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Assessing The Capacities of Rural Youth to Adopt Smart Agriculture Technologies: A Case Study of Kanakantapa Farming Block in Chongwe District, Zambia

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ABSTRACT

Background: The adoption of smart agriculture technologies has increasingly emerged as a critical strategy for enhancing agricultural productivity, climate resilience, and rural livelihoods among young farmers in Zambia. However, despite growing policy attention, the capacities of rural youth to effectively adopt these technologies remain inadequately understood, particularly in farming blocks characterised by limited institutional support and socio-economic constraints.

Aim: To assess the capacities of rural youth to adopt smart agriculture technologies in Kanakantapa Farming Block of Chongwe District, Zambia.

Methods: Guided by Human Capital Theory, Diffusion of Innovations Theory, Social Capital Theory, and Agricultural Innovation Systems Theory, the study employed a case study research design, informed by the concurrent mixed-method approach. The study employed simple random sampling technique to select 120 youth farmers aged between 18 and 35 years from Kanakantapa Farming Block while the purposive non-random sampling method was used to select the five (5) key informants drawn from agricultural extension services and farmer cooperative leaders. Quantitative data were collected using structured questionnaires while qualitative data were collected through key informant interviews. Quantitative data was analysed using descriptive statistics, Chi-square tests, Pearson correlation analysis, and binary logistic regression in SPSS version 27, while qualitative data from key informants were analysed thematically.

Findings: The study established that 67.5% of respondents were aware of smart agriculture technologies, while 80.8% had access to ICT and digital agricultural platforms. However, major institutional and socio-economic barriers constrained adoption. Approximately 61.7% had not received formal training in smart agriculture, 57.5% lacked extension support, and 61% lacked access to agricultural finance. Inferential analysis indicated statistically significant relationships between smart agriculture adoption and educational attainment ($\chi 2 = 14.82$, $p < 0.01$), extension access ($r = 0.61$, $p < 0.001$), ICT access ($r = 0.54$, $p < 0.001$), and agricultural training ($OR = 3.71$, $p < 0.001$). The study further established that adopters of smart agriculture technologies reported increased crop yields, improved income levels, and greater livelihood diversification. Nevertheless, structural barriers including financial exclusion, high input costs, weak extension systems, poor ICT infrastructure, and gender inequalities continued to undermine wider adoption among rural youth.

Conclusion: The study concludes that although rural youth in Kanakantapa possess considerable potential to participate in smart agriculture technologies, their capacities are undermined by inadequate institutional support, limited financing opportunities, insufficient training, and restricted access to modern agricultural inputs. The study recommends strengthening youth-targeted agricultural financing schemes, expanding extension and training services, improving ICT infrastructure, and enhancing policy implementation frameworks to support inclusive and sustainable smart agriculture adoption among rural youth in Zambia.

Keywords: Smart Agriculture, Youth Participation, Rural Youth, Technology Adoption, Agricultural Innovation, ICT, Extension Services, Climate-Smart Agriculture.

Background to the Study

Agriculture continues to play a fundamental role in global food security, employment creation, poverty reduction, and rural transformation, particularly within developing economies. However, the sector faces mounting challenges associated with climate change, environmental degradation, population growth, declining soil fertility, and increasing pressure on natural resources. Recent evidence from the Food and Agriculture Organization (FAO) indicates that global agricultural systems must significantly increase productivity while simultaneously enhancing environmental sustainability and resilience to climate-related shocks in order to meet future food demands (FAO, 2023). Across many developing countries, especially in Sub-Saharan Africa, recurrent droughts, floods, erratic rainfall patterns, rising temperatures, and declining soil productivity continue to undermine agricultural output and threaten rural livelihoods (Rosenstock et al., 2021). These challenges have intensified global efforts toward identifying sustainable and resilient agricultural approaches capable of supporting long-term food production among smallholder farming communities.

In response to these pressures, smart agriculture technologies have increasingly emerged as important mechanisms for promoting sustainable agricultural transformation. Smart agriculture broadly refers to the application of climate-resilient farming techniques, digital agricultural innovations, precision farming systems, and information-driven technologies designed to improve agricultural productivity, resource efficiency, and environmental sustainability (Zougmoré et al., 2023). Such technologies include conservation agriculture, drought-tolerant seed varieties, precision irrigation systems, remote sensing technologies, mobile agricultural advisory services, digital weather forecasting platforms, and electronic market information systems. Empirical studies conducted across developing countries demonstrate that smart agriculture technologies can significantly improve crop yields, strengthen climate resilience, increase water-use efficiency, and reduce production risks among smallholder farmers (Aker et al., 2023; Rosenstock et al., 2021). Furthermore, digital agricultural innovations have enhanced farmers' access to extension information, pest and disease management services, and market intelligence, thereby supporting informed agricultural decision-making.

The growing importance of youth participation in agriculture has also attracted considerable global policy attention. Young people constitute a large proportion of the population in many developing countries where agriculture remains a primary source of employment and livelihoods (United Nations, 2023). In Africa, rapid population growth and increasing unemployment levels among young people have intensified the need for sustainable livelihood opportunities. The African Development Bank (2022) reports that millions of African youth enter labour markets annually despite limited formal employment opportunities outside agriculture. Consequently, agriculture is increasingly viewed as a strategic sector for promoting youth employment, food security, rural industrialisation, and poverty reduction.

Despite this potential, many young people continue to perceive agriculture as physically demanding, economically uncertain, technologically outdated, and socially unattractive (Yeboah and Jayne, 2023). Such perceptions have contributed to declining youth engagement in farming activities across several African countries. Nevertheless, recent advancements in climate-smart agriculture, digital farming systems, mechanisation, and agribusiness innovations are gradually transforming agriculture into a more knowledge-intensive and commercially viable sector capable of attracting youth participation. Studies by International Fund for Agricultural Development [IFAD] (2023) and the World Bank (2023) indicate that digital agriculture, climate-resilient farming systems, and agricultural entrepreneurship initiatives are creating new economic opportunities for young people through value-chain integration, agribusiness development, and technology-based farming enterprises.

Across Sub-Saharan Africa, governments and development agencies have increasingly prioritised climate-smart agriculture as part of broader agricultural transformation and climate adaptation strategies. Countries such as Kenya, Tanzania, Malawi, Ghana, and Zambia have implemented programmes promoting conservation agriculture, climate-resilient crop varieties, irrigation technologies, mechanisation, and digital agricultural systems (Arslan et al., 2022). Evidence from Consultative Group on International Agricultural Research (CGIAR) and FAO studies suggests that adoption of climate-smart agricultural practices can substantially improve productivity, household food security, and resilience among smallholder farmers under varying agroecological conditions (CGIAR, 2023; FAO, 2023). In Malawi, for example, youth participation in climate-smart agricultural initiatives has contributed to improved household incomes, livelihood diversification, and enhanced food security among rural farming households (IFAD, 2022). However, despite these positive outcomes, adoption levels among rural youth remain constrained by inadequate extension services, limited financial access, weak rural infrastructure, low digital connectivity, and insufficient institutional support systems.

