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ASSESSING THE EFFECT OF TECHNOLOGY USAGE ON AGRICULTURAL PROFITABILITY AMONG SMALLHOLDER FARMERS IN THE NORTH WEST REGION OF CAMEROON

By

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Abstract

The adoption of agricultural technologies is increasingly recognized as a critical factor for enhancing productivity, efficiency, and profitability among smallholder farmers, particularly in developing regions. This study investigates the impact of technology adoption on agricultural profitability among smallholder farmers in the North West Region of Cameroon, a region characterized by subsistence farming practices, infrastructural constraints, and recent socio-political challenges. Utilizing a cross-sectional survey research design, primary data were systematically collected from 300 smallholder farmers across four carefully selected subdivisions, representative of diverse agricultural and socio-economic conditions within the region. The study specifically examined various forms of technology usage, including mobile-based agricultural applications providing market information and weather updates, mechanized farm equipment such as tractors and irrigation systems, and the adoption of improved seed varieties. The multi-variate ordinary least squares regression technique was applied to estimate the association between these technological interventions and agricultural profitability indicator, namely net farm income. The paper finds significant positive relationship between technology usage and agricultural profitability. Particularly, mobile-based technologies, provides accessible and apt market and weather information, besides mechanized farm inputs, emerged as the principally robust predictors of profitability. The findings emphasis the exigent need for targeted policy initiatives intended to accelerate technology dissemination, boost digital literacy, and provide technical support services that address current barriers to technology adoption in rural farming. This paper therefore provides crucial empirical evidence and practical recommendations, significantly contributing to current debates and strategies aimed at sustainable agribusiness development and poverty mitigation in sub-Saharan Africa.

Keywords: *Technology usage, Agricultural profitability, Smallholder farmers, Cameroon, Innovation adoption*

1. Introduction

Smallholder farmers are pivotal for Cameroon's agricultural sector, as they considerably contributing to food security, rural employment, and the country's overall economic expansion (Chimi et al. 2024). In spite of their importance, smallholder farmers often face numerous challenges, including low productivity, inadequate access to markets, deficient infrastructure, insufficient knowledge and skills, and low profitability (Tabe-Ojong and Molua, 2017; Atamja, Kim, Jong-In, 2019). These problems are most palpable in the North West Region of Cameroon, a region characterized by subsistence farming and affected by socio-economic and infrastructural challenges, including an ongoing socio-political unrest (Balgah, Bwifon, and Shillie, 2022; Kibebsii, Angwafo and Egwu, 2025; Johannes & Njong, 2012)

In recent years, the agricultural sector globally and in Cameroon specifically has witnessed rapid advancements in agricultural technologies aimed at boosting productivity and profitability (Mouafo, 2024, Piabuo, 2020). These

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technologies include mobile appliances destined to supply prompt information on weather updates, market prices, and best farming practices; mechanized farming applications like tractors, plows, irrigation systems; and improved seed, pest resistance, and adaptability to climatic conditions (Balgah, Bwifon, and Shillie, 2022). The introduction and use of these technologies offer significant potential to transform old-style farming practices, allowing smallholder farmers to attain greater productivity, improved efficiency, and ultimately high profitability Balgah, Bwifon, and Shillie, 2022, Piabuo, 2020).

Given this backdrop, assessing the role of modern agricultural technology integration and adoption on smallholder farmers' profitability is critically important (Andrianarison et al. 2021; Bime et al., 2014; Kibebsii, Angwafo and Egwu, 2025). This study aims to analyze this association in detail, focusing on the North West Region of Cameroon. Through an exploration of agricultural practices and technology adoption in four sampled subdivisions based on their diverse agricultural and socio-economic characteristics, the study aims to provide useful insights on the dynamics between technology use and farm profitability.

This study contributes to the broader debate on agricultural modernization and economic growth by providing realistic evidence to policymakers, stakeholders, and practitioners. The results are expected to guide targeted interventions, strategies, and policies intended to boost technology diffusion, provide adequate training and support services, and curb existing technological gaps.

