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Institutional Support and Adoption Intensity of Sustainable Reforestation Practices among Smallholder Cocoa Farmers in Nigeria

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Abstract

Sustainable reforestation practices are critical for improving the environmental sustainability and climate resilience of cocoa production systems. However, evidence on the institutional and socioeconomic factors influencing adoption intensity remains limited in Nigeria. This study examined the determinants of adoption intensity among smallholder cocoa farmers in Ondo and Cross River States, Nigeria. A multistage sampling procedure was used to select 300 farmers, comprising 150 participants in institutional reforestation programmes and 150 non-participants. Data were analysed using descriptive statistics, Welch's *t*-tests, an Ordered Probit model and separate Binary Probit models. Programme participants received significantly greater institutional support through extension services, technical training, agroforestry inputs, certification support and financial assistance, resulting in significantly higher adoption intensity ($p < 0.001$). The Ordered Probit model showed that gender, marital status and years of formal education significantly influenced adoption intensity. Binary Probit estimates indicated that repeated training increased the probability of high adoption among programme participants, whereas farming experience, farm size, number of shade trees planted and tree survival rate were the principal determinants among non-participants. Although participants reported greater perceived income improvements, adoption intensity was not significantly associated with annual cocoa income. The findings highlight the importance of sustained institutional support for increasing adoption intensity. Expanding extension services, technical training, access to agroforestry planting materials and institutional partnerships will strengthen sustainable cocoa production, climate resilience and forest landscape restoration in Nigeria.

Keywords: Adoption intensity; Cocoa production; Institutional support; Nigeria; Ordered Probit; Sustainable reforestation.

1. Introduction

Cocoa (*Theobroma cacao* L.) is one of the world's most important perennial cash crops, providing livelihoods for millions of smallholder farmers while contributing significantly to rural employment, export earnings and economic development across the humid tropics (International Cocoa Organization [ICCO], 2024; FAOSTAT, 2024). Nigeria is among Africa's leading cocoa-producing countries, where cocoa remains an important source of household income and foreign exchange earnings (FAOSTAT, 2024). However, sustainable cocoa production is increasingly threatened by declining soil fertility, ageing plantations, deforestation, biodiversity loss and climate change, all of which undermine long-term productivity and the resilience of cocoa-based production systems (Schroth et al., 2004; Wanger et al., 2024).

Historically, cocoa expansion in West Africa has contributed to widespread forest conversion and environmental degradation, resulting in substantial losses of biodiversity and ecosystem services (Ruf & Schroth, 2015; IPBES, 2019). In response, governments, development agencies, certification organisations and private-sector actors have increasingly promoted institutional reforestation interventions that integrate sustainable reforestation practices into cocoa production systems (FAO, 2022; World Cocoa Foundation, 2023). These interventions seek to restore degraded landscapes while simultaneously sustaining or improving cocoa productivity through environmentally sound management practices.

Within cocoa landscapes, sustainable reforestation encompasses the establishment and management of shade trees, enrichment planting, assisted natural regeneration and tree diversification. These agroforestry-based practices enhance soil fertility, improve moisture retention, increase carbon sequestration, conserve biodiversity and regulate microclimatic conditions, thereby strengthening the resilience of cocoa production to climate variability (Somarriba et al., 2013; Asare et al., 2014; Wanger et al., 2024). Consequently, sustainable reforestation has become a central component of climate-smart cocoa production and forest landscape restoration initiatives across West Africa (FAO, 2022; World Cocoa Foundation, 2023).

Despite these recognised benefits, the success of institutional reforestation programmes ultimately depends on farmers' adoption of recommended practices. Adoption is a complex behavioural process shaped by interactions between farmers' socioeconomic characteristics and the institutional environment in which they operate. Previous studies have consistently shown that factors such as education, gender, household labour, farming experience and farm size influence

technology adoption, while extension services, farmer training, technical assistance and access to production inputs reduce information and resource constraints that hinder adoption (Feder et al., 1985; Anderson & Feder, 2007; Knowler & Bradshaw, 2007; Meijer et al., 2015).

However, empirical evidence on sustainable reforestation adoption among cocoa farmers in Nigeria remains limited. Most previous studies have analysed adoption as a binary decision, distinguishing only between adopters and non-adopters, with relatively little attention given to differences in adoption intensity. Furthermore, few studies have examined whether institutional support modifies the socioeconomic factors influencing adoption by explicitly comparing programme participants and non-participants. Consequently, there remains limited understanding of how institutional interventions shape farmers' adoption behaviour under different institutional conditions.

This study addresses these knowledge gaps by examining the institutional and socioeconomic determinants of sustainable reforestation practice adoption among smallholder cocoa farmers in Ondo and Cross River States, Nigeria. Specifically, adoption intensity is analysed using an Ordered Probit model, while separate Binary Probit models are estimated for programme participants and non-participants to identify differences in the determinants of adoption under contrasting institutional environments. By integrating institutional and household-level perspectives, the study provides new empirical evidence on farmers' adoption behaviour and offers policy insights for strengthening institutional reforestation programmes aimed at promoting climate-resilient cocoa production and forest landscape restoration in Nigeria and other cocoa-producing countries.

2. Literature Review

2.1 Sustainable Reforestation Practices in Cocoa Production Systems

Sustainable reforestation has become a key strategy for enhancing the environmental sustainability and long-term productivity of cocoa production systems. It involves the establishment, restoration and management of trees within cocoa farms to improve ecosystem functions while sustaining agricultural production (Schroth et al., 2004; Asare et al., 2014). Unlike conventional cocoa monocultures, sustainable reforestation promotes diversified agroforestry systems in which cocoa is integrated with timber, fruit and indigenous tree species that provide both ecological and economic benefits (Somarriba et al., 2013).

Common sustainable reforestation practices include shade tree establishment, enrichment planting, assisted natural regeneration and tree diversification (FAO, 2022). These practices improve soil fertility through nutrient cycling, reduce soil erosion, conserve soil moisture, regulate microclimatic conditions and increase carbon sequestration, thereby enhancing the resilience of cocoa production systems to climate variability (Asare et al., 2014; Wanger et al., 2024). Appropriate shade management also supports biodiversity conservation by improving habitat quality and ecological connectivity within agricultural landscapes (Schroth et al., 2004).

Beyond environmental benefits, sustainable reforestation contributes to farmers' livelihoods by diversifying farm income through timber, fruits, fuelwood and other tree products while reducing dependence on cocoa alone (Somarriba et al., 2013). Consequently, tree-based cocoa systems improve both farm resilience and the long-term sustainability of cocoa production.

Growing international concern over cocoa-driven deforestation has accelerated the promotion of sustainable reforestation through initiatives such as the Cocoa and Forests Initiative, Rainforest Alliance certification and national forest restoration programmes (FAO, 2022; World Cocoa Foundation, 2023). These initiatives encourage the integration of trees into cocoa farms while reducing pressure on natural forests, positioning sustainable reforestation as an important strategy for simultaneously improving agricultural productivity, biodiversity conservation, climate-change mitigation and rural livelihoods (Wanger et al., 2024).

2.2 Institutional Support and Adoption of Sustainable Reforestation Practices

Institutional support plays a critical role in promoting the adoption of sustainable agricultural innovations among smallholder farmers. Government agencies, extension services, research institutions, certification organisations, development partners and private-sector actors facilitate adoption by providing technical knowledge, production inputs, financial support and market incentives that reduce the risks associated with adopting new technologies (Anderson & Feder, 2007; Meijer et al., 2015).

