Journal of Arts, Humanities and Social Science (JAHSS)

ISSN: 3006-9491 (Online)

Volume 2 Issue 1, (2025)

https://doi.org/10.69739/jahss.v2i1.304

https://journals.stecab.com/jahss

Published by
Stecab Publishing

Research Article

Examining the Effects of Agricultural Technology Adoption for Agricultural Productivity and Household Income on Small Scale Farmers: A Study of Mkushi District

*[1]Mutinta Habanyama, [2]Kelvin Chibomba

About Article

Article History

Submission: January 19, 2025
Acceptance : February 27, 2025
Publication : March 18, 2025

Keywords

Agricultural Productivity, Agricultural Technology, Household Income, Small Scale Farmers

About Author

[1] Department of Social Research, Information and Communications University, Lusaka, Zambia

[2] Department of Humanities, Information and Communications University & Research and Development Center, Lusaka, Zambia

Contact @ Mutinta Habanyama
habanyamamutinta35@gmail.com

ABSTRACT

In Zambia, over half of the population lives below the poverty line, struggling to meet basic calorie needs, with many children experiencing stunting. Smallholder farmers in Mkushi face multiple challenges, including low crop yields and limited access to modern agricultural technologies. This study explores the factors influencing the adoption of agricultural technologies among smallholders, assesses their impact on household income, and identifies barriers to widespread adoption. A mixed-methods approach was employed, combining quantitative surveys of smallholder farmers with qualitative interviews of key stakeholders. The analysis highlights critical factors influencing technology adoption, including education, land size, credit access, extension services, market access, and community influence. Farmers adopting advanced agricultural technologies experience significant gains in crop productivity and household income. Improved seeds have the highest adoption rate (40%), followed by fertilizers (35%), pesticides (32%), irrigation systems (25%), and farm machinery (15%), support 35% , resistance to change 20% and lack of information 10%. Despite these benefits, several challenges hinder adoption. The most significant barrier is high costs, affecting 50% of farmers, followed by limited access to credit (40%), lack of technical support (35%), inadequate information (10%), and resistance to change (20%). These findings underscore the need for targeted interventions to enhance access to modern agricultural practices. Strengthening financial support systems, expanding agricultural extension services, and improving farmer training programs can foster greater adoption. The study emphasizes that addressing these barriers can enhance food security, economic stability, and overall agricultural productivity among small-scale farmers in Zambia

Citation Style:

Habanyama, M., & Chibomba, K. (2025). Examining the Effects of Agricultural Technology Adoption for Agricultural Productivity and Household Income on Small Scale Farmers: A Study of Mkushi District. *Journal of Arts, Humanities and Social Science, 2*(1), 74-85. https://doi.org/10.69739/jahss.v2i1.304

1. INTRODUCTION

1.1. Background

Agriculture is a key driver of economic growth in many developing countries, contributing to food security and poverty reduction. However, smallholder farmers who make up the majority of the farming population in these countries face numerous challenges in their quest to increase productivity and improve their livelihoods. One of the most significant challenges is the lack of access to improved agricultural technologies, which can help increase crop yields and improve household income (Namonje-Kapembwa, & Thelma, 2016; Mrema *et al.*, 2020).

The vast majority of Zambians rely on agriculture as their principal means of livelihood. Agriculture and related agribusinesses are the largest employer (85%) and a major component of gross domestic product (about 15%) and export earnings (about 50%). Maize production is a very important source of food and farm income for smallholders, accounting for about 80% of their total value of crop production (Hamukwala, 2021; Jayne *et al.*, 2007). The crop is also a staple food for much of southern Africa. For many of these countries, its supply is essential to food security and domestic stability. Due to a low per capita income (US$ 350 in Zambia), the cost of maize is an important determinant in the cost of food (Sichoongwe, 2014).

A huge challenge facing Zambia is to increase maize productivity and the incomes of smallholder farmers, both of which have remained very low. Rising productivity could improve the competitive position of maize in both rural and urban markets. Improving the competitive position of maize in Zambia is also justified by the growing recognition of the need for new strategies for developing agriculture in semi-arid areas that are prone to drought. Zambia experiences recurrent droughts, which tend to be severe in agro-ecological region I. Zambia has experienced 4 droughts in the last four decades. In the period 1976-2007, droughts were experienced in the 1986/87, 1991/92, 1994/5 and 2004/05 seasons (Environmental Council of Zambia, 2000; Mungoma, 2007; Thurlow *et al.*, 2009). This challenge is unfortunately shared by most other countries in the region.

In response to this challenge, the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) have over the past two decades been working with national agricultural research institutes to adapt breeding techniques to Sub-Saharan Africa. Through this effort, more than 50 new maize hybrids and open-pollinated varieties have been developed and provided to the farmers through seed companies and Non-Governmental Organizations (NGOs). Varieties that are bred to tolerate drought can produce 20-50% higher yields during drought years than other maize varieties. However, the extent to which such varieties have been adopted remains unknown, even in the drought-prone regions (Sitko & Jayne, 2014).

Zambia has an integrated seed system that includes the formal and informal sectors and in which both public and private sectors play significant roles. Previously, the government played a controlling role in the entire chain from breeding to seed production and marketing, as well as quality control and certification. All this changed following economic liberalization of the 1990s. A number of private companies have since invested in seed breeding, production, and marketing.

Despite the potential benefits of agricultural technology adoption, many smallholder farmers in developing countries still rely on traditional farming practices, leading to low productivity and incomes (Hamazakaza *et al.*, 2016; Kassie *et al.*, 2017). This study sought to assess the effects of agricultural technology adoption on agricultural productivity and household income among smallholder farmers in Mkushi, Zambia.

1.2. Statement of the problem

About 70% of the African population depends on Agriculture for their livelihood. Nonetheless, agriculture productivity is low and food security is still a challenge (Ayim, 2022). In Zambia, more than half of the country's 17.8 million people live below the poverty line. 48% of people are unable to meet their minimum calorie requirements and 35% of children are stunted. Smallholder farmers in Mkushi, Zambia, face various challenges, including low crop yields and limited access to modern agricultural technologies. The low adoption rates of agricultural technologies, such as improved seed varieties, fertilizers, and irrigation systems, have been identified as a significant impediment to increased agricultural productivity and household income (Akudugu *et al.*, 2018).This study sought to address the following research questions: What is the impact of agricultural technology adoption on crop yields in Mkushi? How does agricultural technology adoption affect household income among smallholder farmers? What are the main barriers to the adoption of agricultural technologies by smallholder farmers in Mkushi?

