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Determinants of Farmer Participation in the Implementation Phase of Revitalisation Programme of Selected Smallholder Irrigation Schemes in KwaZulu-Natal, South Africa

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ABSTRACT

The current irrigation schemes in Sub-Saharan Africa perform below expectations, resulting in unreliable, inadequate, and inequitable access to water. It was reported that revitalised smallholder irrigation schemes with high levels of farmer participation have performed better than supply-driven schemes with low levels of farmer participation. The purpose of the study is to investigate how certain socioeconomic and demographic factors, farmer attitudes, RESIS awareness, and access to irrigation water affect a farmer's level of participation in the RESIS implementation phase. Survey results from 350 irrigation farmers in four selected schemes in KwaZulu-Natal province revealed that marital status, farmer attitudes, and access to water all had a statistically significant effect on farmer participation levels during the RESIS implementation phase. It is essential to note that these factors may vary across different irrigation schemes due to variations in biophysical and socioeconomic factors. The implementation guidelines for the RESIS programme should therefore take these variations into account.

Keywords: Irrigation Schemes, Farmer Participation, Smallholder Farmers, Revitalisation.

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1. INTRODUCTION

Agricultural irrigation development is considered a crucial cornerstone for ensuring food security, promoting economic growth, and facilitating adaptation to climate change (World Bank, 1982; Cleaver, 1993; Hamidov & Helming, 2020). Effective irrigation management significantly contributes to several of the United Nations' Sustainable Development Goals (United Nations Development Programme [UNDP], 2015). Nevertheless, current irrigation schemes in Sub-Saharan Africa perform below expectations, resulting in unreliable, inadequate, and inequitable access to water (Merrey *et al*., 2018). Due to this, Sub-Saharan Africa is hindered from reaching its developmental goals in the irrigation sector (Shah *et al*., 2020). In response to some of the emerging challenges of the 1970s, policymakers revisited options to improve irrigation development (Inocencio *et al*., 2003). Challenges included a growing population, a decrease in government budgets for irrigation projects, increased competition among water users (agriculture, domestic, and industrial), poor water management, poor irrigation system operation and maintenance, and concerns regarding the environment (Molden *et al*., 2007; Turral *et al*., 2010). Governments financed, constructed, operated and maintained most irrigation schemes, with farmers left out of the management process (Bjornlund *et al*., 2020). In the 1980s, the challenges associated with irrigation schemes in Africa intensified (Bjornlund *et al*., 2020). Various researchers (Higginbottom *et al*., 2021; Carter, 1989; Fanadzo & Ncube, 2018; Bjornlund & Pittock, 2017; Bjornlund *et al*., 2020) identified five significant limitations of African irrigation schemes, i.e., high capital costs, exaggerated and overestimated gains, a lack of understanding of the social reality, the absence of management skills and responsible human resources, and the neglect of operations and maintenance. Furthermore, most studies on African irrigation schemes also identified an overly centralised and bureaucratic management system as a major limitation (Ofosu *et al*., 2014; Higginbottom *et al*., 2021). A more integrated community-based management mechanism resulted from this recognition. Thus, management transfer became a key strategy (Shah *et al*., 2002; Cambaza *et al*., 2020). Management transfer can be categorised differently according to the mode of implementation and phases, such as irrigation management transfer (IMT), participatory irrigation management (PIM), turnover or responsibility transfer (Woodhouse *et al*., 2017). These terms are often used interchangeably, despite their differing definitions (FAO, 1999; Khadra et al., 2017). FAO (2007) defined the philosophy of participatory management as "increased ownership, decision-making authority, and active participation in the operation and maintenance of irrigation systems would create or force a binding commitment from water users to be more effective and responsible towards their obligations" (as cited by Pék, 2021).

In South Africa, PIM/IMT policies were adopted and referred to as Revitalisation of Smallholder Irrigation Schemes (RESIS), which aimed at rehabilitating irrigation infrastructure and providing farmers with access to input and output markets, training, financial support and assistance with the establishment of functional institutions within irrigation schemes (DAFF, 2015; Mudhara & Senzanje, 2020). Reinders *et al*. (2010) defined an irrigation scheme as "an agricultural project involving multiple holdings that depend on a shared distribution system for access to irrigation water and, in some cases, on a shared water storage or diversion facility". Van Averbeke *et al.* (2011) specifically define the term 'smallholder irrigation scheme" in the context of South Africa as "an irrigation scheme that was constructed specifically for occupation and use by Black farmers". Smallholder irrigation schemes are critical to rural livelihood, particularly in arid regions, where crop production depends on irrigation due to erratic rainfall and high evaporative demand (Fanadzo & Ncube, 2018; Serote *et al*., 2021). In South Africa, Smallholder Irrigation Schemes (SIS) were established after recognising the importance of smallholder farmers to the local communities. Smallholder irrigation schemes are an essential means of achieving food security, creating jobs, and alleviating poverty, particularly in rural areas (Van Averbeke, 2012; Sinyolo et al., 2014). Although the South African government continues to invest heavily in smallholder irrigation schemes, many of them remain inefficient or collapse when state support is withdrawn (Van Averbeke *et al*., 2011). Between 2016/17 and 2019/20, the South African government invested approximately R64.4 billion in agriculture, rural development, and land reform (National Treasury, 2023). Even though different government departments participated in the RESIS programme, it was the Department of Agriculture (at provincial level) that was responsible for its implementation. The extent to which beneficiaries are involved in the revitalisation process from the beginning determines their sense of ownership over the new and rehabilitated infrastructure. Irrigating farmers or beneficiaries of the RESIS programme should be included in all decision-making processes. Therefore, the RESIS programme should be driven by demand. The selection of an irrigation system should be made in consultation with beneficiaries (Dennison & Manona, 2007). Dennison and Manona (2007) reported that revitalised schemes with high levels of farmer participation have performed better than supply-driven schemes with low levels of farmer participation. In accordance with the 'Continental Irrigation and Agricultural Water

Development Framework for Africa,' governments and implementation agencies should not manage the processes of identification, design, supervision of construction, and farmer organisation; instead, they should focus on facilitating the process based on demand (AU-SAFGRAD, 2018, p. 22).

The level of farmer participation in revitalised schemes has been the subject of several studies. These studies (Nnadi & Akwiwu, 2008; Kgosiemang & Oladele, 2012; Botlhoko & Oladele, 2013; Nxumalo & Oladele, 2013; Etwire *et al.*, 2013; Sithole *et al.*, 2014; Haile, 2016; Mthombeni, 2018) investigated factors influencing farmer participation in agricultural projects and concluded that household size, program effectiveness, constraints and effectiveness of government departments, age, gender, entrepreneurship, and household income are determinants of farmer participation in general. Muchara *et al.* (2014) examined the factors influencing farmer participation in collective activities aimed at improving the management of previously government-funded schemes. Water scarcity and low farmer literacy had a negative impact on collective activities, according to a study by Muchara et al. (2014). Fawole and Tijani (2013) investigated farmers' awareness and participation in extension activities, including research, extension services, and input supply services, and found a positive relationship between respondents' awareness and their participation in these activities.

A review of the literature reveals a lack of studies on the effects of farmers' awareness (knowledge) and attitudes on their level of participation during the implementation phase of PIM/IMT policies, such as the RESIS in South Africa. In addition, the study explores the effect of socioeconomic and demographic factors on farmers' level of participation during the RESIS implementation phase. In this study, farmer participation during the RESIS implementation phase refers to two principal ways: (1) resource contributions; and (2) administration and coordination efforts (Cohen & Uphoff, 1980).

2. RESEARCH METHODOLOGY

The research employed a quantitative design and involved surveying 345 farmers across four SISs in the KwaZulu-Natal Province. Data was collected through questionnaires, employing a multistage sampling procedure. The selection of the four SISs (NdumoB-NIS, Makhathini-MIS, Mooi River-MRIS, and Tugela Ferry-TFIS) was based on their participation in the RESIS programme. The researchers obtained a list of farmers from each respective SIS through extension officers, with a total of 49 from NIS, 778 from MIS, 380 from MRIS, and 771 from TFIS. To select the farmers, the formula outlined by Naing *et al*. (2006) was utilised:

$$S = \frac{N}{1+N\,(e)^2} \qquad (1)$$

To ensure greater accuracy, more farmers were interviewed from each scheme based on specified population sizes and confidence levels. It was assumed that these farmers would have experienced the implementation process of RESIS and developed certain attitudes toward the programme and its implementers. The study deliberately sampled farmers who have been actively farming since 2010 from MIS (85), MRIS (74), and TFIS (88) (Table 1). However, some statisticians argue that census methods should only be used for populations smaller than 100. Therefore, a survey was conducted on all irrigation farmers in the NIS.

TABLE 1: Number of Farmers Sampled from Selected Irrigation Schemes

Irrigation Schemes	Population	Sample size per scheme	
		Calculated	Interviewed
Makhathini	778	85	111
Ndumo B	49	-	49*
Mooi River	380	74	75
Tugela Ferry	771	88	110
Total	2124		345

Note: All Ndumo B farmers were interviewed.

Quantitative data were collected through a questionnaire comprising four distinct sections. These sections included socioeconomic and demographic factors, farmers' awareness of RESIS, farmers' attitudes toward the RESIS Programme and its implementing officials, and farmers' access to water for irrigation. The effectiveness of RESIS programmes was determined by examining the adequacy, timeliness, and equity of irrigation infrastructure. The resulting data was compiled into a comprehensive summary in Table 2.

TABLE 2: Description of Variables in the Study

Variable Description	Level of Measurement

Farmer Participation Index of RESIS stages (FPID-decision making, FPII-implementation, FPIB-benefit, FPIE-sharing and evaluation)	Continuous variables (%)
The farmer has adequate, equitable and timely access to water	0=No 1=Yes
Age	years
Size of the household	Number of persons per household
Gender	0=Female 1=Male
Educational level of the household head	0=non-formal education, 1=Primary education (Grade 1-6), 3=Secondary education (Grade 7-12), 4= Tertiary education (Certificate/Diploma/Degree)
Size of the household farm/plot	Number of hectares
Marital status of the household head	Singe=0 Married=1
Farmers' knowledge of the RESIS Programme	1=Yes 0=No
Attitudes of farmers toward RESIS irrigation infrastructure services	Likert scale of 1 to 5*
Attitudes of farmers toward RESIS output market services	Likert scale of 1 to 5
Attitudes of farmers toward RESIS financial support services	Likert scale of 1 to 5
Attitudes of farmers toward RESIS training services	Likert scale of 1 to 5
Attitudes of farmers toward the RESIS institutional arrangement support	Likert scale of 1 to 5
RESIS implementers have a participatory approach during the RESIS process	Likert scale of 1 to 5
RESIS implementers are efficient and effective	Likert scale of 1 to 5

RESIS implementers fairness	Likert scale of 1 to 5

***Note**: Likert scale of 1 to 5 refers to=1-Strongly disagree, 2=Disagree, 3=Neutral, 4=agree and 5=Strongly agree

To describe farmers' socioeconomic and demographic factors, RESIS awareness, attitudes toward the RESIS programme, implementers (government officials, agencies, and contractors) and access to water, as well as farmers' level of participation during the RESIS implementation phase, descriptive statistics (mean, percentages, and standard deviations) were used. The multiple regression model was also used to identify the various factors that have a statistically significant association with the farmers' level of participation during the RESIS implementation phase. An explanatory model involves multiple independent variables predicting the dependent variable. Multiple Linear Regression Models take the following form:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots \dots + \beta_n X_n + U \text{.. (2)}$$

In this model, Y represents the Farmer Participation Index (FPI) across four irrigation schemes during the RESIS implementation phase, and α indicates the value of the dependent variable when the independent variables are zero. Each β estimate shows how the average change in Y relates to a unit of change in X, while controlling for other explanatory variables in the model. In this Multiple Linear Regression Model, age, gender, education level and household land size were included as independent variables to represent demographic factors hypothesised to affect farmers' participation level during RESIS stages based on reviewed literature (Sheikh *et al.*, 2014; Alam *et al.*, 2012; Muchara *et al.*, 2014; Botlhoko & Oladele, 2013; Phali, 2020; Sharaunga & Mudhara, 2018). Additionally, farmers' attitudes towards the RESIS and its implementers, as well as farmers' awareness of the RESIS, were also included in the model as independent variables.

Arnstein's (1969) Ladder of Citizen Participation theory approach was used by various scholars (Okoth & Mbugua, 2018; Ndlovu, 2021; Zondi, 2021) to critically analyse the type and level of farmer participation in various agricultural projects. A similar approach was employed in this study to evaluate farmer participation during various phases of the RESIS programme. Table 4 indicates that the modified version of Arnstein's ladder of participation in the democratic process used in this study was developed by Aref *et al*. (2010). According to Aref *et al.* (2010), six types of participation are grouped into three levels: non-participation (1 -

manipulation, 2-information), symbolic participation (3 - consultation, 4-interaction, 5 - partnership) and genuine participation (6-empowerment). Genuine participation occurs when farmers contact RESIS implementers and ask for their intervention with farmers directly involved in the RESIS implementation, and farmers are mandated to contribute resources and assist with project administration and coordination (empowerment).

TABLE 4: Assessment of Farmers' Level and Type of Participation during the Implementation Phase of the RESIS Programme.

Level	Types of participation	Characteristics
3. Genuine Participation (High)	Empowerment	Farmers were empowered to participate in RESIS implementation as either locally hired employees or as members of various project advisory or decision-making committees. Farmers were also members of water user associations and irrigation scheme leadership committees, which played a role in coordinating their activities with those of the project (Arnstein, 1969; Cohen & Uphoff, 1980).
2. Symbolic Participation (Average)	Partnership Interaction Consultation	Farmers were consulted, interacted with, and partnered with RESIS implementers. Farmers received training on participation, but they were not mandated to contribute their resources or participate in project administration or coordination (Arnstein, 1969; Cohen & Uphoff, 1980).
1. Non-participation (Low)	Informing Manipulation	Farmers were aware of or informed of the available opportunities to participate, but RESIS implementers' favourable environment, such as training, was not created for farmers (Arnstein, 1969; Cohen & Uphoff, 1980).

Farmer Participation Index FPI_{scheme} measures farmer participation in RESIS stages by calculating the ratio between 'actual participation' (the rated level of farmer participation) and 'possible participation' (the maximum level of farmer participation), expressed as a percentage. Mathematically, it can be expressed as follows (Hasan *et al*., 2006):

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$$FPI_{scheme} = \frac{1}{3} + \left(\frac{FPa_{non}}{FP_p} + \frac{FPa_{symb}}{FP_p} + \frac{FPa_{genuine}}{FP_p}\right) \times 100 \quad (3)$$

Where,

FP_p = farmers' possible level of participation (genuine participation, level 3) during the RESIS implementation stage.

FPa_{non}= Farmers' actual level of participation (non-participation, level 0)
FPa_{symb} = Farmers' actual level of participation (symbolic participation, level 2)

$FPa_{genuine}$ = Farmers' actual level of participation (genuine participation)

As a result, FPI could vary from 0 to 100, with 0 indicating no participation and 100 indicating full participation.

3. RESULTS

Table 3 shows that 48.70% of farmers in revitalised SISs were single. The overall distribution of population across the four SISs was women (54.49%) versus men (45.51%). Farmers owned plot sizes of 4.66 ha on average across four SISs. According to the respondents' educational levels across four SISs, 40% of them had access to primary education. Across four SISs that were revitalised, the average household size was 8.04. The average age of most farmers in the four SISs was 54.38 years. Based on the study's findings, 51.60% of farmers in each of the four SISs were aware of the RESIS programme. Regarding farmers' attitudes towards the RESIS programme, farmers in all four SISs exhibited a generally positive attitude towards institutional support (3.515), training and extension services (3.366), and irrigation infrastructure (2.489); however, they showed negative attitudes towards input and output markets (2.451), financial assistance (2.060), and irrigation infrastructure (2.489). Nonetheless, the participatory approach (2.623), efficiency and effectiveness (2.858), and fairness (3.799) of RESIS implementers were generally regarded favourably or positively by farmers in all four revitalised SISs. Less than 50% of farmers in four revitalised SISs did not participate in the RESIS implementation stage, according to the FPII for the RESIS implementation stage, which was 55.58%. In general, 52.75% of farmers in the four rehabilitated SISs had equitable, timely, and adequate access to water for irrigation.

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TABLE 3: Descriptive Results of the Socioeconomic and Demographic Factors, Farmer's Access to Water for Irrigation, Level of Participation, Awareness, and Attitudes towards RESIS Programme

Variable Description	Level of Measurement
Age	54.38 (13.94)
Household size	8.04 (3.43)
Gender	Female: 54.49%, Male: 45.51%
Marital status	Married: 48.70%, Single: 51.30%
Education level	Non-formal: 24.06%, Primary: 40.00%, Secondary: 26.96%, Tertiary: 8.99%
Plot size	4.66 (5.13)
The farmer has adequate, equitable and timely access to water	Adequate: 82.32% Equitable: 79.13% Timeliness: 62.03% General: 52.75%
Farmer Participation in RESIS Implementation (FPID)	55.58%
Farmers' knowledge of the RESIS Programme	Yes: 51.60%
Attitudes of farmers toward RESIS irrigation infrastructure services	2.489* (0.988)
Attitudes of farmers toward RESIS output market services	2.451 (1.102)
Attitudes of farmers toward RESIS financial support services	2.060 (0.861)
Attitudes of farmers toward RESIS training services	3.366 (0.936)

Attitudes of farmers toward the RESIS institutional arrangement support	3.515 (0.856)
RESIS implementers have a participatory approach during the RESIS process	2.623 (0.887)
RESIS implementers are efficient and effective	2.858 (0.883)
RESIS implementers fairness	3.799 (0.680)

The results of the multiple linear regression model are shown in Table 4. The model indicates that farmers' level of participation during the implementation stage is positively associated with their marital status, with a statistically significant difference ($p < 0.05$). Regarding the attitudes of farmers towards the RESIS programme, the availability of financial support had a statistically significant ($p < 0.05$) positive effect on the farmers' level of participation during the programme's implementation stage. In terms of farmer attitudes towards RESIS implementers, fairness was statistically significantly ($p < 0.01$) positively affecting farmers' level of participation during the RESIS implementation stage. In contrast, farmers' attitudes towards the role of the RESIS programme in providing robust institutional support had a statistically significant ($p < 0.10$) negative effect on farmers' level of participation during the RESIS implementation stage. Finally, farmers' access to water for irrigation was found to have a statistically significant ($p < 0.10$) positive effect on farmers' level of participation during the RESIS implementation stages.

TABLE 4: Determinants of Farmer Participation across RESIS Implementation Stage in the MIS, MRIS, NIS And TFIS

Independent Variables	RESIS Implementation stage
Age	-0.018 (0.019)
Household size	-0.029 (0.064)
Gender	0.102

	(0.398)
Marital status	0.575** (0.246)
Education level	-0.239 (0.182)
Plot size	0.049 (0.049)
RESIS Knowledge	0.459 (0.388)
Attitude towards revitalised irrigation infrastructure	0.034 (0.243)
Attitudes towards market access by RESIS	0.024 (0.191)
Attitudes towards financial support access by RESIS	0.569*** (0.228)
Attitudes towards training access by RESIS	0.177 (0.250)
Attitudes towards institutional support access by RESIS	-0.539* (0.287)
Attitudes towards the participatory approach of RESIS Implementers	0.018 (0.231)
Attitudes towards the effectiveness and efficiency of RESIS Implementers	0.362 (0.247)
Attitudes towards the fairness of RESIS Implementers	1.294*** (0.350)
Access to water for irrigation	0.767* (0.422)
Y Intercept	2.595 (1.767)
Number of obs.	**345**
F(16, 328)	**3.15**
Prob > F	**0.000**

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R-squared	**0.1333**
Root MSE	**3.1085**

Note: ***, **, *; significant at 1%, 5% and 10%, respectively. Values in parentheses indicate standard deviation.

4. DISCUSSIONS

Marital status had a positive impact on farmers' participation during the implementation, benefit sharing, and evaluation stages of the RESIS programme (Table 4). According to the results, married farmers are more likely to participate in the RESIS programme during its implementation and during the benefit-sharing phase. The results align with those of Nnadi and Akwiwu (2008), who found that farmers' concerns about household welfare and food security are linked to their marital status, influencing their willingness to participate in agricultural projects. In addition, Haile (2016) found a positive correlation between farmers' marital status and participation in agricultural extension programmes. Farmers who were married had a good understanding, support, and encouragement from their spouses.

Farmer attitudes towards RESIS financial support have statistically significantly positively affected their level of participation during RESIS implementation (Table 4). These results indicate that farmers in all revitalised smallholder irrigation schemes were more motivated to participate in RESIS implementation. Farmers generally were dissatisfied with financial support, scoring 2.060 on an attitude scale (Table 3). From personal communication with extension officers responsible for revitalising irrigation schemes, it was found that most of the time, the government did not provide farmers with cash but instead vouchers to purchase production inputs. Farmers had only been given cash (as a relief grant) during the COVID-19 pandemic. These results align with those of Sithole et al. (2014) and Etwire et al. (2013), who also concluded that farmers can be motivated by access to funds through credit or grants. Mthombeni (2018) found that the funding framework in South Africa was not well-suited for emerging farmers but rather catered to existing commercial farmers. Hence, the government in South Africa introduced the Comprehensive Agriculture Support Programme (CASP) and Ilima/Letsema to cater specifically to food security, subsistence, emerging smallholder, and commercial farmers (DAFF, 2015). Farmers were encouraged to participate in RESIS's implementation stage because of their positive attitudes towards RESIS's financial support, in agreement with the reviewed literature (Sithole *et al*., 2014; Etwire *et al*., 2013), which showed that to encourage farmers' active participation in agricultural developmental programmes, credit or grants should be accessible through financial institutions or government departments.

Survey results revealed that farmers across the four irrigation schemes exhibited positive attitudes toward supportive institutional arrangements (Table 3). Nonetheless, farmers' attitudes towards access to institutional support were unexpectedly negatively affected by their level of participation during the RESIS implementation stage (Table 4). This finding contradicts the existing literature (Sirikwa, 2015; Phali et al., 2020; Mwadzingeni et al., 2020), which suggests that farmers are more likely to participate in collective activities when they have access to supportive and robust institutional arrangements. Additionally, access to functional formal and informal institutions should create an appropriate environment for socialising, interacting, and settling disputes, allowing time to focus on farming operations to produce high yields and incomes (Mwadzingeni *et al*., 2020). The study's findings indicate that although farmers were satisfied with the institutional support provided by the RESIS programme, this may have been a primary factor in their limited involvement during the programme's implementation phase. It is possible that most farmers elected committees within their irrigation schemes to act on their behalf during the RESIS implementation phase, especially as coordinators or administrators of projects. Strong institutional support may also result in fewer opportunities for individual farmers to participate, but more opportunities for a small group of elite farmers to participate.