Agricultural extension and farmer training are among the most effective institutional mechanisms for promoting sustainable reforestation. Extension services improve farmers' awareness of agroforestry technologies, while continuous training strengthens technical competence in tree establishment, shade management, soil conservation and climate-smart cocoa production

(Anderson & Feder, 2007; Meijer et al., 2015). Such capacity-building programmes reduce information constraints and increase farmers' confidence in implementing recommended practices. Institutional provision of improved seedlings, planting materials and complementary inputs further encourages adoption by lowering the initial investment costs of reforestation (Knowler & Bradshaw, 2007). Likewise, access to financial support enables farmers to overcome liquidity constraints that often discourage long-term investments in tree-based production systems (Abdulai & Huffman, 2014).

Certification and sustainability programmes have also become important drivers of sustainable cocoa production. Initiatives such as the Rainforest Alliance and the Cocoa and Forests Initiative promote environmentally responsible farming through technical assistance, compliance training and market incentives that encourage the integration of sustainable reforestation practices into cocoa production systems (World Cocoa Foundation, 2023). Participation in these programmes strengthens farmers' access to institutional networks, extension services and premium markets, thereby increasing the likelihood of adopting recommended practices.

Evidence suggests that institutional interventions are most effective when delivered as integrated support packages combining extension, training, input provision and financial incentives, rather than as isolated services (FAO, 2022; Meijer et al., 2015). Such coordinated approaches simultaneously address technical, informational and financial barriers, thereby accelerating the adoption and sustained implementation of sustainable reforestation practices among smallholder cocoa farmers.

2.3 Socioeconomic Determinants of Sustainable Reforestation Practice Adoption

The adoption of sustainable reforestation practices is influenced by farmers' socioeconomic characteristics, household resource endowments and farm-specific conditions. The Agricultural Household Model posits that farm households simultaneously make production, consumption and investment decisions under conditions of imperfect markets and resource constraints (Singh et al., 1986). Consequently, adoption reflects farmers' assessment of the expected costs, risks and long-term benefits of sustainable reforestation relative to their available labour, land, capital and technical knowledge.

Age has been widely examined as a determinant of agricultural technology adoption, although empirical evidence remains mixed. Younger farmers are generally considered more willing to

experiment with new technologies and undertake long-term investments, whereas older farmers may benefit from greater farming experience, accumulated knowledge and stronger social networks that facilitate adoption (Rogers, 2003; Meijer et al., 2015). The direction of the age effect therefore depends largely on the production context and the characteristics of the innovation.

Education consistently enhances farmers' capacity to acquire, process and apply technical information, thereby reducing uncertainty associated with new technologies (Feder et al., 1985; Meijer et al., 2015). Better-educated farmers are more likely to understand extension recommendations, evaluate the long-term benefits of sustainable reforestation and participate effectively in institutional support and certification programmes.

Gender also influences adoption through differential access to land, labour, credit and extension services. In many sub-Saharan African countries, male farmers generally possess greater control over productive resources, although evidence indicates that women achieve comparable adoption outcomes when provided with similar institutional support (Doss & Morris, 2001; Meinzen-Dick et al., 2014). Household size may facilitate adoption by increasing the availability of family labour for tree establishment and management, although larger households may also face greater consumption pressures that constrain investment (Knowler & Bradshaw, 2007).

Farming experience and farm size have likewise been identified as important determinants of adoption. Experienced farmers may possess greater technical knowledge and confidence in implementing sustainable production practices, while larger farms provide greater flexibility for integrating trees and other agroforestry components without substantially reducing cocoa production (Feder et al., 1985; Wainaina et al., 2020). Membership of farmer organisations further promotes adoption by facilitating information exchange, collective learning and improved access to extension services and institutional programmes.

Although these socioeconomic characteristics have been widely associated with technology adoption, their influence varies across institutional and ecological settings. Recent evidence suggests that their effects are strengthened when farmers have access to extension services, technical training, agroforestry inputs and other forms of institutional support (Aryal et al., 2018; Meijer et al., 2015). Accordingly, this study examines adoption behaviour by jointly considering socioeconomic characteristics and institutional support as complementary determinants of sustainable reforestation practice adoption among smallholder cocoa farmers.

2.4 Theoretical Framework

This study is underpinned by three complementary theoretical perspectives: the Diffusion of Innovations Theory, the Agricultural Household Model, and the Potential Outcomes Framework. Together, these theories explain how institutional interventions influence farmers' adoption of sustainable reforestation practices, how households allocate production resources under resource constraints, and how the causal effects of institutional interventions on adoption outcomes can be evaluated. Collectively, they provide the conceptual basis for analysing the relationships among institutional support, adoption behaviour and sustainable cocoa productivity.

2.4.1 Diffusion of Innovations Theory

The Diffusion of Innovations Theory, developed by Rogers (1962) and refined in the fifth edition of *Diffusion of Innovations* (Rogers, 2003), explains how new technologies and practices spread through social systems over time. The theory proposes that adoption depends on farmers' perceptions of an innovation's relative advantage, compatibility, complexity, trialability and observability. Innovations perceived as beneficial, compatible with existing farming systems, easy to implement, testable and capable of producing visible results are more likely to be adopted.

The theory also recognises that adoption is facilitated by communication channels, extension services and social learning, leading to different categories of adopters ranging from innovators to laggards (Rogers, 2003). Within cocoa production systems, sustainable reforestation practices—including shade tree establishment, agroforestry, enrichment planting and soil conservation—represent innovations whose adoption depends largely on farmers' access to information, technical knowledge and institutional support. Institutional reforestation programmes therefore accelerate adoption by providing extension services, technical training, demonstration activities and agroforestry inputs that reduce information barriers and improve farmers' confidence in implementing recommended practices.

Accordingly, the Diffusion of Innovations Theory provides the theoretical foundation for analysing the institutional and socioeconomic factors influencing farmers' adoption intensity of sustainable reforestation practices.

2.4.2 Agricultural Household Model

The Agricultural Household Model (AHM), developed by Singh, Squire and Strauss (1986), explains how farm households simultaneously make production, consumption and resource allocation decisions under conditions of imperfect markets and limited resources. Unlike conventional production models, the AHM recognises that household welfare and farm production decisions are jointly determined by available land, labour, capital, market opportunities and institutional conditions.

Within cocoa production systems, adopting sustainable reforestation practices requires farmers to allocate land, labour and financial resources to investments whose benefits are realised over the long term. Consequently, adoption decisions depend not only on expected economic returns but also on household characteristics, resource endowments and production constraints. Institutional support—including extension services, farmer training, agroforestry inputs and financial assistance—can relax these constraints by improving technical knowledge and reducing the costs and risks associated with sustainable reforestation.

The Agricultural Household Model therefore provides the theoretical basis for including household and farm characteristics—such as age, education, household size, farming experience, farm size, marital status and farmer association membership—as explanatory variables in the empirical analysis of adoption behaviour.

2.4.3 Potential Outcomes Framework

The Potential Outcomes Framework (Rubin, 1974; Rosenbaum & Rubin, 1983) provides the conceptual basis for estimating the causal effects of interventions using observational data. The framework recognises that each individual has two potential outcomes: one under treatment and another under non-treatment. Because only one outcome is observed, the unobserved outcome represents the counterfactual, creating the fundamental challenge of causal inference.

In agricultural research, participation in institutional programmes is typically non-random because farmers self-select into interventions or are selected according to specific socioeconomic and institutional criteria. Consequently, programme participants and non-participants may differ systematically in both observable and unobservable characteristics, leading to potential selection bias. The Potential Outcomes Framework provides the basis for econometric approaches designed to address this problem, including propensity score methods, instrumental variable estimators and endogenous treatment-effects models (Rubin, 1974; Rosenbaum & Rubin, 1983).