2. Literature Review

The use of technologies in farming has long been documented as indispensable for bolstering farm productivity, efficiency, and farmers' incomes. Feder et al. (1985) provided an early comprehensive review, highlighting several factors like economic incentives, information propagation, and farmers' socio-economic status as key determinants influencing farmers' decisions to adopt agrarian innovations. They demonstrated that adoption rates increase considerably when pure economic advantages are evident and reachable information is provided. As demonstrated by Balgah et al., (2022), the implementation of ICTs significantly improves agricultural performance. In some areas of the Northwest Region, ICT adoption rate of 87.5%, which is treble the national average has been observed, potentially as an adaptation strategy to combat the ongoing war (Balgah et al., 2022). The use of mobile phones by the farmers can influence food' prices and profitability (Piabuo et al., 2020). Mwangi and Kariuki (2015) further investigate the drivers of agricultural technologies in developing countries. They found that farmers' education, access to agricultural extension services, credit accessibility, and clear evidence of benefits had a robust effect on the likelihood of technology adoption. They highlighted that technologies that expedite productivity and income are more readily embraced by smallholder farmers.

Empirical studies reveal that adopting improved seed technology has significantly increases crop yields by two to three times compared to traditional methods (Nchinda et al., 2019). This increase in yield, when spported by good agronomic practices, access to information through farmers' cooperatives, and support from extension and research services, significant bolsters agricultural profitability and household income (Nchinda et al., 2019). Also, the use of improved seeds and modern equipment, farmers' education and access to loans, boost both agricultural productivity and profitability (Andrianarison et al., 2021).

Studies have also revealed considerable scope for productivity gains through improved efficiency. Investigation on smallholder rice farmers revealed an average technical efficiency level of 84%, signifying a potential 16% rise in output through enhanced resource use (Atamja et al., 2019). Correspondingly, tomato farmers in the Buea municipality of the South West region exhibited an average technical efficiency score of 68%, with productivity positively impacted by education level, age, and the adoption of farming technologies (Tabe-Ojong & Molua, 2017).

Although agriculture remains the primary contributor to the Cameroon's economy, low productivity persist, owing to farmers' failure to making full use of the available technologies and production methods (Tabe-Ojong & Molua, 2017; Atamja et al., 2019). Farmers' levels of schooling and the nonexistence of good farm-to-market roads have inhibited the adoption of improved technology, particularly for women in the Northwest Region (Lengha, 2017). Unsuitable agricultural practices, such as slash-and-burn strategy and the use of chemical fertilizers, lack of capital, low education levels, no farming experience, limited income, and small farm sizes, reduce productivity and profitability (Kibebsii et al., 2024)

Whereas access to fertilizers can boost the positive effect of technology adoption on profitability and household incomes, proper measures are essential to facilitate access to such inputs (Nchinda et al., 2019). Moreover, limited access to farm loan is a major factor impeding technical efficiency for farmers (Atamja et al., 2019). The lack of infrastructure, with post-harvest technology challenges, market incentives, financial sustainability, and feedback mechanisms have been identified as barriers within the national agricultural extension program (Nyambi, 2012). Government spending on education, health, and road infrastructure can promote convergence in labor productivity, but agricultural spending may increase inequality by disproportionately benefiting the non-agricultural sector (Johannes & Njong, 2012).

To boost agricultural profitability and technology adoption among smallholder farmers in Cameroon's Northwest Region, farmers should increase farm sizes while adopting improved seeds and novel production techniques (Tabe-Ojong & Molua, 2017). Simultaneously, extension and research services must be strengthened through on-farm demonstrations, result-oriented workshops, and leveraging farmer cooperatives to improve education and information propagation (Tabe-Ojong & Molua, 2017; Nchinda et al., 2019). Ensuring access to agricultural loans and subsidized inputs is also critical

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(Kibebsii et al., 2024; Andrianarison et al., 2021), alongside implementing training programs, seminars, and promoting good agronomic practices for effective technology use (Nchinda et al., 2019; Kibebsii et al., 2024). Sustained ICT adoption requires dedicated awareness campaigns and experience-sharing (Balgah et al., 2022), while boosting productivity and profitability necessitates promoting mechanized agriculture (Kibebsii et al., 2024) and improving infrastructure, particularly roads, to alleviate marketing constraints (Bime et al., 2014).