In this study, farmers across the four irrigation schemes expressed positive attitudes towards the fairness of RESIS implementers (Table 3). According to Batho Principles, government officials should be mindful of fairness and equity when providing services to smallholder irrigation farmers (DPSA, 2023). This is aimed at ensuring that every citizen is afforded an equal and fair opportunity to access government services. Farmers’ attitudes towards the fairness and equity in the allocation of benefits by RESIS implementers statistically significantly positively affected farmers’ participation during the RESIS implementation stage (Table 4). Farmers are likely to participate in the RESIS implementation stage if they perceive fairness and equitable treatment by RESIS implementers during benefit allocations.

The study's results also indicated that farmers had an overall access to water for irrigation of 52.75% (Table 4.8). Access to water for irrigation had a statistically significant positive effect on farmers' level of participation during the RESIS decision-making stages (Table 4). Muchara *et al*. (2014) also concluded that long-term water scarcity discourages farmers from participating actively in collective actions. The current study employed three criteria to assess access to water: reliability, adequacy, and equity. Therefore, farmers' access to reliable, adequate, and equitable water was crucial to their participation in the RESIS implementation phase.

5. CONCLUSION AND RECOMMENDATIONS

This study has determined the variables that influence farmers' level of participation in the RESIS programme during its implementation phase. Farmers' attitudes towards RESIS financial support, their marital status, the fairness of RESIS implementers, and their access to water for irrigation were found to be factors that encouraged farmers to participate in the RESIS implementation stage. However, strong institutional support for revitalised irrigation schemes limits farmer support on an individual basis, allowing elite farmers to be the only ones able to influence irrigation scheme implementation decisions.

The study recommends modifying the implementation guidelines of the RESIS programme to consider factors such as marital status, financial access, fairness, and access to adequate, equitable, and timely water for irrigation. Farmers, on an individual basis, should also be given the opportunity to participate in the implementation of RESIS to ensure their irrigation schemes are revitalised according to their preferences. Because these factors vary from one irrigation scheme to another, guidelines for implementing the RESIS should not be seen as one-size-fits-all. As a result, the implementation guidelines should be determined by the outcomes of evaluating these factors.

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The Impact of Floods on Household Food Security Within uMzimkhulu and Kokstad Local Municipalities, KwaZulu-Natal Province (South Africa): A Comparative Study

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ABSTRACT

In the past three years (2021-2023), the KwaZulu-Natal Province has experienced unusually high rainfall, some of which was caused by Cyclone Idia. The province's geographical location along the coast makes it vulnerable to cyclones that form in the Indian Ocean, resulting in or triggering high rainfall and floods, such as those that occurred during the 2021-2023 floods, which led to flood disasters. Floods also occurred in other provinces, including the Eastern Cape and the Free State. In 2023, the KwaZulu-Natal Province continued to experience heavy rainfall, resulting in severe flooding that led to landslides and significant crop and livestock losses for many households. Floods directly impact access to food. The present study investigates the impact of floods on household food security within the uMzimkhulu and Kokstad Municipalities in KwaZulu-Natal. Data from the study have been analysed and presented using a quantitative survey approach using a structured questionnaire. The survey included 50 households, and purposive sampling was used to select the households or study participants. The study results reveal that more than 80% of respondents from both municipalities reported that their food supply was affected by the flood, as their crops, particularly the main food crops maize and dry beans, were destroyed or washed away. The study also reveals that floods negatively affected food availability and impacted households' income, as households usually sell excess produce to the market to raise extra money for other household needs. According to the findings, floods severely affected Kokstad Municipality, resulting in limited food availability in most households.

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Keywords: Floods, Household Food Security, uMzimkhulu Municipality, Kokstad Municipality, KwaZulu-Natal Province.

1. INTRODUCTION

Floods, as diachronic and international phenomena, affect many people, as well as buildings and infrastructure. Throughout human history, floods have been considered more lethal and have caused greater economic losses than other natural disasters (Angelakis *et al*., 2020).

Over the centuries, disasters have claimed lives, damaged infrastructure, caused diseases, and threatened food security worldwide, including in South Africa. In Africa, 66% of rural households rely on agriculture and land to support themselves or their livelihoods, while only 34% of households obtain significant incomes from non-farming activities (Kupika *et al*., 2019). Food insecurity has been on the rise globally since 2015, largely due to increasing violence and climate-related shocks, according to experts (Drysdale, Moshabela, & Bob, 2019; Swanepoel, Van Niekerk, & Tirivanhu, 2021; Shushu *et al*., 2024). By 2050, the world's population is estimated to reach 9.7 billion people. Africa is expected to account for more than half of this rise, making it an increasingly important driver of food demand (Gashu, Demment, & Stoecker, 2019; Shushu *et al*., 2024). Obviously, there is a relationship between food production and the environment, as food production is highly dependent on the environment. The current disastrous conditions in South Africa can negatively impact household food security, as well as food prices and exports of maize and other crops.

According to the Food and Agriculture Organisation (2019), flooding can affect food security for over 5.6 million people across several African nations. Furthermore, floods can damage crops, cause soil erosion, and result in the loss of livestock, further reducing food availability (Parida & Prasad Dash, 2020).

The South African agricultural sector is of great importance to rural areas, as it is a significant source of livelihood and income. Ngcamu (2022) argues that the nature and magnitude of the impact of climate-related natural disasters depend on the nature and intensity of the disaster, as well as the vulnerability and preparedness of people in the affected community. Small-scale farmers will be disproportionately affected by climate change-related disasters, thereby increasing their vulnerability to food insecurity and poverty.

The indirect impacts of floods on smallholder farmers include changes in productivity and the quality of crops produced, as well as various agricultural costs aimed at eliminating or minimising these changes. Additionally, floods have direct impacts on weather conditions, which ultimately affect agricultural practices (Callaghan, 2021). However, Ajala (2020) emphasises that the effects of floods and other hazards, such as droughts and typhoons, have negative impacts on food security. For example, they can reduce agricultural productivity; damage the means of production, facilities, and infrastructure; and limit farm planting options, thereby threatening people's livelihoods. Mazibuko and Letsoko (2024) state that South Africa is one of the African countries naturally susceptible to natural hazards, which result in a negative impact on household food security levels.

Considering the increasing population growth and the consequential loss of arable land in South Africa due to flood disasters, studies conducted in the country have shown that the level of food insecurity is currently high, with more than one million households being food insecure (Week & Wizor, 2020). Various studies have been conducted on the impact of floods in KwaZulu-Natal, but none of them have primarily focused on a comparative analysis between two municipalities (Udo & Naidu, 2023; Maziya *et al.*, 2024; Mazibuko & Letsoko, 2024; Amusan, Motswaledi, & Afolabi, 2024; Ndlovu & Zenda, 2024). An article by Udo *et al.* (2023) explores the experiences of local Black African women in adapting to flood impacts within the Durban metropolitan area, therefore the purpose of this study is to analyse the socio-economic characteristics of the families affected by floods within uMzimkhulu and Kokstad Municipalities in KwaZulu Natal (South Africa), and additionally to analyse the impact of floods on household food security within the two municipalities. The study aims to answer the following research questions:

I. What are the socio-economic characteristics of the families affected by floods within uMzimkhulu and Kokstad Municipalities?
II. What are the impacts of floods on household food security within uMzimkhulu and Kokstad Municipalities?
III. What measures were taken by the government to address the impact of floods?

The article is structured as follows: Section 2 contains the literature review, which includes the theoretical framework, while Section 3 presents the methodology. Data collection, analysis, measurement, discussion, and findings are all presented in Section 4, preceding the summary, conclusion, and implications in Section 5. Lastly, Section 6 outlines the recommendations.

2. LITERATURE REVIEW

2.1. Overview of Floods

According to Yan and Liu (2024), natural disasters are categorised into six groups: biological, geophysical, meteorological, hydrological, climatological, and extraterrestrial. Floods are in the hydrological group.

A flood can be defined as an event where the earth's surface cannot absorb all the rain that falls at a particular time, and when the excess water flows over the land (Zorn, 2019). Dube, Goldwell, and Chikodzi (2021) define a flood as an overflow of water onto the land that is referred to as normal dry land that has never been filled with water and then suddenly flooded after heavy rains, resulting in the inundation of areas, and potentially causing damage to infrastructure, agriculture, and communities. Floods can result from a multitude of factors, including climatic conditions, physical features, urbanisation, and human activities such as the use or application of more fertilisers and chemicals during crop planting, as well as vegetation clearing.

There are several different types of floods that an area can experience; only three major types of floods are experienced in the study area: River floods, Pluvial or Flash floods, and coastal floods (Abid *et al*., 2020; Yan *et al*., 2024). Pluvial flooding occurs in rural areas when the rate of precipitation falling on an area exceeds the infiltration rate into the ground, and in urbanised areas, when the floodwater exceeds the capacity of the built storm drain systems. Pluvial flooding can be defined as the rapid and extreme flow of water from high-lying areas into normally dry areas where the land cannot easily absorb large amounts of rainfall water (Falconer *et al*., 2009; Yan *et al*., 2024).

Fluvial flooding, which is like pluvial flooding, usually occurs when an excessive amount of rainfall exceeds the capacity of a river. In some areas, such as North America, fluvial flooding can also be caused by heavy snowmelt and ice jams (Lund, 2012; Changnon, 2008; Yan *et al*., 2024). Lastly, Coastal flooding in low-lying areas is usually caused by wind waves and elevated water levels (Wolf, 2009). These floods are typically generated by large waves, storm surges, high tides, and anomalies in mean sea level.

2.2. Overview of Food Security

There is no single, universally agreed-upon definition of food security; however, the commonly used definition is provided by the World Bank (David & Grobler, 2022). Food security is defined as the secure access by all people in a community or an economy to enough food for a healthy life (Stevens *et al*., 2000). Another definition of food security, closely related to the World Bank definition, is provided by FAO (2019). According to this definition, food security refers to the state of having access to sufficient, nutritious food that meets dietary needs and preferences, enabling an active and healthy lifestyle.

According to these definitions, food security has four components: availability, accessibility, utilisation, and stability. However, David *et al*. (2022) state that there are three key elements related to food security, namely availability, access, and utilisation. The nutritional well-being of household members depends not only on food accessibility but also on its utilisation by them. The three dimensions mentioned above must remain stable over time to ensure sustainable food security. The FAO (2019) states that even if you now consume enough food, you are still considered to have food insecurity if you frequently lack access to food. According to Callaghan (2021), there has been a change in rainfall patterns, which has caused season variability, affecting and manipulating the accessibility of specific types of foods at precise times of the year. As a result, low-income communities are more reliant on market purchases, which causes households to spend a larger portion of their income on food.

2.3. Floods and Food Security

According to Tabari (2020), flooding is a prevalent and destructive natural disaster, with its intensity, frequency, and geographical scope increasing continuously over time. Dube, Godwell, and Chikodzi (2021) claim that the effects of floods at the household level disrupt daily activities, uproot families, destroy infrastructures, and disrupt social and community networks.

The effects of floods are predicted to worsen in the future due to climate change, which is causing sea levels to rise, raising significant concerns. The current levels of flood catastrophe risk in South Africa are anticipated to increase and lead to an increase in the number of flood events because of poor land (agricultural) use practices, an expanding population, and a rise in

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the number of people residing in high flood-risk areas (Davis-Reddy, Vincent, & Mambo, 2017).

According to FAO (2019), grazing fields for livestock are the most affected by floods. Grazing land will be covered by water or eroded, resulting in livestock being without a place to feed or graze. Additionally, it contends that crop production is greatly impacted by flood damage, as the destruction of large areas of crops creates problems and challenges to food security.

3. RESEARCH METHODOLOGY

3.1. Study Area

uMzimkhulu and Kokstad municipalities are found in the southwest of KwaZulu-Natal Province. The two municipalities form part of the family of four (4) local municipalities of the Harry Gwala District Municipality (i.e., Ubuhlebezwe, Dr Nkosazana Dlamini-Zuma, Kokstad and uMzimkhulu). The uMzimkhulu municipality is approximately 115 km from Pietermaritzburg. Kokstad is 86 km from uMzimkhulu town. The Kokstad municipality is located on the border of the Eastern Cape and KwaZulu-Natal.

In KwaZulu-Natal, the uMzimkhulu and Kokstad Local Municipalities are among the areas where many households engage in subsistence agricultural activities to ensure survival. People work on farms, which is a great challenge since major farms and other communal gardens have been highly affected by floods in turn this likely contributes to money linked shortages in the household (Khowa, 2021), it has been confirmed that people of ward one at Kokstad Municipality are food insecure they cannot afford their living anymore as some of them still live in a community hall and being supported with food parcels. Food security remains a concern for households in the study area.

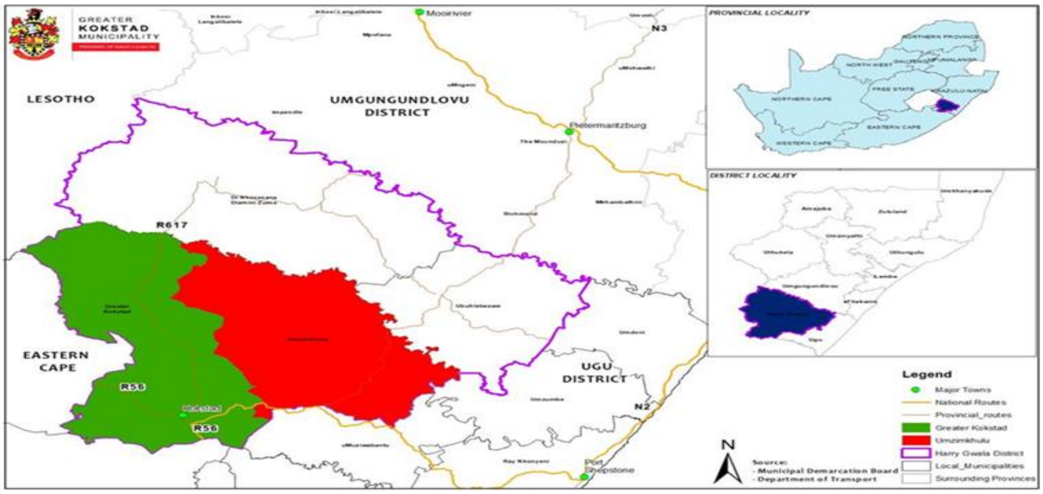

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FIGURE 1: Map Showing the Two Study Sites (uMzimkhulu and Kokstad Municipality) (Source: Greater Kokstad Municipality, 2022)

3.2. Research Design, Population, and Sampling

This study employed a quantitative design, which provides comprehensive coverage of the research objectives. It is particularly effective for analysing and understanding the socio-economic characteristics of households and measuring the effects of floods on household food security. A purposive sample of 50 households was selected from the total study population based on the impact of floods on their farming activities. A total of 30 households were from uMzimkhulu, and 20 households were from Kokstad municipality.

3.3. Data Collection and Analysis

A closed-ended questionnaire, available in both Xhosa and Zulu, was used to collect data from the households. This questionnaire served as the primary data collection instrument for the study. This type of interview is often used simply because it is easy to administer and may also be used to clarify whether certain questions are required or not. Data was collected during October 2023. The descriptive statistics analysis was used to obtain frequencies, percentages, mean, median, and mode to summarise statistical data and illustrate the results.

4. RESULTS AND DISCUSSION

4.1. Descriptive Results

The initial sample of this study consisted of 60 participants. However, due to challenges encountered by the researcher during data collection, including consultations with Ward Councillors, it was determined that 10 participants from Ward 1 at Kokstad Municipality could not participate in the study, as they were still residing in emergency shelters. Consequently, only 50 respondents participated in the study; however, the response rate was 100 percent. Mabuku (2019) states that flood disasters have increased, leading to direct and indirect impacts on societies, including agricultural productivity as well as food availability, accessibility, and stability in communities. Dube (2022) also reveals that households had low asset status and relied heavily on food parcels and social grants, particularly old-age pensions.

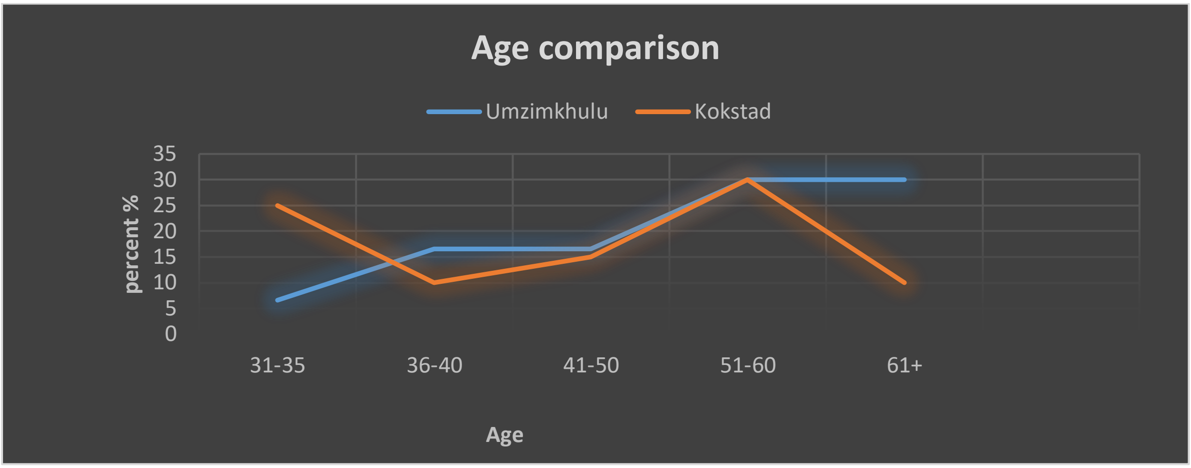

FIGURE 2: Comparative Analysis of the Age Groups of Households

All respondents were adults; children were excluded because they were unable to provide much information related to the study topic. The graph shows that 30% of the respondents were aged between 50 and 60 years in both Municipalities. Ajala (2020) explains that youth do not see farming as a profitable profession. They prefer to be hired by commercial farmers rather than starting their own businesses, and many also relocate to large cities. The graph also shows that 30% of respondents were aged 61 years and above at uMzimkhulu, whereas at Kokstad, only 10% fell within this age range. Additionally, Ibrahim, Ayinde, and Arowolo (2015) believe that older farmers are considered more experienced, which has a positive impact on their productivity.

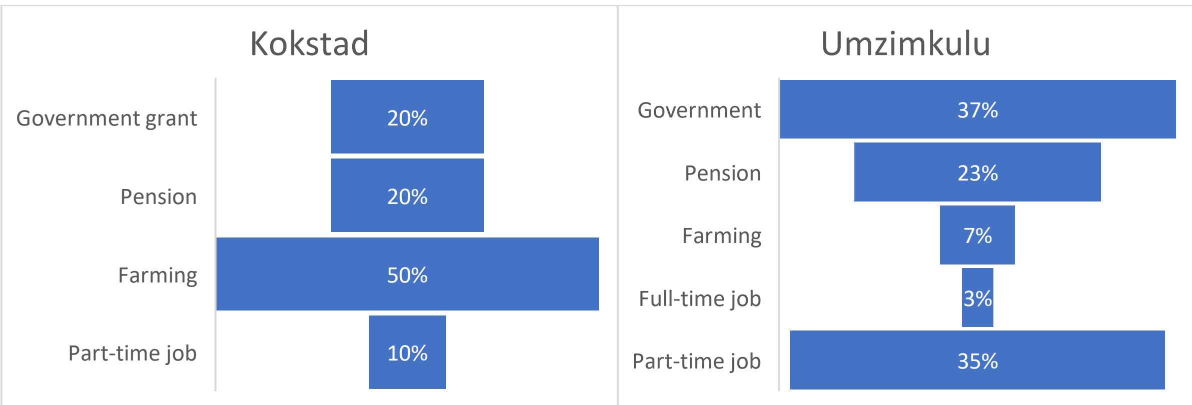

FIGURE 3: Major Source of Income

The study further investigated the participants' major source of income in both municipalities. Figure 3 shows that in Kokstad 10% of respondents said their source of income is from part-time jobs, 20% from pension, 20% government grants and 50% from farming, many respondents need to supplement their income either from a pension or part time job since most of them participate in Expanded Public Works Programme (EPWP) and their salaries are not enough. According to Ajala (2017), most rural households rely on agricultural production for a significant share of their household income, and they also sell to street vendors/hawkers. Figure 3 shows that in uMzimkhulu, 37% of participants rely on government grants, 35% of participants stated they at times get part-time jobs (seasonal jobs) in the nearest commercial farmers, only 3% have a full-time job, and 7% practice farming, 23% said their primary source of income is a pension (from previous employers), but that is not enough since they have to support their grandchildren.

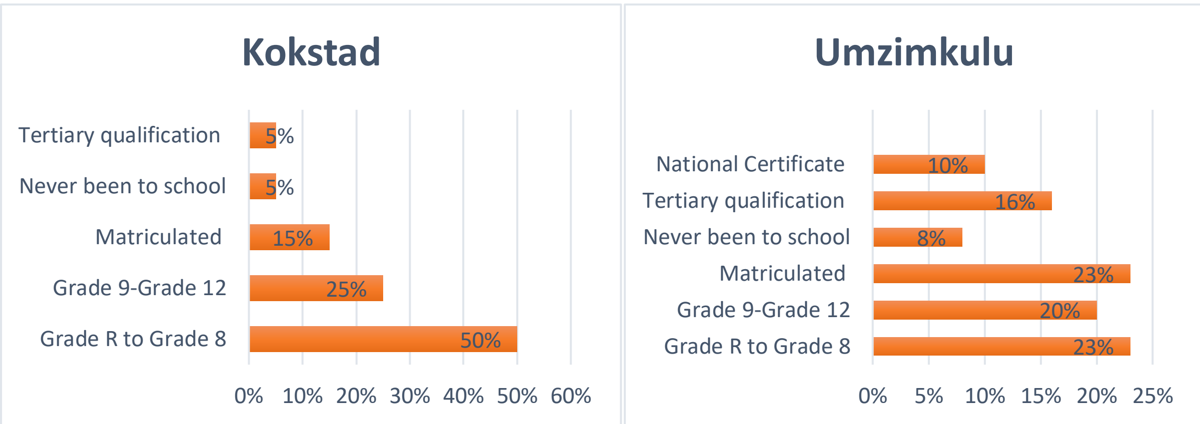

FIGURE 4: Highest Level of Qualification of Participant

In both municipalities, it was observed that most respondents had limited education, as indicated in Figure 4. Only 5% of respondents from Kokstad held a tertiary qualification, whereas 16% of respondents from uMzimkhulu had a tertiary qualification.