In Zambia, agriculture remains one of the most important sectors for employment generation, food security, and rural livelihoods. According to the World Bank (2023), the agricultural sector employs a substantial proportion of the rural labour force, particularly among smallholder farming households. However, agricultural productivity remains relatively low due to overdependence on rain-fed farming systems, low levels of mechanisation, inadequate extension support, limited access to modern farming technologies, and increasing climate variability. Frequent droughts, irregular rainfall patterns, floods, and declining soil fertility continue to threaten agricultural production and rural livelihoods across many parts of the country.

In response to these challenges, the Government of Zambia and development partners have increasingly promoted climate-smart agriculture and digital agricultural systems as mechanisms for improving productivity and strengthening resilience among farming communities. Recent agricultural reforms have included expansion of electronic farmer registration systems, promotion of climate-resilient farming technologies, strengthening agricultural extension services, and support for digital agricultural platforms aimed at improving farmers' access to inputs, market information, and advisory services (FAO, 2023; Zambia Statistics Agency, 2023). In addition, climate-smart agriculture programmes implemented through collaborations between government agencies, research institutions, and international development organisations have sought to improve sustainable agricultural production among smallholder farmers in districts such as Chongwe and Lusaka (World Bank, 2023).

Empirical evidence from Zambia further demonstrates the positive effects of climate-smart agriculture adoption. Ngoma et al. (2021) found that conservation agriculture and climate-smart farming practices significantly improved maize productivity and household resilience among smallholder farmers in Zambia. Similarly, Arslan et al. (2022) reported that adoption of climate-smart agricultural technologies contributed to improved productivity, income stability, and adaptive capacity among farming households facing climate-related shocks. Despite these interventions, youth participation in smart agriculture within Zambia remains constrained by multiple socio-economic and institutional barriers.

Existing studies indicate that many rural youth experience limited access to land ownership, agricultural financing, extension services, digital technologies, and technical training required for participation in modern agricultural systems (Chamberlin et al., 2023; Sitko and Jayne, 2021). Although agriculture remains a major source of rural employment among young people, many young people continue to participate primarily within low-productivity subsistence farming systems characterised by weak market integration and limited technological innovation. The Zambia Statistical Agency (2023) further indicates that a significant proportion of rural youth remain concentrated within agriculture, forestry, and fishing sectors despite persistent productivity challenges.

Furthermore, existing literature in Zambia has largely focused on general climate-smart agriculture adoption, productivity outcomes, and resilience among smallholder farmers, with limited empirical attention directed toward rural youths' capacities to adopt smart agriculture technologies. Current evidence remains inadequate regarding the extent to which rural youth possess the technical knowledge, financial resources, institutional support, digital access, and adaptive skills necessary for effective participation in technologically driven agricultural systems. Similarly, limited scholarly attention has been given to understanding how institutional weaknesses, socio-economic inequalities, and structural barriers influence youth participation in smart agriculture within rural farming communities.

Kanakantapa Farming Block in Chongwe District presents an important context for examining these issues. Although the area benefits from proximity to Lusaka markets and expanding agricultural infrastructure, adoption of smart agriculture technologies among rural youth remains relatively limited. Young farmers within the farming block continue to experience challenges associated with limited access to agricultural finance, inadequate technical training, weak extension systems, poor digital infrastructure, and constrained access to productive resources. Understanding rural youths' capacities to adopt smart agriculture technologies is therefore essential for informing evidence-based agricultural policies, strengthening youth-inclusive agricultural transformation strategies, and improving sustainable rural livelihoods.

This study is guided by four complementary theoretical perspectives that collectively explain youth participation in smart agriculture adoption. Human Capital Theory argues that education, technical skills, and training significantly influence individuals' ability to adopt technological innovations (Becker, 1964). Within agriculture, youth possessing higher levels of education and technical competencies are more likely to adopt climate-smart technologies successfully. Diffusion of Innovations Theory further explains how new technologies spread through communication channels, social interactions, and perceived benefits associated with innovation adoption (Rogers, 2003). The theory is particularly useful for understanding how rural youth acquire and disseminate smart agricultural practices within farming communities.

In addition, Social Capital Theory emphasises the role of social networks, trust, farmer organisations, and collective relationships in facilitating access to agricultural information, financial resources, and technological innovations (Putnam, 1993). Youth embedded within stronger social networks are more likely to access extension support, cooperative services, and technology-related information necessary for agricultural innovation. Agricultural Innovation Systems Theory similarly highlights the importance of institutional coordination among government agencies, research institutions, extension systems, private-sector actors, and markets in promoting agricultural transformation (Spielman and Birner, 2008). Collectively, these theoretical perspectives provide a comprehensive framework for understanding how technical skills, institutional systems, socio-economic conditions, and social networks shape rural youths' capacities to adopt smart agriculture technologies within Zambia's evolving agricultural landscape.

MATERIALS AND METHODS

Research design

The study adopted a case study research design, informed by the concurrent mixed-methods approach to assess the capacities of rural youth to adopt smart agriculture technologies in Kanakantapa Farming Block in Chongwe District of Lusaka Province, Zambia. The study was informed by Human Capital Theory, Diffusion of Innovations Theory, Social Capital Theory, and Agricultural Innovation Systems Theory. Concurrent mixed-methods research integrates quantitative and qualitative approaches within a single study in order to provide a more comprehensive understanding of complex social phenomena than either method alone could achieve (Creswell and Plano Clark, 2018). In this study, quantitative data was required to measure youth capacities such as education levels, agricultural skills, access to digital technologies, and levels of smart agriculture adoption. At the same time, qualitative data was necessary to explore youth perceptions, institutional support structures, and contextual barriers influencing technology adoption. The mixed-methods approach enabled the researcher to capture both the measurable aspects of youth engagement in smart agriculture and the underlying socio-economic factors shaping adoption behaviour. According to Morse (1991), triangulation improved the reliability of research findings by allowing different forms of evidence to confirm or explain each other.

