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Impact and Necessity of ICT Adoption in Agriculture: Insights from Regression Analysis

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Abstract

The integration of Information and Communication Technology (ICT) in agricultural practices is gaining global attention for its potential to enhance traditional farming systems. This case study explores ICT adoption in livestock farming in Sheshegu District, Eastern Cape, South Africa, examining its impact on productivity. Data were collected through interviews and field observations, evaluating the effectiveness of ICT tools, including mobile phones, radios, TVs, and the internet, in improving communication, resource management, market access, and overall farm sustainability. The findings reveal mobile phones (30%) as the most used ICT tool, followed by radios (25%) and TVs (20%). The Regression analysis indicated a positive correlation between perceived benefits (relative advantage) and ease of use (compatibility). The analysis further revealed a negative influence of perceived complexity (-0.20) and limited opportunities for trialability (-0.15), suggesting that adopting new technologies could be complicated if not properly tested. Key challenges include weak mobile signals and language barriers. The study highlights the need for improved infrastructure, digital literacy, and collaborative efforts to enhance ICT-driven agricultural productivity.

Keywords: ICT adoption, Agricultural productivity, Livestock farming, Regression analysis, Sub-Saharan Africa.

1. INTRODUCTION

In recent years, the agricultural sector has witnessed a paradigm shift driven by advancements in information and communication technology (ICT). This shift has immense potential to transform traditional farming practices and enhance productivity, sustainability, and market access in both developed and developing regions [1, 2]. Global research has extensively studied the adoption of

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ICT in agriculture, but its impact in rural areas, particularly in developing countries like South Africa, remains an active area of research and exploration.

The 2023 study by the University of the Witwatersrand[1], reveals that the Eastern Cape province of South Africa has the highest level of food insecurity, with 32% of households affected. It further reveals that over 20% (1 in 5) of South African households are food insecure. However, this challenge varies widely across the country's provinces. For example, provinces that are predominantly rural and have high levels of poverty, such as Limpopo (25%), the Eastern Cape (20%) and KwaZulu-Natal (20%) had the highest proportions of households that relied on agricultural activities to supply their food. Specifically, the Sheshegu district in Eastern Cape Province is home to people living in rural areas, the majority of whom earn their livelihoods from agricultural practices, while others are from tourism or formal jobs.

The necessary improvements to farming activities and information are increasingly facilitated by artificial intelligence (AI) and machine learning (ML) applications, which are key components of ICT integration in agriculture [3]. AI-driven predictive models, for instance, enable more efficient resource allocation, early detection of livestock diseases, and improved market forecasting, especially in rural regions of developing nations [4, 5]. The transmission of information on alternative resource uses, markets, pricing, income, and support services can promote and improve livelihoods, especially in these communities [6, 7]. However, despite the potential benefits of adopting technology in agricultural practices, particularly for rural farmers, there are still limitations and difficulties to overcome, such as a lack of education, carelessness, or resistance to change, in order to enjoy these benefits [8, 9]. Da Silveira et al. [9] addressed this and revealed that various barriers, including technological, economic, political, social, and environmental factors, significantly impact the development of agriculture. Similarly, in South Africa, several rural communities still refuse to use or embrace technology due to historical colonial legacies, cultural and religious factors [10].

This study investigates the impact and need for ICT adoption in agriculture for rural farmers. The study focuses on the Sheshegu district, a rural area located in Eastern Cape Province, South Africa, where livestock farming is a primary source of livelihood for the local community. The main research question explored is how the adoption of ICT, particularly ICT-driven solutions, can enhance productivity and address challenges faced by rural livestock farmers. The study also evaluates farmers' knowledge of ICT and their readiness to adopt ICT-Driven tools that can optimize farming practices and sustainability. The diffusion of innovation theory, a five-step decision-making process (relative advantage, compatibility, complexity, trialability, and observability), was adopted and tested using the regression analysis approach.

The remainder of this paper is organized as follows: Section 2 discusses the related works. Section 3 explains the methods; the results are presented in Section 4, while Section 5 concludes the paper with some recommendations.