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4.2. Comparative Analysis of the Impact of Floods at Kokstad and uMzimkhulu

FIGURE 5: Floods Affected Bridges and Roads in 2022 (Source: HGD Disaster Management, 2022)

All of the respondents in both municipalities agreed that they were affected by floods in different ways. As shown in Figure 5 above, bridges and access roads were also affected. Participants mentioned that it was difficult for them to reach home using their motor vehicles, as access roads and bridges had been washed away. At uMzimkhulu, 3.3% of respondents (1 household) indicated that they lost a family member when their house collapsed. Sixty-three percent of the respondents from uMzimkhulu further explained that they experienced a burst of spring water in their houses, which resulted in damage to furniture and walls, or houses collapsing.

Almost 20% further indicated that floods caused electricity cuts in their area for a period of over a month, which resulted in most of their green groceries rotting as fridges stopped functioning. Musyoki, Thifhufhelwi, and Murungweni (2016) state that floods cause tremendous damage to roads, telephone lines, workplaces, schools, and health facilities. At Kokstad municipality, 59% of the respondents reported that they lost all their agricultural produce in their yard or garden, and their livestock was also affected.

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TABLE 1: Comparative Analysis of How Floods Affected Households in the Study

How Floods Affected Households in The Past Two Years (2021-2022)	Kokstad Municipality		uMzimkhulu Municipality	
	Frequency	Percent	Frequency	Percent
Crops and Livestock Destroyed	12	50	23	76.6
Poultry Structures and Birds Destroyed	3	15	2	6.7
Irrigation System and Fencing Damaged	0	0	02	6.7
Other	5	25	3	10
Total	**20**	**100**	**30**	**100**

As shown above, 50% of respondents from the Kokstad Municipality stated that floods destroyed and washed away their crops and livestock, while 76% of respondents were recorded in the uMzimkhulu Municipality. According to Ajala (2020), the destruction of agricultural land and livestock has the biggest impact, resulting in a significant impact on households' welfare and their socio-economic conditions. A further 15% of participants from Kokstad and 6.7% from uMzimkhulu reported that their poultry structures and birds were also washed away by the floods. At the uMzimkhulu municipality, 6.7% of participants stated that floods destroyed their irrigation systems and garden fences. Twenty-five percent of participants from Kokstad and 10% from uMzimkhulu did not attempt to answer the questions posed to them. This was possibly because floods had affected them very badly. Pictures below show how floods impacted some of the households in the study area.

FIGURE 6: Crops and Fence Damaged by Floods (Source: M. Ngubo)

FIGURE 7: Maize Damaged by Floods (Source: M. Ngubo)

The study also sought to determine the amount of money respondents spent on preparing the land and planting their crops, which had been affected or damaged by floods. Thirty-five percent of respondents from Kokstad and 46.6% from uMzimkhulu, who explained that they grow crops on 0.25 - 1/2 a hectare, used between R500 and R1500. Participants who grow crops on one to three hectares (1-3 hectares) reported using between R2000 and R15000, which includes hiring tractors and purchasing inputs such as fertiliser and seeds. Households that grow crops on more than four (4) hectares explained that they spent between R15 000 and R50 000, which also includes hiring a tractor, purchasing inputs and hiring temporary farm workers to assist in the transplanting of seedlings and weeding. Khowa (2021) found that households allocate a substantial amount of money to preparing or growing crops. However, when floods destroy all their produce, they lose the money they have invested in their fields.

Floods affected food availability in the households. Participants were asked whether the loss of crops due to floods had a significant impact on food availability in their household. A majority of respondents from both municipalities, 90% and 83.33%, respectively, confirmed that the floods certainly affected the availability of food in their households. This agrees with Henderson *et al.* (2020), who state that when flooding destroys crops and livestock, food security is threatened in most households. The study also aimed to investigate how food security was affected in households. The participants explained that low crop yields due to floods had a negative impact on households, affecting the availability of food, as households typically sell excess produce to the market as an income source. Thus, these floods resulted in a significant food shortage. Households now had to dig deep into their pockets to buy basic food (such as vegetables), which they had not previously purchased because they could harvest them from their gardens to feed their families.

4.3. Measures and Interventions Taken by the Government to Mitigate the Impact

Although Government and non-government organisations are trying to assist the flood victims, the support given to them is not enough, resulting in help going unnoticed by most households in the area. This is demonstrated in this study, where the majority of households (40% and 56% from both municipalities) reported not receiving any government assistance. Furthermore, 60% and 44% of respondents were not satisfied with the support or assistance they received. Some were given blankets or groceries, whereas others lost crops; they feel that it might have been better if they had been given agricultural inputs so that they could replant their gardens or plots.

4.4. Measures to Reduce the Impact of Floods

Forty-five percent of respondents from Kokstad and 33.33% from uMzimkhulu agree that the municipality should build strong access roads and bridges, which will direct running water/floods to the nearby streams. Participants (30% and 26.67%) also suggested that municipalities should provide early warnings and offer workshops to increase their knowledge of floods. Immediately after Weather services announce that heavy rains are to be expected, government employees should loudly disseminate this information to the communities, alerting them rather than keeping the information to themselves. From the results, 15% and 16.67% of

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participants from Kokstad and uMzimkhulu, respectively, stated that they had no idea about what to do during a flood incident. Therefore, it is crucial to educate communities about the risks of flooding.

TABLE 2: Measures to Mitigate the Impact of Floods

	Kokstad		uMzimkhulu	
	Frequency	Percentage	Frequency	Percentage
Municipality educates and provides early warning about floods	6	30	8	26.67
The municipality builds strong roads and bridges	9	45	10	33.33
Communities reduce deforestation	2	10	7	23.33
No idea	3	15	5	16.67

5. CONCLUSION AND RECOMMENDATIONS

Floods have a significant negative impact on most sectoral economic activities, resulting in reduced food availability for households. Reduced harvests impact the next planting season, ultimately leading to a food shortage crisis. The study suggests that both government and stakeholders should provide immediate assistance to the flood victims, and that sufficient financial resources should be allocated to the district municipalities. Additionally, the study suggests that programmes designed to raise households' awareness of floods, natural disasters, and risk reduction strategies should be implemented on an ongoing basis. The study concludes that households should diversify their holdings to include livestock and fruit trees, rather than relying on a single commodity, so that when crops are affected by floods, the produce that survives will help maintain food security in the household.

The study recommends that both the government and stakeholders provide immediate assistance to the flood victims, and that sufficient financial resources be allocated to the district municipalities. Municipalities should build strong access roads and bridges that direct running water/floods to nearby streams. Additionally, the study suggests that programmes designed to raise households' awareness of floods, natural disasters, and risk reduction strategies should be implemented on an ongoing basis.

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Awareness and Willingness to Adopt Livestock Tracking Devices to Mitigate Stock Theft Among Eastern Cape Communal Farmers

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ABSTRACT

Stock theft has become increasingly versatile, disrupting rural economies and livelihoods, and jeopardising food security. Animal tracking devices, such as GPS collars, have been suggested as one of the technologies that could help minimise crime by enabling owners to keep track of their animal's live location. Therefore, the objective of this study was to assess the awareness and willingness of communal livestock farmers to adopt livestock tracking devices for that purpose. A further objective was to determine the factors influencing the adoption of livestock tracking devices. Results from the data collected from 137 farmers in two villages show that 28% of farmers were aware of this technology and 42% were willing to purchase it, highlighting its affordable cost of R2500. The results underscore the poor quality of extension services, whose primary role is the dissemination of technology. Results from two logit and tobit models, which were used to determine the probability and extent of willingness to purchase, suggest that several factors, including household size, herd size, keeping sheep, and unfenced rangelands, play significant roles in influencing the farmers' decisions whether to purchase the animal tracking technology or not.

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These findings underscore the need for enhanced extension services and targeted awareness campaigns to promote the adoption of tracking technologies and reduce stock theft.

Keywords: Animal Rustling, Communal Farmers, Digital Technologies, South Africa.

1. INTRODUCTION

Keeping livestock represents a major contributor to the livelihood of most smallholder farm households in most rural areas of South Africa. According to the latest (2021) General Household Survey, 26% of households in South Africa keep livestock. Livestock rearing also constitutes an additional food source (Stats SA, 2021) for several farming households. Shackleton and Ntshudu (2023) established that, in the Eastern Cape, smallholder farmers keep mostly cattle, goats, and sheep for various purposes. Cattle and goats are primarily kept for cultural purposes, such as participating in ritual ceremonies, while sheep are kept for a specific financial practice akin to saving. This latter has been described as a strategic decision since wool in the province is a thriving and lucrative farming enterprise. It is estimated that in 2018, a communal farmer received an average monthly income of R15,000 from wool (Beinart, 2024).

However, this source of livelihood in the province and many parts of South Africa is undermined by stock theft. Stock theft appears to be perpetrated by a syndicate of organised crime, which has been persistent and growing over the years. Data from the South African Police Service (SAPS) reports more than 6000 stock theft cases in the 2022/23 season in the Eastern Cape alone (Clack, 2023). Furthermore, in 2011, stock theft was designated a priority crime in the National Rural Safety Strategy (SAPS, 2023).

Several suggestions have been made to mitigate stock theft in the country. These include branding, tattooing, and the frequent counting of animals, as well as the use of GPS animal tracking devices (Doorewaard, 2020; Lombard *et al*., 2017). Although the latter (GPS collars) has been recommended, very few studies have explored this possibility, especially in smallholder farming. The few existing studies include Zantsi and Kunjana (2021), who have considered the possibility of adopting and using GPS animal tracking devices in smallholder farming systems. Having conducted a comprehensive literature review and analysed data on stock theft, they concluded that the adoption of GPS animal tracking devices depends on four key factors; firstly, awareness about the devices and knowledge of how they work; secondly, the severity of stock theft for a farmer; thirdly, the extent to which livestock contributes to the livelihood of the farmer; lastly, the farmer's income level, access to mobile phones, and his/ her risk behaviour.

However, Zantsi and Nkunjana's (2021) study lacked primary data from smallholders to ascertain if smallholder farmers would be willing to adopt this technology. Hence, in the absence of primary related data, the aforementioned study was speculative and general in its approach to determining the factors that could influence the adoption of livestock tracking devices. Therefore, this study aims to determine whether smallholder livestock farmers are willing to adopt this technology and to identify factors that could increase the likelihood of adoption. This study utilises primary data from 200 communal livestock owners in two villages, one in Alice and the other in Lusikisiki, both located in the Eastern Cape province, where most stock theft hotspot areas are found.

The rest of the paper unfolds as follows: Section 2 reviews relevant literature on the prevalence of stock theft and the extent of livestock tracking devices and smallholder technology adoption. Section 3 presents the data collection and analysis methods, followed by the study's results. Section 4 presents the conclusions drawn from the research results.

2. LITERATURE REVIEW

2.1. Prevalence and Seriousness of Stock Theft

According to the Stock Theft Act 57 of 1959 (now the Judicial Matters Amendment Act 55 of 2002), livestock is defined as 'any horse, mule, ass, bull, cow, ox, heifer, calf, sheep, goat, pig, poultry, domesticated ostrich, domesticated game or the carcase or portion of the carcase of any such stock'. Furthermore, the Act itself refers to stock theft 'as any person who is found in possession of livestock or produce to which there is reasonable suspicion that it has been stolen and is unable to give a satisfactory account of such possession. Importantly, the Act also refers to any person who enters any enclosed land (i.e., fence or any kraal, shed, stable or other walled place) with the intent to steal as guilty of an offence.

Stock theft is a serious crime that affects both smallholder and commercial farmers in South Africa. The Victim of Rural Crime report shows that 0,77% of all households in South Africa incur losses due to livestock during the 2017/18 financial year (StatsSA, 2018). The report further reveals that sheep were the most commonly stolen livestock type, with 270,000 from about 19% households, followed by goats. The number of goats stolen during the year was estimated at just over 170,000 from 30,6% of households. While 177,000 head of cattle were stolen from 23.8% of the households that suffered losses due to livestock theft (Lombard, 2020).

Anthrobus (2002) estimated that the loss due to stock theft in the Eastern Cape amounted to R600 million per year, which was approximately 20% of the province's agricultural GDP. The aforementioned author also estimates that stock theft may be higher in the communal sector than in the commercial sector. Clack (2023) utilised data from the South African Policy Service to demonstrate that rural crime has been a persistent issue for some time, and it remains stubborn, as evidenced by the fact that the numbers have not decreased significantly (Figure 1). The aforementioned author, who has been researching stock theft for over a decade, does not believe that the decline in cases is actually occurring; however, he suspects underreporting, which is also common in the country. The main reason is a lack of trust in the policy system.

For example, a country-wide household-level survey of citizens' attitudes established that more than 60% of South Africans view police as the most corrupt government officials in South Africa (South African Social Attitudes Survey [SASAS], 2013). In the Northwest, Breetzke *et al*. (2022) also observed that farmers did not trust the police and viewed them as incapable of reducing the risk of livestock theft. In some instances, this leads to frustrations and petitions. For example, in 2015, angry farmers in Mpumalanga held a protest against the Ermelo Stock Theft Unit (STU), which, according to them, was failing to arrest perpetrators of stock theft (Viljoen, 2015).

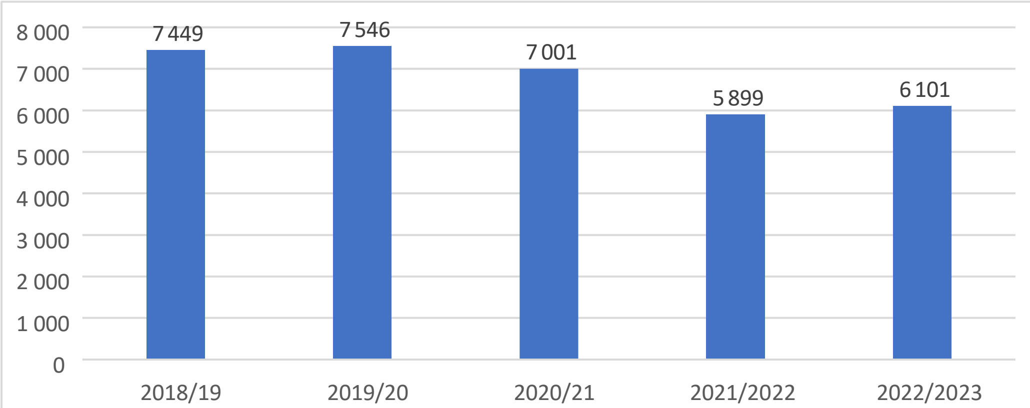

FIGURE 1: Reported Livestock Theft Cases in the Eastern Cape Between 2018/9 -2022/3

In the OR Tambo district municipality, Bahta *et al*. (2016) found that security and safety issues resulting from stock theft were a significant challenge for communal farmers and suggested that communication between communal farmers, community police forums, and police should be improved to reduce this challenge to some extent.

Other communities have already taken action by engaging with the police. Pasiwe *et al*. (2021) report that in 2015, the Amagqunukhwebe Royals (Middledrift, Alice, and Debe Nek areas) chose to share their concerns about stock theft with the provincial police headquarters.

In communal farming areas where grazing is communal, livestock can be stolen from the veld in addition to those stolen from the household kraals at night (Pasiwe *et al*., 2021). The geographical location of rural communities also makes policing very challenging due to their isolation from towns, where most police stations are located (Doorewaard, 2016). These issues make rural communities more prone to stock theft than commercial farming areas, which often have electric fences, security guards on the premises, and conduct regular farm patrols (Maluleke & Mofokeng, 2018).

While the livestock thieves have different motives, for example, some steal and slaughter livestock for their own consumption, while opportunists financially benefit from the theft. However, it is worth noting that most stock theft crimes are organised crime syndicates (Doorewaard, 2020; Pasiwe *et al*., 2021). These syndicates involve 'insiders' who possess knowledge of the farming industry, such as individuals with the skills and expertise in how to herd. Additionally, individuals who know how to slaughter and sell the animals, as well as where or to whom to sell their products, need to be investigated (Bunei *et al*., 2016).

Doorewaard's (2020) study, which interviewed 35 offenders convicted of livestock theft at several correctional facilities across three provinces (Gauteng, KwaZulu-Natal, and the Eastern Cape), found that perpetrators often work in groups, with some operating at a highly organised level that consists of a criminal network. The findings of this research also confirmed that livestock theft perpetrators come from diverse socio-economic backgrounds and that the crime is not limited to any particular race, class, or gender (Doorewaard, 2020).

This organised crime activity is profitable because many of these illegally slaughtered animals end up in the supply chain and are frequently used as a substitute for more expensive animal meat (Manning *et al*., 2016). This is a major concern because, if left unaddressed, it could drive most farmers out of business. This syndicate crime, which not only causes economic loss but also leads to many farm murders, is also associated with poverty and unemployment. In Lesotho, Kynoch *et al*. (2001) found that the level of livestock theft increases following poor yields and in regions with high unemployment rates.

2.2. Strategies for Curbing Stock Theft

Following the intensity and the harmful effects of stock theft, there have been suggestions on how to prevent this crime. They include factors such as livestock branding, keeping and maintaining a livestock register, community and police patrols, employee vetting, the use of security guards, security measures taken on the farm, and the utilisation of technology (Lombard, 2015).

Maluleke (2018) suggested various technologies, such as DNA and Livestock Radio Frequency Identification (RFID), but he also stressed that the value of utilising these technologies is still unknown to livestock owners who prefer to use conventional methods. Studies such as Doorewaard (2020) and Zantsi and Nkunjana (2021) recommended the use of these technologies and have taken the first steps in exploring the possibility of using them, especially GPS collars, among smallholder farmers.

2.3. Strengths of GPS Livestock Tracking Devices

GPS livestock tracking devices offer several key strengths that contribute to enhanced livestock management and improved overall farm efficiency. These include the real-time location and monitoring of livestock, allowing farmers to instantly track their animals' movements, which is crucial for preventing theft, locating lost animals, and ensuring they stay within designated grazing areas (Aquilani *et al*., 2022). Furthermore, GPS livestock tracking devices enable farmers to implement improved grazing management practices. Using these devices, farmers can set up virtual boundaries and receive alerts if animals wander outside predefined areas, helping to manage grazing patterns and prevent overgrazing (Hlimi *et al.,* 2024). Efficient grazing management can lead to healthier pastures and improved utilisation of available resources (Rivero *et al*., 2021).

These devices also offer enhanced security, acting as a deterrent and providing a means of recovering stolen animals by quickly locating their whereabouts (Aquilani *et al*., 2022). Some advanced GPS trackers offer additional features, such as monitoring the health and behaviour of livestock. Abnormalities in movement patterns or changes in activity levels may indicate potential health issues (Hlimi *et al.*, 2024). Many GPS tracking systems come with data analytics tools that allow farmers to analyse historical movement patterns, helping them make informed decisions about pasture rotation, breeding strategies, and overall herd management (Rivero *et al.,* 2021). By preventing livestock losses due to theft or reducing the time spent searching for animals, GPS tracking devices contribute to cost savings and increase overall farm profitability.

In summary, GPS livestock tracking devices offer a range of benefits, including improved security, enhanced management practices, and the ability to make data-driven decisions for more efficient and profitable livestock farming.

2.4. Awareness and Technology Adoption Among Smallholder Farmers

Awareness and the adoption of technology among smallholder farmers can significantly impact agricultural productivity, efficiency, and overall livelihoods. Several factors influence the adoption of technology in this context (Aquilani *et al.,* 2022). On many occasions, Smallholder farmers may not be aware of the available technologies or their potential benefits. Furthermore, limited education and literacy levels among smallholder farmers can hinder their ability to understand and adopt new technologies (Hlimi *et al.,* 2024). Affordability is a significant concern for smallholder farmers. Many advanced technologies can be expensive, making them inaccessible to those with limited financial resources. Inadequate infrastructure, such as a lack of reliable electricity or internet connectivity in rural areas, can impede technology adoption (Aquilani *et al.,* 2022).

Central to the awareness and diffusion of technology is the extension service. Traditional technology reaches farmers through extension officers (Anderson & Feder, 2004). This implies that the effectiveness of extension becomes a factor in how farmers learn about and adopt new technologies. A review of case studies on technology adoption in Sub-Saharan Africa has shown that there are profitable technologies that are not widely diffused due to a weak extension system (Takahashi *et al*., 2019).

In their study of 250 smallholder farmers in the Eastern Cape, Bontsa *et al*. (2023) found that the highest positive perception towards digital technologies was associated with cattle rearing (23.53%), a combination of cattle and goat rearing (21.43%), and maize production (12.32%). This study builds upon this literature and examines the awareness and willingness to consider GPS collars among communal livestock farmers.

3. METHODOLOGY

3.1. Study Sites

The Eastern Cape has a high incidence of stock theft cases in South Africa. Data from the South African Police Service indicate that in 2021, six of the ten hotspot areas in the country were located in the Eastern Cape (SAPS, 2025). Additionally, the Eastern Cape is home to approximately 40% of the country's livestock, yet it is also one of the poorest provinces in South Africa. In 2023, the South African Human Rights Commission (SAHRC) found, following an in-depth investigation, that child hunger in the Eastern Cape qualifies as a disaster and should be declared as such under the Disaster Management Act. This is what compelled us to focus our study on the Eastern Cape. We conducted our research in two villages in different municipalities: Msobomvu, located in the Raymond Mhlaba Local Municipality, and Nkunzimbini, situated in the Ingquza Hill Local Municipality. However, our sample does not allow us to compare these villages.

Msobomvu, located in GPS coordinates (32.6967 S, 26.8595 E), has a population of 1762 in 482 households with an average household size of four persons per household. The working-age population (15-64 years old) makes up 56% of the population in Msobomvu. The village has an almost four-fifths (79%) dependency ratio, implying that few people are economically active. The village is quite populated, with 711 people per square kilometre (StatsSA, 2012).