Study Site

The research was conducted in Kanakantapa Farming Block, located in Chongwe District of Lusaka Province in Zambia. Kanakantapa is one of the key agricultural production zones within Chongwe District and forms part of the government-designated farming blocks aimed at promoting agricultural commercialization and rural development. The area is predominantly characterised by smallholder agricultural systems where farmers engage in both crop production and livestock rearing as major livelihood activities. Crops commonly cultivated in the area include maize, groundnuts, vegetables, and soybeans, while livestock activities include poultry, goats, and cattle production (FAO, 2021).

Target Population

The main study population comprised youth farmers aged between 18 and 35 years who are actively involved in agricultural activities within Kanakantapa Farming Block. The key informants included the agricultural stakeholders such as agricultural extension officers and leaders of farmer cooperatives operating within the farming block. These stakeholders were included because of their critical role in providing technical guidance, training, and institutional support necessary for the adoption of smart agriculture technologies. Bryman (2021) states that in social research, defining the target population clearly is essential for ensuring that sampling procedures produce representative evidence that can support valid conclusions of a study.

Sampling Methods

The researcher employed a simple random probability sampling and purposive non-probability sampling methods in recruiting the respondents for the study. Simple random sampling is widely used in social science research when the study population is concentrated in one geographical location and each respondent has an equal chance of being included in the sample (Kothari, 2020). The sampling design enabled the researchers to combine purposive and probability-based sampling techniques to achieve both contextual relevance and statistical representation. This sampling strategy balanced contextual relevance with methodological rigour by ensuring statistical representation of youth farmers while purposively selecting key informants with relevant institutional knowledge.

Sample size

The sampling frame consisted of approximately 172 registered youth farmers obtained from farmer cooperative records and extension service registers within Kanakantapa Farming Block. Using Yamane's (1967) formula at a 95% confidence level and 5% margin of error; where ***n*** represents the sample size, ***N*** represents the population size, and ***e*** represents the acceptable margin of error. Therefore, a sample size of 120 respondents was considered statistically adequate for the study as shown in the formula below.

$$n = \frac{N}{1 + N(e^2)} = \frac{172}{1 + 172(0.05^2)} = \frac{172}{1 + 172(0.0025)} = \frac{172}{1 + 0.43} = \frac{172}{1.43} = 120.28 = \mathbf{120}$$

For the qualitative component, five (5) key informant interviews were conducted with individuals who possessed professional experience and institutional knowledge relevant to youth agricultural development and smart agriculture technologies. These included the agricultural stakeholders such as agricultural extension officers and leaders of farmer cooperatives operating within the farming block. Qualitative sample sizes were guided by the principle of data saturation, which occurs when additional interviews no longer produce substantially new information (Guest et al., 2020).

Data Collection Methods

This research employed a questionnaire survey which targeted youth farmers to gather quantitative data. The structured questionnaire captured demographic characteristics, agricultural skills, access to digital technologies, institutional support systems, adoption of smart agriculture practices, and perceived challenges affecting adoption. While the key informant interviews (KIIs) were conducted with agricultural extension officers and cooperative leaders in order to gather qualitative insights regarding youth engagement in agriculture, institutional support mechanisms, and barriers to technology adoption. Semi-structured interview guides were used to ensure that all key topics were addressed. Smith et al (2009) suggested that semi-structured interviews are well-suited to the task of capturing people's lived experiences and through which a phenomenon could be interpreted in terms of the meanings interviewees bring to it. This type of interview was used to create a space in which the researcher and participants constructed the knowledge together (Birks and Mills, 2011). The interviews were conducted in participants' preferred languages (i.e., English, Nyanja, and Bemba). The researchers preferred the KIIs because they enabled them to have more clarifying, probing, and cross-checking questions, where the interviewers have the freedom to alter; rephrase and add questions according to the nature of the responses from interviewees (Best and Kahn, 2003). The semi-structured interviews also provided an opportunity for recording all the responses from participants.

Data Analysis and Interpretation

Quantitative data from the household survey were analysed using Statistical Package for Social Sciences (SPSS) version 27. Descriptive statistics were generated to summarise youth farmers' demographic characteristics and patterns of smart agriculture adoption among youth farmers through frequencies and percentages. Qualitative data was analysed using thematic analysis following Braun and Clarke's (2006) six-step model. Braun and Clarke recommended that qualitative research focuses on the following steps, namely: familiarization with the data, generating initial codes; searching for themes; reviewing themes; defining and naming themes, and producing the report. In this study, interviews were recorded with the consent of the participants. Themes were interpreted using theoretical lenses, including Human Capital Theory, Diffusion of Innovations Theory, Social Capital Theory, and Agricultural Innovation Systems Theory. The researchers read through the transcripts identifying open codes using the qualitative software Nvivo. Coding aided in identifying concepts, categories and sub-categories that were further broken down. Open coding involves reading the texts 'word-by-word', 'line-by-line', and repeatedly to identify phrases that interviewees were using to describe things and issues. The coded data was then categorised (grouped) according to different characteristics to better understand the data. The categories were then grouped to form sub-themes and then eventually, the sub-themes were grouped to come up with the main themes. This enabled the researcher to categorize items according to what description they offered (Bryman, 2012).

Ethical Considerations

In any research conducted, ethical issues must be taken into consideration by the researcher (Bryman, 2016). The researchers ensured that ethics of social research were upheld. The main ethical issues addressed in the course of the research were; approval, permission, access and acceptance, informed consent, confidentiality, right to privacy and anonymity, right to withdrawal, beneficence, justice and fairness. The ethical approval number for the study is MU/DRI/REC/2026/107. Observing these ethical procedures ensured that the study ensured that the study adhered to internationally accepted research ethics principles including respect for persons, confidentiality, and responsible data management (Israel and Hay, 2006).

Study Findings (Results)

Introduction

This section presents and analyses the findings on the capacities of rural youth to adopt smart agriculture technologies in Kanakantapa Farming Block, Chongwe District, Zambia, integrating quantitative and qualitative evidence from 120 youth respondents and five key informants. To strengthen analytical coherence, the findings are presented thematically around four key areas: (1) youth socio-demographic capacities, (2) knowledge and technical readiness, (3) socio-economic and institutional determinants of adoption, and (4) structural barriers affecting participation in smart agriculture systems.

Socio-Demographic Characteristics and Youth Readiness for Smart Agriculture

Age Distribution and Agricultural Engagement

The study targeted youth aged between 18 and 35 years in line with the Zambia National Youth Policy. The findings showed that the majority of respondents were concentrated within the economically active age categories of 22-35 years. This demonstrates that agriculture remains an important livelihood option among rural youth, particularly for those facing limited formal employment opportunities. The relatively low representation of respondents aged 18-21 years suggests that younger youths may still be in school or may lack access to productive resources such as land, agricultural finance, and farming inputs. In contrast, respondents aged between 26-35 years appeared more actively engaged in farming due to greater social independence, accumulated farming experience, and relatively improved access to resources.