Despite substantial research exploring factors influencing the adoption of agricultural technologies, there remains a notable gap in the literature concerning the explicit link between technology adoption and agricultural profitability, particularly in challenging contexts such as conflict-affected and infrastructure-constrained areas. The North West region of Cameroon present exclusive challenges, including arm conflict, limited market infrastructure, and insufficient technical and pecuniary assistance to farmers, conditions which expressively impact technology adoption decisions and profitability.

This paper contributes to addressing this gap by explicitly exploring the profitability dimension of technology use among smallholder farmers in the North West region of the country. It leverages two foundational theoretical frameworks: The Theory of Technology Acceptance Model (TAM), initially proposed by Davis (1989), which speculates that perceived usefulness and ease of use influence users' decisions to admit and use new technologies.

Diffusion of Innovations Theory by Rogers (2003), which summaries how, why, and at what degree new ideas and technologies propagate among cultures, underscoring factors such as relative advantage, compatibility, complexity, trialability, and observability as significant drivers of technology dissemination.

3. Methodology

This mixed approach study investigates the effect of agricultural technology adoption on profitability among smallholder farmers in the North West Region of Cameroon. Using a cross-sectional survey design, primary data were collected from 300 randomly nominated farmers in four representative subdivisions. Trained enumerators administered face-to-face structured questionnaires to guarantee data accuracy

The questionnaires captured data on: implemented technologies (e.g., mobile application for information, automatic tools, and improved seeds); usage rate; associated purchase, upkeep, and operation costs; and profitability indicator (net farm income). Main socio-demographic elements (age, gender, education, household size, farming experience) were also collected to control for confounding factors. Data analysis used descriptive statistics (frequencies, means, percentages) to outline farmer characteristics, technology adoption, and economic outcomes.

For inferential analysis, multiple linear regression models were employed to explore and quantify the relationships between agricultural technology usage and profitability indicator, specifically net farm income. The regression models incorporated control variables including age, gender, education level, and farming experience to ensure the results accurately reflected the impact of technology use independent of socio-demographic influences. Rigorous testing for assumptions of linearity, normality, homoscedasticity, and multicollinearity was conducted to validate the reliability and accuracy of the regression outcomes. Significance levels for statistical analysis were set at $p < 0.10$.

Andrianarison et al., (2022) analyzed factors enhancing agricultural profitability under innovation technology: Insights from Cameroon Emphasizes to enhance agricultural profitability following innovation adoption and typically promote adoption itself. The propensity to adopt innovation and the potential gain in productivity increases with education level. Credit permits farmers to adopt the innovation and to purchase high-efficiency pesticides and fertilizers (Andrianarison et al., 2022). This paper follows the argument of reasoning of Andrianarison et al., (2022).

The model is specified as follow:

$$AP = \vartheta_0 + \alpha_1 TU + \alpha_2 AGP + \alpha_3 farm\_exp + \alpha_4 INC + \alpha_5 PEDU + \alpha_6 SEDU + \alpha_7 TEDU + \alpha_8 \text{GEND} + \alpha_9 Member + \varepsilon_1$$

Where

AP represents agricultural profitability measure by net farm income, TU is technology measured by two proxies including mobile phone and mechanized tool (tractor). AGP is agricultural productivity, Fsrm_exp designates farmer's experience expressed as the number of years actively involved in farmed, INC represents the farmer's income in dollars, PEDU is primary education, SEDU denote secondary education, TEDU is tertiary education. GEND represents gender which takes a value of 1 if female and 0 otherwise. Member represent represents membership of a farmer cooperative which is also a dummy that assumes 1 if the farmer belongs to a cooperative and 0 otherwise.

This methodological framework ensured a robust examination of the complex dynamics between technology adoption and agricultural profitability, yielding credible and actionable insights applicable to policy-making and practical interventions in similar agricultural contexts.

4. Results

4.1. Descriptive Statistics

The target population of the study is smallholder farmers in Mezam, Ngo-ketunjia, Donga Mantung and Bui Division. We sampled 75 farmers in each division and with a return rate of 100%, 300 copies were gathered as presented in the figure 4.1 below.