[1] https://www.wits.ac.za/news/latest-news/opinion/2023/2023-04/1-in-5-south-african-households-begs-for-food–the-link-between-food-insecurity-and-mental-health.html

2. RELATED WORK

Several research efforts have focused on the use of information and communication technology (ICT) in agriculture, demonstrating its potential to revolutionise farming methods in various contexts. This has demonstrated that ICT significantly enhances resource management [11], market access [12], and agricultural productivity [13]. For example, Aker's study [1], revealed how mobile phones have changed agricultural markets in sub-Saharan Africa by providing better access to market information, lowering transaction costs, and giving farmers more bargaining power. Furthermore, the study posits that the growth of mobile money services has provided farmers with digital payment options, credit access, and financial transactions, enhancing their financial inclusion and economic opportunities.

More so, recent studies on leveraging the role of machine learning and artificial intelligence have demonstrated the positive impact of Information and Communication Technologies (ICTs) on agricultural productivity. The study by Ayoub Shaikh et al. [4], highlighted the impact of digitalization on agriculture, leading to a surge in data management through ICT through the efforts of machine learning and artificial intelligence in precision agriculture and smart farming. Key technologies such as robotics, IoT devices, and machine learning and their roles in agriculture were examined, and the study identified challenges in applying ICT in agriculture, particularly focusing on AI and machine learning. Similarly, Mana et al. [5], emphasized the need for sustainable agricultural practices to meet the food demands of a projected ten billion people in the next 30 years. The study advocated using smart technologies and Artificial Intelligence (AI) advancements to enhance agricultural operations and contribute to global sustainability goals. They furhter revealed that current agricultural practices prioritize productivity over sustainability, necessitating significant changes to meet future demands. However, smart technologies and AI can help overcome these challenges and promote sustainable agriculture.

There are also specific studies focused on how ICT is being used in livestock farming. In the study by Irungu et al. [14], the impact of ICT on livestock management in Kenya was investigated. They discovered that information and communication technologies (ICTs) have revolutionised livestock management in Kenya by providing farmers, especially the youth, with improved access to essential information on breeding, nutrition, and health through platforms like iCow. Additionally, it was identified that ICTs have played a crucial role in training and capacity building, empowering farmers to make informed decisions, improving productivity, and ultimately enhancing the profitability of livestock management in the country. Similarly, Hashem et al. [15], state that ICTs have revolutionised livestock management by offering data collection, processing, and sharing tools along the agricultural value chain. Emphasising that sensors, wearables, and automation are increasingly used to support livestock management, ensuring sustainability and productivity.

In South Africa, Abegunde et al. [16], looked at how ICT can bridge the information gap for rural farmers, focusing on climate-smart agriculture practices. The research demonstrated that ICT can provide rural farmers with relevant agricultural information, resulting in a 12% higher net return per hectare, as well as increasing awareness of climate change impacts and prompting timely responses. Hence, despite challenges like limited digital literacy and inadequate infrastructure, the benefits of ICT adoption are substantial. This perspective is very relevant to this study, as it reflects the similar challenges faced in the Sheshegu district and the potential benefits of addressing these issues to fully realise the advantages of ICT in livestock farming. Additionally, Tata and McNamara [17], thoroughly analysed the socio-economic factors influencing ICT adoption in rural agriculture. They identified major barriers, such as education, income, gender, and infrastructure, when implementing ICT initiatives in rural agriculture. The research by Mazibuko and Antwi [18], also emphasised the importance of the availability of ICT infrastructure in rural areas because inadequate infrastructure can hinder the effective use of ICT tools.

There is also a growing interest in advanced ICT solutions like precision farming [19, 20], and the Internet of Things (IoT) [21, 22], in agriculture. Dhanaraju et al. [22], explored how IoT can be used to optimise livestock farming by improving the monitoring and management of animal health and environmental conditions. Sensors and smart devices can track vital signs, feeding patterns, and environmental conditions to ensure the well-being of livestock. Also, automation through IoT can streamline tasks like feeding, milking, and waste management, improving operational efficiency. Raj et al. [20], state that farmers can improve overall livestock management practices by utilising precision agriculture, leading to better health outcomes and increased productivity. Similarly, De-Lay et al. [23], supported the view that adopting precision agriculture tools can lead to cost savings, improved net returns, and better production practices in livestock operations. These technologies include remote sensing, auto-steer navigation, and information-intensive bundles. Although these technologies are still in the early stages of adoption in many rural areas, including Sheshegu, they hold significant potential for revolutionising livestock farming.

The existing research provides a strong foundation for this study on ICT adoption and usage in livestock farming. These studies collectively highlight the transformative potential of ICT, the challenges faced in rural contexts, and the crucial role of supportive policies and infrastructure. This study aims to contribute to the ongoing interest and offer practical recommendations for enhancing ICT adoption in rural livestock farming communities in South Africa and other similar regions worldwide.