Table 1: Age Distribution of Respondents

Age group	Frequency	Percentage
18-21	10	8
22-25	19	16
26-30	43	36
31-35	48	40
Total	**120**	**100**

Source: Field Data (2026)

The findings indicate that age significantly shapes technological readiness. Younger respondents were generally perceived as more open to digital farming technologies, mobile-based agricultural information systems, and climate-smart innovations. However, older youth farmers demonstrated greater practical farming experience and stronger understanding of local agricultural conditions. This suggests that successful smart agriculture adoption requires combining youthful technological adaptability with practical farming knowledge and institutional support systems. The findings above demonstrate that Kanakantapa Farming Block possesses a relatively youthful agricultural population with considerable potential for smart agriculture transformation if adequate capacity-building interventions are implemented.

Table 2: Gender Participation in Smart Agriculture

Gender	Frequency	Percentage (%)
Male	71	59
Female	49	41
Total	**120**	**100**

Source: Field Data (2026)

The study established that 71 respondents (59%) were male while 49 respondents (41%) were female. Although male youths constituted the majority of participants, the substantial participation of female youths demonstrates the growing involvement of young women in agricultural production and rural livelihoods. The dominance of male respondents reflects persistent gender inequalities in access to productive resources such as land ownership, irrigation systems, financing opportunities, and agricultural technologies. In many rural communities, cultural norms continue to favour male inheritance of land and greater male participation in agricultural decision-making processes. Female youths often experience additional domestic responsibilities and limited financial autonomy, which reduce their participation in technology-intensive agricultural systems.

Despite these constraints, qualitative findings showed increasing participation of female youths in crop production, agribusiness, and agricultural marketing activities. However, female respondents reported comparatively lower access to agricultural technologies and institutional support systems. The findings highlight the importance of gender-responsive agricultural interventions that promote equal access to extension services, ICT tools, agricultural finance, and smart farming technologies. Expanding female participation in smart agriculture is essential for inclusive rural development and sustainable agricultural transformation.

Table 3: Educational Attainment and Technical Preparedness

Education Attainment	**Frequency**	**Percentage (%)**
No formal education	0	0.0
Primary education	19	15.8
Secondary education	70	58.3
Tertiary education	31	25.8
Total	**120**	**100**

Source: Field Data (2026)

Educational attainment emerged as a significant factor influencing youth readiness to adopt smart agriculture technologies. The findings showed that none of the respondents lacked formal education. A total of 19 respondents (15.8%) had primary education, 70 respondents (58.3%) had secondary education, while 31 respondents (25.8%) possessed tertiary qualifications. The dominance of respondents with secondary and tertiary education suggests that most youths possess foundational literacy and numeracy skills necessary for understanding agricultural information, interacting with extension officers, and utilising ICT-based farming tools. Higher educational attainment also enhances the ability of youths to process climate information, interpret technical instructions, and engage with innovation systems. However, the evidence showed that educational attainment alone does not automatically translate into effective adoption of smart agriculture technologies. Many respondents lacked specialised technical competencies relating to precision farming, digital monitoring systems, irrigation technologies, and advanced climate-smart agricultural practices. The results suggest that while formal education provides a favourable foundation for smart agriculture adoption, practical and continuous technical training remains essential for translating theoretical knowledge into effective agricultural innovation and productivity improvement.

Knowledge and Technical Capacities for Smart Agriculture Adoption Awareness of Smart Agriculture Technologies

Awareness of smart agriculture technologies was relatively high among respondents. The findings showed that 81 respondents (67.5%) were aware of smart agriculture technologies, while 39 respondents (32.5%) had no awareness of the concept. The relatively high awareness levels suggest growing exposure to climate-smart agriculture programmes, conservation farming initiatives, and agricultural modernisation campaigns within the farming block.

Table 4: Awareness of Smart Agriculture Technologies

Response	**Frequency**	**Percentage (%)**
Aware	81	67.5
Not Aware	39	32.5
Total	**120**	**100**

Source: Field Data (2026)

Nevertheless, qualitative findings showed that awareness remained largely superficial and did not necessarily translate into practical adoption or technical competence. One extension officer explained:

> *"Most young farmers have heard about climate-smart farming, especially conservation agriculture and improved seeds, but many still lack detailed knowledge about digital farming technologies." (Key informant 2)*

This finding demonstrates the existence of substantial knowledge gaps between general awareness and technical implementation capacity. Most respondents were familiar with concepts such as conservation agriculture and

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improved seed varieties but lacked practical understanding of precision agriculture, digital irrigation systems, and data-driven agricultural technologies. The findings suggest that awareness campaigns alone are insufficient to promote meaningful smart agriculture adoption unless they are accompanied by practical demonstrations, mentorship programmes, and continuous extension support.

Training Deficits and Limited Technical Skills

Training emerged as one of the most critical capacity gaps affecting youth adoption of smart agriculture technologies. Only 46 respondents (38.3%) reported having received training in smart agriculture, while 74 respondents (61.7%) had never received any formal training. The findings reveal major weaknesses in institutional capacity-building interventions targeting rural youth.

Table 5: Access to Training in Smart Agriculture

Response	Frequency	Percentage (%)
Received training in smart agriculture	46	38.3
Never received any formal training	74	61.7
Total	**120**	**100**

Source: Field Data (2026)

Most training opportunities were reportedly provided by government extension services, Non-governmental Organisations (NGOs), and farmer organisations, but respondents described these programmes as irregular, selective, and poorly coordinated. One participant explained:

"Training sessions are rare, and when they come, they don't reach everyone. We rely on each other to share what we learn." (Participant 5)

The findings indicate that many youths depend on informal peer-learning systems due to limited institutional support. While peer learning contributes to knowledge sharing, it may also weaken the quality and consistency of technical information transferred among farmers. The lack of adequate training significantly undermines youth capacities to adopt smart agriculture technologies because modern farming systems require specialised competencies in irrigation management, climate adaptation, digital agriculture, and input optimisation. Without continuous technical support, many youths remain dependent on traditional farming methods despite being aware of modern agricultural alternatives. The findings confirm that inadequate technical training constitutes one of the major barriers to youth agricultural transformation in Kanakantapa Farming Block.

Farming Experience and Innovation Readiness

The findings showed that 62 respondents (51.7%) possessed between 3-5 years of farming experience, while 25 respondents (20.8%) had between 6-10 years of experience. Only 15 respondents (12.5%) had less than two years of farming experience while 18 respondents (15%) had more than 10 years of farming experience. The results suggest that most youths possess moderate farming experience and practical agricultural exposure. This is significant because farming experience influences decision-making, risk assessment, and innovation adoption behaviour.