Nkunzimbini, located in GPS coordinates: (31.3436 S, 29.6701 E), has a population of 5,728 in 1,168 households with an average household size of five persons per household. The working-age population (15-64) makes up 32% of the population in Nkunzimbini. The village has a 96% dependency ratio, implying that there are very few economically active people. The village is not very populated, with a population density of 553 people per square kilometre (StatsSA, 2012).

3.2. Research Design

To capture the views of our respondents (communal livestock farmers), we have designed a questionnaire which was administered to household heads by native Xhosa speakers, a language spoken in the study areas. The questionnaire was designed in English, and the respondents' views were recorded in English, translated from Xhosa by trained enumerators, most of whom were postgraduate students. The questionnaire captured farmer demographics, in addition to core information about the livestock kept by farmers, as well as their reasons for keeping the animals. Moreover, most importantly, they have not encountered any stock theft in the past 12 months. The questionnaire was pre-tested with ten respondents before validation and then used in the larger sample.

Also, which animals were stolen and from where they were stolen (kraals or grazing lands). This is important because communal farmers graze their animals together in a single common area. Other questions pertained to whether respondents were aware of the livestock tracking devices and whether they would be willing to purchase such devices. Those who were not familiar with the devices were shown a picture of a GPS collar, and we verbally explained how the device works. We then asked if the respondent, now that they knew, would be willing to purchase it. No practical demonstrations were done. The GPS collar device had a retail value of R2 500. A total of 137 household heads who keep stock were interviewed, 69 from Msobomvu in Alice and another 68 from Nkunzimbini in Lusikisiki.

3.3. Data Analysis - Model Description and Estimation Strategy

To ascertain farmers' awareness of livestock tracking devices, we use summary statistics from our data. The logit and probit regression models are used to determine the factors influencing farmers' willingness to purchase livestock tracking devices, where the dependent variable is binary (i.e., willing or not willing). To ascertain the reliability and consistency of our results, both the logit and probit models provide similar results. The logit model uses the cumulative standard logistic distribution function to model the regression function when the dependent variable is binary. The standard form of the logit model is:

$$p(y = 1|x_1, x_2, \dots \dots ., x_k) = \frac{1}{1 + e^{-(\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_k x_k).}}$$

Here, $p(y = 1|x_1, x_2, \dots \dots ., x_k)$ is the probability of the event occurring given the predictor variables $x_1, x_2, \dots \dots ., x_k$. The β values are the coefficients to be estimated. The probit model uses the cumulative standard normal distribution function to model the regression function when the dependent variable is binary. The standard form of the probit model is:

$$E(Y|X) = P(Y = 1|X) = \mu(\beta_0 + \beta_1 x)$$

Here, $E(Y|X)$ is the expected value of Y given X, $P(Y = 1|X)$ is the probability of the event occurring given X, and μ is the cumulative standard normal distribution function. The specified logit and probit models in R version 4.3.2 are:

$$logit <- \; logit \; <- glm(formula \\ = \; Purchase \sim Hsize \; + \; RangFenc \; + \; TypeAnimal \; + \; No.Anim \\ + \; TypeStol \; + \; StolFrm \; + \; `T.No\;Anim`, family \; = \; binomial)$$

$$probit \; <- \; logit \; <- glm(formula \\ = \; Purchase \sim Hsize \; + \; RangFenc \; + \; TypeAnimal \; + \; No.Anim \\ + \; TypeStol \; + \; StolFrm \; + \; `T.No\;Anim`, family \; = \; binomial)$$

We conducted a studentised Breusch-Pagan test to check for heteroscedasticity. The null hypothesis is that, if the p-value is greater than 0.05, the data exhibit homoscedasticity; the alternative is that the data do not exhibit homoscedasticity. The results from the logit and probit models have a p-value greater than 0.05, indicating the presence of heteroscedasticity. Therefore, we corrected the heteroscedasticity by transforming the model.

$$logit < -glm(formula = Purchase \sim Hsize + RangFenc + TypeAnimal + No.Anim + TypeStol + StolFrm + `T.No\ Anim`, family = binomial\ (link\ "logit")$$

$$probit < -glm(formula = Purchase \sim Hsize + RangFenc + TypeAnimal + No.Anim + TypeStol + StolFrm + `T.No\ Anim`, family = binomial\ (link\ "probit")$$

The coefficients in these models do not have a straightforward interpretation, as they do in linear regression, but they can be used to calculate the change in the predicted probability of the outcome for a one-unit change in the predictor variable. In this study, we further calculated the marginal effect.

The marginal effect of a variable in a regression model is the change in the expected outcome that results from a one-unit change in that variable, while holding all other variables constant. In a simple linear regression model without interactions or polynomials, the marginal effect of a variable is simply its coefficient. For example, consider the model:

$$y = \beta_1 x_1 + \beta_2 x_2$$

Here, $\beta_1\ and\ \beta_2$ are the marginal effects of $x_2\ and\ x_1$respectively.

However, in models with interactions or non-linear terms, the marginal effect of a variable is not constant but depends on the values of other variables. For example, in the model:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1^2$$

The marginal effect of $x_1$on y is $\beta_1 + 2\beta_3 x_1$. The marginal effects were calculated using R version 4.3.2

$logitm < -margins\ (logit, type =$ "link")

$probitm < -margins\ (probit, type =$ "link")

The dependent variable, 'willing to purchase,' is regressed against a set of independent variables listed in Table 1 below. Based on the literature, we have hypothesised the influence of each variable in the far-right column.

TABLE 1: Description of Variables Used in the Quantitative Phase

Dependent variable:	**Description**	***Data***	***Expected sign***
Purchase	Farmers' willingness to purchase the GPS collar for tracking livestock	Binary	
Independent Variable			
No. of animals	Herd size		+
Age	Is the age in years of the respondent	Scale	+/-
Gender	Is the sex of the respondent	Binary	+
Mstatus	Is the family status of the respondent	Category	+
Hsize	Is the number of people living with the respondent	Scale	-
RangeFenc	Whether communal rangelands are fenced or not	Binary	+
Landsize	Number of hectares a household has access to	scale	+
Farming activity	Is the level of involvement a farmer has with everyday farming	Category	+/-
Typestol	Is the type of animal stolen from the farm	Category	+

4. RESULTS AND DISCUSSION

4.1. Descriptive Analysis

The farmers' awareness of new technologies determines the likelihood and potential extent of their adoption. Table 2 provides a statistical summary of the variables used in the empirical models. Twenty-eight percent (28%) of respondents in this study were aware of livestock tracking devices. After the respondents had been taught about how the livestock GPS tracking devices work, their use, as well as the unit price of the device, 42% were willing to purchase and try them on their animals. The lack of awareness about the tracking device highlights the poor dissemination of technology by the relevant agricultural extension advisory service, whose major role precisely includes technological dissemination. This inefficiency appears to be typical of rural settings, as Ngcobo *et al*. (2020) also reported a lack of awareness of biogas technologies among rural households in Alice.

A vast majority of respondents in this study were married (82%) and male (75%). Male-headed households tend to dominate livestock rearing in rural communities (see also Ndzungu & Jaja, 2024). Furthermore, respondents in this study fell within the smallholder farmer category, with an average age of 50 and an average household size of eight persons, in line with Statistics South Africa's General Household Survey report (Stats SA, 2022). On average, our respondents have access to 16 hectares of arable land and share grazing land as a community with no restrictions on the number of animals a household can keep.

In terms of livestock keeping, our respondents kept cattle (23%) on average herd (29%), followed by sheep (15%), with an average flock size of 46 animals, and goats (46%) with an average flock size of 35 animals. Of these herd sizes, our respondents lost an average of six animals in the last 12 months to stock theft. By far, sixty-four percent (64%) of the stolen animals were missing from the rangelands on communal grazing lands. Approximately 33% of the rangelands where our respondents grazed their livestock were unfenced, meaning that animals roamed freely without control.

TABLE 2: Summary Statistics for a Range of Variables Used in the Empirical Models

Variable	Mean	Minimum	Maximum
Age	56	23	89
Household Size	8	2	31
Land Size	16.16	0.5	100
Number of animals	48.4	4	121
No of stolen animals	6.4	1	18
Categorical variables (frequencies)			
Do you graze on fenced rangelands	Yes=46 No=91		
Type of animal	Cattle=32, Goat=20, Sheep= 64, Other=21		
Number of animals (average)	Cattle=40, Goat =35, Sheep, 62		
Stolen from	Kraal=46, Range land= 89, Other =2		
Gender	Male=104, Female=33		
Mstatus	Married =112, Single = 21, Widowed =4		

4.2. Determinants of Smallholder GPS Livestock Tracking Devices Adoption

Table 3 below describes the relationships between purchasing a tracking technology (dependent variable) and the independent variables, as well as the additional information on the overall fit of the logistic and probit regression models. Table 4 presents the marginal effect, which represents the change in the probability of the event (in this case, purchasing the device) for a one-unit change in the predictor variable, while holding all other variables constant.

TABLE 3: Determinants of Communal Farmers' Willingness to Purchase Livestock Tracking Devices

Variable	Logit Model	Probit Model
(Intercept)	-0.45 (1.47)	-0.26 (0.85)
Household Size	-0.11 (0.06)	-0.07 * (0.03)

Grazing on un-fenced rangelands	-2.92 ** (1.00)	-1.68 ** (0.54)
Cattle	2.09 (1.39)	1.20 (0.78)
Sheep	3.24 ** (1.26)	1.90 ** (0.68)
Goat	-3.65 * (1.78)	-2.11 * (1.03)
Other animals (horses)	3.99 ** (1.54)	2.26 ** (0.80)
Herd size or no of animals	0.02 ** (0.01)	0.02 ** (0.01)
Goat	-0.03 (0.75)	-0.01 (0.43)
Sheep	3.21 * (1.32)	1.91 ** (0.73)
Stolen from Kraal	0.31 (0.62)	0.16 (0.36)
Stolen from rangelands	-2.51 (1.86)	-1.47 (1.11)
Herd size	0.04 (0.08)	0.02 (0.05)
N	137	
Pseudo R2	0.30	0.31
*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.		

Smaller household sizes are associated with a higher willingness to adopt, as indicated by the negative coefficient, which is statistically significant. The issue of purchasing power seems to be at play. For any given household income, the per capita income for each household member depends on the household size. Thus, smaller households could afford to buy more goods and services than larger households with similar incomes (Maitra & Ray, 2006).

However, the household size, represented by 'Hsize', has a negative impact on the willingness to adopt technology, with marginal effects of -0.11 for the logit model and -0.07 for the probit model, both significant at the 0.05 level. Although a smaller household size has a significant probability of purchasing the technology, its marginal effect is small, meaning that it has a lower probability of being purchased.

Unfenced rangelands have a negative coefficient in both models, indicating that farming on unfenced rangelands reduces the likelihood of purchasing a livestock tracking device, and this effect is statistically significant (Table 3). The unfenced rangelands decrease the probability of communal farmers' willingness to purchase the livestock tracker by 2-3 units, as suggested by the negative marginal effect in both models, which is statistically significant (Table 4). Monitoring cattle movement in a fenced grazing land is much more convenient than doing so in an unfenced communal grazing land, where animals wander all over. The alternative to this decision would be to hire a livestock herder, as most households in the Eastern Cape do (Zantsi, 2023).

However, whether an animal was stolen from the homestead kraal or rangelands does not explain the farmers' willingness to purchase the livestock tracker. Even adding an extra livestock unit does not significantly influence the likelihood of purchasing the device, as the coefficient and marginal effects for this variable are not statistically significant in either model (see Tables 3 and 4). As expected, the number of animals - specifically, cattle, sheep, and goats - a farmer keeps is associated with an increased likelihood of purchasing the device (Table 3). Marginal effect results (Table 4) also suggest that the probability of purchasing livestock tracking devices increases with the number of animals, as indicated by the positive marginal effect in both models, which is statistically significant. However, it can be inferred that knowledge of the type of livestock increases the likelihood of purchasing an animal tracking device. As predicted by Zantsi and Nkunjana (2021), farmers with larger herd sizes may find it more worthwhile to purchase livestock trackers than those with fewer animals, as they would not lose many animals.

This study found statistical significance in both models for sheep and goats. Sheep show a positive coefficient, implying that farmers who keep sheep are more likely to purchase livestock tracking devices because sheep are more vulnerable to theft than goats and cattle. Conversely, goats are associated with a decreased likelihood of purchasing the device, and this is statistically significant in both models.

TABLE 4: Logit and Probit Marginal Effects for the Determinants of Willingness to Purchase Livestock Tracker

Variable	Logit Marginal effect	Probit Marginal effect
Hsize	-0.11 (0.06)	-0.07 * (0.03)
No.Anim	0.02 ** (0.01)	0.02 ** (0.01)
RangFenc1	-2.92 ** (1.00)	-1.68 ** (0.54)
StolFrm1	0.31 (0.62)	0.16 (0.36)
StolFrm2	-2.51 (1.86)	-1.47 (1.11)
T.No Anim	0.04 (0.08)	0.02 (0.05)
TypeAnimal1	2.09 (1.39)	1.20 (0.78)
TypeAnimal2	3.24 ** (1.26)	1.90 ** (0.68)
TypeAnimal3	-3.65 * (1.78)	-2.11 * (1.03)
TypeAnimal4	3.99 ** (1.54)	2.26 ** (0.80)

TypeStol1	-0.03 (0.75)	-0.01 (0.43)
TypeStol2	3.21 * (1.32)	1.91 ** (0.73)
*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.		

5. CONCLUSIONS AND RECOMMENDATIONS

This article aims to assess the awareness of communal farmers regarding animal tracking devices, in light of the alarming stock theft crime in the Eastern Cape, which accounts for approximately 40% of South Africa's livestock. The other objective of the article was to determine the factors that influence the willingness of communal farmers to purchase animal tracking devices to mitigate stock theft and improve animal management. The data from two villages in the Eastern Cape show that only 28% of farmers were aware of the livestock tracking devices, and 42% were willing to purchase them after we demonstrated the devices and their potential to track animals, sharing information on the unit price of the device. These findings have implications for agricultural extension services, which have the mandate of disseminating technology.

Results from two binomial models suggest that the following factors, such as household size, herd size, keeping sheep, and unfenced rangelands, play significant roles in influencing farmers' decisions to purchase or not purchase animal tracking technology. This information could help drive and direct awareness about technologies that can minimise stock theft cases and improve the recovery of stolen animals. Extension officers could drive these awareness initiatives. Since South Africa has the highest extension-to-farmer ratio (Aliber, 2019), it would be more practical and cost-effective to target local farmer organisations or dip tanks to disseminate information about livestock tracking devices.

However, this information would need to be accompanied by awareness of animal identification, which entails branding animals with registered brands and reporting them to the relevant agricultural department to enable the prosecution of offenders and the recovery of animals. Future studies could investigate the farmers' knowledge and awareness of the importance of branding and registering their animal brands.

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More Efficient Drought Relief for the Karoo: Lessons from Australia's Big Dry

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ABSTRACT

Under climate change, multi-year droughts will become a more predictable feature of the Karoo. Australia's Millennium Drought triggered a comprehensive policy reform in which the trade-off between humanitarian relief and structural adjustment to climate change had to be confronted. This paper tells that story, drawing lessons that could improve the efficiency of South Africa's drought relief efforts. This account highlights the adverse consequences that can result from failing to actively pursue structural adjustments to climate change. We can learn from Australia's experience 1) To pay attention to messages that come up from the grassroots level, 2) incentives matter for adaptation, 3) resilience can only be achieved through structural adjustments,4) mental health support should be left to professionals, and 5) better coordination and more transparency should increase readiness.

Keywords: Millennium Drought, Drought Relief, Structural Adjustment, Sheep and Wool, Karoo.

1. INTRODUCTION

> "I haven't taken my wife into the paddock for more than a year … because it's so bad and there's so much death. … I don't want her to see it … I'm struggling to handle it myself." (Perceval *et al*., 2019: 282)

Now approximately four years out of the Karoo drought and quite nervous still about the onset of the next big one, the structures of organised agriculture and members of the grassroots extension fraternity that work in the Karoo are still wondering if we did the right thing, if our efforts made any difference and how many of the farmers we interacted with will never financially recover from the setback of the 2017 – 2021 drought. This drought was one of four major events recorded in the Karoo over the past century, not the deepest nor the longest since

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1927, but sufficiently long and deep to make it the worst drought of the past century (Conradie *et al*., 2025). Being the first significant drought of our generation, we had to adapt to policies and plans designed in the 1960s and last implemented at the time of the country's transition to democracy. Anecdotal evidence suggests that some extension workers were severely emotionally impacted by the drought in their line of duty, while representatives of organised agriculture had to shoulder the significant additional burden of crisis management, coping with the drought on their own farms.

As an economist, I wonder about efficiency, both in terms of how scarce resources were distributed and whether any of our interventions prevented the inevitable. I also worry about rent-seeking and fairness, as well as the mental health of the gatekeepers responsible for distributing drought relief.

South Africa is not the only major livestock-producing country that must face the increased aridity associated with climate change. In Australia, the Millennium Drought, also known as the Big Dry (1997–2008), revealed that the country's drought policy was not fit for purpose under climate change. An extended review of all aspects of drought followed from 2008 onwards, culminating in a seven-year drought agreement reached in 2018. The 2018 agreement laid the foundation for Australia's new Drought Policy (2024).

The review and analysis come in two parts, with Section 2 concentrating on the policy process and Section 3 focusing on the economic and social lessons learnt. The conclusion outlines some principles for South Africa to consider.

2. DROUGHT POLICY IN AUSTRALIA

Towards the end of the Millennium Drought, Australia made a 180-degree U-turn away from viewing drought as a natural disaster to embracing drought as a normal, predictable part of operating in an arid environment. Agriculture lost some of its historical entitlements to government in the reforms, and the process began well before the beginning of the Millennium Drought in 1997 (see Table 1).

By the 1970s, broad-based support for agriculture had evolved into a development programme called the Rural Reconstruction Scheme. In 1976, a disaster relief component was added to the Scheme. The list of natural disasters included drought, but by 1989, this position was revised,

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and drought was removed from the list of natural disasters again. At roughly the same time, reforms in the retail banking sector increased competition in the agricultural credit market, making the lack of business acumen in the farming community apparent. The Government responded by establishing a Rural Financial Counselling Service (RFCS) in 1986. With an office in every town, the RFCS tutored farmers on how to compile farm plans and cash flow budgets, and occasionally assisted them through credit negotiations with commercial banks. At the time, and even today, the primary form of drought relief provided to Australian agriculture is an interest rate subsidy. Therefore, it is in the mutual interest of all stakeholders for the RFCS to become involved in credit negotiations.

TABLE 1: Evolution of Drought Policy in Australia

Date	Policy changes or programme
1971	Rural Reconstruction Scheme
1976	Natural disaster relief arrangements included with Rural Reconstruction
1986	Rural Financial Counselling Scheme for farmers
1989	Drought removed from disaster relief provisions
1992	National Drought Policy actions relief through Exceptional Circumstances declarations
1997	Exceptional Circumstances Policy refined
2008	National Review of Drought Policy
2012	Last Exception Circumstances declarations lapsed
2013	Intergovernmental Agreement on National Drought Programme Reform
2015	White paper on agricultural competitiveness
2018	National Drought Agreement (2018-24) signed
2019	Drought Response, Resilience and Preparedness Plan released
2020	First Future Drought Fund Drought Resilience Funding Plan (2020-24), Future Drought Fund Programs launched
2024	Drought Resilience Funding Plan comes into effect National Drought Agreement (2024-29) released Australian Government Drought Plan published

(Source: Smolinski, 2014; DAFF, 2024)

The RFCS was one of the first organisations to raise the alarm about the degree to which the Millennium Drought impacted the financial reserves of farmers. Later, the RFCS also spoke out about the mental health pandemic that unfolded as the drought progressed. See Perceval *et al*. (2016) for a detailed account of the role and experiences of RFCS officials.

The National Drought Policy (1992) was at the forefront of acknowledging that climate change would lead to normalised droughts and that farmers should be encouraged and assisted to face the increased degree of climate risk. The policy emphasis shifted from financial contributions in the form of subsidised fodder to greater adaptation through improved risk management. Given the role the RFCS has carved out for itself, it was evident that this programme would be a crucial part of the newly formulated government response to drought (see Australian Drought Plan, 2024).

Despite this insight, thinking of drought as a natural disaster did not fade overnight. The National Drought Policy (1992) provided for the declaration of "Exceptional Circumstances" under which some of the old patterns of relief would still be delivered if conditions warranted. Exceptional Circumstances (EC) were defined as occurring in 4-5% of seasons, and each state or territory could gazette its own EC areas. It was soon apparent that climate change would turn the exceptional into the everyday. There was a minor tweak to the policy even before the Millennium Drought got underway, while the call for a major overhaul of drought policy arrived by the end of the Millennium Drought. The last EC Declarations expired in 2012, and from 2013 onwards, every aspect of Australia's drought support policy was being renegotiated.

The reform process moved slowly. It began with an extensive multi-disciplinary research programme in 2008. With the main facts on the table, the Intergovernmental Agreement on National Drought Programme Reform was signed in 2013. The first actual Drought Agreement was not signed until five years later, covering the period from 2018 to 2024. This framework enabled the formulation of a detailed plan, which was accepted in 2019, and a funding model was proposed in 2020. Finally, in 2024, the Australian Government published its Drought Plan (2024) and signed the second Drought Agreement (2024 – 2029).

Three important lessons to draw from the Australian policy process are:

- Grassroots service providers have the best vantage point for observing an unfolding disaster. The government and producer organisations' policymakers will be well served to pay attention to their data and observations.
- Policy reform is a lengthy and tedious process. It is helpful to begin with an agreement in principle before trying to work out the details. It is important to ringfence funding before announcing plans and to attach a multi-year limitation to each agreement, as changing environmental conditions might otherwise overrun the policy process.
- The next crisis is coming. It is best to prepare for it now, in relatively good times. Our policy response must be 1) fit for purpose, 2) orderly and well-resourced and 3) delivered timeously.

3. MILLENIUM DROUGHT: IMPACTS AND LESSONS SUMMARISED

rural communities are affected by drought are numerous, multifaceted, and intertwined. The purpose of Australia's National Review of Drought Policy (2008) was to review the Exceptional Circumstances programme's performance during the first 18 years of its existence. Research examined meteorological, farm productivity, and psychosocial outcomes under climate change, and this brief review highlights only the two lessons that informed subsequent Australian policy (described above in Section 2).