3. METHODS

The study adopts a mixed-methods approach, integrating both qualitative and quantitative methodologies to comprehensively evaluate the influence of ICT, particularly ICT-driven methods, on livestock farming in the rural Sheshegu district of South Africa. The quantitative aspect includes a regression analysis to examine the relationship between ICT adoption factors (relative advantage, compatibility, complexity, trialability, and observability) and farming productivity. The qualitative component includes interviews and field observations to gather in-depth insights into farmers' experiences, challenges, and readiness to adopt ICT-driven tools in their farming practices. Together, these methods provide a robust framework for understanding how ICT adoption impacts productivity and sustainability in rural farming.

3.1 Data Collection

The study employed a non-probability sampling approach, utilizing purposive sampling to ensure the selection of a rural area predominantly engaged in traditional livestock farming methods. Purposive sampling was chosen to focus specifically on the Sheshegu district, where livestock farming plays a critical role in the local economy. A convenience sampling method was then used to select participants based on their availability, schedule, and interest in participating in the study. A total of 77 participants were involved in the study, including 54 male and 23 female small-scale farmers. These participants provided a diverse range of perspectives on the adoption of ICT in livestock farming. Semi-structured, in-depth interviews were conducted to gather insights into their experiences, perceptions, and recommendations on the use of ICT tools in farming. This qualitative data collection was complemented by field observations, where the researchers visited farms to observe first-hand the utilization of ICT technologies in areas such as livestock management, feed optimization, disease monitoring, and market access. The Allflex intelligence app[2] was used to monitor the behaviour of a herd of cows as a sample, which were tagged with colour codes for easy tracking purposes. The technology proved to be 95% effective in tracking the herd, despite power outages and connectivity issues.

3.2 Data Analysis

A combination of descriptive statistics and regression analysis was applied to analyze the collected data. The descriptive statistics provided an overview of variables such as age, education level, access to ICT, and farming outcomes, allowing a summary of the current state of ICT adoption among farmers. The regression analysis was employed to examine the relationship between farming productivity and key ICT adoption factors. This enabled the identification of statistically significant predictors of productivity and offered insights into how specific aspects of ICT usage drive agricultural performance. The qualitative data from interviews and field observations were analyzed to support the quantitative findings.

Formalisation The formalisation of the relationship between ICT adoption and livestock farming outcomes, grounded in the Diffusion of Innovations Theory, involves modelling the influence of various factors identified in the theory. According to Rogers (1962), the key components influencing the rate of adoption include relative advantage, compatibility, complexity, trialability, and observability. These components can be formalised as follows:

Let Y represent the dependent variable (i.e., productivity), and $X_1, X_2, \ldots, X_5$ represent the independent variables corresponding to the components of the Diffusion of Innovations Theory:

- X_1 = Relative Advantage
- X_2 = Compatibility
- X_3 = Complexity
- X_4 = Trialability
- X_5 = Observability

The regression model is given as:

[2] https://www.allflexsa.com/

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \epsilon$$

Where:

- β_0 is the intercept.
- $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are the coefficients of the independent variables.
- ϵ is the error term.

4. RESULTS AND DISCUSSION

The investigation of Information and Communication Technology (ICT) in livestock farming within the Sheshegu district of South Africa has provided several key insights into ICT-driven tools potential to transform traditional agricultural practices. The data analysis revealed significant variation in the levels of ICT adoption among farmers, as well as its tangible impact on livestock productivity and farm management. The regression analysis demonstrated significant relationships between farming productivity and ICT adoption factors. These findings underscore the potential of leveraging machine learning models to predict farming success based on ICT tool usage.

4.1 Demographic of the Sample

The results in Table 1, show that there are more male participants (70%) than female participants (30%) among the participants. Additionally, the majority of the respondents completed Grade 12 education. The age of the respondents ranges from 36 to 65. There are also about 80 percent of respondents who prefer livestock farming, and many of them have been farmers for more than 11 years.

