Impacts of ICT-Based Weather and Market Information Delivery on Pepper Producers' Farmers' Income: Evidence from Wera Woreda, Halaba Zone, Ethiopia

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ABSTRACT

Limited access to timely agricultural information remains a major constraint affecting productivity and market participation of smallholder farmers in Sub-Saharan Africa. Information and Communication Technologies (ICTs) provide new opportunities for delivering weather forecasts and market information that support farm decision-making and income improvement. This study examined the impact of ICT-based weather and market information delivery on the income of pepper-producing smallholder farmers in Wera Woreda, Halaba Zone, Ethiopia.

A mixed research approach was employed using cross-sectional data collected from 174 randomly selected households consisting of ICT users and non-users. Primary data were gathered through structured household surveys, focus group discussions, and key informant interviews, while secondary data were obtained from institutional reports and published sources. Descriptive statistics and Propensity Score Matching (PSM) were applied to estimate the causal impact of ICT utilization on household income.

Results show that mobile phones, radio, and television were the dominant channels through which farmers accessed agricultural information. Logit model results indicate that education level, training exposure, frequency of extension contact, distance to market, and farmers' behavioral characteristics significantly influenced ICT adoption. The PSM estimation revealed that ICT use increased household income of pepper producers by approximately 54.29 percent compared to non-users. However, several constraints limited effective utilization, including inadequate localized weather forecasts, limited ICT skills, language barriers, high service costs, and weak rural infrastructure.

The study concludes that ICT-enabled advisory services significantly enhance farmers' income by improving market participation and climate-related decision-making. Strengthening rural ICT infrastructure, localized information delivery, and farmer training programs is essential to sustain these benefits.

Keywords: ICT, Market Information, Weather Information, Pepper Production, Smallholder Farmers, Income, Propensity Score Matching

INTRODUCTION

Background of the Study

Information and Communication Technology (ICT) based weather and market information delivery refers to the use of digital and communication tools such as mobile phones, radio, television, internet platforms, and satellite systems to disseminate agricultural information to farmers. These technologies enable timely communication, improve access to knowledge, and support informed decision-making in agricultural production systems.

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Agriculture in Sub-Saharan Africa remains highly vulnerable to information gaps related to climate variability, input management, and market price fluctuations. Smallholder farmers often rely on traditional information channels, including extension agents and intermediaries, which limits access to real-time advisory services and reduces their bargaining power in markets. As a result, farmers frequently experience poor timing of planting, inadequate pest and disease management, and unfavorable selling prices.

The rapid growth of the global population and increasing food demand have intensified the need for knowledge-intensive agricultural systems. Modern farming increasingly depends on accurate and timely information regarding weather patterns, input utilization, and market dynamics. Climate change further increases production risks, making access to localized weather forecasting essential for sustainable agricultural productivity (FAO, 2015).

ICT innovations are therefore considered critical tools for improving agricultural efficiency by reducing information asymmetry, strengthening extension delivery, and enhancing market transparency. Through improved access to weather forecasts and price information, farmers can optimize production decisions, reduce uncertainty, and improve income outcomes.

Despite growing investment in digital agriculture, empirical evidence on the economic impact of ICT-based information delivery among pepper-producing smallholders in Ethiopia remains limited. This study addresses this gap by examining the income effects of ICT-enabled weather and market information services among pepper farmers in Wera Woreda, Halaba Zone.

Statement of the Problem

Smallholder farmers frequently operate under conditions of information asymmetry characterized by poor market transparency, weak bargaining power, and limited access to climate information. Farmers often rely on intermediaries and informal communication channels, which results in delayed or inaccurate information regarding prices and weather conditions.

In pepper-producing areas of southern Ethiopia, climate variability, pest outbreaks, and unstable markets significantly affect production and profitability. Traditional agricultural extension systems alone are insufficient to provide timely advisory services to dispersed rural populations. Although ICT initiatives have expanded in recent years, their actual economic impact on smallholder farmers remains inadequately documented.

Existing studies mainly focus on technology adoption or productivity outcomes, with limited empirical analysis linking ICT-based information delivery to household income changes. Consequently, policymakers lack evidence on whether ICT interventions generate measurable economic benefits for farmers. This study addresses this gap by evaluating the income effect of ICT-based weather and market information services.

Objectives of the Study

General Objective

To assess the impact of ICT-based weather and market information delivery on the income of pepper-producing smallholder farmers in Wera Woreda, Halaba Zone, Ethiopia.

Specific Objectives

Objective 1: ICT Utilization and Agricultural Decision Support

1. To examine the role of ICT-based information in addressing climate-related production risks.
2. To analyze the contribution of ICT services in improving farmers' access to market information.

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Objective 2: Adoption Constraints and Opportunities

3. To identify institutional, socioeconomic, and infrastructural factors affecting ICT utilization among farmers.

4. To assess major challenges limiting effective delivery and use of ICT-based agricultural information.

Objective 3: Impact Evaluation

5. To estimate the causal impact of ICT-based weather and market information on household income using econometric methods.