Although this study focuses on the determinants of adoption intensity, the framework remains relevant because it provides the conceptual basis for comparing programme participants and non-participants while recognising that institutional exposure may influence adoption behaviour. It therefore complements the Diffusion of Innovations Theory and the Agricultural Household Model by linking institutional interventions with observed adoption outcomes.

2.4.4 Relevance of the Theoretical Framework to the Present Study

The three theoretical perspectives provide an integrated framework for explaining the adoption of sustainable reforestation practices among smallholder cocoa farmers. The Diffusion of Innovations Theory explains how institutional interventions—including extension services, farmer training, technical assistance and demonstration activities—facilitate the dissemination and adoption of sustainable reforestation practices. It therefore provides the theoretical foundation for analysing the institutional factors influencing adoption intensity.

The Agricultural Household Model explains how farm households allocate land, labour and capital under resource constraints while balancing production objectives and household welfare. This perspective justifies the inclusion of household and farm characteristics, including age, education, household size, farming experience, farm size and farmer association membership, as determinants of adoption behaviour.

The Potential Outcomes Framework provides the conceptual basis for comparing programme participants and non-participants by recognising that participation in institutional reforestation programmes is not random and may be associated with observable and unobservable differences between farmers. This framework supports the comparative analysis of adoption determinants under different institutional conditions.

Collectively, these theories explain how institutional support and socioeconomic characteristics interact to influence farmers' adoption of sustainable reforestation practices. They also provide the theoretical justification for the econometric techniques employed in this study, namely the Ordered Probit model for analysing adoption intensity and the Binary Probit models for examining the determinants of adoption among programme participants and non-participants. This integrated framework underpins the empirical analysis and interpretation of the study findings.

2.5 Empirical Review, Research Gap and Contribution of the Study

Empirical evidence consistently demonstrates that both institutional and socioeconomic factors influence farmers' adoption of sustainable reforestation and agroforestry practices, although their relative importance varies across production environments and institutional settings. Early studies identified education, farm size, extension services and institutional support as major determinants of agricultural technology adoption (Feder et al., 1985; Knowler & Bradshaw, 2007). A systematic review by Meijer et al. (2015) further showed that farmers' knowledge, perceptions and attitudes strongly influence adoption decisions, highlighting the importance of combining technical information with institutional support to achieve sustained adoption.

Recent studies within West Africa reinforce these findings. In Nigeria, Ajayi et al. (2020) reported that although cocoa farmers in Ekiti State were generally aware of agroforestry technologies, adoption remained constrained by inadequate extension services, limited institutional support and poor access to technical information. Likewise, Arimi and Omoare (2021) found that extension contact and access to information significantly increased farmers' willingness to adopt cocoa agroforestry practices in Oyo State, whereas unfavourable perceptions reduced adoption. In Ghana, Kaba et al. (2021) demonstrated that farmers' decisions to establish or retain shade trees were influenced by extension advice, perceived production benefits and long-term livelihood considerations, confirming the importance of institutional support in promoting climate-resilient cocoa systems.

Recent studies published in *Agroforestry Systems* further indicate that institutional policies, improved cocoa varieties, extension recommendations and farmers' perceptions jointly shape land-use decisions within cocoa agroforestry systems. Earlier ecological studies in south-western Nigeria similarly demonstrated that traditional cocoa agroforestry contributes to biodiversity conservation while maintaining household livelihoods, highlighting the potential of tree-based cocoa systems to reconcile agricultural production with environmental sustainability.

Despite these advances, three important knowledge gaps remain. First, most previous studies have examined adoption as a binary decision rather than recognising adoption intensity as a continuum of behavioural responses. Second, relatively few studies have compared adoption behaviour between programme participants and non-participants, limiting understanding of how institutional interventions modify adoption decisions. Third, empirical evidence integrating both institutional

and socioeconomic determinants of sustainable reforestation practice adoption among Nigerian cocoa farmers remains limited.

This study addresses these gaps by integrating institutional and socioeconomic perspectives within a unified analytical framework. Specifically, adoption intensity is analysed using an Ordered Probit model, while separate Binary Probit models are employed to compare the determinants of adoption between programme participants and non-participants. By moving beyond conventional binary adoption analysis, the study provides new empirical evidence on the role of institutional reforestation interventions in shaping sustainable reforestation practice adoption among cocoa farmers. The findings contribute to the literature on climate-resilient cocoa production, agroforestry adoption and forest landscape restoration, while providing policy-relevant evidence for governments, development partners and certification organisations seeking to strengthen institutional support for sustainable cocoa production in Nigeria and other cocoa-producing countries.

2.6 Conceptual Framework

The conceptual framework (Figure 1) illustrates the relationships among institutional support, farmers' socioeconomic characteristics and the adoption intensity of sustainable reforestation practices among smallholder cocoa farmers in Nigeria. It assumes that adoption decisions are jointly influenced by external institutional interventions and farmers' household characteristics.

Institutional support—including extension services, technical training, agroforestry input provision, financial assistance, demonstration activities and participation in sustainability programmes—enhances farmers' access to knowledge, technical skills and productive resources, thereby reducing information and financial constraints associated with sustainable reforestation practices.

Farmers' socioeconomic characteristics—including age, gender, marital status, education, household size, farming experience, farm size and farmer association membership—determine their capacity to acquire information, mobilise resources and invest in sustainable land management practices. The framework further recognises that institutional support may modify the influence of these characteristics on adoption behaviour by improving farmers' access to technical and institutional resources.

Accordingly, institutional support and socioeconomic characteristics constitute the explanatory variables, while adoption intensity of sustainable reforestation practices is the outcome variable. This framework provides the conceptual basis for the Ordered Probit model used to analyse adoption intensity and the Binary Probit models employed to compare adoption determinants between programme participants and non-participants.

