to risks stemming from structural gender barriers. These barriers include limited land rights, restricted access to extension services and credit, smaller farm sizes, and lower levels of mechanization [4,5]. Climate-Smart Agriculture (CSAP) has emerged as an integrated approach to address vulnerabilities by increasing productivity, enhancing resilience (adaptation), and reducing greenhouse gas emissions where feasible (mitigation) [6]. Practices associated with CSAP

encompass conservation agriculture, crop diversification, agroforestry, efficient irrigation, the utilization of drought-tolerant seed varieties, and techniques for soil and water management. These practices hold significant potential for female farmers in Nigeria, enhancing productivity, food security, and resilience to climate shocks [7,8]. Empirical evidence increasingly demonstrates that Climate-Smart Agriculture (CSAP) serves as an effective approach for rural transformation. Environment, Development and Sustainability (2024) reported that the adoption of Climate-Smart Agriculture practices in Nigeria improved household dietary diversity and decreased food insecurity. [8] observed that CSAP adoption was progressively rising in Southeastern Nigeria; however, gender disparities remained, with women trailing men in terms of both awareness and adoption intensity. [9] found a significant correlation between female empowerment through education, cooperative membership, and access to extension and increased rates of CSAP adoption.

Female farmers are essential to the agricultural economy of South-West Nigeria, significantly impacting household food security, income generation, and rural livelihoods. The region, which includes Lagos, Ogun, Oyo, Osun, Ondo, and Ekiti States, features a humid tropical

climate and bimodal rainfall patterns conducive to various crop production systems. Women in this region actively participate in the cultivation of both food and cash crops, such as maize, cassava, yam, vegetables, and cocoa [5]. Female farmers encounter significant systemic challenges, including restricted access to land, credit, modern inputs, and extension services [10,11]. Cultural norms and gender-based disparities limit women's involvement in decision-making processes concerning agricultural technology adoption and farm management [12]. Research indicates that women typically manage smaller landholdings and depend more on rainfed agriculture, rendering them disproportionately susceptible to the negative effects of climate change [13]. The presence of these vulnerabilities, along with reduced educational attainment and limited asset ownership, restricts the capacity to implement climate-smart agricultural practices [14]. Recent years have seen numerous national and regional initiatives aimed at providing training and resource support to women farmers through the Agricultural Transformation Agenda and comparable programs. Adoption rates of climate-smart innovations, including drought-tolerant seeds, efficient irrigation systems, and soil conservation practices, are modest. This is attributed to high input costs, knowledge gaps, and weak institutional linkages [15]. Addressing gendered barriers is crucial for improving agricultural productivity, enhancing resilience to climate shocks, and promoting equitable development in the South-West region. These studies emphasize that gender significantly influences the adoption and advantages of CSAP technologies. Notwithstanding these findings, the adoption of CSAP among female farmers in Southwestern Nigeria continues to be limited. Structural inequalities persistently restrict access to productive resources, technical knowledge, and decision-making autonomy. The region possesses significant potential due to its relatively developed infrastructure, proximity to markets, and established cooperative systems. There is a lack of empirical research that quantitatively assesses the impact of Climate-Smart Agriculture (CSAP) adoption among female farmers through causal econometric methods like Propensity Score Matching (PSM) or Endogenous Treatment Effect Models. This study seeks to address the existing gap by (i) assessing the level of Climate-Smart Agriculture (CSAP) practice adoption among female arable farmers in Southwest Nigeria; (ii) identifying the socio-economic and institutional factors influencing CSAP adoption; and (iii) evaluating the causal effects of CSAP adoption on agricultural productivity and income. The findings offer insights pertinent to policy formulation for the development of gender-responsive interventions aimed at fostering sustainable agricultural transformation, enhancing climate adaptation, and advancing women's economic empowerment in Nigeria.

2. Problem Statement

Female farmers in South-West Nigeria play a crucial role in household food security; however, they encounter significant climate risks and possess limited capacity for adaptation. Gender disparities in resource access,

encompassing land, inputs, credit, and information impede the adoption of enhanced agricultural technologies [16]. As a result, women's agricultural productivity is considerably lower than that of men, which intensifies income inequality and rural poverty. Despite the introduction of CSAPs within Nigeria's agricultural transformation agenda, there is a paucity of empirical evidence regarding their adoption and welfare effects on female farmers. This research examines the determinants and welfare implications of CSAP adoption through rigorous econometric analysis.