1.3. General objective

The general objective of the study is to assess the effect of agricultural technology adoption on agricultural productivity and household income among small-scale farmers in Mkushi. To achieve this, the study has the following specific objectives: to assess the factors that influence the adoption of agricultural technologies by smallholder farmers, to examine the effects of agricultural technology adoption on household income in Mkushi, and to ascertain the limitations in agricultural technology adoption for improving agricultural productivity.

1.4. Research questions

The research questions of this study are as followed:

What factors influence the adoption of agricultural technologies by smallholder farmers, what are the effect of agricultural technology adoption on household income in Mkushi, and what are the limitations in agricultural technology adoption for improving agricultural productivity

1.5. Theoretical framework

Technology adoption is crucial to economic growth, yet levels of technology adoption vary, with limited adoption in many countries. Countries wield considerable technology adoption power and their adoption activities can be leveraged to achieve social, economic, and environmental goals by endorsing specific technologies (Hooks *et al.*, 2021). While adoption of technology in agriculture is fundamental to improving farm productivity, vast literature shows that adoption levels of externally promoted technologies remain low and the pace of adoption is very slow among small-scale farmers in developing countries (Curry *et al.*, 2021). Determinants of adoption are highly dependent on unobserved cultural, contextual, and policy factors, which is evidenced by the small average effects, the large amount of unexplained heterogeneity in all of the average results presented, and the inability of observed factors to explain much of this variability (Ruzzante, 2021). The proposed conceptual framework for this research is the Unified Theory of Acceptance and Use of Technology (UTAUT) Model. The Unified Theory of Acceptance and Use of Technology (UTAUT) model is a widely used theoretical framework that explains how individuals adopt and use technology. The model was developed by Venkatesh *et al.* (2012) and has been used in various studies related to technology adoption in different contexts. The UTAUT model is based on four key constructs that influence the adoption and use of technology: performance expectancy, which refers to the degree to which an individual believes that using the technology will enhance their job performance; effort expectancy, which pertains to the degree to which an individual believes that using the technology will be easy and require less effort; social influence, which is the degree to which an individual is influenced by the opinions and behaviors of others in their social network, such as colleagues or friends; and facilitating conditions, which refer to the degree to which an individual believes that the necessary infrastructure and support systems are in place to enable the successful use of the technology (Misra *et al.*, 2022). The UTAUT model posits that the intention to use technology is determined by these four constructs, and that intention serves as a key driver of actual technology. Overall, the UTAUT model provides a useful framework for understanding the factors that influence the adoption and use of technology and can be applied to a range of different technologies and contexts (Venkatesh *et al.*, 2012).

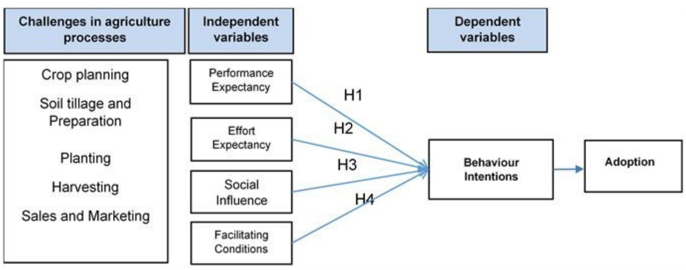

Figure 1. Using the UTAUT model

Using the UTAUT model (Figure 1), Venkatesh refers to the extent to which an individual believes that the use of technology facilitates performing a task of improves his or her job performance and has a positive effect on an individual's behavioral intention to use (Michels *et al.*, 2019).

2. LITERATURE REVIEW

2.1. Factors influencing technology adoption by smallholder farmers

Agricultural technology adoption among smallholder farmers is a multifaceted process influenced by various socio-economic, environmental, and institutional factors. Globally, technology adoption is essential for addressing challenges such as food security, climate change, and rural poverty. Despite its potential, adoption remains uneven, particularly in Sub-Saharan Africa (SSA) and Zambia. This review synthesizes insights from global, regional, and national perspectives, highlighting factors influencing adoption, barriers, and the socio-economic outcomes of agricultural innovations.

Financial access is a pivotal determinant of technology adoption. Studies show that availability of credit allows smallholder farmers to invest in critical innovations such as high-yield seed varieties and irrigation systems. For instance, microfinance initiatives have enabled remote farmers to overcome economic barriers, although their reach remains limited in rural areas (Mwangi & Kariuki, 2015; Simtowe & Zeller, 2011). Furthermore, education and extension services significantly impact adoption. Farmers with higher education levels or access to well-resourced extension systems are more likely to adopt innovative practices, as seen in the Mkushi district of Zambia, where resource constraints have undermined extension effectiveness (Asfaw *et al.*, 2012).

Land tenure security plays a vital role in encouraging long-term technological investments such as soil management or irrigation. Secure land tenure provides farmers with the confidence to adopt practices that have deferred benefits, mitigating fears of land expropriation (Deininger & Jin, 2006). Larger farms tend to adopt new technologies more readily due to better economies of scale and greater risk tolerance. Conversely, fragmented landholdings common in SSA often impede technology adoption, as demonstrated in Zambia where customary land tenure systems present challenges in formalizing land rights (Jayne *et al.*, 2010; Sitko & Jayne, 2014).

Climate variability is a significant driver of agricultural technology adoption. Technologies like drought-resistant seeds and climate-smart irrigation systems help mitigate the risks of erratic weather patterns. In SSA, initiatives such as the Water Efficient Maize for Africa (WEMA) program have demonstrated up to 30% yield increases during drought conditions (Prasanna *et al.*, 2018). Similarly, conservation agriculture (CA) practices have enhanced resilience by improving soil health and water retention, critical for addressing Zambia's vulnerability to climate shocks (Haggblade *et al.*, 2011).

The role of social networks and community dynamics in promoting technology adoption cannot be understated. Peer-to-peer learning within farmer cooperatives facilitates knowledge sharing and risk mitigation. For instance, in Zambia, farmer groups have significantly boosted adoption rates of conservation agriculture by demonstrating practical benefits on communal demonstration plots (Ngoma *et al.*, 2020). Traditional leaders also play a crucial role in influencing community acceptance of innovations, with their endorsement often leading to higher adoption rates.