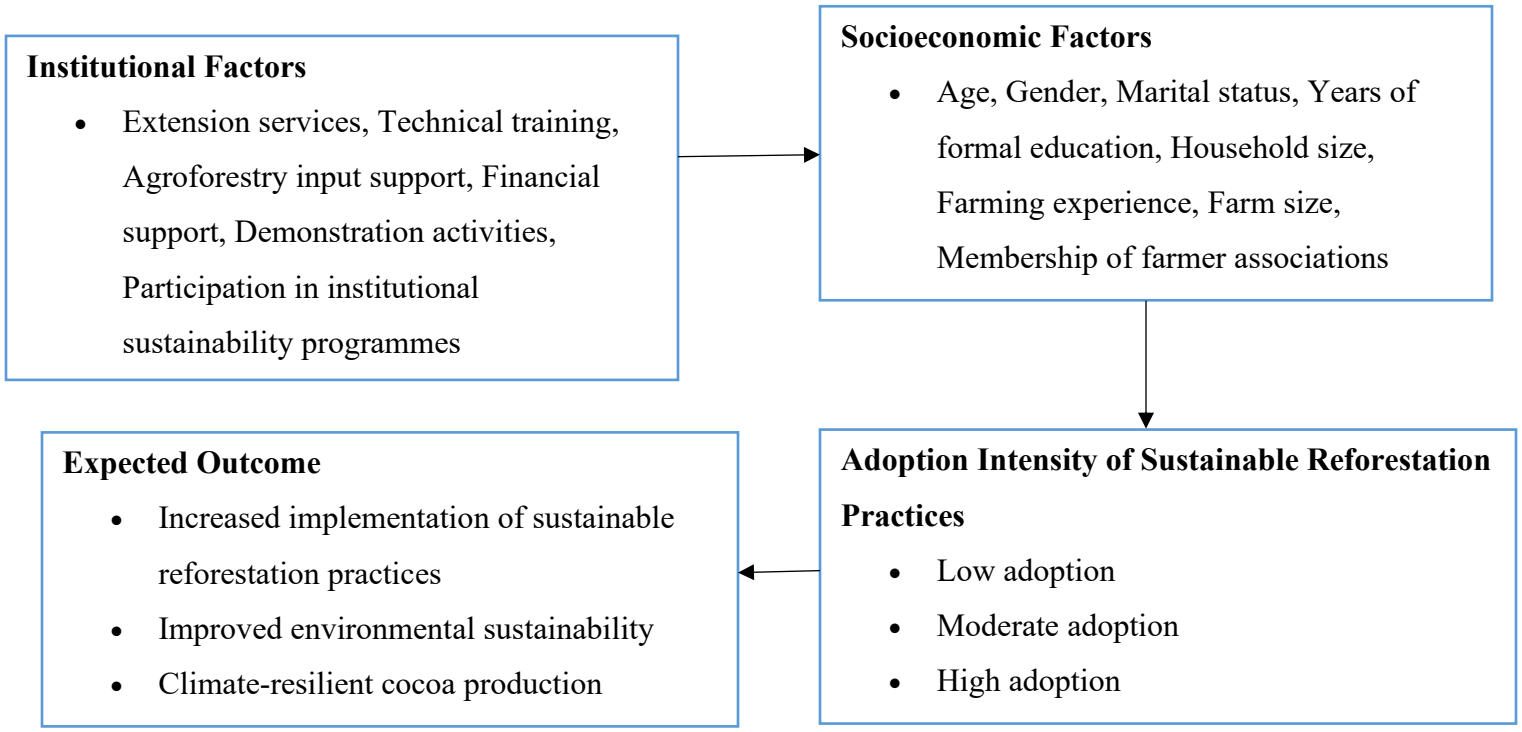

Figure 2.1. Conceptual Framework

3. Materials and Methods

3.1 Study Area

The study was conducted in **Ondo and Cross River States**, two major cocoa-producing states in Nigeria. The states were purposively selected because of their substantial contribution to national cocoa production and their participation in institutional reforestation programmes implemented by government agencies, certification organisations and private-sector actors (Federal Ministry of Environment, 2021; World Cocoa Foundation, 2023).

Ondo State, located in south-western Nigeria (5°45′–8°15′ N; 4°45′–6°00′ E), has a humid tropical climate with annual rainfall of approximately 1,200–2,000 mm and mean temperatures ranging from 21°C to 30°C, providing favourable conditions for cocoa cultivation and agroforestry (NiMet, 2023). Cross River State, located in south-eastern Nigeria (4°28′–6°55′ N; 7°50′–9°28′ E), receives 2,000–3,500 mm of annual rainfall and contains extensive tropical rainforest ecosystems that support cocoa production and forest restoration initiatives (NiMet, 2023; FAO, 2022).

Both states have benefited from institutional interventions implemented by organisations such as the Rainforest Alliance, the Cocoa and Forests Initiative, Olam Food Ingredients, ETG Beyond Beans and government extension agencies. Their contrasting institutional environments provide an appropriate setting for examining the determinants of sustainable reforestation practice adoption among smallholder cocoa farmers.

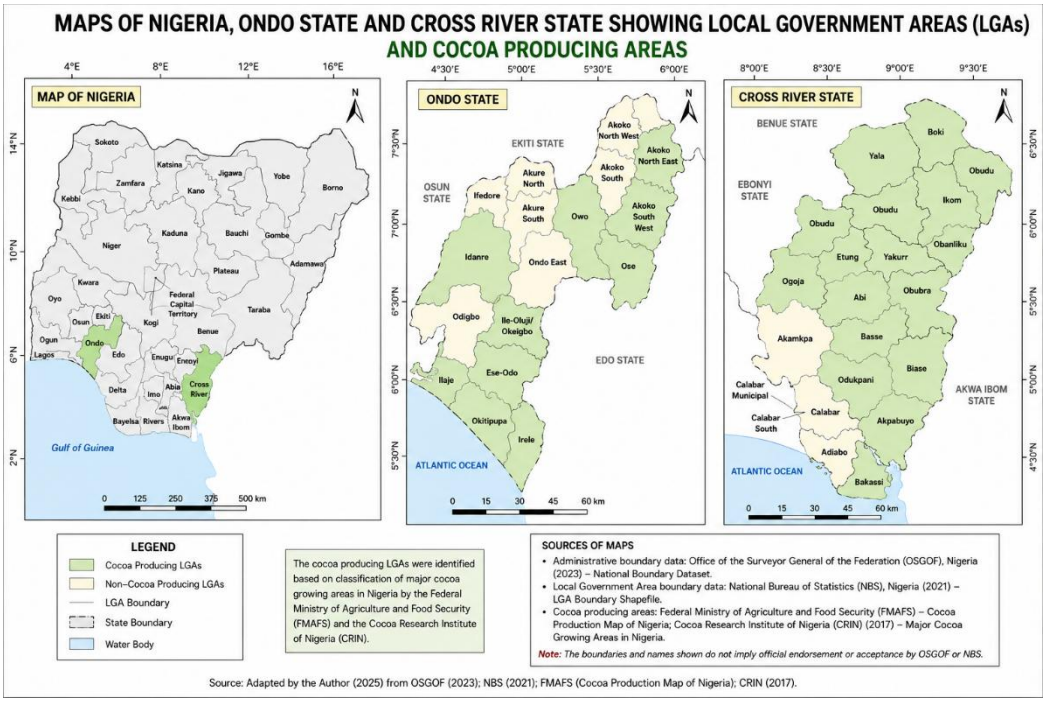

Figure 3.1. Integrated maps of Nigeria, Ondo and Cross River State showing cocoa-producing LGAs.

Sources: Office of the Surveyor General of the Federation (OSGOF), Nigeria (2023), National Bureau of Statistics (NBS), Nigeria (2021), and Federal Ministry of Agriculture and Food Security (FMAFS), and Cocoa Research Institute of Nigeria (CRIN) (2017)

3.2 Sampling Procedure and Data Collection

A multistage sampling procedure was employed. First, Ondo and Cross River States were purposively selected because of their importance in cocoa production and exposure to institutional reforestation programmes. Second, major cocoa-producing Local Government Areas (LGAs) implementing these programmes were purposively selected. Third, cocoa-producing communities were randomly selected within the identified LGAs. Finally, cocoa farming households were randomly selected from farmer association registers, extension records and programme beneficiary lists to ensure adequate representation of programme participants and non-participants.

The study surveyed 300 smallholder cocoa farmers, comprising 150 programme participants and 150 non-participants. Participants were farmers who had benefited from at least one institutional reforestation intervention, including extension services, technical training, agroforestry input support or financial assistance, while non-participants had not received such support during the study period.

Primary data were collected during the 2024/2025 cocoa production season through face-to-face interviews using a structured questionnaire. Information obtained included farmers' socioeconomic characteristics, farm characteristics, institutional support, awareness of sustainability initiatives and adoption of sustainable reforestation practices. The questionnaire was pre-tested outside the study sample and revised before the main survey. Interviews were conducted by trained enumerators, and informed consent was obtained from all respondents. Participation was voluntary, and respondents' anonymity and confidentiality were maintained throughout the study (Israel & Hay, 2006).

3.3 Measurement of Variables

The dependent variable was adoption intensity of sustainable reforestation practices, measured using an adoption index based on the number of recommended reforestation practices implemented by each farmer. The practices included shade tree establishment, enrichment planting, assisted natural regeneration, tree diversification, retention of indigenous tree species and other recommended reforestation practices. Farmers were subsequently classified into ordered adoption categories representing increasing levels of adoption intensity, consistent with previous adoption studies (Feder et al., 1985; Meijer et al., 2015).