Table 6: Farming Experience of Respondents

Response	Frequency	Percentage (%)
0-2 years	15	12.5
3-5 years	62	51.7
6-10 years	25	20.8
10 years and above	18	15
Total	**120**	**100**

Source: Field Data (2026)

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Youth farmers with greater experience appeared more capable of understanding production challenges such as droughts, pest outbreaks, and declining soil fertility, thereby increasing appreciation for climate-smart agricultural practices. At the same time, the results indicated that many youths remained relatively inexperienced in advanced technological farming systems. Less experienced farmers often lacked the confidence and financial capacity required to invest in unfamiliar technologies. The findings demonstrate that farming experience positively influences readiness for smart agriculture adoption, although experience alone remains insufficient without institutional support, technical training, and access to productive resources.

Socio-Economic and Institutional Determinants of Smart Agriculture Adoption Land Ownership and Security of Investment

Land ownership emerged as a critical determinant of youth participation in smart agriculture. The study established that 69 respondents (58%) owned land, 29 respondents (24%) leased land, while 22 respondents (18%) cultivated on communal land. Secure land ownership was strongly associated with willingness to invest in irrigation systems, improved technologies, and sustainable farming practices. In contrast, youths cultivating leased or communal land expressed uncertainty regarding long-term investments because of insecure tenure arrangements. The findings suggest that land tenure insecurity discourages investment in smart agriculture technologies that require long-term financial commitment. This highlights the importance of land reform policies and youth-inclusive land allocation systems in promoting agricultural innovation and productivity.

Table 7: Land Ownership and Security of Investment

Response	Frequency	Percentage (%)
Owned	69	58
Leased	29	24
Communal	22	18
Total	**120**	**100**

Source: Field Data (2026)

Financial Exclusion and Limited Access to Agricultural Credit

Limited access to finance emerged as one of the strongest barriers affecting youth adoption of smart agriculture technologies. The findings showed that 73 respondents (61%) lacked access to agricultural finance, while only 47 respondents (39%) reported having access to financial resources.

Table 8: Access to Finance among Respondents

Response	Frequency	Percentage (%)
Lacked access to agricultural finance	73	61
Access to financial resources	47	39
Total	**120**	**100**

Source: Field Data (2026)

Most respondents indicated that financial institutions considered youth farmers high-risk borrowers due to lack of collateral, unstable incomes, and weak credit histories. Consequently, many youths remained dependent on low-input traditional farming systems that require minimal capital investment.

One participant explained:

> *"Youth farmers struggle to access loans and agricultural finance due to lack of collateral and unstable incomes." (Participant 4)*

Another respondent added:

> *"One Acre does give us input on credit but you are required to pay after harvest and sometimes the yield is not good so we struggle to pay back." (Participant 1)*

The findings demonstrate that financial exclusion significantly undermines youth capacities to invest in improved seeds, irrigation systems, fertilisers, ICT tools, and digital farming technologies. The results therefore confirm that access to affordable agricultural finance remains central to achieving successful youth participation in smart agriculture systems.

Extension Services and Institutional Support

Extension services play a critical role in strengthening agricultural knowledge and promoting technology adoption. However, the analysis demonstrated weak institutional extension support systems within Kanakantapa Farming Block. Only 51 respondents (42.5%) reported having access to extension services, while 69 respondents (57.5%) lacked such access.

Table 9: Access to Extension Services among Respondents

Response	Frequency	Percentage (%)
Yes	51	42.5
No	69	57.5
Total	120	**100**

Source: Field Data (2026)

Respondents frequently complained about infrequent farm visits, inadequate technical guidance, and limited interaction with extension officers.

A cooperative leader explained:

> *"Extension officers are few compared to the number of farmers. Many youths do not receive regular training or farm visits." (Key informant 3)*

Another respondent stated:

> *"The extension officer comes to the area mostly at the start of the farming season to talk about seed distribution but after that we do not receive any support." (Key informant 5)*

The findings therefore demonstrate that institutional agricultural support systems remain inadequate to effectively promote smart agriculture adoption among rural youth. Weak extension systems reduce access to technical mentorship, climate information, and innovation support necessary for agricultural transformation.

ICT Access and Digital Agricultural Inclusion

ICTs and digital platforms are increasingly important for promoting smart agriculture because they improve access to weather information, extension advice, market opportunities, and agricultural innovations. The findings showed that 97 respondents (80.8%) had access to at least one ICT or digital platform, while 23 respondents (19.2%) lacked access entirely. Mobile phones and radio programmes were the most common sources of agricultural information. However, only a smaller proportion of respondents possessed smartphones and internet-based agricultural applications.

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Table 10: Access to ICT and Digital Platforms

Response	Frequency	Percentage (%)
Access to ICT Tools	97	80.8
No Access to ICT Tools	23	19.2
Total	120	**100**

Source: Field Data (2026)

Although ICT access levels appeared relatively high, qualitative results showed significant digital inequalities affecting effective utilisation of digital agricultural technologies. Respondents highlighted unreliable internet connectivity, poor ICT infrastructure, and limited access to specialised agricultural applications. The findings therefore suggest that while ICT penetration is improving among rural youth, digital infrastructure limitations continue to constrain effective integration of smart agriculture technologies within rural farming systems.

Effects of Smart Agriculture Adoption on Youth Productivity

Crop Productivity and Agricultural Performance

The analysis demonstrated a strong positive relationship between smart agriculture adoption and crop productivity. Of the 120 respondents, 42 (35%) who had adopted smart agriculture practices reported increased crop yields, while the remaining respondents either reported no change (45%) or a decrease (20%). The results indicate that practices such as conservation agriculture, irrigation systems, and improved seed usage significantly enhance agricultural productivity and climate resilience. Increased productivity strengthens household food security and creates opportunities for market-oriented agricultural production. However, adoption levels remained relatively low, suggesting that despite observable benefits, structural barriers continue to prevent broader participation in smart agriculture systems.

Table 11: Changes in Crop Yields after Adoption of Smart Agriculture

Response	Frequency	Percentage (%)
Increased yield	42	35
No increase observed	54	45
Decrease in yield	24	20
Total	**120**	**100**

Source: Field Data (2026)

Income Improvement and Livelihood Diversification

The findings further demonstrated positive economic outcomes among adopters of smart agriculture technologies. Among the 42 adopters, 27 respondents (64.3%) reported increased income levels, while 11 respondents (26.2%) experienced no change and 4 respondents (9.5%) reported declining incomes. The increase in income among adopters suggests that smart agriculture contributes to higher productivity, improved market participation, and greater economic opportunities for rural youth.