Supportive policies and robust institutions are critical enablers of agricultural technology adoption. In Zambia, the Farmer Input Support Program (FISP) has improved access to subsidized inputs like fertilizers and hybrid seeds, though implementation challenges such as delayed distributions persist (Tembo & Sitko, 2013). The integration of digital tools into extension services has further enhanced reach, providing timely information on weather, markets, and best practices, particularly benefiting marginalized groups like women (Quisumbing & Pandolfelli, 2010).

2.2. Effects of agricultural technology adoption on household income

Agricultural technologies that facilitate market access, such as mobile platforms providing price information or transportation innovations, play a critical role in increasing household income. Mobile technologies, for instance, enable farmers to receive real-time market price updates, which help them sell their produce at optimal prices (Aker, 2011).

Pest and disease management technologies have significantly improved agricultural productivity globally, resulting in increased household incomes. Pesticides, integrated pest management (IPM), and advanced digital tools like drones and AI-driven pest detection systems have transformed how farmers combat crop losses.

In Zambia, ISFM practices have similarly proven effective. Smallholder farmers in Mkushi who adopted ISFM techniques reported yield increases of up to 40%, with improved soil structure and resilience against soil degradation (Fairhurst, 2012).

2.3. Limitations of agricultural technology adoption to agricultural productivity

Globally, limited access to financing restricts farmers' ability to invest in modern technologies, such as mechanization, irrigation systems, and high-quality inputs. A significant proportion of smallholder farmers lack formal financial services, forcing them to rely on informal lending, which often comes with unfavorable terms (FAO, 2018).

The adoption of modern agricultural technologies requires technical knowledge and skills that many farmers lack. Agricultural extension services are inadequate in many (IFAD, 2019).

In Zambia, policy and institutional barriers are a significant constraint to agricultural technology adoption. Although the government has developed a series of agricultural policies aimed at improving the sector, these policies often lack coherence and continuity, resulting in inconsistent support for technological adoption (Zambia Ministry of Agriculture, 2020).

cultural resistance arises from deeply ingrained farming practices and fear of change. Many farming communities have used traditional methods for generations, making them hesitant to adopt new technologies. This resistance is often rooted in a mistrust of modern innovations, particularly genetically modified organisms (GMOs) or chemical fertilizers, which are perceived as unnatural or harmful to the environment (FAO, 2021).

3. METHODOLOGY

Mkushi District is located in the Central Province of the Republic of Zambia, covering an area of approximately 17,726 square kilometers. It has an estimated population of 117,330, with 58,720 males and 58,610 females, as reported in the 2010 Census of Population and Housing of Zambia (Population Summary Report, 2012). The district is bordered by Serenje to the northwest, Masaiti to the northeast, Luano District, Nyimba, and Chongwe to the south, and Kapiri-Mposhi to the southeast. To the north, it shares a border with the Democratic Republic of Congo.

3.1. Research design

The research design for this study will be a cross-sectional survey. A structured questionnaire will be administered to a sample of farmers in Mkushi, Zambia, to collect data on their agricultural practices, technology adoption, agricultural productivity, and household income. The survey will be conducted in collaboration with local agricultural extension agents (Feder *et al.*, 2010).

3.2. Sample selection

The study population will consist of smallholder farmers in Mkushi, Zambia, who have adopted improved agricultural technologies in the past five years. We will use a stratified random sampling method to select the households to be surveyed, with the strata being defined by the adoption status of agricultural technologies. We will select the sample from the list of households provided by the Agricultural Technology Adoption Agency in the Mkushi district. The sample will be stratified by gender and age of the household head to ensure a representative sample (Kanyamuka *et al.*, 2019).

3.3. Sample size

The formula used to calculate sample size for a population with a known size is based on the Cochran's formula, which is commonly used for determining the sample size for a proportion in such instances.

$n_0 = (Z^2 . p . (1 - p)) / E^2$

Where:

n_0 = Sample size (without finite population correction)

Z = Z-value (e.g., 1.96 for a 95% confidence level)

P = Estimated proportion (if unknown, 0.5 is used as a conservative estimate)

E = Desired margin of error (e.g., 0.05 for a 5% margin)

After calculating no a finite population correction was taken from finite population:

$n = (n_0 / (1 + (n_0 - 1) / N))$

Where:

n_0 = Adjusted sample size (after finite population correction)

N = Total population size

In this case:

N = 117,330 (population of Mkushi)

Desired margin of error E = 0.05

Estimated proportion p = 0.5 (assuming a conservative estimate)

Z-value Z = 1.96 confidence level

Thus, sample size is 100

3.4. Data Collection

To achieve our research objectives, we will conduct a survey of 100 randomly selected households in the Mkushi district of Zambia. The survey will collect information on household demographics, agricultural practices, and technology adoption, as well as household income and consumption. We will also conduct interviews and focus group discussions with farmers and stakeholders, including extension workers, input suppliers, and representatives of agricultural organizations, to gain insights into their perspectives on the adoption and impacts of the technologies.

3.5. Data collection tools

The following tools will be used to collect data:

Survey questionnaires: A survey questionnaire can be designed to collect data from the targeted households on their socio-economic characteristics, agricultural practices, and adoption of agricultural technologies. The questionnaire can also include questions on income, expenditure, and assets.

Focus Group Discussions (FGDs): FGDs will be conducted with a selected group of farmers, extension officers, and other stakeholders to discuss their experiences and perceptions of agricultural technologies and their impact on agricultural productivity and household income.

3.6. Data Analysis

Data analysis will be conducted using the Statistical Package for Social Sciences (SPSS) and Stata software. We will conduct descriptive statistics, regression analysis, and hypothesis testing to analyze the data. Our regression analysis will include both univariate and multivariate models to assess the impact of technology adoption on household income and agricultural productivity, while controlling for other factors that may influence these outcomes.Regression analysis will be used to estimate the impact of agricultural technology adoption on agricultural productivity and household income, while controlling for other relevant factors such as farm size, access to credit, and demographic characteristics of the household (Kanyamuka *et al.*, 2019). We will employ a difference-in-differences (DID) econometric model to analyze the impact of technology adoption on household income and agricultural productivity. The DID model is well suited for this study as it allows for the comparison of changes in outcomes between the treatment group (technology adopters) and the control group (non-adopters) over time. We will also use propensity score matching (PSM) to ensure that the treatment and control groups are comparable in terms of observable characteristics before the adoption of the technology.