The explanatory variables comprised institutional and socioeconomic characteristics hypothesised to influence adoption behaviour. Institutional variables included participation in institutional

reforestation programmes, extension contact, farmer training, access to agroforestry inputs, financial support and awareness of sustainability initiatives. Socioeconomic variables included age, gender, marital status, years of formal education, household size, cocoa farming experience, farm size, labour source, age of cocoa plantation and farmer association membership. These variables were selected based on the theoretical framework and previous empirical studies on agricultural technology adoption (Knowler & Bradshaw, 2007; Meijer et al., 2015; Aryal et al., 2018).

3.4 Analytical Framework

The data were analysed using descriptive statistics, Welch's ***t***-test, an Ordered Probit model and Binary Probit models**.** Descriptive statistics (means, standard deviations, frequencies and percentages) were used to summarise respondents' socioeconomic characteristics, institutional support and adoption behaviour.

Welch's *t*-test was employed to determine whether adoption intensity differed significantly between programme participants and non-participants. The test was preferred to the conventional Student's *t*-test because it provides more reliable inference when group variances are unequal.

The determinants of adoption intensity were analysed using an Ordered Probit model, which is appropriate for ordinal dependent variables with naturally ordered response categories (Greene, 2018; Wooldridge, 2019). To examine whether institutional support altered the factors influencing adoption behaviour, separate Binary Probit models were estimated for programme participants and non-participants. Average marginal effects were computed to facilitate interpretation of the estimated coefficients. All analyses were performed using Stata 18, and statistical significance was evaluated at the 1%, 5% and 10% levels.

3.5 Econometric Model Specification

3.5.1 Ordered Probit Model

Adoption intensity was specified as an ordinal dependent variable representing increasing levels of implementation of sustainable reforestation practices. Accordingly, the Ordered Probit model was estimated as:

$Yi = Xi\beta + \varepsilon i^{*}$

where Yi* is the latent adoption intensity, Xi is the vector of institutional and socioeconomic explanatory variables, βis the parameter vector to be estimated, and εi is the error term assumed to follow a standard normal distribution. The observed adoption categories were generated through threshold (cut-point) parameters, and category probabilities were estimated using the cumulative standard normal distribution function (Greene, 2018).

3.5.2 Binary Probit Model

Separate Binary Probit models were estimated for programme participants and non-participants to examine whether institutional support modified the determinants of adoption intensity. The latent model is specified as:

$Yi = Xi\beta + \varepsilon i^*$

where the observed outcome equals one for farmers with higher adoption intensity and zero otherwise. Marginal effects were estimated to quantify the effect of each explanatory variable on the probability of belonging to the higher adoption category. Parameter significance was assessed using Wald *z*-statistics (Greene, 2018; Wooldridge, 2019).

4. Results and Discussion

4.1 Socioeconomic Characteristics of Cocoa Farmers

The socioeconomic characteristics of the sampled cocoa farmers are presented in Table 4.1. These characteristics are important because they influence farmers' access to productive resources, institutional support and their capacity to adopt sustainable reforestation practices (Feder et al., 1985; Rogers, 2003; Meijer et al., 2015).

Male farmers dominated cocoa production, accounting for 69.3% of programme participants and 61.3% of non-participants, with an overall proportion of 65.3%**.** Female farmers represented 34.7% of the total sample, indicating increasing but still comparatively lower participation in cocoa production. This pattern reflects the gendered distribution of land ownership and production resources commonly reported in sub-Saharan Africa (Doss & Morris, 2001; Meinzen-Dick et al., 2014).

The average age of respondents was 47.5 ± 14.6 years, with mean ages of 47.1 ± 14.4 years and 48.0 ± 14.9 years for participants and non-participants, respectively. Approximately 64.0% of farmers were between 31 and 60 years, indicating that cocoa production was dominated by

economically active individuals capable of undertaking the labour requirements associated with sustainable reforestation practices.

Most respondents were married (77.7% overall), comprising 85.3% of programme participants and 70.0% of non-participants. Married households are generally associated with greater family labour availability, which may facilitate the implementation of labour-intensive agroforestry activities (Knowler & Bradshaw, 2007).

Respondents had an average of 7.8 ± 5.1 years of formal education, with participants averaging 7.2 ± 4.6 years and non-participants 8.5 ± 5.4 years. Although 85.0% had received formal education, only 10.7% attained tertiary education, suggesting that most farmers possessed basic literacy sufficient to participate effectively in extension and training programmes.

Household size averaged 4.0 ± 1.4 persons, while cocoa farming experience averaged 28.6 ± 13.8 years, with 62.0% of respondents having more than 20 years of farming experience. These findings indicate substantial production experience and relatively adequate household labour for implementing sustainable reforestation practices.

Overall, the sampled farmers possessed demographic characteristics consistent with long-established cocoa farming communities. Nevertheless, the observed differences between programme participants and non-participants suggest that socioeconomic characteristics alone are insufficient to explain adoption behaviour. The contribution of institutional support to adoption decisions is therefore examined in the subsequent sections.

Table 4.1. Socioeconomic characteristics of cocoa farmers by institutional exposure group

Variable	Participants (n=150)	Non-participants (n=150)	Total (n=300)
Age (years), mean ± SD	47.1 ± 14.4	48.0 ± 14.9	47.5 ± 14.6
Male (%)	69.3	61.3	65.3
Married (%)	85.3	70.0	77.7
Years of schooling, mean ± SD	7.2 ± 4.6	8.5 ± 5.4	7.8 ± 5.1
Household size, mean ± SD	4.0 ± 1.3	4.0 ± 1.5	4.0 ± 1.4
Cocoa farming experience (years), mean ± SD	28.3 ± 13.0	28.8 ± 14.5	28.6 ± 13.8
Farm size (ha), mean ± SD	1.8 ± 1.1	1.9 ± 1.1	1.9 ± 1.1
Farmer association membership (%)	36.0	35.3	35.7
Family + hired labour (%)	80.7	79.3	80.0
Access to formal credit (%)	0.0	0.0	0.0
Cocoa farm age (years), mean ± SD	36.3 ± 7.8	35.7 ± 9.5	36.0 ± 8.7

4.2 Institutional Reforestation Interventions Received by Cocoa Farmers

The institutional reforestation interventions received by programme participants and non-participants are presented in Table 4.2. Institutional support plays a central role in promoting sustainable reforestation by improving farmers' access to technical knowledge, production inputs and financial resources, thereby reducing barriers to adoption (Anderson & Feder, 2007; Meijer et al., 2015).

As expected, institutional support was substantially higher among programme participants than non-participants. All programme participants (100.0%) received formal training on sustainable reforestation practices, whereas only a negligible proportion of non-participants had similar exposure. Likewise, participants reported markedly greater access to improved tree seedlings, planting materials and financial assistance, reflecting the targeted implementation of institutional reforestation programmes.

Programme participants also demonstrated considerably higher awareness of sustainability initiatives, particularly the Rainforest Alliance and the Cocoa and Forests Initiative, than non-

participants. This greater exposure is consistent with the role of certification schemes and development programmes in promoting environmentally sustainable cocoa production through training, technical assistance and continuous extension support (World Cocoa Foundation, 2023; FAO, 2022).

Overall, the descriptive evidence indicates that institutional interventions substantially improved farmers' access to extension services, technical training, agroforestry inputs and sustainability information. These findings support the Diffusion of Innovations Theory, which posits that effective communication channels and institutional support accelerate the adoption of agricultural innovations by reducing uncertainty and strengthening farmers' technical capacity (Rogers, 2003). The extent to which these interventions influenced adoption intensity is examined in the subsequent econometric analyses.

