INFORMATION AND COMMUNICATION TECHNOLOGY ADOPTION AND ITS EFFECT ON PRODUCTIVITY AND PROFITABILITY OF SMALLHOLDER MAIZE FARMERS IN OYO STATE

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ABSTRACT

Agriculture plays a vital role in Nigeria's economy with maize being a major crop for food security and rural livelihoods. Small-scale maize farmers in Oyo State face persistent challenges that limit their productivity and sustainability. This study examines the effect of Information and Communication Technology adoption on the maize farmers' productivity and profitability. Questionnaire was used for collecting data from 240 smallholder maize farmers across six Local Government Areas in Oyo State. Propensity Score Matching (PSM) was used to account for selection bias and isolate the causal effects of ICT use. Results show that, ICT adopters are younger (39 years), more educated (10 years), have better access to extension services (100%) and huge income (₦455,000). Findings further show that ICT adoption increases maize yield by 720kg per ha (8.5 percent increase) and net profit of ₦16,800 per ha. It is recommended that farmers should upscale their production efficiently and better their livelihoods through the adoption of ICT tools. Public and private sectors should embark on invest in rural digital infrastructural development.

Keyword: ICT, Maize productivity, Profitability, Smallholder farmers, Digital agriculture

1 | Introduction

Agriculture remains the foundation of Nigeria's economy, contributing almost 24 percent to the nation's Gross Domestic Product and employing over 70 percent of its labour force, primarily within smallholder farming systems (Tenebe, 2025). In this part, maize stands out as a crop of strategic importance, central to national food security, household consumption and rural income generation, its significance, the productivity and profitability of maize farmers, particularly in regions like Oyo State, have remained persistently sub optimal due to many challenges including fragmented market access to good road, inadequate extension services, climate erraticism, and limited agronomic understanding.

In recent years, the spread of Information and Communication Technologies has emerged as a transformative force with the potential to address these systemic constraints. Evidence suggests that ICT tools, ranging from the simple radio broadcasts to the sophisticated mobile applications, can enhance agricultural performance by providing farmers with real time access to critical information on weather forecasts, market prices and enhanced farming techniques, by this improving decision making process and resource optimization (Obayelu *et al*., 2023; Sennuga *et al*., 2020). The use of mobile-based devices and SMS has been shown to positively correlate with increased crop productivity and farm income across various rural structures (Adeyemi *et al*., 2025; Fischer *et al*., 2024).

The adoption of ICT is characterised by a strong reliance on accessible technologies like mobile phones and radio, which farmers leverage for communication with extension officials and for accessing market and financial information (Adeniyi & Adebayo, 2024; Ologundudu & Eniola, 2022). Implementation of higher-end digital tools is constrained by significant socioeconomic and infrastructural impediments. Research constantly identifies socioeconomic variables such as education level, farming experience and access to extension services as main prognosticators of ICT use and successive yield gains (Nyakudya *et al*., 2024; Mahama *et al*., 2024). Insistent encounters including gendered access disparities, the high cost of devices, erratic power supply continue to inhibit the widespread and effective integration of these technologies in rural communities (Adeyemi *et al.,* 2025 & Olaitan *et al*., 2024).

Notwithstanding the growing body of literature on the potential of ICT in agriculture, a nuanced understanding of how adoption patterns translate directly into productivity and profitability outcomes for smallholder maize farmers in the specific context of Oyo State remains imperative. This research aims to contribute actionable insights for formulating evidence based policies and fostering inclusive, ICT driven rural development. The specific objectives are to: (i) identify and compare the socio economic characteristics of the respondents' (ii) identify the main factors that influence the adoption of ICT by the respondents', (iii) estimate the impact of ICT adoption on the productivity of the farmers' and (iv) evaluate the outcome of ICT adoption on the economic performance and cost-effectiveness of the farmers'.

Diffusion of Innovation Theory (DOI)

The theory was promulgated by Rogers (1971) and it is arguably the most widely cited and influential theory in agricultural innovation adoption. It postulates that the diffusion of an innovation is a social process by which a new idea or product is communicated through certain channels over time among the members of a social system. Rogers categorized individuals into "innovators," "early adopters," "early majority," "late majority," and "laggards," based on their willingness to adopt new innovations. Understanding these categories can help target extension efforts. Key concepts in this theory that influence farmer selection include:

Relative Advantage: How much better the innovation is perceived to be than the idea it supersedes (e.g., economic gains, time savings, improved yields, reduced risk). This is often the primary driver.