3.7. Ethical Considerations

Ethical considerations will be considered throughout the study. Informed consent will be obtained from all participants before they are included in the study (McDermott *et al.*, 2012). Confidentiality and privacy of the participants will be ensured by anonymizing the data and keeping it secure. We will also seek approval from the relevant institutional review board (IRB) before commencing the study. In addition to informed consent, special attention will be given to the cultural sensitivity of the research process. Since this study is conducted within rural farming communities in Mkushi, it is essential to respect local customs and norms while engaging with participants. Researchers will undergo training to ensure that data collection methods are respectful of participants' cultural backgrounds and do not impose any undue pressure or discomfort. Engaging with local leaders and community representatives before initiating data collection will further help build trust and facilitate smooth interactions with participants, fostering a respectful research environment (Hammersley & Traianou, 2012).

The study will also consider the principle of beneficence, ensuring that participation poses no harm to the individuals involved. Efforts will be made to minimize any physical, psychological, or social risks that participants might face during data collection. For instance, participants will be informed that they can withdraw from the study at any point without facing any consequences. This approach helps safeguard participants' well-being and ensures that they are not subject to any stress or discomfort due to their involvement in the research (Diener & Crandall, 1978).

Finally, the study will uphold transparency and integrity in reporting findings. This includes accurately representing participants' views and experiences and refraining from altering or omitting information that may skew results. The research team will also disclose any potential conflicts of interest and strive to present findings in a manner that does not mislead or harm the community. This commitment to ethical transparency will help maintain the credibility of the research and ensure that its outcomes are beneficial for both the participants and the wider field of agricultural research (Israel & Hay, 2006)

4. RESULTS AND DISCUSSION

4.1. Demographic characteristics

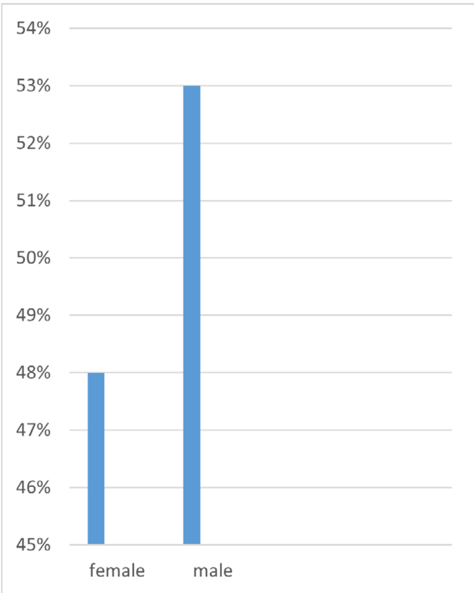

Figure 2. Gender

Figure 2 shows that 53% of respondents were male ,while 48% were females.

4.2. Age distributions

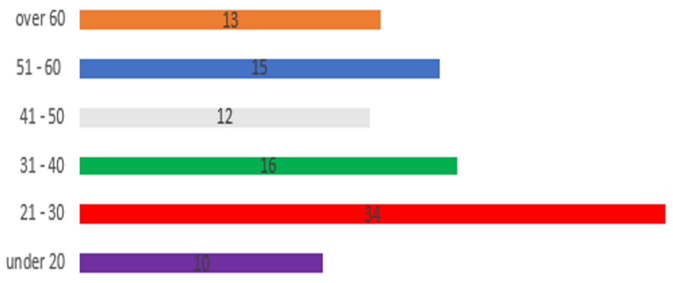

Figure 3. Age distribution of respondents

The age distribution of respondents shows that the largest group falls within the 21-30 age range, comprising 34 participants. This is followed by the 31-40 age group with 16 participants and the 51-60 age group with 15 participants. The 41-50 age group accounts for 12 participants, while those over 60 make up 13 participants. The smallest age group is under 20, with 10 participants. This distribution indicates that younger adults, particularly those in their twenties and thirties, make up the majority of respondents, suggesting that the survey may be especially relevant or accessible to this demographic.

4.3. Education levels

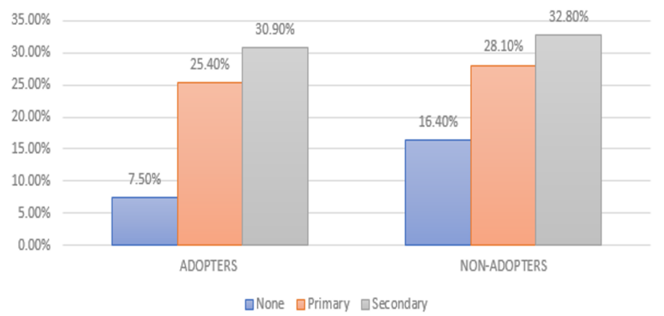

Figure 4. Education levels

The demographic analysis reveals notable differences and similarities between adopters and non-adopters of agricultural technology. In terms of education level, a higher percentage of adopters (36.3%) have attained tertiary education, while non-adopters are more likely to have only primary education (28.1%).

4.4. Marital status

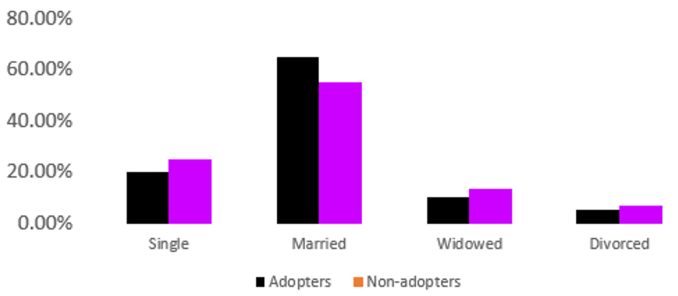

Figure 5. Marital status

Shows that a majority of farmers are married, with 65% of adopters and 55% of non-adopters in this category.

4.5. Income status

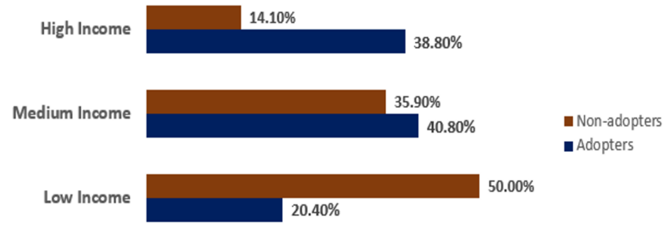

Figure 6. Income status of respondents

Income status shows that adopters generally have higher income, with 38.8% classified as high income, whereas 50% of non-adopters fall into the low-income category.