Research Questions

1. How does ICT-based information support farmers in managing climate and market challenges?
2. What factors influence farmers' adoption and use of ICT services?
3. What constraints limit effective ICT-based information delivery?
4. Does ICT utilization significantly improve smallholder farmers' income?

Significance of the Study

The findings provide empirical evidence for policymakers, development partners, and agricultural institutions on the economic value of ICT-enabled advisory services. The study contributes to improved planning of digital agriculture interventions by identifying factors that enhance adoption and effectiveness. It also offers practical insights for strengthening climate-smart agriculture and market integration strategies aimed at improving rural livelihoods.

Scope and Limitations of the Study

The study was geographically limited to three kebeles in Wera Woreda of Halaba Zone. The analysis focused specifically on pepper-producing smallholder households and ICT-based weather and market information services. Data were collected during the January to July 2021 production period using cross-sectional observations, which limits the ability to capture long-term impacts. Financial and logistical constraints, including COVID-19 restrictions, also influenced field data collection.

LITERATURE REVIEW

Concept of ICT in Agriculture

ICT in agriculture encompasses communication technologies that facilitate information exchange between farmers, markets, and advisory institutions. These technologies include radio broadcasting, mobile communication, internet-based platforms, and digital messaging systems that enhance knowledge dissemination and interaction among agricultural actors.

Digital tools contribute to agricultural development by improving access to extension services, supporting farm management decisions, and strengthening linkages between producers and markets. ICT reduces geographical barriers and enables farmers to access updated production and marketing information that was previously unavailable through conventional systems.

Role of ICT in Addressing Climate and Market Information Problems

Climate variability poses a major challenge for smallholder agriculture. Unpredictable rainfall, temperature changes, and extreme weather events increase production risks and reduce yield stability. ICT-based weather information services allow farmers to adjust planting schedules, manage risks, and adopt climate-smart agricultural practices.

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Market inefficiencies also arise from limited price information and dependence on traders. ICT tools improve market transparency by providing updated price information and market demand signals, enabling farmers to negotiate better prices and select appropriate marketing periods. Access to reliable information therefore enhances farm profitability and reduces exploitation by intermediaries

Challenges and Prospects of ICT-Based Information Delivery

Although ICT offers significant opportunities, adoption among rural farmers faces several constraints. Major barriers identified in the study include limited access to localized weather forecasts, inadequate ICT skills, language limitations, weak infrastructure, limited electricity coverage, and high costs of digital devices

Training plays a critical role in overcoming these barriers. Evidence shows that farmers who receive ICT usage training demonstrate higher capability in accessing and applying agricultural information. Training enhances awareness and improves effective utilization of digital tools, thereby increasing adoption rates

ICT and Smallholder Farmers' Income

Theoretical and empirical studies suggest that improved information access enhances agricultural productivity and income by reducing uncertainty and improving resource allocation decisions. ICT services enable farmers to make better production and marketing choices, resulting in higher efficiency and improved economic outcomes.

By integrating weather advisories and market intelligence, ICT-based systems strengthen farmers' adaptive capacity and support income growth. However, the magnitude of impact depends on access, skills, and institutional support mechanisms, highlighting the need for empirical evaluation using rigorous impact assessment methods such as Propensity Score Matching.

METHODOLOGY

Study Area

The study was conducted in Wera Woreda of Halaba Zone, located approximately 310 km south of Addis Ababa. Pepper production represents one of the main income-generating agricultural activities in the area.

Research Design

A cross-sectional research design combining quantitative and qualitative approaches was employed.

Data Sources

Primary data were collected through:

Structured household survey

Key informant interview

Field observation

Secondary data were obtained from agricultural offices and published sources.

Sampling Procedure

A multistage sampling technique was used. Three kebeles with high pepper production were purposely selected, followed by random selection of farm households.

Data Analysis Techniques

Descriptive statistics summarized household characteristics and ICT access patterns.

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Propensity Score Matching (PSM) was applied to estimate the causal impact of ICT utilization on farmers' income by comparing ICT users with statistically similar non-users.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Sample Households

A total of 174 pepper-producing households drawn from Alemtena, 2nd Choroko, and Lay-Lenda kebeles participated in the study. Descriptive statistics were employed to examine baseline characteristics of ICT users and non-users prior to impact estimation. Understanding these characteristics is essential for assessing comparability between treatment and control groups and for validating the assumptions of Propensity Score Matching.

The mean age of household heads was 38.06 years, indicating that most respondents belonged to the economically active population group. The absence of statistically significant age differences between ICT users and non-users suggests that age did not systematically influence participation in ICT-based information services. Similar findings have been reported in smallholder technology adoption studies where productive age groups show comparable adoption potential (Asfaw et al., 2012).

Average landholding size was 1.79 hectares, with ICT users holding slightly larger farms than non-users; however, the difference was statistically insignificant. This indicates that farm size alone did not determine ICT utilization, implying that information access constraints rather than resource endowment primarily limit adoption. Comparable evidence from SSA agriculture shows that information asymmetry often outweighs physical asset ownership in technology uptake decisions (Aker, 2011).