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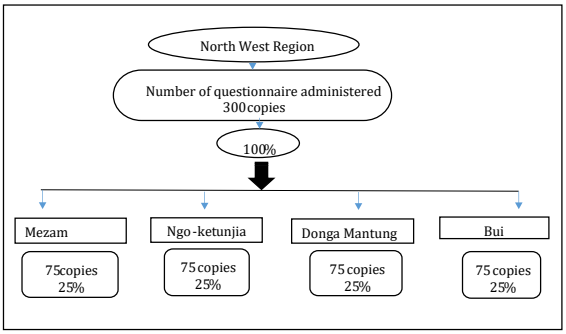

Figure 4.1: Spatial distribution of effective respondents in the four Divisions

In terms of gender distribution, 105 male and 195 females were sampled across four Divisions in the northwest Region as shown in figure 4.2 below. This demonstrates that Small farm holders are mostly female.

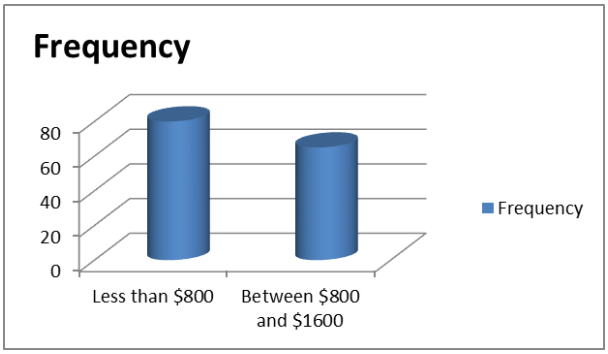

Figure 4.2: distribution of farmers by gender

Regarding the annual income of the farmers, a majority (80) of them had annual income less than $800 while only 10 of them had annual income bigger than $3600. This clearly demonstrates that the farmers experience low profitability.

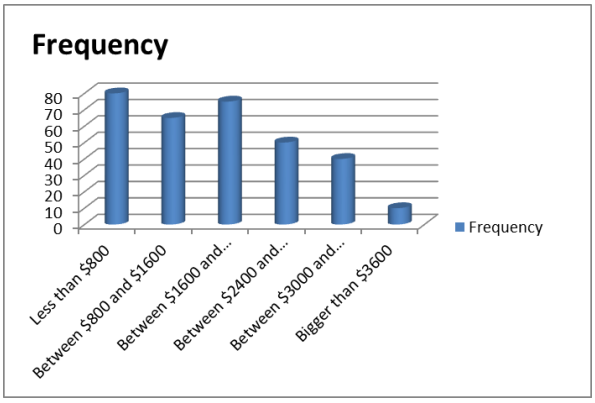

Figure 4.3: Distribution of farmers by Income level

Regarding the use of mobile phone application, 100% of the smaller holder farmers answered in the affirmative. When asked whether they used any mechanized tools, only 5%(15) of the farmers said no. 80% (240) smallholder farmers hired the services of a tractor while 15%(45) of them used cows to plough their farmers as shown by the pie chart below.

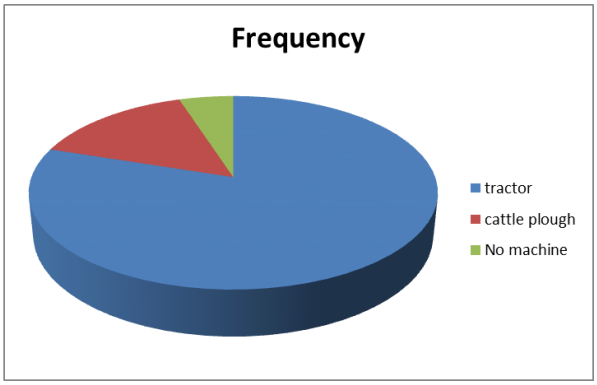

Figure 4.4: The use of mechanized tools

4.2. Regression analysis

The multiple regression analysis conducted in this study revealed that agricultural technology usage significantly contributes to variations in agricultural profitability among smallholder farmers in the North West Region of Cameroon. Specifically, the regression model indicated that approximately 63% ($R^2 = 0.63$) of the variability observed in agricultural profitability indicator, namely net farm income, could be explained by the use of agricultural technologies.