3.1. Drought is Debilitating

While droughts often begin innocently, the most serious ones can leave farmers and their communities financially destitute and psychologically devastated (Wilhite & Glantz, 1985; Edwards *et al*., 2015). Fennel *et al*. (2016) counted amongst the main stressors to livestock farmers 1) drought, 2) financial pressure, and 3) uncertainty about the future, although Edwards *et al*. (2015) argued strongly that it all ties back to the farm's performance on the broader economy. With lines between families and their farms often blurred on smaller properties, uncertainty about the future frequently contributes to concerns about opportunities for children and the care of elderly parents from whom the farm was inherited. One of Kiem and Austin's (2013) respondents mentioned difficult conversations "that must be had with in-laws about packing in the farm". Because business and family are so closely intertwined, the Productivity Commission's Inquiry Report (2009) expressed concerns that money intended for business sometimes went towards family expenses, and vice versa.

Other contributing stressors include dealing with dying animals (Perceval *et al*., 2019), being misunderstood by outsiders, witnessing one's community fall apart due to rent-seeking among community members, and having to repeatedly describe the drought to one official after another (Sartore *et al*., 2008). This created a pervasive feeling of being misunderstood and unappreciated in the broader Australian society. Stress culminates in feelings of hopelessness and paralysis, when even the simplest farming tasks become too difficult. Sheer exhaustion should not be underestimated either (Fennell *et al*., 2016), which can sometimes be triggered by something as trivial as having to fill out yet another complicated online form (Perceval *et al*., 2013) or being asked to attend yet another research focus group (Kiem & Austin, 2013).

The extent of the feelings of overwhelm among farmers and local officials is illustrated by an excerpt from an interview with a high-ranking local development official working in Mildura, Victoria. He called water insecurity "the straw that broke the camel's back" and then proceeded to say "What really hit us hard, if not harder, was commodity prices – and everything else" (Kiem & Austin, 1309) (my emphasis). The complexity and interrelatedness of the problem are obvious from this quote, and the all-encompassing nature of the challenge perhaps poses the greatest risk to effective service delivery. I personally experienced how an extension officer can be emotionally drained along the path described in Wilhite and Glantz's (1985) progression from mild curiosity about rainfall deficits to an intense focus on cost-effective supplementary feeding, and ultimately to total despair and hopelessness, as there is no end in sight to the drought. When supporters become emotionally compromised, they are no longer capable of delivering proper services, precisely at a time when service delivery is most needed. At that point, mental health support and humanitarian relief should be taken out of the hands of local officials, who, in fact, should be referred for treatment themselves if they are expected to continue performing their roles as farm technical and financial advisers.

Ultimately, despair increases suicide risk. In Victoria, Australia, farmers made up a small constant share of suicides in the period since 1970 (Guiney, 2012), although using different data, Hanigan *et al*. (2012) found a substantial increase in suicide risk amongst males aged 30-49 years in New South Wales that correlates with the results of a Hutchinson Drought Index. It was different for women, but the study confirmed seasonal variation in suicide risk associated with the "broken promise" hypothesis, when spring rains fail. The same depressed mood was evident in the Karoo when autumn rains showed up late in 2024 and again in 2025.

In response to a direct question of what might help [farmers] to cope better with the drought, participants in a focus group in New South Wales gave the monosyllabic answer "rain" (Sartore *et al*., 2008), which Kiem and Austin (2013) interpreted as a symptom of research fatigue. This kind of answer could also be simply a sign of frustration with the policy review process and "the Government" in general. Farmers believe that sympathetic and knowledgeable listeners who can provide sound financial advice would be helpful. They also felt that more time to discuss anxiety with local GPs would make a difference, especially if GPs were able to leverage additional psychological help into the community on demand (Sartore *et al*., 2008). Mental health education was identified as a clear way forward, enabling the entire community to recognise the signs of emotional distress and know where to seek help. People believed that acknowledging stress and learning how to manage it in a knowledgeable and practical way would strengthen the social fabric.

Sartore *et al*. (2008) recognised that although most farmers preferred to see a counsellor locally, especially a trusted GP, this could create stigma for those reaching out for help.

> "A cry for help does not always solve the problem… probably the hardest thing is for men to go to a group, to be able to unload what they feel [and not] feel that's going to be talked about all around the trap" (Male farmer recorded in Sartore *et al*., 2008: 7).

The important lessons for humanitarian relief during future South African droughts are:

- Psychological help often does not arrive quickly enough. This causes farmers to carry unresolved trauma even years after the drought (Van der Merwe, in prep).
- Those caught up in drought may find it difficult to articulate the source and nature of their distress. A lack of business acumen can compound the problem.
- Counselling should be provided face-to-face rather than online, ideally dispensed by someone known to and trusted by the farmer, albeit with confidentiality strictly guaranteed. This is a difficult balance to maintain.
- Therapy should be left to mental health professionals. However, extension officers and organised agriculture representatives must be trained to recognise the signs (including, and especially in themselves) and how to refer those in distress.

3.2. Get Big or Get Out

Australian agriculture is export-oriented, a price-taker in global commodity markets, and the sector is largely unsubsidised (Greenville, 2020). According to Asghari *et al*. (2021), government policy favours the consolidation of small, financially viable farms into bigger entities for two main reasons. Firstly, financial reserves allow larger firms to capitalise on the occasional high-rainfall season. Secondly, large firms can leverage economies of scale in marketing, strategic planning and the adoption of lumpy technology.

The need for healthy structural adjustment was recognised by the Drought Policy Review Task Force (emphasis added):

> "Adjustment assistance differs from other forms of industry assistance as the onus for responding to changing market and climatic conditions **always rests with the individual producer**. Its purpose is to provide producers with the opportunity to respond to changing conditions without detracting from the need for adjustments to be made. Those producers **not capable of responding** to longer-term market pressures or who have lost prospects in the industry **should be encouraged to leave**" (McInnes *et al*., 1990: 86).

Asghari *et al*. (2021) reported that 68% of farmers operating under Exceptional Circumstances Declarations did not need financial assistance. The most common cry for help came from people aged 50-70 who operated family farms, which were both their homes and businesses. Couples often had farming history on both sides of the family, with the husbands commonly handling the physical aspects of animal husbandry and the wives taking charge of bookkeeping and finances, and by implication also of household finances and homeschooling. The wives were therefore perhaps carrying most of the stress of farms failing financially. The vulnerable were small to medium-sized operations generating incomes in the bottom 30-40% of business income across all sectors. The characteristics of vulnerable farmers were 1) a lack of financial agility, 2) an inability to get things done in good time, 3) a general lack of business skills and 4) an unfounded belief that the government should come to their rescue (Asghari *et al*., 2021).

As indicated in McInnes *et al*. (1990), self-reliance has been a part of the Australian drought management discourse for a long time and occupies the entire focus of programmes and policies delivered by states and territories (as opposed to the Federal Government). Howden *et al*. (2008) grouped drought preparedness under three headings: pasture, pest, and animal

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management, acknowledging the importance of conducive policies and R&D support in each arena.

Good pasture managers pursue sustainable rangeland utilisation. There are two sides to this equation: knowing one's farm's carrying capacity and knowing one's flock's grazing requirements. In South Africa, legal oversight is provided by the Conservation of Agricultural Resources Act (CARA, Act 43 of 1983), whose regulations lay out carrying capacity norms (RSA, 2018) and the scientific calculations of grazing requirements (RSA, 2001). Meissner *et al*. (1983) established the standard large stock unit (≡ equivalent to 450 kg of medium-frame steer gaining 500g daily by freely grazing on natural grass pasture with 55% digestibility). Every other type of livestock is linked to one large stock unit (LSU) based on relative energy requirements. The resulting Meissner factors vary more by the size of the animal than by breed, although Meissner *et al*. (1983) and the current CARA regulations continue to quote conversion factors by breed. Prior to the last revision of the regulations, Herselman (2000) pointed out that typical ewe weights have been increasing since 1983, which requires a wholesale revision of the Meissner coefficients in the new regulations (or simply a different way of reporting the information). Herselman's warning was not heeded. The South African small stock industry continues to use inappropriate factors, thereby underestimating grazing requirements, which leads to the unsustainable use of the Karoo's rangeland.

Optimal stocking rates are a complicated decision influenced by the medium-term climate outlook, the cost of transport and fodder, local labour markets, and road infrastructure conditions. Du Toit (2010) proposed a vegetation index based on a depreciated moving average of annual rainfall, which can be developed in Excel for farms where thirty years of rainfall history are available. Scientists routinely use a variant of Du Toit's index that ignores depreciation and can include or ignore rising temperatures (Milton *et al*., 2023). The Specialised Precipitation (and Evaporation) index, SP(E)I, can be downloaded from the internet on a course grid across the world, as can Normalised Difference of Vegetation Index (NDVI), a product of remote sensing available to the Western Cape Department of Agriculture. However, for these constructive measures of grazing conditions, farmers need to be made aware of their existence, have sufficient internet connectivity and computer skills to access the data, and understand how to link the climate outlook, via an appropriate set of Meissner factors, to their farm's stock table.

Australian farmers have spreadsheets with embedded climate forecasts to support livestock management decisions. Karoo farmers have nothing like it, although a multidisciplinary team comprising rangeland ecologists, animal nutritionists, and economists should be able to do this easily. Such a product will support evidence-based decision-making, which should improve farmers' financial agility and, consequently, limit the damage inflicted by the next drought.

A related question concerns the optimal degree of culling, a decision that involves a trade-off between short-term fodder expenses and long-term recovery. Achieving an optimal balance will enhance long-term sustainability. The old heuristic recommended a one-third reduction, with the remaining sheep supported by state-subsidised maize, to which no transport cost applied. Alternatively, flocks would be transported free of charge to rented pastures. One of the last reports on rebates for stock feed transport appeared in the 1999 Abstract of Agricultural Statistics (Directorate of Statistical Information, 1999). This source indicates that stock feed subsidies accounted for 25% and transport rebates for an additional 2.25% of total Department of Agriculture subsidies in 1995. Both items dropped to zero by 1998. During the past drought, the Western Cape Department of Agriculture provided drought relief of 21 LSU per farm to bona fide farmers, totalling more than R350 million from 2016 to 2020. Other Cape Provinces distributed token amounts, and it remains an open question 1) what the effect on recovery was of the drought relief disbursed in the various districts of the Western Cape and 2) what the optimal level of stock removal is from the farmer's point of view if there is no drought relief forthcoming.

In addition, Asghari *et al.* (2021) pointed out that good pasture managers do much more than just manage optimal stocking rates. They prevent erosion and consider how to maximise rainfall effectiveness in high-intensity storms, which are expected to become more common due to climate change (Ziervogel *et al.*, 2014). They must implement pest management, which in South Africa includes controlling locust outbreaks, the spread of woody weeds (such as Prosopis and others), the spread of communicable diseases (like foot-and-mouth disease), and controlling meso-predator populations. In animal husbandry, selecting for heat-tolerant strains is most important. Good shepherds will consider adjusting mating and lambing times to account for the heat. An efficient system will pamper ewes in lamb and newly weaning lambs with supplementary doffer and sufficient shade and/or spray cooling. Good managers also keep a close eye on budgets and market conditions throughout the various stages of drought, paying special attention to standing fodder reserves and feed stocks. It is crucial to know when to start feeding, what constitutes a total mixed ration and how such a ration can be obtained at the minimum cost (Asghari *et al*., 2025).

Asghari *et al*. (2021) agreed with McInnes *et al*. (2009) regarding the potential benefits of harnessing economies of scale to maximise accumulation and savings during good times. However, these authors warned against taking on debt and failing to set aside financial and fodder reserves during good times. Investing in infrastructure in preparation for the next drought could include improvements to water storage facilities, expanding feedlots, enhanced fencing, and investing in automatic feed dispensing equipment to reduce labour costs during the next drought. If all else fails, income diversification, for instance, taking on-farm jobs, might offer a solution to the most marginal operations.

Adaptation to drought could be facilitated by providing farmers with access to relevant evidence of climate change, relatable to their own weather observations, and plausible and easy-to-understand medium-term climate forecasts, ideally already embedded in rangeland management and budgeting software (Howden *et al*., 2008). Three to six months' advanced warning of a coming drought would be ideal (Asghari *et al*., 2021), and this is why it is so important to adapt Australian planning software for local conditions. Farm media could play a crucial role in disseminating relevant climate data to their readership. Demonstration plots and farmer-to-farmer extension are recognised as effective extension tools, and the government should conduct and publish the results of field trials. Howden *et al*. (2008) also called for protection against establishment failure for early adopters, as well as logistical support to facilitate the delivery of new technologies. Another example of logistical support is maintaining a ready supply of essential vaccines to respond to disease outbreaks and keeping farm trunk roads in good condition to transport large loads of feed during a drought.

The main lessons South Africans can learn from the Australian experience are:

- Get big or get out while there is still some capital to salvage.
- Drought relief funding has a high opportunity cost, and it is therefore appropriate that drought relief programmes should pass relatively stringent cost-benefit tests. In South Africa, economists have yet to begin to investigate this issue.
- Strong expertise in rangeland management must be maintained, with key results fed through to farmers in structured and well-funded extension programmes.

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- Ensure that farmers have all the necessary tools to do the job, such as effective vaccines and well-maintained farm-to-market roads.
- Maintain adequate biosecurity to allow South African commodities to be exported to the most lucrative global markets.
- Monitor and try to improve on-farm productivity at every phase of the drought cycle (between and during droughts and during recovery).

3.3. OTHER RURAL BUSINESSES

One of the key insights from Australia's (2008) drought review was that financial pressure and stress do not stop at the farm gate. Local businesses should therefore qualify for some degree of support too, but subject to the same structural adjustment provisions imposed on primary producers.

3.4. AUSTRALIA'S NATIONAL DROUGHT PLAN (2024)

The Drought Agreement (2018) rests on three pillars

1) Drought is a normal feature of the Australian climate.
2) Agriculture must be self-reliant.
3) Preparation equals better risk management.

In line with these three principles, the Agreement sets out stakeholder roles and responsibilities across the drought cycle to prepare for, respond to needs during the acute phase of the drought, and support farmers during recovery. The three main budget items arising from the 1992 Drought Policy's Exceptional Circumstances programme were interest rate subsidies in districts with EC proclamations (37%), farm management deposits (26%) and relief payments (26%) (Productivity Commission, 2009). Farm Management Deposits enable farmers to save tax-free for future droughts. Australia's drought relief budget was slashed by almost three-quarters during the latter part of the Millennium Drought. Farm Management Deposits were phased out, while interest rate subsidies rose as a share of the total, and (humanitarian) Relief Payments retained its share of the budget.

In the new plan, the federal government is responsible for coordinating and administering the National Drought Agreement and the Future Drought Fund. It also funds and delivers the Farm Household Allowance, which entails:

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- Livelihoods grants for a maximum of four years out of ten.
- Pharmacological grants for those with mental health and other medical conditions.
- Professional risk assessments of the farming business and the household's mixed livelihood strategies.
- Retraining grants for those wishing to exit.

As a single point of entry for those seeking financial relief to meet living costs as opposed to business loans, the Farm Household Allowance combines immediate humanitarian relief with opportunities for structural adjustment during the acute phase of a drought. The emphasis is on seeking professional advice to assess business viability. It also provides resources for Australian citizens who wish to retrain for other occupations outside of agriculture. This is accomplished through a range of tax and financial instruments, under the guidance of dedicated RFCS case workers. The RFCS has proved its worth and continues to be funded by the Federal Government. The Federal Government is also responsible for climate forecasting, including timely warnings to support changes in farm management.

According to the Drought Plan (2024), states and territories must develop Future Drought Fund initiatives in consultation with all local stakeholders, including First Nations, to promote productivity and resilience, prevent environmental degradation and ensure that animal welfare standards set in state legislation are complied with.

The two spheres of federal and local government government join hands to:

- Design and deliver better service delivery that is consistent with the principles outlined in the National Drought Agreement.
- Identify the intersecting risks and opportunities in responding to, recovering from, and preparing for drought.
- Support the Rural Financial Counselling Service.
- Roll out programs to improve business acumen and resilience on farms and in rural communities.
- Share information (weather, market data and drought predictions) and post early warnings of developing droughts.
- Support rural economies generally.

- Build an evidence-based policy environment which includes monitoring and evaluation.

South Africa's organised agriculture and the Departments of Agriculture can learn a lot from Australia's new approach to drought management. The RFCS' success lies in being backed up by 1) sufficient funding, 2) the right incentives, 3) regular timeous forecasts that farmers can work with, and 4) technical expertise in the fields of animal husbandry, pasture management and farm financial management. Given the state of South Africa's public finances, funding will be limited and ought to only be forthcoming if the industry can demonstrate that more than R1 is generated for every R1 of public funding spent on improving climate resilience. In this respect, extension officers specialised in economic analysis, working with development economists, have a huge role to play in making South African agriculture more climate resilient.

All Karoo stakeholders should be encouraged to:

- Consider a Lekgotla to discuss drought management in the context of climate change.
- Form PPPs for all major centres across the landscape to avoid duplication and fruitless expenditure.
- Host the SAWS and other international service providers, such as Australia's Bureau of Meteorology, Nebraska's Drought Monitor or SAEON on an industry-sponsored single online weather portal.
- Set up the portal so that all drought applications for the entire Karoo (all three Cape Provinces) can be made through the same site.

4. CONCLUSION

Drought is, and will continue to be, an increasingly familiar feature of the arid western half of South Africa under climate change. Outdated drought relief policies from the mid-20th century must take this reality into account so that they can be made fit for purpose once more. This work is urgent, and the financial survival of entire communities depends on it being done well.

The Australians chose to focus on building a stronger livestock industry instead of trying to rescue every farm. South Africa will ignore this lesson at our peril. The worst droughts inevitably end in humanitarian disasters, and for that, the Australian government provided appropriately too, but not under the auspices of the Department of Agriculture, Fisheries and

Forestry (DAFF). DAFF's exclusive purpose is to promote and deliver agricultural productivity growth so that viable farms can be made stronger and more internationally competitive. The owners of non-viable farms also deserve help, especially in retraining for new livelihoods; however, such social interventions do not belong under the auspices of a Department of Agriculture. This lesson, too, is ignored at our peril.

Finally, despite the hardship of Australia's Big Dry, the country remains optimistic about the prospects of small stock farming. They believe there are sufficient new technologies to support productivity growth, which can easily offset the losses in productivity caused by climate change. This kind of optimism underpins sustainable use; without it, marginal rangelands will be overexploited, stripped of their natural productivity and left as deserts. May this not be the future of the Succulent and Nama Karoo Biomes of our land.

5. NO CONFLICT OF INTEREST

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Determinants of Commercialising Indigenous Chicken Production in South Africa: New Evidence Post-COVID-19

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ABSTRACT

Commercialising indigenous chicken production offers substantial potential for smallholder farmers in developing countries to improve rural livelihoods and alleviate poverty. However, despite strong market demand for indigenous chickens, few farmers have successfully scaled up production to commercial levels since the COVID-19 pandemic. This study investigated factors influencing the commercialisation of indigenous poultry production systems using a cross-sectional research design. A total of 150 farmers were surveyed, and a multiple regression model was applied to identify key determinants of commercialisation. The findings indicate that access to extension services ($p < 0.01$), gender ($p < 0.05$), household size ($p < 0.05$), loadshedding ($p < 0.01$), transportation costs ($p < 0.01$), reduced income ($p < 0.05$), market distance ($p < 0.01$), and COVID-19-related disruptions ($p < 0.05$) significantly influence commercialisation levels. Regression analysis confirmed that loadshedding and market access were among the most critical constraints, with farmers facing severe operational challenges due to inconsistent electricity supply and limited market penetration. Additionally, post-pandemic trends, including persistent supply chain disruptions and rising feed costs, continue to hinder commercialisation efforts. To address these challenges, the study recommends targeted government interventions, such as improving extension services, investing in value-adding processing equipment, and establishing centralised transportation systems. Additionally, policies should consider the unintended consequences of market interventions to avoid potential distortions. Strengthening access to

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markets and mitigating transaction costs could enhance commercialisation prospects and contribute to the sustainable development of the indigenous poultry sector.

Keywords: Commercialisation, Household Commercialisation Index, Indigenous Chickens, Multinomial Logistic Regression Model, Small-Scale Farmers.

1. INTRODUCTION

The commercialisation of small-scale agriculture entails expanding production and marketing capacity to transition successfully from subsistence to commercial farming. For many African countries that depend on the agricultural sector for economic growth and development, commercialisation of agricultural practices proves to be the best strategy to generate income and make a living (FAO, 2014; Omiti *et al*., 2018; Pingali & Rosegrant, 1995; Timmer, 1997; von Braun, 1995; World Bank, 2008). Over time, relying solely on small-scale farming has proven to be an unreliable approach to achieving sustainable food security and improving rural livelihoods (Fabricius *et al*., 2023). One of the economic benefits of commercialisation is that it results in specialisation and eventually leads to a better comparative advantage, increased productivity, innovation, and efficiency (Diao *et al*., 2020).

The commercialisation of small-scale farming generally results in a greater volume of goods being produced and distributed on a national scale, as well as increased specialisation at the regional and farm level (Kurosaki, 2003). Furthermore, commercialisation serves as a connecting force between the input and output sides of the economy, fostering a dynamic interplay that enhances resource allocation, stimulates demand, and ultimately drives economic growth through increased production and consumption.

The commercialisation of primary agriculture involves three distinct stages: (i) subsistence, (ii) semi-commercial and (iii) well-commercialised enterprise. The primary goal in subsistence agriculture is to produce crops or livestock for home consumption. Households grow food in small plots to meet their family needs and produce no surplus. Commercial farming, on the other hand, involves producing crops or livestock for sale. Commercial farmers aim to maximise profits and increase production. This type of farming relies heavily on improved technology and the extensive use of fertiliser, pesticides, and machinery. Semi-commercial farming combines elements of both subsistence and commercial agriculture. Here, farmers aim to produce food for both home consumption and profit (Pingali & Rosegrant, 1995).