4.6. Family size and Land size

Table 1. Means and standards Dev. Family and land

Variable	Category	Adopters	Non-Adopters (N=48)	Total (WOO)
Family Size	Mean	5.12	5.39	5.22
Standard Deuaua	Median	1.67	1.72	1.70
Land Sue (acres)	Mean	5.16	5.14	5.15
		s.20	s.oo	s.lO
Standard Deviation		2.12	216	2.14
		_0.6to Il	Oto ll	-0.6to Il

Regarding family size, adopters have an average of 5.12 members per household, slightly smaller than the 5.39 members in non-adopter households; however, both groups share a median family size of 5. Land size is almost identical across the groups, with adopters having an average of 5.16 acres and non-adopters 5.14 acres, though adopters' land size includes a range that extends into negative values, which will be addressed in real applications.

4.8. Agricultural technology adoption and productivity

Table 2. Agricultural Productivity between Adopters and Non-Adopters Descriptive statistics for agricultural Productivity

Group	Sample Size (N)	Mean productivity	Median productivity	Standad Deviation	Range
Adaptors	52	32.97	28.61	9.64	22.02 to 79.12
Non-adaptors	48	30.69	30.07	10.20	8.22 to 52.11

Table 2 presents a comparison of agricultural productivity between adopters and non-adopters of agricultural technology. For adopters (N=52), the mean productivity is 32.97, with a median of 28.61, indicating that the central tendency of productivity is slightly above 48. The standard deviation of 9.64 suggests moderate variability, and the productivity range spans from 22.02 to 79.12. For non-adopters (N=48), the mean productivity is 30.69, with a median of 30.07, showing lower central productivity compared to adopters. The standard deviation of 10.20 indicates slightly higher variability in this group, with the productivity range extending from 8.22 to 52.11.

4.9. Agricultural technology adoption

The of agricultural technologies among respondents shows a preference for improved seeds, with the highest adoption rate at 40% participants. Fertilizers follow closely, with 35 users, while pesticides are adopted by 32% participants. Irrigation systems are less commonly used, with 25% participants, and farm machinery has the lowest adoption rate, with only 15% users. This distribution suggests that respondents are more inclined to adopt inputs like seeds and fertilizers, which directly enhance crop yield, while larger investments in machinery and irrigation are less common, potentially due to higher costs or access limitations as indicated.

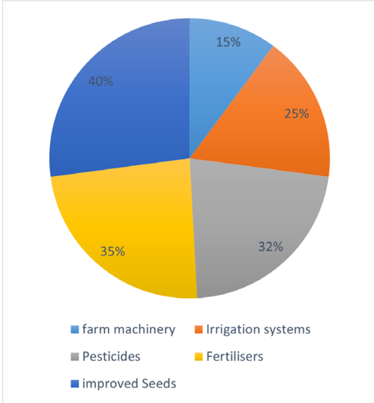

Figure 7. Adoption of agricultural Technologies

Table 3. Statistical Tests and Analysis Results on Agricultural Technology Adoption

Step	Test/Analysis	Result	Interpretation
Normality Test	Shapiro-Wilk Test	Adopters: Test Statistic = 0.995, p = 0.794 Non-Adopters: Test Statistic = 0.986, p = 0.220	Both groups are approximately normally distributed ($p > 0.05$ for both groups).
Homogeneity of Variances	Levene's Test	Statistic = 0.388, p = 0.534	Variances are approximately equal between adopters and non-adopters ($p > 0.05$).
Independent t-Test	t-Test	t = 15.31, $p < 0.001$	Significant difference in productivity: adopters have significantly higher productivity than non-adopters.
Effect Size	Cohen's d	d = 1.84	Large effect size, meaning the difference in productivity is both statistically and practically significant.
Logistic Regression (Example)	Coefficients and Odds Ratios	Education: OR = 1.240, $p < 0.001$ Land Size: OR = 1.569, $p < 0.001$ Credit Access: OR = 1.234, $p < 0.001$	Positive association with technology adoption for education, land size, and credit access.
Model Summary	Pseudo R-squared & Likelihood Ratio Test	Pseudo R^2 = 0.450, Chi-square = 85.6, $p < 0.001$	The model explains 45% of the variability in technology adoption and is statistically significant.

The statistical tests conducted to assess the relationship between agricultural technology adoption and productivity, addressing the core objectives of the research. The normality test results confirm that agricultural productivity is normally distributed for both adopters and non-adopters, ensuring the validity of further statistical analyses. The Levene's test indicates that the assumption of equal variances between the two groups holds, allowing for the use of an independent t-test. The t-test results reveal a statistically significant difference in productivity, with adopters demonstrating higher productivity compared to non-adopters, directly addressing the research objective of understanding the impact of technology adoption on productivity. The effect size (Cohen's d = 1.84) further supports this finding, indicating that the observed difference is not only statistically significant but also practically meaningful. Additionally, the logistic regression analysis highlights key factors—such as education, land size, and credit access—that influence the likelihood of adopting technology, offering insights into the drivers of adoption. Other influencers include extensions services, market access, community influence. Lastly, the model summary suggests that the model explains a significant portion (45%) of the variability in technology adoption, reinforcing the reliability of the analysis in answering the research questions. Overall, the table synthesizes the statistical evidence linking agricultural technology adoption to increased productivity and identifies key factors that influence adoption, directly supporting the research objectives.

4.10. Factors influencing adoption

Table 4. Farmers with higher education levels

category	factors	percentage
main factors	Education	230%
	land size	25%
	access to credit	25%
Other factors	market access	20%
	extension services	16%
	climate change	20%

Farmers with higher education levels are more likely to adopt agricultural technologies due to better understanding and awareness, Access to financial resources enables farmers to afford inputs, equipment, and services necessary for adopting technologies, Larger farms tend to adopt technology faster because the benefits of mechanization and innovations are more pronounced on a larger scale. , Farmers closer to markets are more likely to adopt technologies, as they have better incentives due to access to buyers and higher returns. Availability of agricultural extension services provides farmers with the knowledge and technical support needed to implement technologies., Unpredictable weather patterns influence the adoption of resilient and adaptive technologies, such as drought-resistant seeds or irrigation systems