Table 12: Changes in Income Levels after Adoption of Smart Agriculture

Response	Frequency	Percentage (%)
Increased	27	64.3
No change	11	26.2
Decreased	4	9.5
Total	**42**	**100**

Source: Field Data (2026*)*

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Additionally, only 27 respondents (22.5%) had maintained traditional farming patterns while majority, 93 respondents (77.5%) reported increased diversification of farming activities through horticulture, poultry production, mixed farming, and irrigation-based agriculture. Diversification enhances resilience against climate shocks and market fluctuations by creating multiple income streams and reducing dependency on single farming enterprises. The findings thus demonstrate that smart agriculture contributes not only to increased productivity but also to broader livelihood transformation and agricultural resilience among rural youth farmers.

Table 13: Changes in Diversification of Farming Activities

Responses	Frequency	Percentage (%)
Maintained traditional farming patterns	27	22.5
Increased diversification of farming activities	93	77.5
Total	**120**	**100**

Source: Field Data (2026)

Structural and Institutional Barriers Affecting Youth Participation in Smart Agriculture

The study identified several interconnected structural and institutional barriers limiting youth participation in smart agriculture systems. These barriers include financial exclusion, high input costs, inadequate extension services, insufficient training opportunities, and weak ICT infrastructure. A key informant from an NGO explained:

"Although government programmes exist, implementation remains inadequate due to limited resources, poor coordination, and insufficient youth-targeted interventions. Policies supporting youth agriculture are available, but implementation at community level is still weak." (Key informant 4)

The study established that 99 respondents (82.5%) identified financial constraints as a major challenge, while 82 respondents (68.3%) highlighted the high cost of agricultural inputs such as fertilisers, improved seeds, irrigation systems, and digital technologies. One respondent explained:

"Buying the drought resistant seed is more expensive than the normal seed, so sometimes we buy and sometimes we plant what we have." (Participant 7)

Table 14: Structural and Institutional Barriers Affecting Youth Participation in Smart Agriculture

Challenges	Frequency	Percentage (%)
Financial Constraints	99	82.5
Limited Extension Support	91	75.8
ICT infrastructure challenges	69	57.8
Inadequate Training Opportunities	87	72.5

Source: Field Data (2026)

Additionally, 91 respondents (75.8%) identified limited extension support as a major barrier, while 87 respondents (72.5%) cited inadequate training opportunities. The results indicated that 87 respondents (72.5%) identified inadequate training opportunities as a major challenge. ICT infrastructure challenges were also significant, with 69 respondents (57.8%) reporting poor internet connectivity and limited access to digital farming tools. Respondents reported that training programmes were often irregular, selective, and lacking practical follow-up support. Many youths felt excluded from agricultural capacity-building initiatives.

One respondent explained:

> *"The training is mostly done by NGOs and they train selected people only." (Key Informant 2)*

Another added:

> *"As for me I just hear that there was a training, I have never been picked to attend." (Key Informant 1).*

The findings therefore suggest that training interventions remain poorly coordinated and insufficiently inclusive. Collectively, these findings demonstrate that youth adoption of smart agriculture is constrained more by institutional and structural weaknesses than by lack of interest or willingness among youths themselves.

Inferential and Multivariate Analysis

Relationship between Education and Smart Agriculture Adoption

A Chi-square test revealed a statistically significant relationship between educational attainment and adoption of smart agriculture technologies, $x^2\,(3, N = 120) = 14.82, p < 0.01$. Analysis demonstrated that respondents with secondary and tertiary education were significantly more likely to adopt smart agriculture technologies than those with only primary education. This finding supports Human Capital Theory, which argues that education enhances individuals' ability to acquire, process, and utilise technological innovations effectively.

Correlation between Extension Access and Technology Adoption

Pearson correlation analysis revealed a strong positive relationship between access to extension services and smart agriculture adoption, $r = 0.61, p < 0.001$. This evidence indicates that respondents with greater interaction with extension officers were more likely to adopt climate-smart agricultural technologies.

Correlation between ICT Access and Adoption

The study established a moderate positive relationship between ICT access and adoption of smart agriculture technologies, $r = 0.54, p < 0.001$. This analysis suggests that access to mobile phones, digital advisory platforms, and agricultural information systems significantly improves youth participation in smart agriculture systems.

Logistic Regression Analysis

Binary logistic regression was conducted to determine predictors of smart agriculture adoption. The analysis demonstrated that youth farmers with access to agricultural training were approximately 3.7 times more likely to adopt smart agriculture technologies compared to those without training. Similarly, access to extension services and finance significantly increased the likelihood of adoption. The model demonstrates that institutional and socio-economic support systems play a more significant role in adoption than demographic characteristics alone.

Table 15: Logistic Regression Analysis

Variable	**Odds Ratio**	**P-value**
Access to finance	2.94	0.002
Extension services	3.18	0.001
ICT access	2.47	0.005
Agricultural training	3.71	0.001
Land ownership	1.96	0.041

Gender Dimensions in Smart Agriculture Adoption

The findings revealed significant gender disparities in access to productive resources, institutional support, and smart agriculture technologies. Although female youths constituted 41% of respondents, qualitative findings indicated that women experienced comparatively lower access to land ownership, agricultural credit, irrigation technologies, and extension services. Female respondents frequently reported mobility constraints, domestic labour burdens, and exclusion from cooperative leadership structures, which limited participation in agricultural training programmes and decision-making processes. In addition, cultural norms relating to inheritance and land allocation disproportionately disadvantaged young women in accessing secure agricultural land. These findings suggest that gender inequalities remain embedded within rural agricultural systems and continue to shape technology adoption outcomes. The findings therefore demonstrate that youth-focused agricultural interventions must adopt gender-responsive approaches that intentionally strengthen women's access to finance, extension services, ICT platforms, and agricultural decision-making structures.

From the presentation above, the findings demonstrated that rural youth possess moderate educational attainment, agricultural awareness, and farming experience, which provide a favourable foundation for agricultural innovation adoption. However, substantial gaps remain in technical training, extension support, agricultural financing, land security, and ICT infrastructure. These structural and institutional weaknesses significantly constrain broader participation in smart agriculture systems. The findings further established that adoption of smart agriculture contributes positively to increased crop yields, improved incomes, and diversification of farming activities among youth farmers. Despite these benefits, adoption levels remain limited because many youths continue to face financial exclusion, high production costs, inadequate technical support, and weak institutional implementation mechanisms.