Table 4.2. Institutional reforestation interventions received by cocoa farmers

Variable	Participants (%)	Non-participants (%)	p-value
Received reforestation training	100.0	0.0	<0.001
Received agroforestry inputs	99.3	0.0	<0.001
Mean number of training sessions	10.25 ± 5.81	0.00 ± 0.00	<0.001
Mean number of trees planted	19.55 ± 7.92	15.54 ± 10.90	<0.001
Mean tree survival (%)	76.73 ± 19.88	76.50 ± 27.26	0.933

Awareness and institutional exposure also differed markedly between programme participants and non-participants. Almost all programme participants were aware of the Rainforest Alliance (99.3%) and the Cocoa & Forests Initiative (98.7%), compared with 48.7% and 5.3% of non-participants, respectively ($p < 0.001$). Similarly, certification under the Rainforest Alliance was substantially higher among participants (98.0%) than non-participants (2.0%), while virtually all participants (100.0%) reported awareness of sustainable reforestation practices compared with 82.7% of non-participants ($p < 0.001$). Financial assistance was received by 98.0% of programme participants but only 4.7% of non-participants ($p < 0.001$). In contrast, willingness to expand reforestation practices was high in both groups (98.0% versus 96.7%) and did not differ significantly ($p = 0.317$). These findings further demonstrate that institutional programmes

substantially improved farmers' exposure to sustainability initiatives, certification schemes and financial support.

4.3 Adoption Intensity of Sustainable Reforestation Practices among Cocoa Farmers

4.3.1 Adoption of Individual Sustainable Reforestation Practices

The adoption of individual sustainable reforestation practices by programme participants and non-participants is presented in Table 4.3. Significant differences were observed between the two groups across all five practices ($p < 0.001$). Agroforestry was practised by 91.3% of programme participants compared with 42.7% of non-participants ($\chi^2 = 78.15$; $p < 0.001$). Similarly, tree retention was reported by 99.3% of participants and 85.3% of non-participants ($\chi^2 = 18.84$; $p < 0.001$), while tree planting was practised by 98.7% and 79.3%**,** respectively ($\chi^2 = 26.69$; $p < 0.001$). More pronounced differences were observed for soil conservation and certification compliance. Soil conservation was adopted by 45.3% of programme participants but by none of the non-participants ($\chi^2 = 85.36$; $p < 0.001$), whereas certification compliance was reported by **83.3%** of participants compared with only 1.3% of non-participants ($\chi^2 = 203.23$; $p < 0.001$). These findings indicate that institutional reforestation interventions promoted the adoption of a broader range of sustainable reforestation practices rather than isolated technologies.

Table 4.3. Adoption of sustainable reforestation practices

Practice	Participants (%)	Non-participants (%)	χ^2	p-value
Agroforestry	91.3	42.7	78.15	<0.001
Tree retention	99.3	85.3	18.84	<0.001
Tree planting	98.7	79.3	26.69	<0.001
Soil conservation	45.3	0.0	85.36	<0.001
Certification compliance	83.3	1.3	203.23	<0.001

4.3.2 Adoption Intensity Categories and Adoption Index

The distribution of adoption-intensity categories and adoption indicators is presented in Tables 4.5 and 4.4. Programme participants consistently exhibited higher adoption intensity than non-participants. While 82.0% of participants attained the high adoption category, none of the non-participants reached this level. Conversely, 82.7% of non-participants were classified as medium

adopters and 17.3% remained in the low adoption category. The overall distribution differed significantly between the two groups ($\chi^2 = 211.31$; $p < 0.001$), indicating a strong association between programme participation and higher adoption intensity.

The adoption indicators further reinforce this pattern. Programme participants recorded a significantly higher mean adoption score (4.18 ± 0.82) than non-participants (2.09 ± 0.98) ($p < 0.001$). Similarly, the mean adoption index among participants (83.60 ± 16.40%) was approximately twice that of non-participants (41.73 ± 19.65%) ($p < 0.001$). These results demonstrate that institutional support was associated not only with the adoption of individual practices but also with greater overall intensity of sustainable reforestation practice implementation.

Table 4.4. Adoption Intensity and Adoption Outcomes of Sustainable Reforestation Practices

Variable	Programme participants	Non-participants	Test statistic	p-value
Adoption intensity category (%)				
Low	0.0	17.3		
Medium	18.0	82.7		
High	82.0	0.0	$\chi^2 = 211.31$	<0.001
Adoption indicators				
Mean adoption score	4.18 ± 0.82	2.09 ± 0.98	Welch t = 20.03	<0.001
Mean adoption index (%)	83.60 ± 16.40	41.73 ± 19.65	Mann–Whitney U	<0.001
Cocoa farm under reforestation >50% (%)	78.7	38.0	χ^2	<0.001
Regular reforestation activities (%)	70.7	24.0	χ^2	<0.001

Note: Adoption scores were compared using Welch's t-test, while adoption indices were additionally assessed using the Mann–Whitney U test because of the non-normal distribution of the adoption measures.

4.3.3 Institutional Support and Adoption Outcomes

The adoption outcomes presented in Table 4.5 further demonstrate the practical implications of higher adoption intensity. A substantially larger proportion of programme participants (78.7%) allocated more than half of their cocoa farmland to sustainable reforestation compared with 38.0%

of non-participants ($p < 0.001$). Similarly, regular implementation of reforestation activities was reported by 70.7% of participants compared with only 24.0% of non-participants ($p < 0.001$).

Overall, the descriptive evidence indicates that institutional reforestation interventions were associated with greater adoption of individual sustainable reforestation practices, higher adoption intensity and more extensive implementation of reforestation activities on cocoa farms. These findings provide preliminary evidence that institutional support contributes to strengthening sustainable reforestation among cocoa farmers. The subsequent econometric analysis builds on these descriptive results by identifying the institutional and socioeconomic factors that significantly influence adoption intensity while controlling for farmers' observable characteristics.

4.4 Determinants of Adoption Intensity of Sustainable Reforestation Practices

The determinants of adoption intensity were analysed using a pooled Ordered Probit model and separate Binary Probit models for programme participants and non-participants. The Ordered Probit model was estimated for the full sample because adoption intensity comprised three ordered categories (low, medium and high), while the Binary Probit models were used to examine whether the determinants of adoption differed according to programme participation.

The pooled Ordered Probit model was estimated using 299 observations after excluding one observation with incomplete household-size information. The model provided an adequate fit to the data (Log-likelihood = –261.782; AIC = 549.56; BIC = 597.67), indicating that the selected explanatory variables satisfactorily explained variations in adoption intensity. The explanatory variables comprised demographic, socioeconomic, farm and institutional characteristics identified from the theoretical framework and previous empirical studies. Table 4.7 (available in the Supplementary Material) presents the definitions, measurement scales and expected signs of the explanatory variables included in the econometric models. The estimated coefficients from the pooled Ordered Probit and the group-specific Binary Probit models are presented and discussed in the following sections.

4.4.1 Pooled Ordered Probit Estimates

The pooled Ordered Probit estimates and corresponding average marginal effects are presented in Tables 4.5, respectively. The results indicate that gender, marital status and years of formal education significantly influenced farmers' adoption intensity of sustainable reforestation

practices, whereas age, household size, cocoa farming experience, farm size, age of cocoa farm, farmer association membership and labour source were not statistically significant.