4.11. Impact of Technology Adoption on Household Income

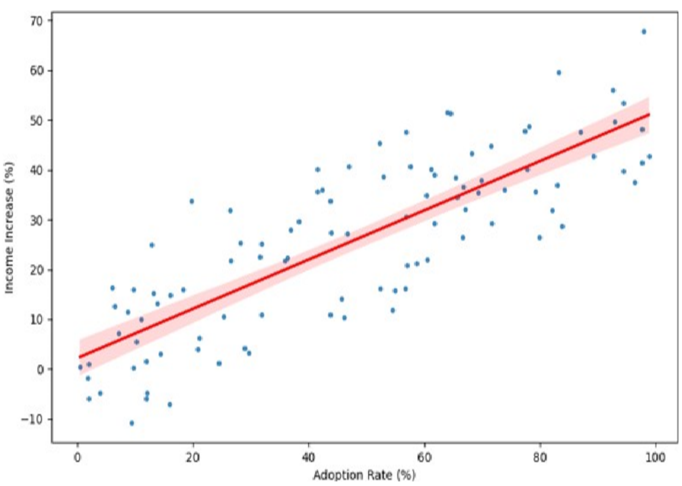

Figure 8. Technology Adoption and Household income

The scatter plot illustrates the impact of technology adoption on household income, showing a positive correlation between adoption rate and income increase. As the adoption rate of agricultural technologies rises, there is a corresponding increase in household income percentage. The trend line, highlighted in red with a confidence band, suggests a steady upward trend, indicating that households with higher technology adoption rates generally experience greater income growth. Although there is some variability, the overall pattern suggests that technology adoption significantly contributes to household income improvements, reinforcing the economic benefits of embracing modern agricultural practices.

Table 5. Regression analysis for the impact of agricultural technology adoption on household income

Predictor Variable	Coefficient (B)	Standard Error	T.Statistic	P.Value
Inteltept	1500.00	400.00	3.75	<O.OOI
Adoption Status (ßl)	1200.00	300.00		<O.OOI
Land	250.00	50.00	5.00	<O.OOI
Family Size (113)	-50.00	20.00	-2 50	0 012
Access to Market Information	80.00	30.00	2.67	0.008

Model Statistic	Value
R.squared	0.45
Adjusted R.squared	0.43
F.statistic	32.50
P-value (F-statistic)	<O.OOI

Table 5 shows that agricultural technology adoption, land size, family size, and access to market information all significantly impact household income. Adoption status has the largest effect, with adopters seeing an increase of 1200 units in income, which is statistically significant. Land size also positively affects income, with each additional hectare increasing income by 250 units. Conversely, family size has a negative effect on income, with each additional family member reducing income by 50 units. Finally, better access to market information leads to a positive increase in income by 80 units per 1% increase in access. The model explains 45% of the variation in household income, with the overall model being statistically significant.

4.12. Yield increase

Figure 9 illustrates an increased yield production of 35% with adopters, while 15% of crop yield from nun adopters. this shows that adopting agricultural technology improves your crop yield leading to more income in households.

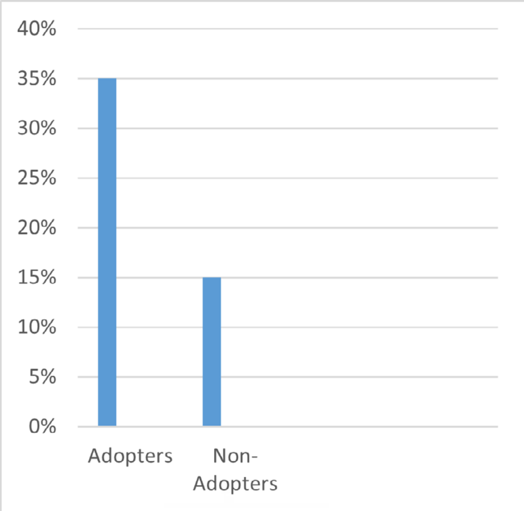

Figure 9. Yield production

4.13. Limitations in Technology Adoption

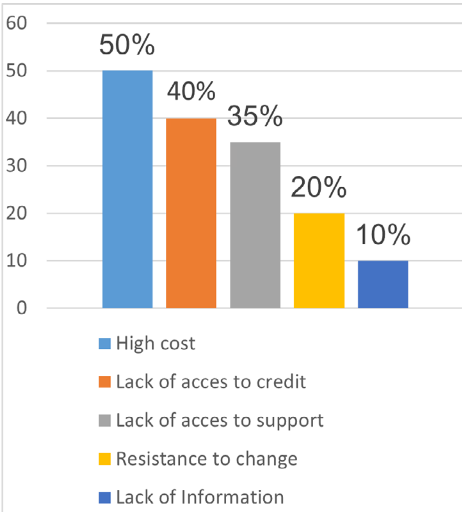

Figure 10. Limitation in Agricultural Technology Adoption

The bar graph reveals that the most significant barrier to technology adoption is high costs, indicating that expenses are a primary hurdle for many individuals, particularly in agricultural contexts. This is closely followed by the lack of access to credit, suggesting that financial constraints are a substantial limitation to embracing new tools and innovations. A notable challenge is the lack of technical support, highlighting the need for more training and educational resources to facilitate effective implementation of technology. Additionally, resistance to change reflects a cultural or psychological barrier, showing that some individuals remain hesitant or skeptical about transitioning from traditional practices.

4.14. Strategies for overcoming challenges

Farmers employ various strategies to overcome barriers to technology adoption, including seeking support from extension services, joining cooperatives, accessing microfinance, and collaborating with NGOs. These strategies help smallholder farmers gain access to resources and knowledge needed for effective technology adoption. The pie chart above illustrates the strategies farmers overcome adoption challenges, showing the importance of extension services and cooperative membership

4.15. People willing to adopt Knew technology

Table 6. Peoples' willingness to adopt Knew technology

Willing to adopt	Don't want to adopt
78%	20%

Table 6 shows out of 100% 78% of farmers are willing to adopt agricultural technology practices while 20% are still resisting to new technologies.

4.16. Discussion and Implication of Findings

The discussion critically examines agricultural technology adoption , emphasizing the role of socio-economic, financial, and infrastructural factors. Adoption trends reveal that improved seeds (preferred by 40 participants) and fertilizers (35 participants) are more readily adopted due to their direct yield benefits, whereas technologies like irrigation systems (25 participants) and machinery (15 participants) see limited use, often due to their higher costs. Socio-economic characteristics further shape adoption patterns; for example, younger farmers, who often possess greater openness to innovation, and those with higher education levels, which equip them to assess advanced methods such as precision agriculture, are more likely to adopt modern practices (Kiprutto, Rotich, & Riungu, 2015; Michels *et al.*, 2019). However, systemic gender disparities, which restrict women's access to land and financial resources, continue to hinder their participation in technology adoption (Ragasa & Mazundule, 2018).