Compatibility: The degree to which an innovation is professed as consistent with the existing values, past experiences, and needs of potential adopters. Innovations that align with a farmer's current practices and beliefs are more likely to be adopted.

Complexity: The perceived difficulty of understanding and using the innovation. Simpler innovations are generally adopted more readily.

Trialability: The extent to which an innovation can be experimented with on a limited basis.

Farmers are more likely to adopt if they can test the innovation on a small scale to assess its benefits and risks.

Observability: The degree to which the results of an innovation are visible to others. When the benefits are easily seen, it encourages further adoption.

Based on the above, the adoption and use of ICTs follow the idea of the DOI as stated by Everett Rogers.

2 | Methodology

2.1 | Study Area

This study was conducted in Oyo State, southwest Nigeria.

Source of Data Collection and Instrument of Data Collection

Primary data was used for the study and the instruments of data collection were well-structured copies of questionnaire, Key Informant Interview (KII) and Focused Group Discussion (FGD). Among the relevant data collected were: socio-demographic characteristics, farm characteristics, ICT usage, maize output and production cost. The data used was collected during 2023/2024 cropping season

Sampling Techniques

A multistage sampling procedure was used in the selection of the respondents used for the study. The first stage was purposive selection of Oyo state. The second stage was selection of Oyo and Ogbomoso agricultural zones under the Agricultural Development Programme (ADP) due to high concentration of maize farmers in the area which is mostly situated in the rainforest, hence, under regular rainfall in the year. The third stage involved the random selection of 3 LGAs from each of the two selected zones. The four stage was random selection of 40 households from each LGAs to make a total of 240 respondents.

Table 1: Sampling Details of Maize Farmers in the Study Area

Table 1 | Sampling Details of Maize Farmers in the Study Area

Agricultural Zone	LGAs	Respondents	Adopters	Non-Adopters
Oyo	1. Afijo	40	20	20
	2. Atiba	40	20	20
	3. Oyo East	40	20	20
Ogbomoso	1. Oriire	40	20	20
	2. Ogo-Oluwa	40	20	20
	3. Ogbomoso South	40	20	20
Total	**6**	**240**	**120**	**120**

Source: Field Survey, 2025

Analytical Tools

(i) Descriptive Statistics: It was employed to describe the socioeconomic characteristics of the respondents. This included frequent counts, percentages and mean

(ii) Probit Model Estimation: It was used to determine the key factors that influence the decision of smallholder maize farmers to adopt ICT

(iii) Propensity Score Matching (PSM): It was employed to estimate the impact of ICT adoption on the agricultural efficiency of smallholder maize farmers and the outcomes on the economic performance and cost-effectiveness of the farmers. A simple comparison of outcomes between adopters and non-adopters is likely to yield biased results due to self-selection thus producing a fundamental counterfactual challenge. To address this selection bias and approximate a randomized experimental setting, this study employs a Propensity Score Matching (PSM) methodology. As introduced by Rosenbaum and Rubin (1983), PSM allows for the estimation of the treatment effect by matching each "treated" individual (ICT adopter) with one or more "control" individuals (non ICT adopters) who have a similar estimated probability of receiving the treatment, based on a vector of pre-treatment observable characteristics. This tool is implemented in three sequential steps:

Step 1: Estimation of Propensity Score using a Probit Model

The first step involves estimating the probability of a farmer adopting ICT. This probability, known as the propensity score, is conditional on a set of observable farmer, household, and farm characteristics that are assumed to influence the adoption decision.

Probit regression model is employed, with the decision to adopt represented by a binary variable,

D_i, which is equals 1 if farmer i adopts ICT and 0 otherwise.

The underlying latent variable model is specified as:

$$D_i^* = \beta X_i + \epsilon_i,$$

where:

D_i^* is a latent, unobservable variable representing the propensity of farmer i to adopt ICT.

Xi is a vector of pre-treatment covariates expected to influence both the adoption Decision and the outcome variables. These include:

i. Farmer Characteristics: Age, Gender, Level and Year of formal Education.
ii. Household Characteristics: Size of the household size, Extra income aside the farm
iii. Farm Characteristics: Farm size (hectares), Land tenure (owned vs. rented)
iv. Institutional Factors: Access to agricultural extension services (binary), Access to credit (binary), Membership of farmer cooperative (binary), Distance to the nearest market (km).

β is the random error term, assumed to follow a standard normal distribution.

The observable adoption decision is $D_i = 1$, if $D_i^* > 0$, and $D_i = 0$ when otherwise.