Gender exerted a significant negative effect on adoption intensity ($\beta = –0.397$; $p = 0.009$). The marginal effects indicate that female farmers were 14.4 percentage points less likely to attain the high-adoption category and correspondingly more likely to remain in the low- and medium-adoption categories than male farmers. This finding suggests that persistent disparities in access to productive resources and institutional support continue to constrain women's adoption of sustainable reforestation practices, consistent with previous studies (Doss & Morris, 2001; Meinzen-Dick et al., 2014).

Marital status positively influenced adoption intensity ($\beta = 0.420$; $p = 0.017$). Married farmers were 14.9 percentage points more likely to attain the high-adoption category than unmarried farmers, possibly reflecting greater household labour availability and improved resource mobilisation for implementing labour-intensive reforestation practices. Similar findings have been reported by Knowler and Bradshaw (2007) and Aryal et al. (2018).

Years of formal education exhibited a negative and highly significant relationship with adoption intensity ($\beta = –0.062$; $p < 0.001$). Each additional year of schooling reduced the probability of high adoption by approximately 2.2 percentage points. Although contrary to conventional expectations, this result may indicate that more educated farmers diversify into non-farm activities or rely less on institutional support, while practical training provided through reforestation programmes substitutes for formal education in influencing adoption decisions (Feder et al., 1985; Meijer et al., 2015).

The remaining explanatory variables were not statistically significant ($p > 0.05$), suggesting that demographic characteristics and institutional exposure explained adoption intensity more strongly than general farm and household characteristics in the pooled sample.

Because programme participants and non-participants differed substantially in their level of institutional support, separate Binary Probit models were estimated to examine whether the determinants of adoption varied across the two groups.

Table 4.5. Pooled Ordered Probit estimates

Variable	Coefficient	Std. Error	z	p-value
Age	-0.008	0.011	-0.76	0.448
Female	-0.397***	0.151	-2.62	0.009
Married	0.420**	0.177	2.38	0.017
Years in school	-0.062***	0.018	-3.43	<0.001
Household size	0.003	0.055	0.05	0.956
Farming experience	-0.009	0.013	-0.69	0.491
Farm size	-0.084	0.064	-1.33	0.184
Age of cocoa farm	0.016	0.010	1.61	0.108
Farmer association	0.093	0.145	0.64	0.522
Family labour	-0.087	0.188	-0.46	0.644
Hired labour	-0.033	0.504	-0.07	0.947

Model Statistics

Statistic	Value
Observations	299
Log likelihood	-261.782
AIC	549.56
BIC	597.67

4.4.2 Binary Probit Estimates for Programme Participants

To examine the determinants of high adoption intensity among beneficiaries of institutional reforestation programmes, a Binary Probit model was estimated using programme participants only. Since participants were classified into either medium or high adoption categories, the dependent variable was coded as 1 = high adoption intensity and 0 = medium adoption intensity. The estimated coefficients and average marginal effects are presented in Table 4.6.

The results indicate that years of formal education, cocoa farming experience, farm size and institutional training significantly influenced the probability of attaining high adoption intensity.

Years of formal education exerted a significant negative effect on adoption intensity ($\beta = –0.153$, $p = 0.001$), suggesting that more educated farmers were less likely to attain the highest adoption level. Similarly, cocoa farming experience negatively influenced adoption ($\beta = –0.071$, $p = 0.041$), indicating that farmers with longer production experience were relatively less likely to intensify sustainable reforestation practices. Farm size also showed a negative effect ($\beta = –0.253$, $p = 0.049$), implying that implementing multiple reforestation practices may become more difficult as farm size increases because of higher labour and management requirements.

In contrast, institutional training significantly increased the likelihood of high adoption ($\beta = 0.056$, $p = 0.037$). The positive marginal effect confirms that repeated training enhanced farmers' capacity to implement multiple sustainable reforestation practices, highlighting the importance of continuous technical support in strengthening adoption intensity.

The remaining explanatory variables—including age, gender, marital status, household size, age of cocoa farm, farmer association membership, number of trees planted and tree survival rate—were not statistically significant ($p > 0.05$).

Overall, the findings indicate that among programme beneficiaries, continuous institutional training was the principal factor promoting higher adoption intensity, whereas formal education, farming experience and larger farm size were associated with lower probabilities of intensive adoption.

Table 4.6. Binary Probit estimates for programme participants

Variable	Coefficient	Std. Error	z	p-value	dy/dx	Std. Error	Z	p-value
Years spent in school	-0.153***	0.047	-3.26	0.001	-0.033***	0.009	-3.24	0.001
Cocoa farming experience	-0.071**	0.035	-2.05	0.041	-0.015**	0.007	-2.12	0.034
Farm size	-0.253**	0.129	-1.97	0.049	-0.055**	0.027	-2.04	0.041
Training sessions attended	0.056**	0.027	2.09	0.037	0.012**	0.006	2.16	0.031
Other variables (not statistically significant)								

Model Statistics

Statistic	Value
Observations	149
Log likelihood	-57.702
Pseudo R^2	0.182

Note: Dependent variable = 1 if the farmer belongs to the high adoption-intensity category and 0 if the farmer belongs to the medium adoption-intensity category. Average marginal effects (dy/dx) are reported. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.4.3 Binary Probit Estimates for Programme Non-participants

A separate Binary Probit model was estimated for non-participants to identify the factors influencing the likelihood of attaining medium adoption intensity relative to low adoption intensity in the absence of institutional reforestation support. The dependent variable was coded as 1 = medium adoption intensity and 0 = low adoption intensity. The estimated coefficients and average marginal effects are presented in Table 4.8.

The results indicate that gender, marital status, cocoa farming experience, farm size, number of shade and multipurpose trees planted, and tree survival rate significantly influenced adoption intensity among non-participants.

Gender exerted a negative effect ($\beta = -0.514$, $p = 0.086$), suggesting that female farmers were less likely to attain medium adoption intensity than their male counterparts. Marital status also had a negative influence ($\beta = -0.765$, $p = 0.048$), indicating that married farmers without institutional support were less likely to achieve higher adoption levels, possibly because of competing household resource demands.

In contrast, cocoa farming experience positively influenced adoption intensity ($\beta = 0.058$, $p = 0.043$), suggesting that experienced farmers relied on accumulated knowledge to implement sustainable reforestation practices. Farm size also showed a positive relationship ($\beta = 0.309$, $p = 0.067$), implying that farmers with larger holdings had greater flexibility to integrate tree-based practices.

The number of shade and multipurpose trees planted emerged as the strongest positive determinant of adoption intensity ($\beta = 0.086$, $p = 0.001$), while tree survival rate also had a significant positive effect ($\beta = 0.013$, $p = 0.025$). These findings indicate that successful tree establishment and survival encouraged farmers to adopt additional sustainable reforestation practices.

The remaining variables—including age, years of formal education, household size, age of cocoa farm and farmer association membership—were not statistically significant ($p > 0.05$).

Overall, the results suggest that, in the absence of institutional support, adoption intensity depended primarily on farmers' own experience and successful on-farm implementation of reforestation practices rather than external technical assistance. This contrasts with the findings for programme participants, where institutional training emerged as the principal driver of higher adoption intensity.