Financial access plays a pivotal role in facilitating technology adoption. Farmers with access to reliable credit systems are better equipped to invest in high-quality inputs, as credit mitigates the financial burden of initial costs. Studies have shown that microfinance and mobile banking platforms, such as Kenya's M-Pesa, provide vital alternatives for smallholders unable to secure formal credit, thus promoting the use of technologies like drought-resistant seeds (Manda *et al.*, 2016). Nonetheless, barriers like high interest rates and insufficient collateral remain significant challenges for many smallholders, necessitating the expansion of tailored financial products like low-interest loans and subsidy programs (Ayim, 2022).

Agricultural extension services and rural infrastructure are equally crucial for promoting adoption. Extension officers provide essential technical knowledge, and regular interaction with these services increases the likelihood of adopting advanced practices such as mechanized farming (Choudhury & Abbas, 2017). However, extension services in SSA are often underfunded and inaccessible, particularly in remote areas, leading many farmers to depend on peer networks. Infrastructure deficiencies, including poor roads and inadequate storage facilities, exacerbate these challenges by increasing transportation costs and limiting market access (Kansiime *et al.*, 2018). Improving rural infrastructure and leveraging social networks could significantly enhance adoption rates by reducing logistical barriers and promoting collaborative learning through cooperatives.

Technology adoption also profoundly impacts agricultural productivity and household income. Empirical studies reveal yield improvements of 30% to 100% from the adoption of technologies like high-yield crop varieties and mechanization, depending on environmental conditions (Michels *et al.*, 2019). Drought-resistant crops, for example, have sustained higher yields in SSA's variable climate, while precision agriculture tools, such as GPS-guided farming, have optimized input efficiency (Ruzzante, 2021). These advancements directly boost household incomes by enabling farmers to sell surplus produce, reinvest in their farms, and improve living standards. Market-oriented farming has been shown to increase incomes by 20% to 50%, allowing investments in education, healthcare, and resilience against future shocks (Kansiime *et al.*, 2018).

Despite these benefits, cultural resistance and environmental challenges continue to hinder adoption. Many farmers remain hesitant to abandon traditional practices, which are deeply rooted in cultural identity, even when presented with evidence of improved productivity (Kansiime *et al.*, 2018). Additionally, factors like soil degradation and water scarcity further complicate the adoption process, as technologies often require specific environmental conditions for optimal performance (Vanlauwe *et al.*, 2010). Promoting sustainable practices, such as conservation agriculture and integrated soil fertility management, could mitigate these challenges by improving environmental compatibility and adoption rates.

To promote widespread adoption, comprehensive strategies must address these barriers. Expanding microfinance institutions, implementing low-interest loan programs, and utilizing mobile banking platforms are critical for overcoming financial constraints (Ayim, 2022). Strengthening extension services through investments in training and digital platforms, such as mobile apps and SMS advisories, can bridge knowledge gaps and improve outreach (Michels *et al.*, 2019). Infrastructure improvements, including rural road networks and storage facilities, can reduce transportation costs and market barriers, further encouraging adoption. Additionally, fostering social networks and peer learning through cooperatives and community-based training programs has proven effective in disseminating successful practices and fostering innovation (Ragasa & Mazundule, 2018).

5. CONCLUSIONS

The study highlights that adopting agricultural technologies is crucial for enhancing productivity and household income among smallholder farmers, playing a significant role in improving food security and reducing poverty. Factors like education, access to credit, and farm size are key determinants of technology adoption, yet financial constraints, poor infrastructure, and traditional practices limit wider adoption. Addressing these barriers is essential to ensuring equitable access to modern farming methods. The research emphasizes that realizing the broader economic and food security benefits of technology adoption requires targeted efforts, including policy reforms, infrastructure development, and educational initiatives. These measures are necessary to foster a sustainable agricultural transformation, contributing to long-term economic growth and poverty alleviation

ACKNOWLEDGMENTS

I would like to express our heartfelt gratitude to the Information and Communications University (ICU) for their resources, guidance, and expertise were instrumental in facilitating the successful completion of this research. I am deeply grateful to my Supervisor for his unwavering support and understanding, which has been a constant source of motivation during this journey.

REFERENCES

Akudugu, M., Guo, E., & Dadzie, S. (2012). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions? *Journal of Biology, Agriculture and Healthcare, 2*(3).

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food policy, 37*(3), 283-295. https://doi.org/10.1016/j.foodpol.2012.02.013

Ayim, C., Kassahun, A., Addison, C., & Tekinerdogan, B. (2022). Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature. *Agriculture & Food Security, 11*(1), 22. https://doi.org/10.1186/s40066-022-00364-7

Central Statistical Office (CSO). (2012). *Census of Population and Housing: Population Summary Report.* Lusaka: Central Statistical Office.

Choudhury, M. A., & Abbas, A. (2017). Agriculture as a social wellbeing system in food security: An epistemological study. *Theoretical Economics Letters, 7*(3), Article 3032. https://doi.org/10.4236/tel.2017.73032

Curry, G. N., Nake, S., Koczberski, G., Oswald, M., Rafflegeau, S., Lummani, J., ... & Nailina, R. (2021). Disruptive innovation in agriculture: Socio-cultural factors in technology adoption in the developing world. *Journal of Rural Studies, 88*, 422-431. https://doi.org/10.1016/j.jrurstud.2021.07.022

Deininger, K., & Jin, S. (2006). Tenure security and land-related investment: Evidence from Ethiopia. *European Economic Review, 50*(5), 1245–1277. https://doi.org/10.1016/j.euroecorev.2005.02.001

Environmental Council of Zambia. (2000). *State of the Environment Report 2000.* Lusaka: Environmental Council of Zambia.

Fairhurst, T. (2012). *Handbook for Integrated Soil Fertility Management in Africa: A Resource for Smallholder Farmers.* Nairobi: CAB International.

FAO. (2018). *The State of Food Security and Nutrition in the World 2018: Building Climate Resilience for Food Security and Nutrition.* Rome: Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization of the United Nations (FAO). (2021). *The State of Food and Agriculture 2021: Making Agrifood Systems More Resilient to Shocks and Stresses.* Rome: FAO.