3. Literature Review

Empirical research demonstrates that socio-economic factors, such as age, education, family size, and agricultural experience, influence the adoption of climate-smart technologies [17,18]. Moreover, access to extension services and involvement in cooperatives are crucial for the dissemination of technology [19]. [20] established that climate adaptation techniques in Nigeria improved productivity and reduced vulnerability, whereas [21] emphasized the need of gender-sensitive initiatives. However, scant research has focused on female farmers in the South-West geopolitical zone, underscoring the need for customized policy insights. Research in South-West Nigeria indicates that smallholder farmers implement a blend of Climate-Smart Agricultural Practices (CSAPs) customized to their specific agro-ecological contexts. Standard techniques encompass modified planting schedules, crop diversification, enhanced seed varieties, residue management, contour farming, ridging, agroforestry, and small-scale irrigation [21,22].

Adoption is seldom a straightforward binary decision; farmers frequently utilize various tactics. Adoption intensity, defined as the number of CSAPs implemented simultaneously, has been shown to predict welfare outcomes better than the adoption of single practices [23]. Various socioeconomic and institutional issues affect the execution of CSAPs in Nigeria. Education, farm size, access to credit, extension services, tenure security, and perception of climate risk often act as critical predictors [23,20]. Gender profoundly influences nearly all of these determinants. Female farmers generally oversee smaller land parcels, exhibit reduced literacy levels, and are less frequently in possession of land titles, thereby restricting their access to loans secured by collateral. Domestic obligations create labor and time limitations that hinder the adoption of labor-intensive climate-smart agriculture practices, such as terracing and agroforestry. Institutional considerations exacerbate these issues. In many regions of South-West Nigeria, extension networks are predominantly male-dominated, and training dates frequently conflict with women's availability. As a result, female farmers depend more on informal information networks, potentially restricting their access to technical information regarding new technologies [24].

Financial exclusion is significant: women's access to formal financing is markedly inferior to that of men, hindering investments in irrigation or enhanced seed types. Impact assessments employing cross-sectional and quasi-experimental approaches generally demonstrate that the

implementation of CSAP increases farm productivity and revenue, with differences in the extent of enhancement depending on individual practices and gender. [22] utilized an endogenous switching regression model to demonstrate that the adoption of soil and water conservation methods significantly enhanced rice yields and farm revenue in South-West Nigeria. Research indicates that the utilization of improved seeds and crop diversity increases production stability and strengthens income resilience. Female farmers frequently experience reduced revenue development owing to limited farm sizes and constrained market access. Climate-Smart Agricultural Practices (CSAPs) that diversify cropping systems and adjust planting schedules enhance family food availability and stability [21]. Women, primarily responsible for household food procurement, receive immediate improvements in nutritional diversity and reductions in seasonal hunger through these behaviors. The benefits depend on women's authority over production decisions and market outcomes. CSAPs may augment empowerment by elevating women's decision-making authority and control over agricultural resources, as well as income. Research in Sub-Saharan Africa, particularly in Nigeria, indicates that climate-smart agriculture initiatives might effectuate gender transformation when they emphasize training and finance access for women [25]. Neglecting gender in adoption initiatives perpetuates inequality, as evidenced by instances when men benefit from mechanization while women's burdens intensify without equivalent improvements in autonomy. Adoption studies in Nigeria utilize several analytical approaches. Binary logit and probit models are employed for individual practice analysis, whereas multivariate probit models tackle the concurrent adoption of interconnected CSAPs. Intensity models, such as Poisson and negative binomial, quantify the number of adopted practices.

Researchers employ strategies such as Propensity Score Matching, Endogenous Switching Regression, and Instrumental Variable methods to address self-selection bias [22,23]. Gender is integrated via interaction terms or by estimating distinct models for male-led and female-led households. A significant methodological disadvantage is the lack of panel data, which restricts the capacity to assess long-term resilience or income impacts. Moreover, there is a dearth of research that measures non-economic benefits, such as time allocation, empowerment, and nutritional effects, which are especially pertinent to women's welfare. Notwithstanding the expanding corpus of literature, many deficiencies remain. There is an absence of causal, gender-disaggregated evidence about the long-term welfare impacts of CSAPs in South-West Nigeria. The interplay of CSAPs, especially the impact of simultaneous implementation of several practices on female farmers, has not been adequately researched. A scarcity of implementation and design research evaluates gender-responsive extension and credit distribution strategies. A weakness is present in longitudinal analyses centered on inter-seasonal resilience and asset accumulation. Addressing these gaps requires the implementation of mixed-methods approaches that combine quantitative effect evaluation with qualitative gender analysis.