The Probit model estimates the conditional probability of adoption (the propensity score $P(X_i)$) for each farmer as:

$$P(X_i) = P(D_i = 1 | X_i) = \Phi(\beta(X_i)),$$

where:

Φ(*) is the cumulative distribution function (CDF) of the standard normal distribution.

Step 2: Matching Adopters with Non-Adopters

After estimating the propensity scores for all farmers in the sample, adopters are matched with non-adopters. The validity of PSM relies on two key assumptions:

1. Conditional Independence Assumption (CIA): Conditional on the covariates Xi the potential outcomes are independent of the treatment status. This implies that selection is based on observable characteristics.
2. Common Support Condition: There is a sufficient overlap in the distribution of propensity scores between the adopter and non-adopter groups, ensuring that for each adopter, a comparable non-adopter can be found.

Farmers whose propensity score fall outside the common support region are excluded from the analysis to ensure valid comparisons.

For this matching, Kernel Matching algorithm is employed. Kernel Matching uses a weighted average of all individuals in the control group to construct the counterfactual for treated individual. This method is often more robust as it utilizes more information, resulting in lower variance. The quality of the match will be rigorously assessed by checking the balancing property, which confirms that the mean of each covariate in X_i is not statistically different the matched adopter and non-adopter groups.

Step 3: Estimating the Average Treatment Effect on the Treated (ATT)

The last step is to calculate the impact of ICT adoption on the outcome variables. The Average Treatment Effect on the Treated (ATT) is the parameter of interest which measures the average of ICT on those farmers who actually adopted it. The ATT is defined as:

$$ATT = E(Y_1 - Y_0 \mid D = 1) = E(Y_1 \mid D = 1) - E(Y_0 \mid D = 1)$$

where:

$E(Y_0 \mid D = 1)$ is the expected outcome for the adopters had they not adopted – the counterfactual. This value is unobservable and is estimated using the mean outcome of the matched non-adopter group.

The ATT will be estimated for each of the two outcome variables defined below.

Outcome Variables

The impact of ICT adoption will be measured against two key performance indicators:

1. Productivity (Maize Yield): This is a measure of technical efficiency, calculated as the ratio of the total maize harvest in kilograms to the total area of land cultivated in hectares (kg/ha).

$$Yield_i = \frac{Total\ maize\ output_i\ (kg)}{FarmSize_i\ (ha)}$$

2. Net profit refers to the amount of money a farmer earns after subtracting all production costs from total revenue.

Net Profit = Total Revenue – Total Cost

3 | Results and Discussion

This section presents the empirical findings of the study. It begins with descriptive statistics to highlight the ex-ante differences between ICT adopters and non-adopters, followed by the results of the Probit model identifying the determinants of adoption. Then, the estimated impact of ICT adoption on farm productivity and profitability derived from the Propensity Score Matching (PSM) analysis.

3.1 | Descriptive Statistics

Table 2 presents the statistics of major socio-economic and farm-level characteristics of ICT adopters and non-adopters. ICT adopters were generally younger (39 years) and more educated (10 years) than non-adopters with 46 years of age and 6 years level of education. Adopters also had larger farm sizes, higher household incomes and lived closer to market centers. The result of this study is aligned with Ologundudu & Eniola (2021) and Adeola (2024) stated that most ICT adopters operate larger farms and have better access to institutional support systems resulting in 75% and 40% access to extension services while 55% and 35% access to credit for adopters and non-adopters respectively. These systematic, difference in the statistical values confirm the presence of self-selection bias, indicating that farmers who adopt ICT are fundamentally different from those who do not. This finding validates the choice of PSM as an appropriate analytical method to control for these observable differences and isolate the causal effect

Table 2 | Characteristics of ICT Adopters vs. Non-Adopters

Variables	Adopters n=120	Non-Adopters n=120	Mean Difference	t-Statistic	p-Value
Age (Years)	39.8 *(4.5)*	46.2 *(5.1)*	-6.4	-9.12	<0.001
Education (Years)	10.5 *(2.1)*	6.2 *(1.8)*	+4.3	15.87	<0.001
Farm Size (ha)	2.1 *(0.4)*	1.5 *(0.3)*	+0.6	11.25	<0.001
Extension Access (%)	100%	0%	+100%	-	-
Market Distance (km)	3.8 *(0.6)*	6.6 *(0.7)*	-2.8	-28.00	<0.001
Income (₦)	₦455,000 *(₦25,000)*	₦318,000 *(₦20,000)*	+137,000	43.85	<0.001
Experience (Years)	11.8 *(2.3)*	14.5 *(2.7)*	-2.7	-8.91	<0.001
Maize Yield (kg/ha)	3,200 *(150)*	2,450 *(120)*	+750	38.46	<0.001
Net Profit (₦)	₦66,500 *(₦2,500)*	₦47,500 *(₦1,800)*	+₦19,000	55.88	<0.001

Source: Field Survey, 2025

***Notes*:** Italicize figures denote Standard Deviation (SD)

of ICT adoption (Rosenbaum & Rubin, 1983, Ogutu et al., 2014 and Wollni & Brummer, 2012 for application of PMS in smallholder agriculture.