Other socio-economic variables including education level, extension contact frequency, and ICT training exposure showed observable differences, suggesting their potential role in influencing ICT adoption behavior.

Determinants of ICT Use among Pepper Producers

The logit model estimation identified key factors influencing farmers' participation in ICT-based weather and market information services. Frequency of extension contact, education level, farmer awareness, ICT training participation, and proximity to markets significantly increased the likelihood of ICT utilization, while greater distance from towns reduced adoption probability.

These findings highlight that ICT adoption is not purely a technological issue but strongly associated with institutional support and human capital development. Training enhances farmers' ability to interpret digital information, thereby improving effective usage. Similar results were documented by Nyamba (2017), who reported that ICT training significantly improves farmers' capacity to use mobile-based agricultural information systems.

Extension services also play a complementary role by facilitating trust and awareness in digital platforms. This supports the argument that ICT functions as an extension amplifier rather than a substitute for traditional advisory systems (World Bank, 2016).

Propensity Score Matching Diagnostics and Model Validity

To address selection bias arising from non-random participation in ICT services, Propensity Score Matching (PSM) was employed. The matching procedure ensured that ICT users and non-users were comparable based on observable characteristics.

The estimated propensity scores satisfied the common support condition, indicating sufficient overlap between treatment and control groups. Kernel density distributions confirmed improved similarity after matching. Covariate balance tests showed substantial reduction in standardized mean differences, while the decline in pseudo-R^2 values after matching indicated successful elimination of systematic differences between groups.

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The joint significance test further confirmed that observable covariates no longer explained treatment assignment after matching, validating the robustness of the counterfactual comparison. These diagnostics demonstrate that the estimated treatment effects can be interpreted as credible impacts of ICT usage rather than pre-existing household differences.

Impact of ICT-Based Weather and Market Information on Farmers' Income

The core objective of the study was to estimate the income effect of ICT-based information delivery. The Average Treatment Effect on the Treated (ATT) obtained from matching estimators revealed that ICT users achieved significantly higher annual income compared to non-users.

Results indicate that ICT utilization increased household income by approximately **54.29 percent** relative to comparable non-user households. This finding provides strong empirical evidence that access to timely weather forecasts and market price information improves farm decision-making and economic outcomes.

The income gain can be explained through several mechanisms:

First, weather information enables farmers to adjust planting and harvesting schedules, reducing climate-related production risks. Second, market information improves bargaining power by reducing dependence on intermediaries and minimizing price uncertainty. Third, improved information access enhances input allocation efficiency and reduces transaction costs.

These results align with previous empirical studies demonstrating that digital agricultural information services contribute to productivity and income growth among smallholders (Aker & Mbiti, 2010; Fabregas et al., 2019).

In the Ethiopian context, ICT tools increasingly support market integration and climate adaptation strategies.

Role of ICT in Addressing Market and Climate Information Constraints

Farmers reported that ICT tools such as mobile phones, radio, and television were the primary channels for accessing agricultural information. ICT services reduced information delays, improved awareness of market prices, and supported responses to climate variability.

Access to market information helped farmers select appropriate selling periods and negotiate better prices. Similarly, weather updates supported risk-reducing practices, contributing to more stable income outcomes. These findings reinforce theoretical arguments that information access reduces market inefficiencies and strengthens smallholder participation in value chains (Jensen, 2007).

Constraints Limiting Effective ICT Utilization

Despite positive impacts, several barriers constrained effective ICT adoption. Major challenges included limited locally relevant weather forecasts, inadequate ICT skills, language barriers, infrastructure limitations, electricity shortages, and high device costs.

These constraints suggest that technological availability alone is insufficient. Institutional investment in localized content delivery, digital literacy training, and rural infrastructure expansion is required to sustain ICT benefits. Without addressing these structural limitations, income gains from ICT adoption may remain uneven across farming communities.

DISCUSSION AND POLICY IMPLICATIONS

The findings demonstrate that ICT-based weather and market information delivery significantly improves farmers' income by enhancing decision quality and reducing information asymmetry. The positive ATT estimate confirms that digital information services function as an economic productivity tool rather than merely a communication platform.

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The study contributes to existing literature by providing micro-level causal evidence using PSM methodology within a pepper production system in Ethiopia. The results support broader development arguments that digital agriculture can accelerate rural transformation when combined with extension support and farmer training.

Policy interventions should therefore prioritize: expansion of rural ICT infrastructure integration of ICT with extension systems farmer capacity building in digital literacy development of localized weather advisory services

Strengthening these components will enhance the scalability and sustainability of ICT-driven agricultural development.

CONCLUSION

ICT-based weather and market information delivery contributes significantly to improved income among pepper-producing smallholder farmers. Access to timely information enhances production efficiency, strengthens market participation, and reduces uncertainty.

RECOMMENDATIONS

- Expand rural ICT infrastructure coverage.
- Provide farmer training on digital information utilization.
- Integrate ICT services within agricultural extension systems.
- Promote affordable and localized information platforms.
- Strengthen collaboration among government institutions and service providers.

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