4. Methodology

The study employed a multistage sampling technique to select 480 female farmers across six states in South West Nigeria. Primary data were collected using structured questionnaires. Descriptive statistics characterized the respondents, while a Probit model analyzed the factors influencing CSAP adoption. The Endogenous Treatment Effect Model (ETEM) was utilized to assess the causal influence of CSAP adoption on productivity and income. The ETET mitigates selection bias by simultaneously estimating the adoption decision and the outcome equations.

4.1. Study Area

The study was conducted in South-West Nigeria, comprising six states: Lagos, Oyo, Ogun, Osun, Ondo, and Ekiti. The region lies between latitudes 6°N and 9°N and longitudes 2°E and 6°E, with an estimated population exceeding 35 million. The area experiences a humid tropical climate characterized by a bimodal rainfall pattern (March–July and September–November) and average annual rainfall of 1,500–2,500 mm. Agriculture is dominated by food crops such as cassava, maize, yam, plantain, and vegetables. Female farmers are actively involved in crop cultivation, processing, and marketing but face limitations due to land tenure systems and socio-cultural barriers [26].

4.2. Sampling Technique and Data Collection

A multistage sampling technique was employed. In the first stage, three states (Oyo, Ogun, and Ondo) were randomly selected from South-West Nigeria. In the second stage, two agricultural zones were selected from each state. In the final stage, 80 female farmers were randomly sampled from each zone, giving a total of 480 respondents. Structured questionnaires were used to collect primary data on socio-economic characteristics, adoption of CSAPs, and income levels.

4.3. Analytical Framework

4.3.1. Probit Model Specification

The Probit model was used to analyze the likelihood of female farmers adopting climate-smart agricultural practices (CSAPs) in Southwest Nigeria. The model posits the presence of an unobserved latent variable (Y^*) that indicates the farmer's inclination to adopt CSAPs. The relationship is expressed as follows:

$$Y^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \mu$$

Here, Y^* is the latent (unobserved) variable. The observed binary variable (Y) takes the value 1 if the farmer adopts CSAPs and 0 otherwise.

$$Y = 1 \text{ if } Y^* > 0; \quad Y = 0 \text{ otherwise}$$

The probability that a farmer adopts CSAPs is given as:

$$P(Y = 1 | X) = \Phi(X'\beta)$$

Where, Φ = cumulative distribution function (CDF) of the standard normal distribution,

β = vector of parameters to be estimated, and

X is a vector of explanatory variables such as age, education, household size, farm size, income, and access to extension services.

4.3.2. Treatment Effect Model Specification

The Treatment Effect Model (TEM) was employed to assess the impact of adopting climate-smart agricultural practices on the income of female farmers. This method addressed potential selection bias resulting from both observed and unobserved variables.

The model is specified in two stages:

1. Selection Equation (Adoption Decision):

$$A_i^* = Z_i\gamma + u_i$$

$$A_i = 1 \text{ if } A_i^* > 0; A_i = 0 \text{ otherwise}$$

Where A_i^* is the latent adoption variable, Z_i is a vector of explanatory variables influencing adoption, γ is a parameter vector, and u_i is an error term.

2. Outcome Equation (Impact of Adoption):

$$Y_i = X_i\beta + \delta A_i + \varepsilon_i$$

Where Y_i = outcome variable (e.g., farm income),

X_i is a vector of control variables,

A_i is the treatment (adoption) indicator,

δ captures the treatment effect, and ε_i is the error term.

The Average Treatment Effect on the Treated (ATT) is estimated as:

$$ATT = E(Y_{1i} - Y_{0i} | A_i = 1)$$

Where Y_{1i} is the potential outcome if the farmer adopts CSAPs, and Y_{0i} is the potential outcome if not.

4.3.3. Description of Variables Used in the Probit Model

This table presents a summary of the variables proposed to affect the likelihood of CSAP adoption among female farmers. Socioeconomic factors, including education, farm size, and extension contact, are anticipated to positively affect adoption decisions. Conversely, distance to market and limited access to credit may decrease the likelihood of adoption. This has also been established by some researchers like [6,18,27,28] [29,30,31] [32,33,34] in their work.