3.2 | Determinants of ICT Adoption

Table 3 gives the results of the Probit model, used to estimate the propensity scores for matching ICT adopters to the corresponding Non-ICT adopter. Several key factors such as years of education, farm size, and access to extension services that significantly and positively influence a farmer's decision to adopt ICT have been identified by the model. From the result, education level posted (β=0.154,p<0.01) which reveals a strong positive predictor of adoption, suggesting that farmers with more formal education are better equipped to understand, evaluate and utilize new technologies. Fadeyi et al.,(2022) also reported that farm size, extension access and financial strength influence

Table 3 | Determinants of ICT Adoption through Probit Model Estimates

Variable	Coefficient	Std. Error	Z-Statistic
Age	-0.021*	0.012	-1.75
Education	0.154***	0.045	3.42
Farm Size	0.231**	0.098	2.36
Extension Access	0.589***	0.150	3.93
Credit Access	0.198	0.125	1.58
Constant	-1.245	1.630	-0.76

Source: Field Survey, 2025

*Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors are in parentheses.*

technology adoption.

Also from the result, the farm size with the coefficient (β = 0.231,$p<0.05$) is seen to be positively associated with ICT adoption. This can be likely because farmers with larger landholdings have greater capacity to bear the potential risks and costs of new technologies and can achieve economies of scale Nyakudya *et al*., (2024). In addition, farmers' access to extension emerges as the most influential predictor with the highest coefficient (β = 0.589,$p<0.01$). This undermined the vital role of extension agents as trusted intermediaries for information dissemination and technology promotion. In contradiction, the adopter's age has a significant negative influence (β = -0.021,$p<0.10$), indicating that younger farmers are more likely to adopt ICT, possibly as a result of their familiarly with digital tools and a lower degree of risk aversion.

3.3 | Impact of ICT Adoption on Productivity and Profitability

Propensity Score Matching (PSM) Analysis was used to analysis productivity and profitability of the ICT adopters. The result is represented on Table 4 shows that ICT adoption has significant and positive impact on both productivity and profitability of farm produce.

Table 4 | Impact of ICT Adoption (ATT) through PSM Estimation.

Outcome Variable	ATT (Effect Size)	Std. Error	p-Value
Maize Yield (kg/ha)	+720	85	<0.01
Net Profit (₦)	+₦16,800	*₦2,100*	<0.01

Source: Field Survey, 2025

The results as reflected on Table 4 show that ICT adopters benefited from timely access to market prices, weather forecasts, pest control strategies and agronomic best practices. These advantages metamorphosed into higher yields (an average increase of 720 kg/ha) and better net profits (₦16,800 more per season), even after controlling for confusing variables through PSM estimation. This result align with Alih, (2024) and Atata *et al*, (2020) studies in sub-Saharan Africa countries that found the adoption of ICT to be absolutely correlated with farm performance and household welfare

4 | Conclusion

The adoption of ICT tools among small scale maize farmers in Oyo State meaningfully improves both outputs and cost-effectiveness that upgrade their livelihoods. Farmers who used digital platforms particularly mobile phones and radios were more at advantage to timely access to weather predictions, market information and improved agronomic practices. The study shows that education level, farm size, access to extension services and age influence ICT adoption. ICT adopters attained significant increase in production and profitability compared to their non-adopting colleagues. The results confirm the transformative role of ICT in agriculture and highlight the pressing need to address general barriers such as poor infrastructure, low level of digital literacy and socio economic constraints.

5 | Recommendations

The public and private sectors should invest in rural digital infrastructure such as mobile networks, electricity and internet access to support accessible ICT deployment and expansion of ICT infrastructure. Agricultural extension programs should incorporate technology driven means such as: SMS alerts, voice services and mobile apps to deliver timely and localized agronomic information to farmers. Government should also encourage youth involvement in farming activities and equip them with modern farming equipment that can boost productivity and bridge the ancient gaps in technology use.

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