4.2 Adoption of ICT Tools and Services

The findings about the usage of ICT tools and services by the farmers for agricultural development reveal that these technologies are employed for various purposes, significantly contributing to their farming practices (see FIGURE 1). The farmers use ICT devices and services for communication with extension advisors (20%), accessing market and weather information (15%), adopting new technology (3%), communication among each other (37%), internet research (4%), and obtaining information from non-governmental organisations (18%). Notably, the high usage rate (37%) for farmer-to-farmer communication underscores the importance of local social networks facilitated by ICTs. Mobile phones, in particular, help the farmers enhance their social capital by fostering local networking. Additionally, the 15% usage rate for market information highlights the potential of ICT to store and transmit crucial market data, enabling farmers to better negotiate prices and access markets more effectively. The frequent use of ICT for extension guidance (20%) indicates that the farmers actively seek advice from extension officials. This interaction is crucial for disseminating

Table 1: Demographic characteristics of the farmers

Variables	Frequency	Percentage (%)
Gender		
Male	54	70
Female	23	30
Educational level		
Grade 1-6	8	10
Grade 7-9	23	30
Grade 12	30	40
Diploma	8	10
Degree	8	10
Age		
36-55	38	50
56-64	23	30
65+	16	20
Type of farming		
Livestock	61	80
Mixed farming	16	20
Duration in Farming		
1-6 years	8	10
7-10 years	23	30
11-15 years	30	40
16+ years	16	20

knowledge and support. However, the adoption of new technology remains low (3%), partly due to limited internet literacy. This gradual adoption rate can leave certain technological advancements underutilised despite their potential to enhance agricultural productivity. It is evident that some farmers remain unaware of the agricultural benefits of ICTs or choose not to engage with these technologies due to a lack of interest or awareness. Hence, more efforts are needed to educate and motivate farmers about the diverse applications of ICT in agriculture.

4.3 ICT Devices and Services Used for Agricultural Purposes

The findings regarding the ICT tools and services used among the farmers for agricultural purposes reveal that mobile phones (30%), radios (25%), TVs (20%), the internet (4%), and cameras (15%) are the most frequently used ICT devices and service platforms. This result highlights that mobile phones are the primary ICT tools used for agricultural activities among the farmers, as shown in Table 2. The prevalence of mobile phones can be attributed to the rapid expansion of mobile network services in rural areas. Mobile phones have become essential for smallholder farmers, providing easy access to market information and extension services. Mobile phones are particularly popular due to their portability and multifunctionality, often integrating radios, cameras, and internet access. While radios and televisions have traditionally been important extension tools, the results suggest that their current utilisation is not as effective as mobile phones. This shift underscores the evolving

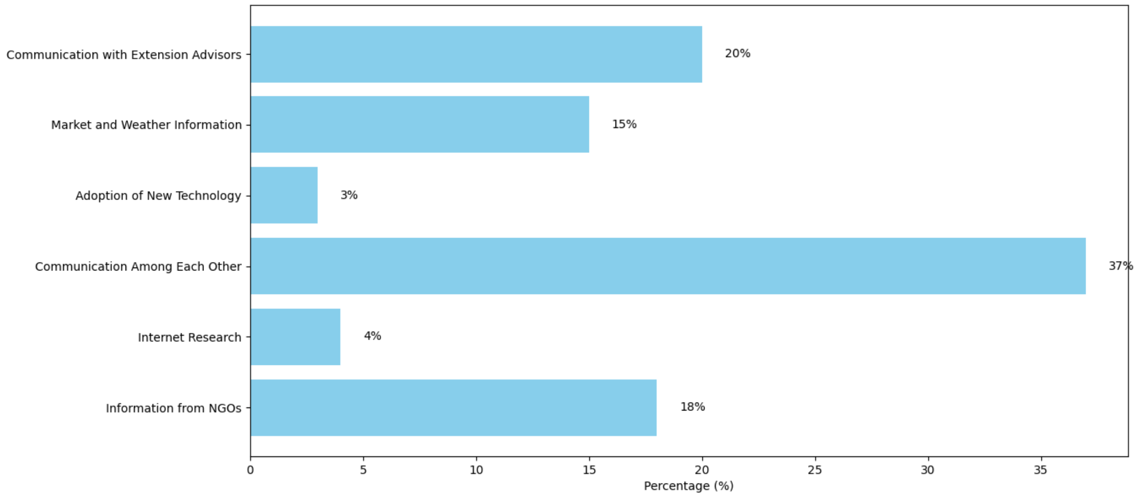

Figure 1: Adoption of ICT Tools and Services.

Table 2: ICT Devices and Services Used for Agricultural Purposes

ICT Device/Service	Usage Percentage (%)
Mobile Phones	30%
Radios	25%
TVs	20%
Internet	4%
Cameras	15%

landscape of ICT usage in agriculture, emphasising the growing importance of mobile technology in supporting the needs of small-scale farmers.