Table 1. Description of Variables Used in the Probit Model

Variable	Description	Measurement	Expected Sign
Adopt (Dependent Variable)	Adoption of Climate Smart Agricultural Practices (CSAP)	1 = Adopted, 0 = Not adopted	
Age	Age of the female farmer	Years	±
Educ	Years of formal education attained	Number of years	+
Hh_Size	Number of persons in the household	Number	±
Farm_Size	Total land cultivated by the farmer	Hectares	+
Income	Annual farm income	Naira (₦)	+
Access_Ext	Access to extension services	1 = Yes, 0 = No	+
Credit	Access to credit facilities	1 = Yes, 0 = No	+
Coop	Membership in a cooperative society	1 = Member, 0 = Not a member	+
Awareness	Awareness of climate-smart practices	1 = Yes, 0 = No	+
Marital	Marital status of the respondent	1 = Married, 0 = Otherwise	+
Farm_Exp	Years of farming experience	Years	+
Dist_Market	Distance to nearest market	Kilometers	−

4.4. Method of Data Analysis

Descriptive statistics, including frequencies and percentages, were employed to summarize socio-economic characteristics. The Probit model analyzed factors affecting CSAP adoption, whereas the Treatment Effect Model evaluated its impact on income. All analyses were performed utilizing Stata 17.

5. Results and Discussion

5.1. Socio-Economic Characteristics of Female Farmers

Table 2 presents the socio-economic characteristics of 480 female farmers surveyed in South-West Nigeria. The results showed that 48.9% of respondents were within the age range of 40 to 59 years, indicating a significant presence of middle-aged women engaged in agricultural activities in the region. This demographic is generally considered active, experienced, and skilled in the adoption of innovative practices. [17] identified similar age

distribution patterns in their study on gendered climate-smart agriculture adoption in Nepal, observing that middle-aged farmers demonstrated a higher responsiveness to new technologies. The level of education has a substantial impact on adoption behavior. The findings reveal that around 60.4% of respondents had attained at least secondary education, suggesting a comparatively elevated literacy rate among female farmers in South-West Nigeria relative to national rural averages. Educated farmers exhibit improved abilities to analyze agricultural information, engage in training, and understand the long-term benefits of climate-smart practices [18]. Furthermore, 54.2% of farmers operated on land ranging from 1 to 3 hectares, categorizing them as small to medium-scale producers. This aligns with the general framework of smallholder agriculture in Nigeria. Limited landholdings can restrict economies of scale, especially in the execution of resource-intensive CSAPs [35]. Access to institutional resources significantly influences adoption. Over 56% had access to credit, while 64.6% utilized extension services. The results suggest that the institutional environment in the study area is moderately supportive, although gaps remain. [19] and [36]

emphasized the critical importance of extension services and access to credit in enhancing technology adoption and resilience to climatic stresses. The socio-economic characteristics reveal a population with moderate educational attainment, constrained land resources, and improved institutional access, all of which influence the capacity and willingness to adopt climate-smart agricultural practices.

Table 2. Socio-Economic Characteristics of Female Farmers

Variable	Category	Frequency	Percentage (%)
Age (years)	20–39	155	32.3
	40–59	235	48.9
	≥60	90	18.8
Education	No formal	75	15.6
	Primary	115	24.0
	Secondary	170	35.4
	Tertiary	120	25.0
Farm size (ha)	<1	110	22.9
	1–3	260	54.2
	>3	110	22.9
Access to credit	Yes	270	56.3
	No	210	43.7
Extension contact	Yes	310	64.6
	No	170	35.4

Source: Field survey (2025)

5.2. Probit Estimates of Factors Influencing CSAP Adoption

The Probit model was used to analyse the factors influencing CSAP adoption among female farmers as seen in Table 3. The findings demonstrate that education level, farm size, credit access, extension contact, and cooperative membership are statistically significant at the 5% level. Education demonstrates a positive and significant coefficient (0.310; $p=0.001$), indicating that educated female farmers are more inclined to adopt CSAPs. This supports the assertion by [16] that education improves the capacity to understand and utilize innovative technologies. [17] similarly found that female farmers with higher education levels exhibited greater responsiveness to sustainable agricultural techniques. The size of the farm exhibits a positive correlation ($\beta = 0.225$; $p=0.002$), indicating that farmers with larger landholdings are more inclined to adopt Climate-Smart Agricultural Practices (CSAPs), likely due to enhanced financial and physical resources that facilitate experimentation with new technologies. Access to credit ($\beta = 0.340$; $p=0.002$) and extension contact ($\beta = 0.415$; $p=0.001$) are the most significant factors, indicating that institutional support is essential for technology diffusion. The findings align with the work of [19] and [26], highlighting the significant influence of financial and informational capital on women's adoption decisions. Cooperative membership ($\beta = 0.282$; $p=0.017$) significantly increases the likelihood of adoption, underscoring the role of social capital and collective learning. Farmer groups enhance peer learning, lower transaction costs, and raise awareness of innovative agricultural practices [18]. The analysis reveals a negative

correlation between age and the adoption of CSAPs (-0.045 ; $p=0.012$), suggesting that younger female farmers are more inclined to implement these practices. Younger farmers tend to be more open to innovation, have a higher risk tolerance, and respond better to extension activities. The Probit results indicate that the adoption of CSAP among female farmers is influenced by education, access to institutions, and social participation.