The proxies employed for TU are respectively mobile-based technologies, mechanized farming tool (tractors), and irrigation systems in columns (1), (2) and (3) of Table 4.1.

Table 4.1: OLS estimates on the effect of technology use on profitability

Variables	Coeff.	Coeff.	Coeff.
TU	0.6734*** (0.221)	0.881** (0.421)	1.033*** (0.121)
AGP	2.113*** (0.931)	2.121*** (0.843)	2.113*** (0.931)
Farm_exp	0.214* (0.126)	0.214* (0.126)	0.214* (0.126)
INC	1.132** (0.553)	1.132** (0.553)	1.132** (0.553)
PEDU	0.913** (0.453)	0.743** (0.373)	0.913** (0.453)
SEDU	0.534** (0.261)	0.614** (0.288)	0.534** (0.261)
TEDU	0.118** (0.058)	0.113** (0.055)	0.111** (0.050)
GEND	1.221 (0.775)	1.441 (0.905)	1.117 (0.811)
Member	0.983* (0.584)	0.983* (0.584)	0.983* (0.584)
Obs. R^2	300 0.63	300 0.67	300 0.65

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*Note: *, **, and *** represent significance at the 10%, 5% and 1% levels respectively. The dependent variable is agricultural profitability (AP).*

A closer examination of the results highlighted that mobile-based technologies, such as applications providing timely market information and weather forecasts, emerged as particularly influential in predicting higher profitability (0.673, p value=0.003). The coefficient of the regular utilization of mobile applications is 0.407 with a p-value of 0.043, indicating its positive and significant effect on AP. Mobile application usage enhances decision-making capabilities, reduced uncertainty, and improved marketing efficiency, ultimately leading to higher net incomes and better return on investments.

Mechanized farming tools, including tractors (with a coefficient of 0.881 and a p-value=0.050) and irrigation systems (with a coefficient of 1.033 and p-value=0.000), are also significant predictors of agriculture profitability. Farmers employing mechanization reported higher yields, more efficient resource utilization, and lower labor costs, translating directly into enhanced profitability outcomes. Additionally, the adoption of improved seed varieties was associated with increased profitability, primarily due to their higher yields, better resistance to pests and diseases, and greater resilience to climatic fluctuations.

Agricultural productivity (AGP) also stands out as an important predictor of AP. Its coefficient of 2.113 and a p-value of 0.003, suggests that a unit increase in AGP raises AP by 2.113 units, result which is significant at the 1% level.

The farmer's experience is also an important determinant of AP with a coefficient of 0.214 and a p-value of 0.076. This positive and statistically significant coefficient suggests that as the farmer's experience increases, agricultural profitability skyrockets in the study area. Enhanced farmer's experience helps the farmers to adjust the use of technology, reduce cost of production and establish relationship with readily available buyers which reduces post-harvest losses and increases profitability.

The farmer's income level (INC) was also found to be an important and significant driver of AP with a coefficient of 1.132 and a p-value of 0.043. This indicates that as farmer's income goes up by 1 unit, AP increases by 1.132 units and the result is statistically significant at the 5% level. More income means that the farmer can acquire more technology, improved inputs, afford storage and transportation costs.

The level of education of the farmer was also found to be an important and significant factor contributing to AP within this study area. The coefficient of primary education (PEDU), secondary education (SEDU) and tertiary education (TEDU) are respectively 0.913, 0.534 and 0.118. Also, these coefficients are all significant at the 5% level. It is therefore evident that while education has a positive and significant effect on AP, this efficient diminishes with increasing level of education as suggested by the estimated coefficients.

The coefficient of gender (GEND) is 1.221 with a p>0.1, indicating that gender does not have a statistically significant effect on AP in the study area

Belonging to a farmer's cooperative (Member) is also an important and significant driver of AP. With a coefficient of 0.983 and a p-value of 0.056, it is evident that Member has a positive and significant influence on AP. Under the canopy of farmer's cooperative; the farmers get free training, subsidized seeds and almost free fertilizer for the farms. Also, the farmer's cooperative collect the farm produces and market them a formal market, raising the profitability of each farmer.