In recent years, African countries have been transitioning their small-scale poultry production systems towards a semi-commercial model. This strategic shift has demonstrated potential for enhancing income stability for rural households, improving overall agricultural productivity, and bolstering food security within the rural areas (Frequin *et al*., 2009). The successful integration of indigenous chicken farming with commercial practices has yielded positive outcomes in countries such as Ethiopia, Kenya, Tanzania, and other African nations (Muchadeyi *et al*., 2011). A study conducted by Hoffmann (2012) suggests that the success of the above countries is attributed to strong government support, effective policies, and private investment.

In line with other African countries, the South African government has demonstrated its commitment to supporting indigenous chicken farmers by introducing various funding schemes and policy frameworks. Programmes such as the Comprehensive Agricultural Support Programme (CASP), Ilima/Letsema, and the AgriBEE Fund aimed to assist smallholder poultry farmers with financial resources, infrastructure, and extension services (DAFF, 2010; NDA, 2018). However, despite these interventions, their impact remains inconclusive, as many farmers continue to struggle with commercialisation (Aliber & Hall, 2012). Challenges such as poor implementation, lack of follow-up support, and administrative inefficiencies have contributed to the limited success of these initiatives. According to Aliber and Hall (2012), one of the major reasons for these failures is the absence of comprehensive research prior to programme implementation. As a result, many smallholder poultry farmers have lost confidence in transitioning to commercial farming due to the unreliable execution of policies and insufficient long-term support.

Conclusively, the demand for indigenous chicken meat in South Africa continues to grow significantly, yet small-scale farmers have been hesitant to expand production to meet this market opportunity, particularly in the wake of the COVID-19 pandemic. This trend aligns with findings from Siyaya and Masuku (2013) in Swaziland, highlighting a broader reluctance among indigenous chicken farmers to transition to commercial-scale production, despite favourable market conditions. To unlock the full potential of this sector and address the growing demand, further research is imperative to identify and analyse the specific barriers hindering farmers' adoption of commercial practices in the post-pandemic landscape. Such research would not only inform targeted interventions but also contribute to the sustainable development of the indigenous poultry industry, benefiting both farmers and consumers.

2. LITERATURE REVIEW

2.1. Theoretical Literature

Theoretical studies have been instrumental in understanding the determinants of agricultural commercialisation, particularly in smallholder poultry farming. The commercialisation process is shaped by both internal and external factors (Pingali & Rosegrant, 1995; von Braun *et al*., 1991). External factors, including market access, credit availability, infrastructure, government policies, and regulatory frameworks, influence the farmer's ability to operate beyond subsistence levels (Omiti *et al*., 2018; Pender *et al*., 2006). Internal factors such as farm management practices, financial literacy, production scale, and household labour availability also play a critical role in determining commercialisation outcomes (FAO, 2014; World Bank, 2008).

The Theory of Agricultural Commercialisation (Pingali & Rosegrant, 1995) suggests that smallholder farmers gradually transition from subsistence farming to semi-commercial and full commercial farming as they improve their access to inputs, markets, and information. However, the Transaction Cost Theory (Coase, 1937) highlights that market participation depends on the ability to minimise costs associated with transportation, information asymmetry, and price fluctuations. Barrett (2008) argues that high transaction costs create entry barriers, discouraging smallholders from engaging in formal markets.

The New Institutional Economics (NIE) framework (North, 1990) further explains that weak institutions, poor infrastructure, and a lack of enforcement mechanisms can undermine smallholder commercialisation efforts. Empirical studies have supported these theoretical perspectives, demonstrating that successful commercialisation requires a holistic approach that integrates policy support, financial access, and production efficiency (Dorward *et al*., 2004; Leavy & Poulton, 2007). These theoretical insights provide a foundation for examining the specific determinants influencing indigenous chicken commercialisation in South Africa, particularly in a post-pandemic context.

2.2. Empirical Literature

Several empirical studies have explored the commercialisation of indigenous poultry farming across Africa, highlighting key determinants and challenges. Maumburudze *et al*. (2016) investigated poultry commercialisation in Zimbabwe and found that market accessibility, proper poultry housing, and water availability significantly influenced commercialisation. Similarly, Dutta (2012) examined small-scale poultry production in Nigeria, identifying production constraints, economic limitations, and marketing challenges as critical factors.

In Swaziland, Siyaya and Masuku (2013) found that commercialisation was largely driven by price fluctuations, the number of chickens sold, and domestic consumption preferences. In Uganda, Akidi *et al*. (2018) emphasise that commercialisation efforts were hindered by high feed costs, inadequate housing, vulnerability to predators, and frequent disease outbreaks. These findings align with Muchadeyi *et al*. (2011), who report that government interventions in Nigeria facilitated commercialisation by addressing input supply and infrastructure gaps.

Despite these findings, many of these studies predate the COVID-19 pandemic and do not capture its disruptions on supply chains, input costs, and market access. In South Africa, the government introduced initiatives such as the Comprehensive Agricultural Support Programme (CASP) and AgriBEE funding to assist smallholder poultry farmers (DAFF, 2010; NDA, 2018). However, Aliber and Hall (2012) argue that these programmes have yielded mixed results, with challenges related to poor implementation, lack of post-funding support, and inefficient extension services.

A significant research gap remains in understanding how the post-pandemic economic environment has shaped poultry commercialisation in South Africa. The rising costs of inputs, electricity shortages (loadshedding), and inconsistent market linkages necessitate a deeper investigation into the current barriers faced by smallholder poultry farmers. This study aims to fill this gap by analysing the determinants influencing commercialisation and proposing targeted policy interventions.

3. RESEARCH METHODOLOGY

The study was conducted in Buffalo City Metropolitan Municipality, Eastern Cape Province, South Africa. The Buffalo City Metro municipality is renowned for its fertile soils and ideal grazing land, which are well-suited for livestock production. A recent report from the National Department of Agriculture indicates that Buffalo City Municipality is among the top five poultry producers in South Africa, making it an ideal location for this study.

The study employed a cross-sectional research design, allowing for the collection, evaluation, and interpretation of data at a single point in time (Creswell & Creswell, 2018). This design was selected due to its effectiveness in analysing relationships between variables and providing insights into commercialisation factors.

3.1. Sampling Approach

The study employed a stratified random sampling technique to ensure a representative selection of indigenous chicken farmers across the municipality. The strata were defined based on farm size, income levels, and geographical location to capture the diversity in farming conditions and market access. A total of 23 strata were formed using the demographic profiling of residents from a list of registered poultry farmers obtained from the Department of Agriculture. Within each stratum, random sampling was used to select participants, resulting in a total sample size of 150 farmers. This approach ensured that the study accounted for variations in production scale, market participation, and commercialisation constraints.

3.2. Data Collection

A permit letter was obtained from the municipal councillor and traditional leaders to facilitate the collection of primary data. Data were collected using a semi-structured questionnaire, which allowed for flexibility in exploring farmers' experiences and commercialisation challenges (Babbie, 2010; Creswell, 2009).

To minimise interviewer bias, enumerators underwent training on standardised interview protocols, ethical considerations, and techniques to reduce response distortion. Additionally, a pilot test of the questionnaire was conducted with 10 farmers, allowing for adjustments to enhance clarity and improve the effectiveness of the questions. The questionnaire covered aspects such as farmers' socioeconomic characteristics, production practices, market access, and commercialisation constraints.

3.3. Analytical Method

The Household Commercialisation Index (HCI) was used to assess the level of commercialisation among smallholder farmers, calculated as follows:

$$HCI = \frac{\text{Gross Value of sale}_{\text{ij}}}{\text{Gross value of production}_{\text{ij}}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This measure reflects the proportion of total production sold in the market, aligning with previous research on smallholder commercialisation (Okezie *et al*., 2012; Randolph, 1992; Rao *et al*., 2015). The HCI was chosen over alternative measures, such as market participation ratios, because it provides a clearer indication of commercialisation intensity rather than mere market engagement. The Gross Values in this study were determined by calculating the total revenue generated from the sale of indigenous chickens. This was computed as follows:

$$Gross\ Value = \sum (Quantity\ of\ chickens\ sold\ \times Selling\ price\ per\ chicken) \ldots\ldots.. (2)$$

where:

The Quantity of Chickens Sold represents the total number of indigenous chickens sold by each farmer during the study period, and the Selling Price per Chicken refers to the average market price received by farmers at the time of sale.

This method aligns with prior research on agricultural commercialisation (Okezie *et al*., 2012; von Braun *et al*., 1995) and provides a reliable measure of commercialisation intensity. Additionally, variations in market conditions, seasonal price fluctuations, and informal sales were considered to ensure accuracy in Gross Value estimations.

Furthermore, a multiple regression model was employed to identify key determinants of commercialisation. The model, based on Gujarati and Porter (2009), is expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots\dots\dots \beta_n X_n + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Where:

Y represents the degree of commercialisation, measured using the HCI. The independent variables (x) included in the model are gender, age, household size, educational level, access to extension services, farm size, distance to markets, access to electricity, feed price, loadshedding, COVID-19 pandemic effects, market access, and income level.

β_0= Intercept or constant term; $\beta_1, \beta_2, \dots. \beta_n$ = Slope or regression coefficient; $X_1, X_2, \dots\dots X_n$ = Independent variables and μ_i = Error term.

3.4. Diagnostic Tests

To ensure the validity and reliability of the regression model, several diagnostic tests were conducted. Multicollinearity was assessed using the Variance Inflation Factor (VIF), where independent variables with a VIF greater than 10 were considered problematic and re-evaluated to mitigate potential issues of multicollinearity. Heteroscedasticity was tested using the Breusch-Pagan test, which helped determine whether the variance of the residuals was constant across observations, ensuring homoscedasticity in variance. Additionally, omitted variable bias was checked using the Ramsey RESET test, which confirmed whether all relevant factors were included in the model, preventing specification errors that could distort the findings. These tests strengthened the robustness and reliability of the regression analysis, ensuring that the model met key econometric assumptions.

4. RESULTS OF THE STUDY

4.1. Socioeconomic Characteristics

This section describes the key socioeconomic characteristics of research participants and explains the status of commercialisation amongst farmers in the study area. The study's results reveal a gender disparity in the sampled population, with 62% of the farmers being male and 38% being female. This finding aligns with Monde (2003), who emphasises the role of men in household decision-making processes, and Randela (2005), who suggests that male dominance in household financial decisions contributes to their prevalence in commercial small-scale chicken production. The age distribution of participants indicates that adults dominate small-scale chicken production in Buffalo City Municipality. Approximately 57% of respondents fell within the 36-50 age range, compared to 10% and 15% for those below 35 and above 51 years old, respectively.

To ensure that participants provide honest responses regarding their level of income, respondents were offered a predefined income category (see Table 1). A significant finding of the study was that 95% of participants reported an income between R0 and R5,000 per month. This limited financial capacity presented a major hurdle for these farmers in achieving commercialisation. With a primary focus on meeting basic household needs, such as food, securing the resources necessary to meet commercial production standards becomes highly challenging.

Furthermore, the study revealed a significant disparity in market access, with only 25% of respondents having the ability to sell their products directly to formal markets. This limitation highlights the need for enhanced market linkages for these farmers (Mupenzi *et al*., 2022). The researcher also observed a correlation between market access and participation in government initiatives. Farmers who were funded through government projects were more likely to sell their chickens to the market compared to non-participants. This highlights the potential benefits of such programmes in fostering commercialisation. Additionally, more than 50% of the respondents reported a lack of extension services in the region.

TABLE 1: Demographic Characteristics of Survey Respondents (N = 150)

Variables		Coding	Frequency (n)	Percent (%)
Gender	Male	0	57	38
	Female	1	93	62
Age	18- 35	0	8	10
	36-50	1	43	35
	51-79	2	23	15

	> 80	3	23	15
Household size	1-3 members	0	45	20
	4-6 members	1	75	50
	7-9 members	2	30	20
	> 10	4	0	10
Level of education	No formal education	0	30	15
	Primary	1	60	30
	Secondary	2	45	45
	Tertiary	3	15	10
Farm size	0.5-1.4	0	75	50
	1.5-2.4	1	45	30
	2.5-3.4	2	15	10
	>3.5	3	15	10
Level of income	R0-R1000	0	38	25
	R1001-R3000	1	75	50
	R30001-5000	2	30	20
	> 5000	3	8	5
Access to market	Yes	0	128	25
	No	1	23	85
Access to extension	Yes	0	75	50
	No	1	75	50
Access to electricity	Yes	0	113	75
	No	1	38	25

4.2. Commercialisation Level of Small-Scale Chicken Farmers

In line with previous research (Alemu *et al.*, 2006; Barrett, 2008; Pingali, 1997), this study employed the HCI to quantify the degree of commercialisation among small-scale chicken farmers in Buffalo City Metropolitan Municipality. The HCI considered both total chicken production and total chicken sales. According to Jaleta *et al*. (2009), the scale of commercialisation is defined as follows: 0 to 30% indicates subsistence-oriented farmers, 31 to 65% indicates semi-commercialised farmers, and 66 to 100% indicates fully commercialised farmers. The results of this study were based on the following scale:

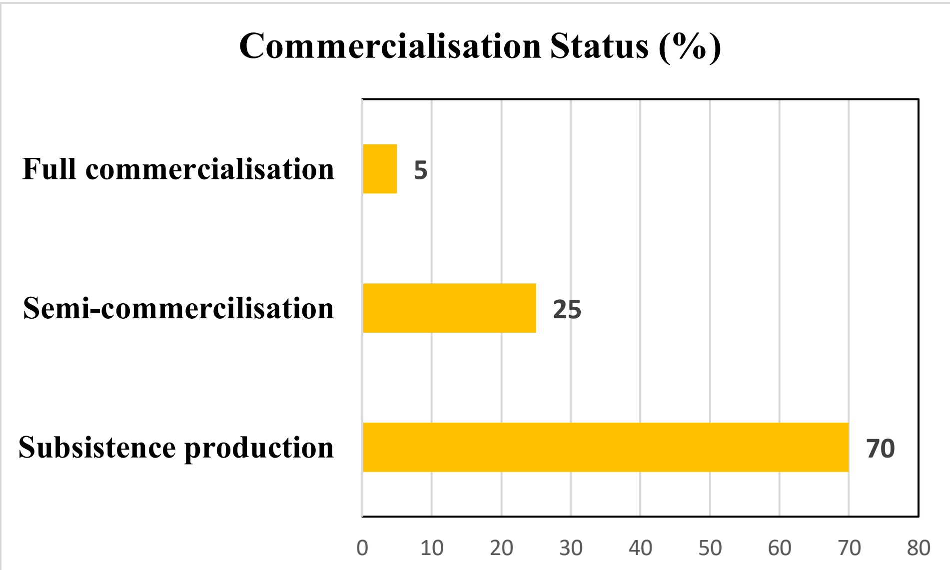

FIGURE 1: Farmers' Level of Commercialisation

The results depicted in Figure 1 reveal that a significant portion (70%) of the study participants were involved in subsistence production, meaning they kept indigenous chickens primarily for household consumption. Only a small percentage (5%) focused solely on producing chickens for making a profit (full commercialisation). The remaining farmers (25%) exhibited a "semi-commercialisation" approach, raising chickens for both home consumption and the market. The findings presented in Figure 1 suggest that a significant challenge for small-scale chicken farmers in Buffalo City is the limited access to markets. These results underscore the need for further research to identify and analyse the key factors that would enable these farmers to transition from subsistence to commercial production. The following section presents the results of a multiple regression model, highlighting the major determinants of commercialisations amongst indigenous chicken farmers.

4.3. Factors Influencing the Commercialisation

To analyse the factors influencing the degree of commercialisation achieved by small-scale chicken farmers, this study employed a multiple regression model (Minten *et al*., 2023). This model analyses the relationships between several independent variables and the different categories of a commercialisation outcome (subsistence production, semi-commercial, and full commercialisation) (McCullagh & Nelder, 1989). The independent variables included in the model are factors such as age, gender, household size, income level, transportation costs, distance to markets, access to production machinery, access to electricity, farm experience, level of income, loadshedding, post-pandemic effects, and grading and standard requirements. The results of the model are summarised in Table 2 below.

TABLE 2: Multiple Regression Analysis Result of Factors Influencing Commercialisation

Variables	Notations	Marginal effect	Standard error	t-value
Gender	X_1	0.0209	0.0115	0.95
Age	X_2	0.3592*	0.1958	1.83
Household size	X_3	0.0367***	0.2437	-0.81
Educational level	X_4	0.0442***	0.2017	-1.27
Access to extension	X_5	0.1036***	0.0293	3.54
Level of income	X_6	0.0218	0.2127	0.10
Distance to markets	X_7	-0.054	0.0586	-0.92
Access to electricity	X_8	0.0109***	0.0053	2.08
Feed price	X_9	-0.0356***	0.0197	3.32
Loadshedding	X_{10}	-0.0123***	0.0084	2.66
COVID-19	X_{11}	0.0127***	0.1455	0.50
Access to markets	X_{12}	0.0412***	0.1733	1.69
Log likelihood		-67.5600		
Pseudo R^2		0.7944		
Chi-square		15.34		

***, **, * Significant at 1%, 5% and 10% respectively

Table 2 shows a log likelihood of -67.56 and a chi-square of 15.34, which are both significant ($p < 0.01$) and Pseudo R2 (0.79), implying that the model has a good fit to the data. The results of the model also reveal that variables such as gender, household size, level of education, loadshedding, distance to markets, transport cost, feed cost, extension services, and the post-pandemic effect were statistically significant at the 5% confidence level. The following section presents a rigorous statistical examination of the individual variables significantly impacting commercialisation.

Gender: The model's results revealed a significant association ($p < 0.020$) between gender and the commercialisation level, with a positive coefficient for gender. This finding aligns with Quisumbing *et al*. (2014), suggesting that male household heads are most likely to engage in market-oriented small-scale chicken production. Other possible explanations for this gender gap could include traditional gender roles where males are expected to undertake more physically demanding farming tasks, potentially influencing a focus on raising chickens for market purposes.

The study found a statistically significant relationship ($p < 0.044$) between **educational status** and commercialisation level, but with a negative coefficient. This suggests that as a farmer's educational level increases, the likelihood of engaging in commercial chicken production might decrease. However, a negative coefficient does not necessarily imply a causal relationship. While some farmers with higher education may pursue more lucrative careers, as suggested by Amare *et al*. (2018), others may choose to venture into commercial farming.

The study revealed a significant positive relationship ($p < 0.037$) between **household size** and the level of commercialisation. This aligns with a study by Randela *et al*. (2008), suggesting that larger households with more members contribute to additional labour on the farm, potentially leading to increased production. This means that larger households have the potential to produce more output for commercial sale compared to smaller households.

Loadshedding: The results from the model indicate a statistically significant relationship at ($p < -0.012$) probability level, but with a negative sign. This suggests that loadshedding negatively impacts the commercialisation efforts of indigenous chicken farmers. This means that as loadshedding increases, the level of commercialisation tends to decrease. A recent report by the World Bank (2024) also emphasises the link between access to electricity and increased productivity and commercialisation potential in the agricultural sectors of developing countries.

The analysis revealed a significant negative association ($p < -0.054$) between the **distance** travelled by farmers to the markets and the level of commercialisation. This implies that farmers located farther away from markets were less likely to sell their chickens commercially. This finding underscores the importance of accessible markets for facilitating commercialisation among small-scale chicken producers. A relevant study by Mupenzi *et al*. (2022) highlights the challenges faced by small-scale farmers in accessing profitable markets due to limited infrastructure and logistical constraints. Furthermore, **market access** clearly plays a very significant role in the commercialisation efforts of participants ($p = 0.041$). These findings align with a recent study by Jones *et al*. (2023), which investigated small-scale chicken production in developing countries and emphasised the critical role of market access in achieving commercialisation.

The results of the model confirm a significant inverse relationship ($p = -0.0356$) between **feed prices** and farmers' willingness to participate in commercial chicken practices. As feed prices increase, the level of commercialisation declines, indicating a detrimental impact on the industry. These findings align with those of Zondi *et al*. (2021), who also found a similar negative correlation between input costs and the commercialisation of indigenous crops among smallholder farmers in South Africa.

The study identified a significant positive association ($p < 0.02$) between **access to extension officers** and the level of commercialisation. This suggests that farmers who have access to extension services are more likely to engage in commercial chicken production. Extension officers play a crucial role in providing training and essential skills necessary to produce marketable chickens, potentially influencing farmers to shift their production towards the market. Brown and Miller (2023) acknowledge the importance of extension services in providing technical knowledge and support to small-scale poultry producers.

Lastly, the results of the model (p = 0.0127) confirmed that the **COVID-19 pandemic** significantly hindered the level of commercialisation amongst research participants. Notably, 25% of farmers involved in producing indigenous chickens for profit reported that disruptions, such as lockdowns, travel restrictions, and staff shortages, severely impacted their access to essential inputs and markets, aligning with findings from Bartik *et al.* (2020). Research participants reported post-pandemic recovery as a significant challenge, highlighting the financial strain imposed by escalating feed prices. This price increase has persisted in the post-pandemic period, squeezing farmers' profit margins and limiting their potential to continue rearing chickens commercially.

5. CONCLUSION AND RECOMMENDATIONS

This study's primary objective was to examine the key factors affecting the commercialisation of small-scale indigenous chicken farming in the post-COVID-19 pandemic era. The results highlight key constraints, including high transportation costs, long distances to markets, a lack of extension services, feed price volatility, and the impact of loadshedding, all of which hinder smallholder farmers from fully transitioning to commercial poultry production. Additionally, post-pandemic effects, including disruptions in transportation and logistics as well as increased input costs, continue to limit commercialisation efforts. These findings emphasise the need for targeted interventions that address structural barriers and support smallholder farmers in scaling up their operations.

Farmers who were struggling to commercialise reported a list of factors that hindered their transition to commercial practices, including high transportation costs, a lack of extension officers, long distances to markets, and expenses associated with transport and feed costs. Furthermore, these farmers lacked access to proper poultry processing equipment, hindering their ability to meet market quality standards and add value to their products. Power outages (loadshedding) presented an additional challenge, particularly for commercial producers who were unable to maintain adequate storage conditions for slaughtered chickens, resulting in product spoilage and reduced quality.

In addition, the study's results revealed that, post-pandemic, poultry farmers continued to face multiple socioeconomic dynamics that limited their success in commercialising their practices. Some of the key post-pandemic effects include farmers' inability to access markets due to ongoing disruptions in transportation and logistics. These disruptions negatively impact the farmers' ability to sell their chickens on time and profitably. Another prevailing challenge from the pandemic reported by farmers includes input shortages that have led to increased costs of essential farming inputs such as feed and fertiliser. The substantial increase in feed costs poses a significant challenge for small-scale poultry farmers aspiring to commercialise their operations. The prevailing feed prices create a considerable financial burden that hinders their ability to compete in the market and successfully commercialise.