Haggblade, S., Tembo, G., & Donovan, C. (2011). *Conservation farming in Zambia.* Food Security Research Project Working Paper No. 47.

Hall, B., & Khan, B. (2002). *Adoption of new technology.* New Economy Handbook.

Hamazakaza, P., Smale, M., & Kasalu, H. (2016). Maize yield response to fertilizer in Zambia: Implications for strategies to promote smallholder productivity. *Food Security, 8*(5), 971–986.

Hammersley, M., & Traianou, A. (2012). *Ethics in Qualitative Research: Controversies and Contexts.* London: SAGE Publications.

Hamukwala, P. (2021). The role of agricultural markets in poverty reduction in Zambia. *Journal of Development Perspectives, 10*(2), 45–63.

Hooks, D., Davis, Z., Agrawal, V., & Li, Z. (2022). Exploring factors influencing technology adoption rate at the macro level: A predictive model. *Technology in Society, 68*, 101826. https://doi.org/10.1016/j.techsoc.2021.101826

IFAD. (2019). *Rural Poverty Report 2019: Challenges and Opportunities for Reaching the Rural Poor.* Rome: International Fund for Agricultural Development.

Israel, G. D., & Hay, R. A. (2006). Factors influencing the adoption of sustainable agricultural practices among small-scale farmers in developing countries. *Journal of Sustainable Agriculture, 28*(3), 35–52.

Jayne, T. S., Mather, D., & Mghenyi, E. (2007). Principal challenges confronting smallholder agriculture in sub-Saharan Africa. *World Development, 35*(10), 1651–1675.

Kansiime, M. K., Wambugu, S. K., & Shisanya, C. A. (2018). Determinants of farmers' adoption of climate-smart agriculture practices in smallholder systems: Evidence from Kenya. *Journal of Environmental Management, 220*, 124–134.

Kanyamuka, J., Manda, J., Chilima, C., & Mangani, R. (2019). Understanding farmers' perceptions of climate change variability and adaptation strategies in Malawi: Evidence from Lilongwe District. *International Journal of Climate Change Strategies and Management, 11*(5), 668–684.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change, 80*(3), 525–540.

Kiprutto, K., Rotich, R., & Riungu, C. (2015). Socio-economic and institutional factors influencing the adoption of improved maize varieties in Kenya. *Journal of Agricultural Science and Technology, 17*(1), 12–24.

Kiptot, E., & Franzel, S. (2012). Gender and agroforestry in Africa: A review of research in the last decade. *Agriculture and Human Values, 29*(3), 289–301.

Lwasa, S. (2011). Analyzing the factors influencing technology adoption in agriculture: A case of smallholder farmers in Uganda. *Agricultural Economics, 42*(2), 1–13.

Manda, J., Alene, A. D., Gardebroek, C., Kassie, M., & Tembo, G. (2016). Adoption and impacts of sustainable agricultural practices on maize yields and incomes: Evidence from rural Zambia. *Journal of Agricultural Economics, 67*(1), 130–153.

McDermott, J., Staal, S., Freeman, H. A., Herrero, M., & Van de Steeg, J. (2012). Sustaining intensification of smallholder livestock systems in the tropics. *Livestock Science, 130*(1–3), 95–109.

Michels, T., Jaskiewicz, P., & Gomez-Mejia, L. R. (2019). How uncertainty shapes family firm innovation: A real options perspective. *Entrepreneurship Theory and Practice, 43*(2), 338–361.

Misra, P., Singh, R., & Yadav, A. (2022). Advances in agricultural technology for sustainable crop production. *Agriculture and Food Security, 11*, Article 105.

Mrema, G. C., Baker, D., & Kahan, D. (2020). *Agricultural mechanization in sub-Saharan Africa: Time for a new look.* Rome: Food and Agriculture Organization of the United Nations.

Mungoma, C. (2007). Adoption of improved maize varieties by smallholder farmers in Zambia. *African Crop Science Journal, 15*(1), 63–76.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development, 6*(5), 208–216.

Namonje-Kapembwa, T. & Thelma, P. (2016). Productivity and welfare effects of sustainable agricultural intensification practices among smallholder farmers in Zambia. *Food Policy, 62*, 147–156.

Ngoma, H., Mason, N. M., & Sitko, N. J. (2020). Does minimum tillage reduce labor requirements and raise household incomes? Evidence from Zambia. *Agricultural Economics, 51*(5), 755–773.

Prasanna, B. M., Cairns, J. E., Zaidi, P. H., Beyene, Y., Makumbi, D., Gowda, M., Magorokosho, C., & Zaman-Allah, M. (2018). Beat the stress: Breeding for climate resilience in maize for the tropical rainfed environments. *Theoretical and Applied Genetics, 131*(3), 541–556.

Quisumbing, A. R., & Pandolfelli, L. (2010). Promising approaches to address the needs of poor female farmers: Resources, constraints and interventions. *World Development, 38*(4), 581–592.

Ragasa, C., & Mazundule, P. (2018). The influence of farmer education on technology adoption and productivity. *Agricultural Systems, 163*, 1–15.

Ruzzante, S. (2021). Agricultural technology adoption: A review of the role of risk preferences. *World Development, 146*, Article ID: 105563.

Sichoongwe, K. (2014). *Determinants and impact of agricultural credit on smallholder farmers in Zambia: A case study of Mazabuka District.*

Sitko, N., & Jayne, T. (2014). Exploiting economies of scale in agricultural marketing: The case of emerging farmer groups in Zambia. *Food Policy, 46*, 34–45.

Tembo, S., & Sitko, N. J. (2013). Technical efficiency of smallholder maize production in Zambia: A stochastic frontier approach. *Agricultural Economics, 44*(1), 1–12.

Thurlow, J., Diao, X., & Zhu, T. (2009). *The impact of climate variability and change on economic growth and poverty in Zambia.* IFPRI Discussion Paper.

Vanlauwe, B., Wendt, J., Giller, K. E., Corbeels, M., & Six, J. (2010). A systems approach to conserving soil organic matter and enhancing nutrient use efficiency in sub-Saharan Africa. *Agronomy for Sustainable Development, 30*(1), 45–51.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly, 36*(1), 157–178.

Zambia Ministry of Agriculture (2020). *Annual Report on Agricultural Development. Lusaka: Zambia Ministry of Agriculture.*