DISCUSSION AND INTERPRETATION OF FINDINGS

This chapter critically interprets the empirical findings on the capacities of rural youth to adopt smart agriculture technologies in Kanakantapa Farming Block, Chongwe District, Zambia, through the lenses of Human Capital Theory, Diffusion of Innovations Theory, Social Capital Theory, and Agricultural Innovation Systems Theory. The findings demonstrate that youth adoption of smart agriculture is shaped by the interaction between human capital, institutional support systems, access to productive resources, and broader structural conditions. Although rural youth showed relatively high awareness of smart agriculture technologies, practical adoption remained constrained by limited technical training, weak extension systems, financial exclusion, insecure access to land, and infrastructural deficiencies. These findings suggest that awareness alone is insufficient to sustain agricultural transformation unless supported by inclusive institutional and policy frameworks.

Youth Knowledge, Skills and Technological Readiness

The findings indicated that most respondents were aware of smart agriculture technologies such as conservation farming, drought-resistant seed varieties, irrigation systems, and mobile-based agricultural advisory services. However, practical competencies remained uneven because fewer respondents had received formal agricultural training or continuous technical support. This distinction between awareness and operational capability is significant because technology adoption requires more than information exposure; it requires the technical ability to apply innovations effectively within local farming systems. These findings support Human Capital Theory, which emphasises that investments in education, training, and skills development increase productivity and innovation adoption (Becker, 1964). Although many youths possessed secondary-level education, educational attainment alone did not automatically translate into technological competence. The study therefore confirms that rural youth require specialised and practice-oriented agricultural training in order to utilise smart agriculture technologies productively. Similar findings were reported by Yeboah and Jayne (2021), who argued that formal education without practical extension support has limited influence on agricultural innovation uptake among African youth.

The findings also reinforce Rogers' Diffusion of Innovations Theory, which explains that adoption is influenced by how individuals perceive the complexity, compatibility, and usefulness of innovations (Rogers, 2003). Respondents frequently described smart agriculture technologies as technically demanding due to limited demonstrations and inadequate field-based guidance. This suggests that technologies perceived as complex are less likely to diffuse effectively within rural communities lacking strong institutional support structures. Recent studies similarly demonstrate that youth adoption of climate-smart agriculture improves when technologies are accompanied by practical demonstrations, peer learning, and extension-based mentoring systems (Makokha et al., 2020; Geza et al., 2021).

The study established that access to extension services remained inconsistent. Although some respondents benefited from agricultural advisory services, many reported limited interaction with extension officers because of transport challenges, understaffing, and weak institutional funding. This finding is important because extension systems act as critical intermediaries connecting research institutions, farmers, and agricultural policy systems. From the perspective of Agricultural Innovation Systems Theory, weak extension coverage reflects broader institutional inefficiencies that undermine agricultural transformation processes (Spielman and Birner, 2008). Similar evidence from Sub-Saharan Africa shows that regular extension contact significantly increases farmers' likelihood of adopting climate-smart technologies and improving productivity outcomes (Ojo et al., 2020; Chamberlin et al., 2023).

Digital access emerged as another important dimension influencing youth capacities. Most respondents had access to mobile phones and agricultural radio programmes, suggesting growing digital penetration in rural Zambia. Access to ICT platforms improved opportunities for obtaining weather information, market prices, and farming advice. These findings align with Klerkx et al. (2022), who argued that digital agriculture is increasingly reshaping agricultural innovation systems through improved information access and decision-making support. However, persistent challenges relating to internet connectivity, unstable mobile networks, and high data costs revealed the existence of a rural digital divide. The findings therefore demonstrate that digital agriculture cannot achieve transformative outcomes in the absence of reliable rural infrastructure and affordable digital services (Rose et al., 2021).

Socio-Economic and Institutional Determinants of Adoption

The study established that socio-economic and institutional conditions strongly influence youth participation in smart agriculture. Land ownership and tenure security emerged as critical determinants affecting investment decisions. Youth with secure access to land were more willing to adopt long-term agricultural technologies such as irrigation systems, soil conservation practices, and improved seed varieties. In contrast, respondents operating under temporary or communal land arrangements demonstrated lower willingness to invest in technologies requiring long-term commitment. These findings correspond with recent studies showing that secure land tenure increases farmers' confidence to adopt climate-smart agricultural practices because it reduces uncertainty regarding future land use (Mhlanga et al., 2021). The findings additionally support Diffusion of Innovations Theory because perceived risk and compatibility influence technology adoption behaviour. Where land tenure remains insecure, agricultural innovations are often perceived as financially risky investments with uncertain long-term returns.

The study also found that financial exclusion significantly constrained youth adoption of smart agriculture technologies. Most respondents lacked access to formal agricultural credit due to collateral requirements, unstable incomes, and restrictive lending procedures. Consequently, many youths relied on informal savings groups and cooperatives whose financial capacities remained insufficient for large-scale technological investments. These findings demonstrate that access to finance remains one of the most significant structural barriers limiting youth participation in agricultural modernisation. The findings align with Mutengwa et al. (2023), who identified limited financial access as a major constraint affecting climate-smart agriculture adoption in Southern Africa. Similarly, Koomson et al. (2020) observed that farmers with access to agricultural finance are more likely to adopt improved technologies and withstand climate-related production risks. From the perspective of Agricultural Innovation Systems Theory, the exclusion of rural youth from formal financial systems reflects institutional weaknesses within agricultural innovation ecosystems. This suggests that agricultural transformation strategies targeting rural youth must integrate inclusive financing mechanisms, youth-specific credit facilities, and subsidised technology acquisition programmes.

Smart Agriculture and Productivity Outcomes

The findings demonstrated that adoption of smart agriculture technologies contributed positively to farm productivity among many respondents. Most participants who adopted improved farming practices reported increased crop yields, improved resource utilisation, and better resilience to climatic variability. These outcomes confirm that smart agriculture technologies possess significant potential to strengthen food production systems and rural livelihoods among youth farmers. The findings are consistent with the Food and Agriculture Organization (2023) which found that climate-smart agriculture improves productivity and adaptive capacity among smallholder farmers. Similar evidence by Zougmoré et al. (2023) showed that conservation farming, improved seed systems, and efficient water management technologies contribute significantly to yield enhancement and environmental sustainability.

The study further established that productivity improvements were more evident among respondents who had received technical training and extension support. This finding reinforces Human Capital Theory by demonstrating that technological adoption alone is insufficient without the accompanying skills required for effective implementation. However, some respondents reported stagnant or declining yields despite technology adoption. Qualitative findings indicated that poor-quality agricultural inputs, erratic rainfall, and inadequate technical support often undermined expected productivity gains. This demonstrates that agricultural technologies do not operate independently of broader environmental and institutional conditions.