4.4 Challenges and Barriers

The majority of farmers who use ICT devices and services for agricultural purposes face significant challenges, including a weak signal (50%), not knowing when agricultural programs air (25%), a lack of electricity (6%), and language barriers (18%). These results highlight two key issues (Figure 2): weak mobile phone signals and the challenge of accurately determining when agricultural programs air on radio and television. Farmers often complain about inadequate advertisements for agricultural programs and constantly changing broadcast schedules. Inadequate network coverage is a major issue, making it challenging for farmers to use mobile phones effectively. Additionally, language barriers present another obstacle, as most ICT devices and services are available in English, while many of the farmers prefer and are more conversant in their local languages. This suggests that developing ICT tools and services that are language-compatible with the local community can improve smallholder farmers' access to valuable agricultural information, which is crucial for enhancing productivity and market access.

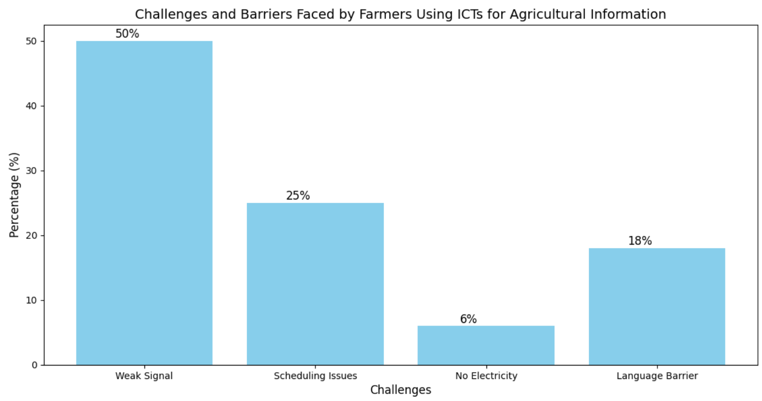

Figure 2: Challenges and Barriers Faced Using ICTs for Agricultural Purposes.

4.5 Regression Model Analysis

To further understand the impact of the different factors on ICT adoption by the farmers, a regression model based on the Diffusion of Innovations Theory was applied. The model included the following independent variables: relative advantage X_1, compatibility X_2, complexity X_3, trialability X_4, and observability X_5. The dependent variable Y was agricultural productivity.

The farmers provided information on various aspects of ICT adoption, which were quantified into specific variables (as shown in Table 3). These variables were scored based on the farmers' perceptions and experiences with ICT tools in their agricultural practices. The independent variables (X_1 to X_5) correspond to the following:

- X_1 (Relative Advantage): The perceived benefit of using ICT tools.
- X_2 (Compatibility): How well the ICT tools fit with existing practices.
- X_3 (complexity): The perceived difficulty of using the ICT tools.
- X_4 (Trialability): The ability to experiment with ICT tools before full adoption.
- X_5 (Observability): The visibility of the benefits of using ICT tools.

Table 3: The Regression Analysis Model for ICT Adoption Factors

Variable	**Coefficient (β)**	**Standard Error (SE)**	**t-value**	**p-value**
Intercept (β_0)	1.2	0.25	4.80	<0.001
Relative Advantage (X_1)	0.35	0.10	3.50	0.001
Compatibility (X_2)	0.30	0.12	2.50	0.014
Complexity (X_3)	-0.20	0.08	-2.50	0.014
Trialability (X_4)	-0.15	0.07	-2.14	0.035
Observability (X_5)	0.05	0.09	0.56	0.577

Given the regression equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \epsilon$$

and substitute the coefficients from the table:

$$Y = 1.2 + 0.35X_1 + 0.30X_2 - 0.20X_3 - 0.15X_4 + 0.05X_5 + \epsilon$$

The regression analysis results provide insights into how various factors related to ICT adoption influence farming productivity among the rural farmers. Using the coefficients derived from the model, the relative importance and impact of each factor can be understood. The intercept (β_0) is 1.2, which represents the baseline level of farmer productivity when all independent variables are zero. This baseline provides a starting point for evaluating the effects of each factor. The relative advantage X_1 has a positive coefficient of 0.35, indicating that an increase in perceived benefits of ICT tools is associated with higher farming productivity. Compatibility X_2 also positively influences productivity with a coefficient of 0.30, suggesting that ICT tools that align well with existing farming practices enhance efficiency. Conversely, complexity X_3 and trialability X_4 have negative coefficients of -0.20 and -0.15, respectively, indicating that higher perceived complexity and difficulties in experimenting with ICT tools reduce productivity. Observability X_5, with a coefficient of 0.05, shows a minimal and statistically insignificant impact on productivity. This detailed regression model highlights the critical areas for intervention, such as simplifying ICT tools and making them more compatible with current farming practices to boost productivity in small-scale farming communities.