Conclusively, the results of this study align with key economic theories of market participation, particularly transaction cost economics (TCE) and institutional barriers theory. According to TCE (Coase, 1937; Williamson, 1985), high transaction costs—such as high transportation costs, lack of market information, and institutional inefficiencies—can prevent smallholder farmers from fully commercialising. The study's findings confirm this, as factors such as market distance, transportation costs, and lack of extension services were significant deterrents to commercialisation. Moreover, institutional barriers, such as inconsistent government support, lack of formalised market structures, and regulatory constraints, align with the institutional theory perspective (North, 1990), which argues that weak institutions create uncertainties that hinder smallholder market participation. These theoretical insights reinforce the need for policy interventions aimed at reducing transaction costs and strengthening institutional support mechanisms to facilitate the commercialisation of indigenous chicken production.

To address these challenges, the government can play a pivotal role by providing centralised transportation services within specific areas, accessible to all small-scale chicken farmers residing in the study area. Successful case studies in other agricultural sectors support the recommendation for centralised transportation systems. For instance, in Kenya, the establishment of agricultural transport cooperatives has improved smallholder access to markets by reducing per-unit transport costs and enabling bulk transportation (Mugenda *et al*., 2021). An extension office can oversee the efficient allocation and operation of this transport system. This approach has proven successful in South Africa, as demonstrated by the Department of Rural Development in Limpopo's provision of shared tractors to rural maize farmers.

Furthermore, this study recommends integrating information communication technologies (ICT) into existing extension services to effectively disseminate indigenous chicken production knowledge, fostering adoption and ultimately boosting productivity and commercialisation. Establishing marketing platforms and networks is also crucial, as it enables farmers and traders to exchange information on stock levels and prices of indigenous chickens and their products. Additionally, training farmers on market-oriented production and effective price determination can empower them to thrive in the commercial landscape.

While this study provides valuable insights into the determinants of indigenous chicken commercialisation, future research should employ mixed-methods approaches to capture both quantitative trends and qualitative farmer experiences. A panel data analysis would be particularly beneficial in assessing commercialisation dynamics over time, identifying long-term policy impacts, and accounting for temporal variations in factors such as market access, government support, and input costs. Additionally, future studies could explore the role of digital platforms and e-commerce in facilitating commercialisation, given the increasing adoption of online agricultural marketplaces in developing economies.

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7. INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board at the University of Fort Hare, with protocol code REC-270710-028-RA and a date of approval of 23 October 2023.

8. INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in this study.

9. DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors on request.

10. CONFLICTS OF INTEREST

The author declares no conflict of interest.

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Variable description

Variable	Theoretical Description	Expected Outcome
Gender	Males are more likely to engage in commercial farming due to access to resources and decision-making power.	+
Age	Older farmers may have more experience but may also be risk-averse, affecting commercialisation decisions.	+/-
Household Size	Larger households provide more labour, enabling higher production and increased commercialisation.	+
Educational Level	Higher education levels improve business skills and access to market opportunities, though highly educated individuals may seek off-farm jobs.	+/-
Access to Extension Services	Access to extension services enhances knowledge, adoption of modern techniques, and market access, boosting commercialisation.	+
Farm Size	Larger farms allow for economies of scale, leading to higher commercialisation levels.	+
Distance to Markets	Longer distances increase transportation costs and limit market participation, discouraging commercialisation.	-
Access to Electricity	Access to electricity facilitates storage, processing, and marketing, supporting commercialisation.	+
Feed Price	High feed costs increase production expenses, reducing profitability and commercialisation incentives.	-
Loadshedding	Frequent power outages disrupt production, affecting farmers' ability to scale up operations.	-
COVID-19 Pandemic Effects	Pandemic effects, such as input shortages and market disruptions, negatively impact commercialisation efforts.	-
Market Access	Access to formal markets increases the likelihood of selling at competitive prices, enhancing commercialisation.	+
Income Level	Higher income levels enable investment in inputs, technology, and expansion, promoting commercialisation.	+

Source: Author’s compilation

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The Impact of Climate Change on the Livelihoods of Small-Scale Crop Farmers in Lepelle Nkumpi District, Limpopo Province, South Africa

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ABSTRACT

This study aimed to evaluate the effects of climate change and extreme weather events on the livelihoods of small-scale farmers, as well as to determine the adaptation strategies employed by households affected by climate change in the Lepelle Nkumpi region of Limpopo. A comprehensive survey was conducted using a stratified sampling method, with individual questionnaires administered to a total of 40 participants. Additionally, two focus group discussions were explicitly held with farmers. Findings reveal that farmers perceive climate change as a real phenomenon, citing rising temperatures, erratic rainfall, and an increase in more frequent droughts and floods. These changes have led to reduced agricultural production and financial losses. In response to the challenges posed by climate change, small-scale farmers are implementing various adaptive strategies, including crop diversification, adjusting planting schedules, utilising irrigation, and applying fertilisers. However, their adaptation efforts are hindered by limited financial resources, restricted access to finance, lack of skills, and inadequate access to agricultural inputs and technologies. The study emphasises the importance of providing enhanced support to small-scale farmers, including agricultural extension services, local early warning systems, diversified livelihoods, climate-sensitive farming techniques, and increased awareness of climate change.

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Keywords: Small-Scale Farmers, Climate Change, Impacts, Adaptation, Lepelle Nkumpi.

1. INTRODUCTION

According to Ziervogel and Taylor (2020), South Africa exhibits climatic variability over many temporal scales. Pasquini *et al*. (2019) assert that the present global climate change models indicate substantial climate change effects in South Africa. Ziervogel *et al*. (2017) emphasise the importance of climate change as a significant issue in South Africa. They note that the country has experienced a notable rise in mean annual temperatures, surpassing the observed global average of 0.65°C by a factor of at least 1.5 over the past five decades. Additionally, the frequency of extreme rainfall events has also shown an upward trend. According to Fitchett *et al*. (2020), the impact of climate change on various aspects of South Africa, including water resources, food security, health, infrastructure, ecosystem services, and biodiversity, is of considerable concern.

Bellprat *et al*. (2019) have documented that historical records indicate fluctuations in South Africa's climate, characterised by alternating wet and dry phases that correspond to occurrences of floods and droughts. These climatic variations are notably influenced by El Niño or Southern Oscillation events, which are projected to increase in frequency due to the effects of climate change. Moreover, the examination of historical records reveals notable escalations in the magnitude of extreme precipitation occurrences and rising atmospheric temperatures. The potential impacts of shifting precipitation and temperature patterns encompass various aspects, including soil erosion rates and water availability (Mastrorillo *et al*., 2018). Additionally, these changes pose risks for waterborne diseases and can have indirect health consequences (Ndlovu & Zenda, 2024). Furthermore, alterations in rainfall patterns can influence the occurrence and severity of drought events (Edossa *et al*., 2019). Moreover, these climatic shifts can have implications for crop yields, food security, rural livelihoods, biodiversity, and ecosystem services (Midgley & Bond, 2015; Ndlovu & Zenda, 2024).

The negative effects of climate change significantly impact farmers' ability to sustain their livelihoods, particularly in agrarian regions such as Limpopo Province. As the majority of the population in this province relies on agriculture, they are highly vulnerable to climate variability and extreme weather events. The Intergovernmental Panel on Climate Change (IPCC, 2021) emphasises that changes in weather patterns and climate conditions have a direct impact on the livelihoods of thousands of small-scale farmers, thereby exacerbating poverty and food insecurity.

These adverse effects have led to a range of socioeconomic challenges, including low agricultural productivity, unemployment, reduced household incomes, and insufficient food production (Shayegh *et al*., 2020). Despite growing recognition of these challenges, a critical gap remains in research on integrating climate adaptation strategies, interventions, and sustainable agricultural practices to enhance rural livelihoods. At the national level, there is a lack of comprehensive studies providing actionable insights for strengthening the resilience of small-scale farmers to climate shocks.

This study seeks to address this gap by examining the impact of climate change on rural livelihoods in the Lepelle Nkumpi District of Limpopo Province. It aims to contribute to existing knowledge by developing recommendations, promoting climate-resilient agricultural practices, and proposing strategies for improving rural livelihoods. Given the urgency of the climate crisis, research on the adaptation strategies employed by small-scale farmers and their effectiveness is crucial for informing both policy and practice.

2. METHODOLOGY

2.1. Study Area

The research was conducted in Limpopo Province, which is recognised as the fifth-largest province among South Africa's nine provinces (South African Government, 2013). The province under consideration comprises six districts, specifically Greater Sekhukhune, Mopani, Capricorn, Waterberg, and Vhembe, as shown in Figure 1 (LDA, 2012). Nevertheless, the primary focus of this study was directed towards the district of Lepelle Nkumpi.

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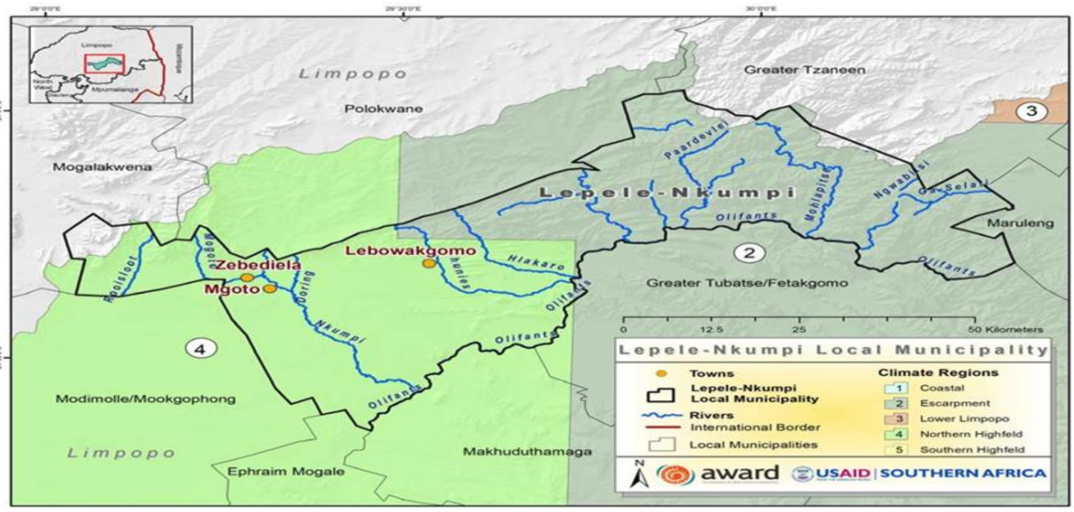

FIGURE 1: The Five Distinct Climate Regions of the Olifants River Catchment (Source: South African Government, 2013)

According to Oni *et al*. (2012), the province's total land area is 12.46 million hectares, representing approximately 10.2% of South Africa's total land area. The province being examined displays three distinct climate regions: The low veld, characterised by arid and semi-arid conditions; the Middle Veld and High Veld, which are semi-arid regions; and the Escarpment region, which has a sub-humid climate and receives an annual rainfall of 700mm (LDA, 2012). The agricultural sector in the province of Limpopo has a capacity for cultivating a wide range of agricultural commodities, including tropical fruits, cereals, and vegetables. This ability can be attributed to the prevailing climatic variations within the region.

The geographical coordinates of the Municipality of Capricorn are 23.6123 °S and 29.2321 °E, as shown in Figure 1. This municipality spans an approximate area of 3,484 km^2 within the Lepelle Nkumpi District, as reported by the South African Government in 2013. Lepelle Nkumpi District is situated in the southeastern region of Limpopo Province. The parish in question is the smallest among the four parishes in the district, accounting for approximately 16% of the district's total geographic area (LDA, 2012). A rural setting characterises the majority of the town. The region is geographically partitioned into a total of 29 administrative districts, with one of them being the municipality known as Lebowakgomo.

Additionally, within the Capricorn District, there exists a growth point that comprises one of these districts. The district under consideration exhibits a notable feature of diminished precipitation levels, typically falling within the range of 450 to 500 mm per year. Consequently,

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the region faces a scarcity of water resources, which manifests in the form of acute water shortages and recurring droughts.

According to the South African Weather Service (SAWS, 2020), there has been a notable fluctuation in the precipitation coefficient, with a recorded variance of 30.78%. This suggests a discernible trend of decreasing precipitation levels over successive years. According to the Environmental Study (2009) and the South African Weather Service (SAWS, 2020), the municipality of Lepelle-Nkumpi experiences an average yearly temperature of around 20°C. The average temperature during the summer months is roughly 23°C, while during the winter months it remains around 20°C (Lepelle-Nkumpi Agricultural Hub, Environmental Analysis, 2019).

2.2. Data Collection

Data were collected from smallholder farmers using a mixed-methods approach, incorporating both questionnaires and focus group discussions. Quantitative data were obtained through structured questionnaires administered to farmers in Capricorn villages, located in the Lepelle Nkumpi area of Limpopo. These questionnaires were designed to capture measurable aspects of agricultural practices, climate change impacts, and the adaptive strategies employed by farmers.

The questions were carefully crafted to ensure clarity and relevance, avoiding technical jargon to accommodate varying literacy levels among respondents. To enhance the validity and reliability of the instrument, the questionnaires underwent a comprehensive pretesting phase. This involved conducting pilot tests with a small group of farmers from the target population to identify and rectify potential issues in question wording, order, and overall design. Feedback from these pretests led to necessary revisions, ensuring that the final version effectively captured the intended information and was easily understood by the respondents. This rigorous pretesting process is essential in survey research, as it helps identify and address problems that could affect data quality and the overall success of the study.

To complement the quantitative data, focus group discussions were conducted with individuals actively engaged in agricultural production as members of various farming groups. These discussions provided a platform for participants to share their perspectives, experiences, and beliefs regarding climate change and its effects on their livelihoods. The focus group method was selected for its cost-effectiveness, interactive nature, and ability to facilitate in-depth exploration of complex issues through dialogue and collective reflection.

Focus group discussions were conducted with members of various farming groups to explore their perspectives on climate change and its impact on their livelihoods. Each group consisted of 20 participants, totalling 40 participants across all groups. This size facilitates in-depth interaction and ensures diverse viewpoints. The discussions were guided by a semi-structured set of open-ended questions designed to elicit detailed responses and encourage dialogue among participants. To capture the richness of the conversations, all sessions were audio-recorded with participants' consent, and a trained observer took comprehensive notes. The recorded discussions were transcribed verbatim, and the data were analysed using thematic analysis to identify recurring themes and patterns. This approach allowed for a nuanced understanding of the participants' experiences and beliefs regarding climate change.

Additionally, field observations were carried out to collect qualitative data. Farmers were observed in their natural environment while engaging in routine agricultural activities. This approach allowed the research team to document firsthand the farming practices and adaptive responses employed in real-world settings. By integrating structured questionnaires, focus group discussions, and direct observations, this study ensured a comprehensive and holistic understanding of the challenges faced by smallholder farmers in the region.

2.3. Sampling

A stratified sampling method was employed to choose 40 small-scale crop farmers from the Lepelle Nkumpi region of Limpopo. A stratified sample was selected from household heads who agreed to take part in the study. Stratified sampling involves dividing the population into subgroups or strata based on specific criteria before selecting samples from each stratum. Afterwards, a space is selected from every subgroup. In this scenario, the population was divided into strata, or groups, based on two key factors: the number of small-scale crop farmers and their level of involvement in crop production. This stratification likely aimed to organise the population for analysis or decision-making purposes within the crop farming sector.

A small sample of 40 small-scale crop farmers was used due to practical constraints such as time, resources, and accessibility, which often limit the feasibility of large-scale data collection. Stratified sampling ensures that even with a small sample size, the study captures key variations within the population by selecting representative subgroups. This approach enhances the validity and reliability of findings while maintaining efficiency in data collection and analysis. Additionally, in studies focused on specific farming communities, smaller samples can still provide meaningful insights, especially when qualitative depth and targeted analysis are prioritised over large-scale statistical generalisations.

2.4. Data Analysis and Interpretation

Qualitative data were analysed using content analysis, a systematic and rigorous qualitative research method that facilitates the identification, interpretation, and contextualisation of patterns, themes, and meanings within textual or qualitative data. Content analysis enables an in-depth examination of the language, concepts, and relationships embedded within the data, allowing researchers to derive nuanced insights beyond mere word frequency (Özkan & Gezer, 2024). This approach involves categorising and coding data to discern recurring themes, contextual meanings, and relational patterns, thereby enhancing the interpretive depth of qualitative research. Content analysis is particularly valuable in social sciences, communication studies, and interdisciplinary research, as it provides a structured yet flexible framework for analysing diverse sources, including interviews, policy documents, reports, and media content. The method ensures both transparency and replicability, supporting rigorous qualitative inquiry while accommodating the complexity of human expressions and interactions. Its systematic nature allows researchers to mitigate bias by establishing clear coding frameworks, thereby enhancing the validity and reliability of the findings. Consequently, content analysis was chosen for this study due to its ability to provide an empirical and theoretically grounded understanding of the data while preserving the richness and contextual depth of qualitative information.

The descriptive analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 22 software to determine the means, modes, and frequencies of the variables.
Ethical approval for this study was obtained from the University of the Free State, ensuring that all research activities adhered to the institution's ethical guidelines and principles. In compliance with ethical research standards, informed consent was obtained from all participating farmers prior to the commencement of data collection. Participants were thoroughly briefed on the study's purpose, procedures, potential risks, and benefits, enabling them to make informed decisions about their involvement. To uphold confidentiality and

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protect the identities of all participants, strict anonymity measures were implemented, including the use of pseudonyms and secure data storage protocols. Additionally, all collected information was handled with the highest level of integrity, ensuring that participants' rights, privacy, and dignity were safeguarded throughout the research process.

3. RESULTS AND DISCUSSION

3.1. Demographic Characteristics of Participants

3.1.1. Gender of Participants

A total of 40 respondents were sampled from nine villages in Lepelle Nkumpi in Limpopo Province. As illustrated in Table 1, both groups of respondents consisted of an equal number of participants, with 20 individuals identifying as male (50%) and 20 individuals identifying as female (50%). Throughout history, the agricultural sector has always been associated with male labour. However, there is an increasing demographic of women who are actively participating in the agricultural sector. According to the Farming Portal (2019), the proportion of women farmers in sub-Saharan Africa who engage in smallholder farming ranges from 60% to 80%.

However, the percentage of women who own land in this region is considerably lower, estimated to be between 15% and 20%. The age distribution among both groups differed, and this will be further elaborated upon in the subsequent section. This study was also conducted to examine the involvement of women in agriculture, as it has traditionally been perceived as a male-dominated field, especially in this district. This is the reason the number of respondents, regardless of gender, is equal. The data presented in Table 1 illustrate the even distribution of male and female participants in the research conducted.

TABLE 1: Summary Statistics of a Survey Carried Out in Lepelle Nkumpi District (n=40)

Gender distribution	Percentage
Male	50%
Female	50%
Age (Years)	
18-25	48%
26-35	20%
36-45	15%

46-55	8%
56-65	8%
66-75	15%
Farm size	
0 to 0.5 ha	55%
0.6 to 1 ha	25%
More than 1 ha	20%

3.1.2. Age of Participants

The age group with the highest percentage of registered farmers was individuals aged 18 to 25 years, constituting 48% of the overall population (Table 1). The demographic group generally known as "youth", which includes those aged 18 to 35 years, constituted 6.5% of the overall population of registered farmers (Stats South Africa, 2021). The findings of this study demonstrate a greater proportion of individuals engaged in agricultural activities among the youth demographic (18–35 years old) in comparison to the older demographic (36–70 years old). A considerable proportion of young farmers have indicated that their choice to pursue farming is primarily influenced by the prevailing circumstances, characterised by elevated levels of unemployment and poverty. The results of the census data are consistent with the survey results, indicating that 48% (n = 17) of the respondents belong to the 18- to 35-year age group, which qualifies them to be classified as "youth" according to the defined criteria. The remaining individuals were categorised into the following age groups: 36–45 years (n = 8; 15%), 46–55 years (n = 6; 8%), 56–65 years (n = 3; 8%), and over 65 years (n = 6; 15%) (Table 1).

3.1.3. Farm Size

The majority of farmers participating in this survey engage in agricultural activities on communal property, with only 2% operating on privately owned farms (Table 1). In South Africa, tribal organisations manage and own the majority of communal land, which is primarily rural property. Communal tenure can be defined as a circumstance when a collective entity possesses secure and exclusive rights to own, manage, and/or utilise land and natural resources, sometimes referred to as common pool resources (Communal Land Rights Act 11 of 2004).

These resources encompass a wide range of land types, including agricultural lands, grazing areas, forests, and trees, as well as aquatic resources such as fisheries, wetlands, and irrigation waters (Communal Land Rights Act 11 of 2004). When land ownership is mostly communal, there are little incentives to practise sustainable land management efficiently (Zenda & Malan, 2021). This is because communal land tenure often lacks clear individual property rights, leading to a situation where land resources are used collectively without direct accountability for degradation or overexploitation.

During the interview, several farmers emphasised the advantages of engaging in farming activities on communal land, primarily due to the exemption from monthly levies. However, a notable challenge they encountered was the difficulty in managing the presence of other individuals' livestock in the vicinity, which resulted in crop damage. The survey findings indicate that a significant proportion of farmers, including 55% (n = 22), possess land holdings ranging from 0 to 0.5 hectares. Additionally, 25% (n = 10) of farmers reported farming on land between 0.6 and 1 hectare. It is essential to note that these farmers do not own any land; instead, the land is held under the community land tenure system. Among the surveyed population of farmers, it was observed that a significant majority, specifically 55%, possessed at least one hectare of land. However, it is worth noting that only a mere 25% of farmers actually owned the land they cultivated. This finding was based on n = 8, or 20% of the total population.