Table 3. Probit Estimates of Factors Influencing CSAP Adoption

Variable	Coefficient	Std. Error	z-value	p-value
Age	-0.045	0.018	-2.50	0.012
Education	0.310	0.095	3.26	0.001
Farm size	0.225	0.071	3.17	0.002
Credit access	0.340	0.110	3.09	0.002
Extension contact	0.415	0.123	3.38	0.001
Cooperative membership	0.282	0.118	2.39	0.017
Constant	-1.732	0.462	-3.75	0.000

Source: Field Survey (2025)

5.3. Treatment Effect Model Results

Table 4 displays the results of the Treatment Effect Model (TEM), estimating the causal effect of adopting climate-smart agricultural practices on farm income. The coefficient for adoption ($\beta = 0.542$; $p=0.002$) is positive and statistically significant, indicating that female farmers who adopted CSAPs achieved higher incomes compared to non-adopters, after accounting for selection bias. This outcome is consistent with the findings of [18], which indicated that the adoption of multiple CSAPs in Ethiopia resulted in a 25–30% increase in agricultural income. [17] demonstrated that climate-smart practices notably improved the welfare of smallholder farmers in South Asia. Education ($\beta = 0.128$; $p=0.007$) and access to credit ($\beta = 0.215$; $p=0.021$) exhibited positive correlations with income. This indicates that farmers with higher education levels are more adept at utilizing resources effectively, while access to credit facilitates investment in productive inputs. The Average Treatment Effect (ATE) is estimated at ₦45,600, reflecting the income gain associated with CSAP adoption. In contrast, the Average Treatment Effect on the Treated (ATT) indicates that adopters realized higher mean incomes compared to non-adopters. The findings indicate that the adoption of CSAP improves the economic welfare and climate resilience of female farmers, aligning with the conclusions of [35] and [36]. The findings indicate that providing women with access to credit, extension services, and cooperatives enhances technology adoption and yields significant economic advantages.

Table 4. Treatment Effect Model Results

Parameter	Coefficient	Std. Error	t-value	p-value
Adoption (D=1)	0.542	0.175	3.10	0.002
Education	0.128	0.047	2.72	0.007
Credit access	0.215	0.093	2.31	0.021
Farm size	0.185	0.067	2.76	0.006
Constant	8.923	0.534	16.72	0.000

Source: Field Survey (2025)

5.4. Average Treatment Effect (ATE) of Climate-Smart Agricultural Practices (CSAP) Adoption on Farm Income

The estimation of treatment effects indicates that the adoption of climate-smart agricultural practices (CSAP) results in a significant average increase in household farm income of ₦45,600 as revealed in Table 5. This finding indicates that farmers participating in CSAP through practices like utilizing drought-tolerant seeds, implementing mulching, and optimizing irrigation achieve greater productivity and income stability relative to non-participants. This is consistent with the findings of [14] and [11], which indicate that the adoption of climate-resilient agricultural techniques enhances the resilience and profitability of smallholder farmers. The positive and significant Average Treatment Effect indicates that the adoption of CSAP is essential for enhancing farmers' welfare and alleviating income shocks related to climate in Southwest Nigeria.

Table 5. Average Treatment Effect (ATE) of Climate-Smart Agricultural Practices (CSAP) Adoption on Farm Income

Variable	Description	Estimated Effect (₦)	Interpretation
ATE (Adopters vs. Non-Adopters)	Average Treatment Effect of CSAP adoption on farm income	₦45,600	Adoption of CSAP led to an average increase of ₦45,600 in annual farm income compared to non-adopters.

Source: Author's computation from field survey data, 2025.

6. Conclusion and Policy Implications

The study concludes that Climate-Smart Agricultural Practices significantly enhance the productivity and income of female farmers in South West Nigeria. However, adoption is constrained by gender-specific barriers such as limited access to extension services and financial resources. Policy efforts should therefore focus on empowering women through inclusive agricultural programs, training, and improved access to credit and technology. Strengthening institutional frameworks that support female farmers' participation in climate adaptation initiatives is essential for achieving sustainable agricultural transformation and gender equity in Nigeria.

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