4.6 Discussions

The study revealed several positive outcomes linked to the adoption of Information and Communication Technology (ICT) in agriculture, particularly its capacity to enhance livestock farming productivity in rural areas. However, the findings also highlight crucial factors that influence the effectiveness of ICT interventions in this context. One of the key factors identified is the nature and accessibility of the ICT tools and services being utilized. Mobile phones emerged as the dominant technology, with a usage rate of 30% among farmers, underscoring the importance of prioritizing mobile-friendly solutions in ICT development for agriculture. In comparison, traditional tools like radios and televisions, while still relevant (with 25% and 20% usage, respectively), showed a gradual decline in adoption, signifying a shift toward more mobile-based solutions. This transition emphasizes the need to adapt agricultural extension services and information dissemination strategies to fully leverage the growing reach and versatility of mobile technology, especially given that 37% of farmers use ICT primarily for communication among themselves.

The regression analysis, grounded in the innovation diffusion theory, offered deeper insights into the relationship between ICT adoption and farming productivity. The model demonstrated a strong positive correlation between perceived benefits (relative advantage) and ease of use (compatibility) of ICT tools, which contributed significantly to increased productivity levels. This underscores the importance of designing ICT solutions that are not only innovative but also tailored to fit within the existing farming practices of rural communities. The analysis further revealed a negative influence of perceived complexity (-0.20) and limited opportunities for trialability (-0.15), suggesting that farmers may be deterred from adopting new technologies if they are too complicated or if they are not given sufficient opportunity to test these technologies in a low-risk environment.

Moreover, the findings emphasize the critical need for user-centered design principles in developing ICT tools for agriculture. ICT solutions should be designed to be intuitive and easy to use, allowing farmers to gradually experiment with and gain confidence in the tools before fully committing to their adoption. The importance of addressing external challenges such as weak network coverage (reported by 50% of the respondents) and language barriers (faced by 18%) also became evident. Solutions that prioritize mobile-friendly applications, address complexity, and provide hands-on training will be crucial for ensuring the successful and widespread adoption of ICT in rural farming communities.

4.7 Recommendations

The study's findings suggest several key recommendations to improve the effectiveness of ICT interventions in enhancing agricultural productivity among smallholder farmers in rural areas. These recommendations are based on the empirical evidence gathered through both descriptive and regression analysis, and they aim to address the core challenges identified in the study:

- Prioritizing a Mobile-First Approach – The study revealed that mobile phones are the most widely used ICT tool among farmers, surpassing traditional technologies like radios and televisions. As such, future ICT development for agriculture should focus on mobile-first applications catering to smallholder farmers' specific needs.
- Improving Digital Literacy – A key barrier to the adoption of ICT is the low level of digital literacy among rural farmers. This can be addressed by providing targeted training programs to improve their understanding and usage of digital tools. These training programs should be culturally appropriate, use local languages, and cover all ICT applications relevant to livestock farming.

5. CONCLUSION

This study investigated the impact and necessity of ICT adoption in agriculture among small-scale livestock farmers in the Sheshegu district, Eastern Cape Province, South Africa. The findings provide essential insights for policymakers, researchers, and practitioners aiming to leverage technology for agricultural development in remote rural communities across sub-Saharan Africa. While ICT presents promising benefits for improving productivity, resource management, and market access, its implementation in rural farming is met with several challenges. Key barriers include limited infrastructure—such as unreliable electricity and inadequate internet connectivity—alongside issues related to digital literacy, language barriers, and affordability, which hinder broader adoption.

The results of this study underscore the potential of ICT to revolutionize livestock farming in rural areas like Sheshegu. By embracing technology, farmers can overcome traditional limitations, improve productivity, and enhance their livelihoods. However, while the regression analysis provides valuable insights into the relationships between ICT adoption factors and farming productivity, the sample size limits the generalizability of these findings. Future research should aim to involve a larger, more diverse sample to validate these initial results and explore additional factors, such as the role of AI-driven tools, that may influence the effectiveness of ICT adoption in agriculture.

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