However, the analysis also revealed factors negatively impacting profitability outcomes, notably the limited adoption and inconsistent usage of technologies due to high costs and insufficient training. Farmers encountering economic constraints or inadequate access to technical training and extension services witnessed difficulties in employing available technologies. This narrow and uneven adoption significantly reduced the potential profitability from the use of technology.

These findings highlight the importance of addressing financial obstacles and expanding training and support programs. Increasing accessibility to reasonable technological solutions and improving rural extension services could significantly diminish these challenges, thereby increasing profitability potential for smallholder farmers.

5. Discussion

The findings of this study align with previous studies emphasizing the positive influence of technology adoption on agricultural performance. However, this research uniquely contributes to the existing literature by providing specific quantitative insights into how various technologies directly influence profitability among smallholder farmers. While corroborating the conventional positive nexus between technology use and improved farm performance, the study significantly advances the comprehension of the differential efficacy of specific technological interventions.

Mobile-based technologies, such as applications that provide market information, weather forecasts, and agricultural advisories, were particularly impactful and more readily adopted compared to capital-intensive mechanized equipment. This observation aligns with broader discussions in the literature that underscore mobile technology's comparative accessibility, affordability, and immediate utility for smallholder farmers. Unlike more expensive mechanized tools, mobile technologies require relatively minimal financial investment and are highly scalable, making them suitable for widespread adoption in resource-constrained contexts such as North West Cameroon.

Conversely, while mechanization significantly boosts productivity and efficiency, it often encounters considerable barriers owing to high initial investment and constant maintenance costs. This explains why such technologies demonstrate modest effects in this study, as the majority of

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smallholder farmers cannot afford finances or external support to regularly maintain and fully utilize these technologies.

Also, though the study shows that education and agricultural extension support are important in facilitating factors affecting the efficacy of technology adoption. Farmers with better access to educational resources and training programs did not realize high agricultural profitability compared to farmers with less education who struggled with technology integration, as the coefficient of educational attainment diminished with higher level of education.

These nuanced intuitions demonstrate the necessity for precisely targeted, context-appropriate policy interventions to speed up technology adoption. Key policy priorities include guaranteeing greater accessibility and affordability of technologies; particularly mobile-based solutions together with significant investment in consolidating agricultural education, training programs, and extension services.

6. Conclusion and Policy Implications

Data analysis from 300 smallholder farmers in four subdivisions in Cameroon's North West Region reveals that the adoption and effective use of agricultural technologies significantly enhances agricultural profitability**.** Technologies such as mobile apps and mechanized tools, as well as improved seeds positively influence net farm income. Mobile-based technologies produced the most significant effect, owing to their accessibility and affordability in smallholder settings. However, the study highlights that making full use of these technologies for improved productivity and profitability is inhibited by critical barriers. Inadequate rural infrastructure, high technology costs, and restricted access to training and extension services hinder full adoption and effective use, thereby curbing profitability gains from technological innovation.

Based on the analysis, the following policy measures are recommended:

Rural infrastructure development**,** including transportation networks, consistent supply of electricity, and broadband connectivity, to create an enabling environment for technological integration must be prioritized.

The Implementation of comprehensive digital literacy schemes and tailoring of farmers' training initiatives to equip them with the competencies required exploiting mobile and mechanized technologies effectively, must be prioritized.

Directed financial incentives such as subsidies or cost-sharing mechanisms to ease the acquisition and maintenance costs for agricultural technologies should be introduced. Concurrently, agricultural extension services that can provide constant technical assistance and practical guidance have to be strengthened.

Foster public-private partnerships to pool resources, leverage specialized expertise, and ensure scalable utilization of modern farming technologies. Such collaborations are contributory in driving innovation, expanding distribution channels, and improving farmer adoption rates.

Moving forward, future studies should use panel methodologies to systematically assess the long-term impacts of technology adoption on profitability. Furthermore, comparative regional analyses would be useful for corroborating these findings and generating insights relevant to other agricultural regions within Cameroon.

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