Table 4.7. Binary Probit estimates for non-participants

Variable	Coefficient	Std. Error	z	p-value	dy/dx	Std. Error	z	p-value
Female respondent	-0.514*	0.299	-1.72	0.086	-0.093*	0.053	-1.74	0.082
Married	-0.765**	0.387	-1.98	0.048	-0.138**	0.068	-2.03	0.042
Farming experience	0.058**	0.029	2.03	0.043	0.011**	0.005	2.10	0.036
Farm size	0.309*	0.169	1.83	0.067	0.056*	0.029	1.89	0.059
Shade/multipurpose trees planted	0.086***	0.024	3.66	0.001	0.015***	0.004	3.99	<0.001
Tree survival rate	0.013**	0.006	2.24	0.025	0.002**	0.001	2.33	0.020
Other variables								

Model Statistics

Statistic	Value
Observations	150
Log likelihood	-46.611
Pseudo R^2	0.326

Note**:** Dependent variable = 1 if the farmer belongs to the high adoption-intensity category and 0 if the farmer belongs to the medium adoption-intensity category. Average marginal effects (dy/dx) are reported. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 4.8. Binary Probit estimates for programme non-participants

Variable	Coefficient	Std. Error	z	p-value	dy/dx	Std. Error	z	p-value
Female respondent	-0.514*	0.299	-1.72	0.086	-0.093*	0.053	-1.74	0.082
Married	-0.765**	0.387	-1.98	0.048	-0.138**	0.068	-2.03	0.042
Farming experience	0.058**	0.029	2.03	0.043	0.011**	0.005	2.10	0.036
Farm size	0.309*	0.169	1.83	0.067	0.056*	0.029	1.89	0.059
Shade/multipurpose trees planted	0.086***	0.024	3.66	0.001	0.015***	0.004	3.99	<0.001
Tree survival rate	0.013**	0.006	2.24	0.025	0.002**	0.001	2.33	0.020
Other variables								

Model Statistics

Statistic	Value
Observations	150
Log likelihood	-46.611
Pseudo R^2	0.326

Note**:** Dependent variable = 1 if the farmer belongs to the medium adoption-intensity category and 0 if the farmer belongs to the low adoption-intensity category. Average marginal effects (dy/dx) are reported. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.5 Comparative Discussion of Adoption Determinants

The three econometric models provide complementary evidence on the determinants of adoption intensity of sustainable reforestation practices among smallholder cocoa farmers. The pooled Ordered Probit model identified the overall socioeconomic determinants of adoption intensity, while the Binary Probit models demonstrated how institutional reforestation interventions modified these relationships among programme participants and non-participants.

Across the pooled sample, gender, marital status and years of formal education significantly influenced adoption intensity. Female farmers were less likely to attain higher adoption levels, reflecting persistent inequalities in access to productive resources, extension services and agricultural inputs, as widely reported in sub-Saharan Africa (Doss & Morris, 2001; Meinzen-Dick et al., 2014). Married farmers, however, were more likely to achieve higher adoption intensity, suggesting that household labour availability and family support facilitate the implementation of labour-intensive reforestation practices.

The negative relationship between formal education and adoption intensity, observed in both the pooled and participant-specific models, contrasts with conventional expectations. This suggests that practical knowledge acquired through institutional training and extension services may substitute for formal education, reducing the importance of schooling in farmers' adoption decisions (Feder et al., 1985; Meijer et al., 2015).

The participant-specific model highlights the central role of institutional training in promoting high adoption intensity. Repeated training significantly increased farmers' likelihood of implementing multiple sustainable reforestation practices, demonstrating the importance of continuous technical support in strengthening farmers' knowledge and confidence. In contrast, adoption among non-participants depended primarily on farming experience, farm size, tree establishment and tree survival, indicating that farmers without institutional support relied largely on accumulated experience and observable on-farm outcomes when making adoption decisions.

These findings demonstrate that institutional interventions influence not only the level of adoption but also the mechanisms through which adoption occurs. Without institutional support, adoption is largely experience-driven, whereas participation in institutional programmes shifts adoption towards a knowledge-driven process reinforced by extension services, training and technical assistance.

The results provide empirical support for the Diffusion of Innovations Theory (Rogers, 2003), which emphasises the role of communication and institutional support in accelerating innovation adoption, and the Agricultural Household Model (Singh et al., 1986), which explains how household resources and institutional conditions jointly shape production decisions. They further suggest that institutional interventions can partially offset socioeconomic constraints by strengthening farmers' technical capacity and facilitating the adoption of sustainable reforestation practices.

From a policy perspective, the findings indicate that reforestation programmes should prioritise continuous farmer training, regular extension services and sustained technical support alongside the provision of planting materials. Particular attention should also be directed towards women and other resource-constrained farmers to ensure equitable access to institutional support and accelerate the adoption of sustainable reforestation practices in Nigeria's cocoa sector.

5. Conclusion

This study examined the institutional and socioeconomic determinants of sustainable reforestation practice adoption among smallholder cocoa farmers in Ondo and Cross River States, Nigeria. The findings demonstrate that institutional reforestation interventions substantially increased adoption intensity by improving farmers' access to extension services, technical training, agroforestry inputs and financial support. Programme participants consistently exhibited higher adoption intensity than non-participants, highlighting the critical role of institutional support in promoting sustainable reforestation within cocoa production systems.

The econometric analyses further revealed that adoption behaviour was shaped by both institutional and socioeconomic factors, although the determinants differed between programme participants and non-participants. Among programme beneficiaries, continuous institutional training emerged as the principal driver of higher adoption intensity, whereas adoption among non-participants depended largely on farming experience and successful on-farm implementation. These findings indicate that institutional interventions influence not only the level of adoption but also the mechanisms through which adoption occurs.

By analysing adoption intensity and comparing programme participants with non-participants, this study extends existing evidence on agroforestry adoption and provides empirical insights into the role of institutional support in promoting sustainable cocoa production. The findings underscore the importance of sustained institutional engagement in advancing climate-resilient agriculture and forest landscape restoration in cocoa-producing regions.

Future research should employ longitudinal data to examine the long-term sustainability of adoption behaviour and assess how institutional interventions influence adoption dynamics over time.

5.1 Policy Implications

The findings suggest that expanding institutional reforestation programmes is essential for increasing the adoption of sustainable reforestation practices among cocoa farmers. Beyond distributing planting materials, interventions should prioritise continuous farmer training, regular extension services and sustained technical support, as these were found to be the strongest institutional drivers of adoption intensity.

Policies should also improve farmers' access to quality agroforestry inputs and affordable financial support to reduce investment constraints associated with long-term tree establishment. In addition, targeted interventions are required to improve women's access to extension services, training and productive resources in order to reduce gender disparities in adoption.

Finally, stronger collaboration among government agencies, research institutions, certification organisations and private-sector actors is necessary to deliver coordinated reforestation programmes that simultaneously enhance cocoa productivity, strengthen climate resilience and contribute to forest landscape restoration in Nigeria.

5.2 Limitations and Future Research

This study has several limitations that should be considered when interpreting the findings. First, the use of cross-sectional data limits the ability to examine changes in adoption behaviour over time or establish long-term causal relationships between institutional support and adoption intensity. Future studies should employ longitudinal or panel data to assess the sustainability of adoption and the persistence of institutional effects.

Second, the study focused on cocoa farmers in Ondo and Cross River States. Although these states are among Nigeria's major cocoa-producing regions, the findings may not be directly generalisable to other production environments with different institutional or agroecological conditions. Comparative studies across other cocoa-producing regions and countries would improve the external validity of the results.

Third, adoption intensity was measured using five major sustainable reforestation practices. Future research could develop broader indices that incorporate additional ecological and climate-resilience indicators to provide a more comprehensive assessment of sustainable land management.

Finally, this study focused primarily on adoption behaviour. Future research should investigate the long-term effects of sustained adoption on cocoa productivity, household welfare, biodiversity conservation, carbon sequestration and climate resilience using longitudinal data and rigorous impact-evaluation approaches.

Despite these limitations, the study provides robust empirical evidence on the role of institutional support in promoting sustainable reforestation practice adoption among cocoa farmers and offers useful insights for future research and policy development.

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