Similarly, the analysis demonstrated that increased productivity did not always translate into significantly improved incomes. Although many respondents experienced income growth due to higher yields and improved market participation, others remained constrained by fluctuating commodity prices, high transportation costs, and expensive agricultural inputs. These findings support Mutambara et al. (2020), who argued that productivity gains alone cannot guarantee rural economic transformation unless farmers possess reliable market access and supportive value chain systems. The findings therefore suggest that youth-focused agricultural policies should integrate production support with broader market development, infrastructure investment, and rural commercialisation strategies.

Structural Barriers Affecting Youth Participation in Smart Agriculture

The study identified persistent structural barriers limiting sustainable youth engagement in smart agriculture. Financial constraints, high agricultural input costs, weak extension systems, poor ICT infrastructure, and insecure land access collectively reduced youth capacity to participate effectively in technology-driven farming systems. These structural limitations demonstrate that agricultural transformation among rural youth is not solely determined by individual willingness to innovate, but also by the institutional environment within which agricultural activities occur. The high cost of fertilisers, irrigation equipment, mechanisation technologies, and improved seeds emerged as a particularly important challenge. Even where youth expressed willingness to adopt modern farming practices, affordability constraints limited implementation. These findings align with Zougmoré et al. (2023), who observed that the high cost of climate-smart agricultural technologies remains a major barrier among resource-constrained farmers in Sub-Saharan Africa.

The findings further highlight broader inequalities affecting youth participation in agricultural development. Rural youth often occupy disadvantaged positions within agricultural systems characterised by limited asset ownership, weak institutional representation, and inadequate policy targeting. Consequently, agricultural transformation policies that fail to address structural inequalities are unlikely to achieve meaningful youth inclusion. The study argues that sustainable smart agriculture adoption requires integrated interventions involving institutional reform, rural infrastructure development, inclusive financing systems, affordable input support, and strengthened agricultural extension services.

Although Zambia has adopted several youth and climate-smart agricultural policies, implementation gaps remain substantial at community level. The findings revealed contradictions between policy intentions and practical delivery systems. While national agricultural frameworks emphasise youth empowerment and digital agricultural transformation, rural extension systems remain underfunded, understaffed, and poorly coordinated. Similarly, youth-targeted financing programmes remain inaccessible to many rural youths due to collateral requirements and bureaucratic lending procedures. These institutional weaknesses reproduce structural inequalities that continue to marginalise rural youth within agricultural innovation systems. The findings therefore suggest that the challenge is not the absence of policy frameworks, but rather weak implementation capacity, inadequate rural investment, and insufficient institutional accountability mechanisms.

CONCLUSION

The study demonstrates that rural youth in Kanakantapa Farming Block possess moderate potential to adopt smart agriculture technologies, but this potential remains constrained by significant structural and institutional barriers. Although awareness of agricultural innovations was relatively high, practical adoption capacities were weakened by limited technical training, inadequate extension support, financial exclusion, insecure land tenure systems, and poor rural infrastructure. The findings also demonstrate that smart agriculture technologies can improve productivity, resilience, and household incomes when supported by effective institutional systems. However, uneven outcomes across respondents indicate that agricultural technologies alone cannot transform rural livelihoods without complementary investments in capacity development, financing systems, digital infrastructure, market access, and policy support. The study further confirms that youth can play a transformative role in agricultural modernisation in Zambia if supported through integrated and inclusive agricultural development strategies that strengthen both individual capacities and institutional systems. The study concludes that sustainable youth engagement in smart agriculture requires integrated policy interventions that simultaneously strengthen technical capacity, financial inclusion, institutional support, and rural infrastructure development.

RECOMMENDATIONS

The study recommends that government ministries, agricultural institutions, NGOs, financial institutions, and development partners strengthen integrated youth-centred smart agriculture programmes in rural Zambia. Priority should be placed on practical agricultural training, digital literacy, climate-smart farming techniques, agribusiness entrepreneurship, and continuous extension support tailored to the needs of rural youth. Government should further improve rural ICT infrastructure, internet connectivity, irrigation systems, market access, and transport networks to enhance technology utilisation and productivity outcomes. Youth-friendly agricultural financing mechanisms, including low-interest loans, cooperative financing schemes, village savings groups, and input subsidy programmes, should be expanded to address financial exclusion among young farmers. In addition, land allocation policies should promote secure and equitable youth access to agricultural land in order to encourage long-term investment in smart agriculture technologies. Institutional coordination among agricultural ministries, educational institutions, private sector actors, and local authorities should also be strengthened to improve implementation of digital agriculture initiatives. The study contributes to knowledge by providing empirical evidence on the multidimensional capacities influencing youth adoption of smart agriculture technologies in rural Zambia. It demonstrates that smart agriculture adoption is not determined solely by awareness or education levels, but by the interaction between technical skills, institutional support, financial inclusion, infrastructure, and policy systems. The study additionally contributes localised evidence from Kanakantapa Farming Block, thereby expanding existing literature on youth participation, rural innovation, and agricultural transformation in developing countries.

Limitations of the Study

The study was limited geographically to Kanakantapa Farming Block in Chongwe District, which may reduce the generalisability of the findings to other rural regions with different socio-economic, environmental, and institutional conditions. Another limitation relates to the cross-sectional nature of the study, which restricted the ability to observe long-term adoption trajectories and seasonal agricultural variations. The reliance on selfreported productivity and income data may also have introduced recall bias and over-reporting among respondents. Although qualitative interviews were used to triangulate findings, future studies should incorporate longitudinal farm-level productivity measurements and observational data to improve reliability.

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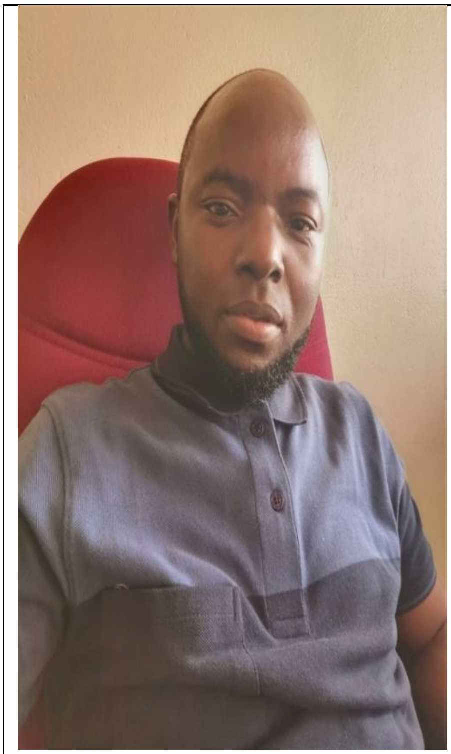

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