3.1.4. Education Level of Participation

Since the 1970s, there has been a consistent upward trend in the unemployment rate among the youth population in South Africa (Kanbur, 2009). Presently, South Africa is positioned as the fourth nation globally in terms of its proportion of unemployed young people. According to data from 2014, the unemployment rate among individuals aged 15–24 who were actively seeking employment was 52.6% (Stats SA, 2021). According to Statistics South Africa's Quarterly Labour Force Survey for the fourth quarter of 2022, it is evident that Limpopo Province has the third-highest expanded unemployment rate at 49.9%. This ranking places Limpopo behind the Eastern Cape Province, which holds the highest expanded unemployment rate at 53%. As of the initial quarter of 2023, a significant proportion of the unemployed population in South Africa had an educational attainment level below matriculation, which corresponds to Grade 12. Approximately 41% of the unemployed population consists of individuals who have completed their matriculation year, while graduates constitute nearly 3% of the overall unemployed demographic.

According to the survey findings, it was observed that 43% (n = 17) of the participants possess a tertiary qualification, while 10% have completed their matriculation (Table 2). The remaining participants lack educational qualifications. A total of nine individuals, accounting for 23% of the sample, reported not having attended any formal educational institution. Additionally, ten participants, representing 25% of the sample, indicated that they completed their education from Grade 1 to Grade 12 (Table 2).

TABLE 2: Educational Qualifications of Participants

Highest education level	**Number of participants**	**Percent**
Matriculated	4	10%
Grade 1 to Grade 12	10	25%
Tertiary qualification	17	43%
Never been to school	09	23%
Grand Total	**40**	**100%**

3.1.5. Type of Crops Produced by Participants

According to Molele (2016), Limpopo Province in South Africa is renowned for its significant agricultural contributions, earning it the title of the "Bread and Fruit Basket" of the country. The province is responsible for producing approximately 60% of various agricultural products, including fruits, vegetables, maize meal, wheat, and cotton (Drysdale *et al*., 2019). The fertile soils of the Limpopo region support the cultivation of various crops, including maize, coffee, peaches, litchis, papayas, tomatoes, potatoes, and tea plantations. The cultivation of maize, alongside other crops, is essential for food security in the area, as it provides a staple food source for the local population (Mukwada *et al*., 2021). The study reveals that a significant proportion of small-scale farmers in this particular location prioritise the cultivation of vegetables over field crops. As illustrated in Figure 2, the predominant crop among the farmers surveyed was tomatoes, accounting for 28% of the total number of participants (n = 11). Following closely behind were spinach and cabbage, which were produced by 18% of the farmers (n=7). A larger proportion of the participants engaged in vegetable farming. Out of the total sample size of farmers (n = 5), 13% were engaged in the cultivation of green peppers, whereas just one farmer (n = 1; 2%) was involved in the production of okra. There was a limited number of farmers involved in the production of field crops, specifically yellow maize farmers (n = 5; 13%) and soybean farmers (n = 3; 8%).

Overall, the study underscores the strategic significance of vegetable farming in Limpopo Province, highlighting its crucial role in sustaining local livelihoods, ensuring food security, and promoting economic development. Given the province's vast agricultural potential, targeted interventions such as improved access to markets, value-chain development, and climate-smart agricultural practices could further enhance productivity and sustainability among small-scale farmers in the region.

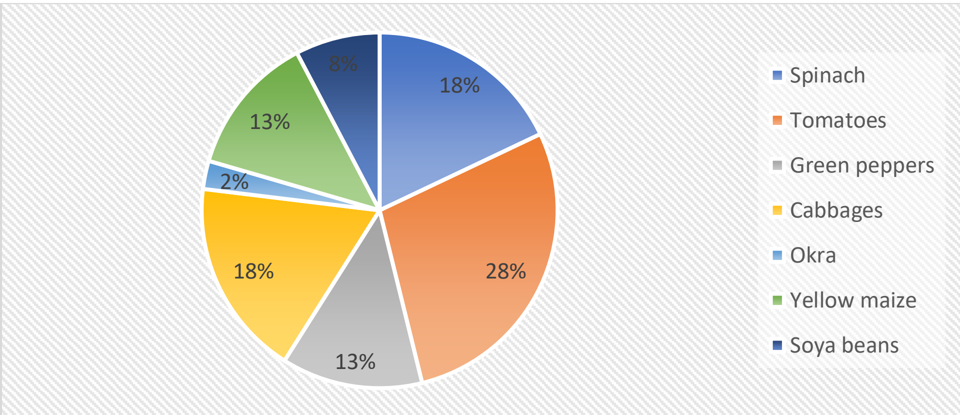

FIGURE 2: **Type of Crops Produced by Participants**

3.1.6. Number of Years in Farming of Participants

The data collected from the study reveal that a greater proportion of farmer respondents (50%) had engaged in agricultural practices for a duration of 2 to 5 years (Figure 3). The study's findings align with statistical data from South Africa's farmer register, which indicates that the high unemployment rate has led to an increase in the number of young individuals engaging in farming activities since 2019 (Cowling, 2021). Most of the farmers in this study started farming in 2018. A small proportion of respondents, specifically 8% (n = 3), have reported having engaged in farming for a duration of 6 to 12 years. Similarly, 5% (n = 2) of respondents have indicated a farming experience of 13 years or more. Additionally, there is a subset of farmers who have engaged in farming for a duration of 1 to 5 months (n = 5; 13%) and another subset who have been involved in farming for a duration of 6 months to 1 year (n = 10; 25%).

The diversity in farming experience among respondents highlights the dynamic nature of the agricultural sector, characterised by a continuous influx of new farmers alongside a smaller proportion of more experienced individuals. This distribution has important implications for agricultural extension services, training programmes, and policy interventions. The presence of a significant number of relatively new farmers highlights the need for targeted support, including access to credit, technical assistance, and knowledge-sharing platforms. Moreover, the relatively small number of long-term farmers suggests the need for mechanisms to retain experienced farmers and leverage their expertise for the benefit of the broader farming community.

Overall, the findings indicate a growing engagement in farming, driven by economic conditions and evolving livelihood strategies. The increasing number of young and new farmers presents opportunities for innovation, the adoption of climate-smart agricultural practices, and the strengthening of sustainable farming systems. However, ensuring their long-term success will require comprehensive support structures, including access to resources, training, and market linkages.

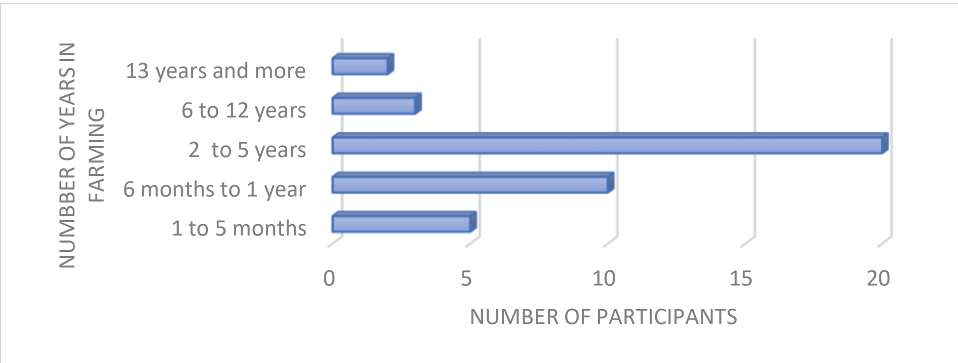

FIGURE 3: **Number of Years in Farming of Participants**

3.1.7. Race of Participants

Numerous ethnic groups, differing from one another in terms of cultural practices, linguistic variations, and racial characteristics, comprise Limpopo's demographic makeup. According to 2021 statistics, the demographic composition of the population is as follows: 97.3% of individuals identify as Black, 2.4% identify as White, 0.2% identify as Coloured, and 0.1% identify as Indian or Asian (Stats SA, 2021). The province exhibits the lowest proportion and second-lowest aggregate count of white South Africans within the nation. Additionally, it exhibits the highest proportion of individuals identifying as black among all the provinces. The survey findings align with those reported by Stats South Africa, as all respondents (n = 40; 100%) identified as belonging to the black racial group. This indicates that the majority of individuals residing in this particular region (Lepelle Nkumpi) are of Black ethnicity. The demographic pattern can be attributed to historical factors, migration trends, and socioeconomic dynamics that have shaped settlement patterns in Limpopo.

4. THE EFFECT OF CLIMATE CHANGE ON CROP PRODUCTION

4.1. Poor Quality Fruits

Elevated temperatures have significant implications for crop yield, primarily manifesting in two distinct ways: impeding vegetative growth and reducing fruit set. The combination of excessive transpiration and elevated temperatures imposes constraints on fruit crops that are susceptible to significant transpiration losses (Little, 2019). These farmers experienced a significant decline in the quality of their tomato crops, cabbage heads, and spinach. The dynamic nature of the environment is simultaneously giving rise to pronounced instances of drought and flooding. These alterations render fruit trees vulnerable to adverse growing conditions, infestations by pests, fungal infections, and other related challenges (Agnolucci, 2020).

In the previous year, the Intergovernmental Panel on Climate Change (IPCC, 2021) delineated five prospective global warming scenarios that encompassed varying degrees of fossil fuel utilisation and emissions. The analysis incorporated various climate scenarios, all of which consistently indicated significant alterations in tomato production within the next three to four decades. In general, the study revealed a projected decrease of approximately six percent in tomato production worldwide by 2050, compared to the baseline period of 1980–2009 (IPCC, 2021). This decline is attributed to the anticipated rise in air temperature. Furthermore, the analysis indicates that the five alternative future scenarios exhibit minimal variation in their impact on tomato production.

4.2. Increase in Diseases and Pests

According to Maponya (2012), the research findings indicate that the prevailing climatic conditions in Limpopo Province are primarily characterised by a prolonged period of drought. Consequently, this severe drought has led to a diminished availability of grazing land, water resources for livestock, and irrigation facilities, thereby exerting a substantial influence on agricultural livelihoods and contributing to food scarcity. According to farmers, there has been an observed rise in the prevalence of diseases such as verticillium wilt, which is a soil-borne disease. Certain farmers decided to transition from cultivating tomatoes to spinach due to their difficulties in effectively managing a rapidly escalating disease outbreak.

The escalating threat to food security and the environment is attributed to the exacerbation of plant pests that inflict significant damage on economically vital crops, a phenomenon primarily driven by the consequences of climate change (FAO, 2021). The responders have reported the emergence of new pest and disease incursions as a result of the irregular rainfall and fluctuating temperature variations. The farmers emphasised the significance of "aphid attacks" on cabbage as a notable pest issue. The agricultural practitioners have also observed these incursions throughout the summer months, particularly in periods characterised by high temperatures. The farmers have also noted the occurrence of these incursions throughout the summer, particularly during times of high temperatures. The findings of the Intergovernmental Panel on Climate Change (IPCC, 2022) also indicate that the production systems of smallholder farmers face immediate challenges due to rising temperatures, which lead to heat stress on plants, less water availability, decreased overall productivity, and the emergence of novel pests and diseases.

4.3. The Effect of Climate Change on Farmers' Livelihoods

The adverse repercussions of climate change and variability have had a detrimental effect on the well-being of the majority of rural smallholder farmers. Rural regions have witnessed a decline in agricultural production, crop failures, the emergence of human diseases, pest and disease infestations, inadequate water supplies, a scarcity of agriculture-based food products at the household level, and food insecurity (Mutekwa *et al*., 2019). The aforementioned impacts have presented a significant challenge to global food security and the livelihoods of farmers worldwide, thereby jeopardising the overall well-being of smallholder farmers in rural areas. This is primarily due to the heavy reliance of rural smallholder farmers on natural resources, such as agriculture, that are sensitive to climatic conditions, for their sustenance (Debela *et al*., 2015). The next section elucidates the impact of climate change on individuals' means of subsistence.

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4.4. Socioeconomic Effect on Agricultural Production

During the focused group conversations conducted, the farmers confirmed the exacerbation of climate fluctuations on an annual basis. They expressed that they had received less precipitation since the beginning of January in the current year, and the dry spells were observed to be intensifying, thereby harming their overall welfare. According to smallholder farmers, climate change has led to extended periods of drought, decreased precipitation, and increased temperatures, resulting in a decline in agricultural productivity. The farmers expressed that the insufficiency of water for irrigation posed a significant obstacle, as the adverse alterations in precipitation patterns detrimentally impacted their means of subsistence. Consequently, they were compelled to postpone their planting activities in anticipation of rain, only to find themselves unable to plant due to the late season. The aforementioned findings support Bellprat *et al.*'s (2019) claim that the province of Limpopo has experienced severe droughts, heatwaves, and reduced precipitation. The adverse climatic impacts have a detrimental influence on the livelihoods of farmers, leading to a scarcity of food resources.

Based on the participants' feedback, it was evident that climate change had a negative impact on the food security of their households. This was largely attributed to the occurrence of crop losses over a two-year period. The study revealed that a significant majority of farmers (90%) exhibited heightened vulnerability, as they reported enduring substantial agricultural losses in terms of food production throughout the preceding two-year period. In its 2007 report, the Intergovernmental Panel on Climate Change (IPCC) predicts a reduction in agricultural production in sub-Saharan Africa from 21% to 9% by 2080 as a consequence of climate change. According to the paper, it is anticipated that the increase in temperatures during precipitation events will have a detrimental impact on the production of staple foods, potentially leading to a decrease of up to 50%.

The findings underscore the need for policymakers, researchers, and agricultural stakeholders to develop targeted interventions that support vulnerable farming communities. Enhancing access to climate-resilient farming techniques, promoting agroecological approaches, and integrating indigenous knowledge systems into climate adaptation strategies could help mitigate the risks posed by climate change and safeguard food security in sub-Saharan Africa.

4.5. Emotional Effect on Farmers' Livelihoods

The emotional well-being of farmers has been observed to be adversely impacted by the negative consequences of climate change (Table 3). The protracted droughts led to a loss of optimism among certain farmers, as they experienced significant losses in the preceding year and faced ongoing challenges in recovering from these losses. The farmers emphasised their recognition of their susceptibility to climate-related risks, particularly the adverse effects of climate change, such as less rainfall leading to drought. The farmers expressed a heightened level of confusion and worry as they struggled with the uncertainty of whether to persist with their agricultural activities in the face of diminished rainfall resulting from prolonged drought conditions.

Despite being directly impacted by climate change, some farmers remain unaware of its causes and long-term consequences. This lack of awareness can often be attributed to limited access to reliable information and inadequate education on climate-related issues. In many rural areas, farmers may lack exposure to formal climate change education or receive information in a form that is inaccessible or not tailored to their specific contexts. Additionally, there is often a gap between scientific knowledge and local, practical knowledge.

In some cases, farmers might attribute weather anomalies to natural variability, relying on traditional explanations rather than recognising them as symptoms of broader climatic changes. Socioeconomic factors, such as illiteracy, limited access to technology, and low income, can also restrict farmers' ability to access and process information related to climate change. Furthermore, the urgency of immediate agricultural needs may overshadow longer-term concerns, such as climate change, leaving limited space for farmers to engage with environmental issues, even if they are experiencing their effects. This creates a significant challenge in fostering effective climate change adaptation strategies, as understanding the issue is the first step toward proactive and informed action.

TABLE 3: **Effect of Climate Change on Farmers' Livelihoods**

Type of effects	Concepts	Quotes from farmers
Socioeconomic effects	Declining crop yields increased. Increased water scarcity Increased new pest & disease invasions	"Our crop yields have gone down, so we don't have enough food." Lower profits "It hasn't rained, so there's no water and no crops." "We keep losing crops in our fields because of new pests, like aphids."
Emotional effects	Loss of hope Fearful Helpless	"We keep on losing our crops." "If these prolonged droughts persist and there's no rain, we are afraid we will struggle of hunger and food insecurity." "The issue of climate change is beyond our control, there's nothing we can do."

The primary concern of these farmers revolves around the agricultural sector, which serves as the foundation of their overall livelihood. They expressed distress due to the adverse impact of unfavourable weather conditions on their food security and the subsequent constraints it imposes on their livelihood opportunities. Rural residents expressed a strong desire to make progress and implement methods aimed at mitigating the impacts of climate-related pressures and risks. Nevertheless, individuals perceived the current circumstances as being outside of their sphere of influence, resulting in a sense of helplessness. This sentiment arises from the perception that their indigenous knowledge, which is both cost-effective and readily available, appears to be obsolete. Furthermore, there is a lack of sufficient support mechanisms available to address the challenges posed by climatic threats.

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5. ADAPTATION AND MITIGATION STRATEGIES UTILISED BY FARMERS ON CLIMATE CHANGE

5.1. The Utilisation of Several Cultivars

The United Nations' Food and Agriculture Organisation (FAO) recommends the use of modified crops and varieties, encompassing both herbaceous and tree crops, as a climate-smart approach to mitigate risks, preserve soil and water resources, and enhance water efficiency. The utilisation of modified crops and varieties, whether annual or perennial, serves to mitigate the adverse effects of climate change on agricultural systems while simultaneously ensuring consistent agricultural productivity.

The survey findings suggest that a significant proportion of the smallholder farmers examined (60%, n = 40) utilise a strategy characterised by the diversity of crop kinds and varieties as their primary approach. To mitigate the effects of climate change, some farmers (n = 14, 35%) have adopted alternative varieties of crops or modified the crops they plant. According to the FGDs, smallholder farmers were occasionally compelled to adopt new crops or abandon old ones due to the effects of climate change.

The introduction of novel crops or varieties, as well as the revival of traditional crops, contributes to the diversification of agricultural production. This diversification has a positive impact on biodiversity and ecosystem services, especially when these crops are cultivated in conjunction with conservation agriculture practices. These practices include minimising soil disturbance, maintaining permanent soil organic cover, and diversifying crop species. Based on the survey findings, a small proportion of farmers (n = 2, 4%) have adopted the cultivation of drought-resistant varieties as a strategy to alleviate the adverse effects of recurrent droughts in the region. These droughts have become more prevalent as a consequence of climate change. It is worth noting that farmers who have adopted this approach primarily cultivate maize and soybean crops. One instance of a drought-tolerant crop that has been widely embraced by a majority of farmers, as evidenced by the findings from the focus group discussions (FGDs), is the indigenous short maize variety and wild cherry tomato.

The findings suggest that while some farmers are gradually integrating drought-resistant varieties, there is a need for further extension services, knowledge dissemination, and policy support to encourage broader adoption. Investments in seed distribution programmes, farmer training initiatives, and climate-smart agriculture incentives can play a pivotal role in scaling

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up the cultivation of resilient crop varieties. Furthermore, integrating indigenous knowledge with modern agricultural techniques can offer holistic solutions that enhance productivity while maintaining ecological balance.

5.2. Changing the Time of Planting

According to the survey findings, it can be inferred that a significant proportion of the studied population, specifically 90% (n = 30), has made adjustments to their planting schedules and fertiliser usage as a means of mitigating the potential risks associated with the considerable fluctuations in rainfall patterns observed in the region. Farmers in South Africa are implementing several adaptation measures to mitigate production risk. These tactics encompass the cultivation of crop types with shorter growing periods, adjusting planting schedules based on rainfall patterns, adopting water collection techniques in furrows adjacent to plants, and augmenting the utilisation of irrigation methods. According to the FAO (2018), it is observed that natural fluctuations in climatic factors, such as precipitation and temperature, can prompt small-scale farmers to adapt their planting and harvesting schedules as a means of coping. To mitigate crop production risks, smallholder farmers employ staggered planting techniques. For instance, some farmers opt for dry land planting before the arrival of rainfall, while others choose to plant right after the commencement of the first significant rains.

These findings highlight the dynamic nature of smallholder farming in the face of climate change and underscore the importance of continuous innovation, knowledge-sharing, and support to strengthen farmers' adaptive capacity. Strengthening access to climate information services, improving extension support, and investing in sustainable water management technologies will be essential in ensuring the long-term resilience of South Africa's smallholder agricultural sector.

5.3. Mixed Farming

Farmers have embraced the practice of mixed farming as a means to mitigate risks and adapt to the challenges posed by climate change. The individuals engage in livestock husbandry, specifically raising cattle and goats, while cultivating a diverse range of crops, including maize, tomatoes, cabbage, and soybeans (Conradie, 2020). The practice of mixed farming is crucial in the context of climate change adaptation, as it serves to mitigate the risks associated with over-dependence on a singular agricultural production system. According to Issahaku *et al*. (2019), the integration of livestock and agricultural production is recognised as a strategy for enhancing farm diversification and improving farmers' adaptive capacity. As climate change continues to impact agricultural production, extension services should encourage and support the adoption of mixed farming systems to ensure long-term food security and environmental sustainability.

6. CONCLUSION AND RECOMMENDATIONS

To enhance the resilience of farmer livelihoods amid the fluctuations brought about by climate change, it is imperative for the Department of Agriculture to actively participate in this endeavour. This is particularly crucial given that a significant proportion of those impacted by these changes are impoverished and reside in rural regions. The Department of Agriculture, Land Reform, and Rural Development should provide targeted subsidies to farmers by supplying high-quality, climate-resilient seed cultivars with strong resistance to pests. Additionally, the government should invest in the establishment and maintenance of efficient irrigation infrastructure to enhance water security for agricultural production.

To improve climate change awareness, the department should mandate Agricultural Advisors to conduct regular, structured information sessions in rural areas. These sessions should include practical demonstrations, farmer training workshops, and knowledge-sharing platforms to ensure that rural communities understand climate risks and adopt adaptive farming practices. Furthermore, it is advisable to extend invitations to all stakeholders in order to enhance the knowledge and capabilities of farmers.

Climate change has been observed to have differential impacts on individuals based on their gender. Further research is warranted to assess the gendered aspects of climate change's impact on small-scale farmers and their corresponding adaptation strategies.

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Perceptions of Small-scale Farmers on the Adoption of ICTs for Accessing Agricultural Information in Mahikeng, Northwest Province, South Africa

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ABSTRACT

This study evaluates the perceptions of small-scale farmers in Mahikeng, Northwest Province, South Africa, regarding the use of Information and Communication Technology (ICT) in agriculture. The findings indicate that most respondents (94%) view ICT as a valuable tool for implementing change, enhancing access to agricultural information, and improving productivity. Specifically, 62.8% agreed that ICT increases access to information, while 63.6% believed it boosts productivity. Farmers also acknowledged the benefits of ICT in reducing travel time and expenses (61.1%) and expanding market access and networks (70.2%). Education was found to have a significant positive impact on ICT adoption (coefficient = 1.190649, p ≤ 0.01), indicating that higher education promotes ICT literacy. However, gender and reliance on traditional information sources were negatively correlated with ICT perceptions, reflecting barriers to adoption. Notably, 53% of farmers believed that ICT improves the quality of services. Awareness of ICT benefits for extension services also played a key role in shaping positive perceptions (coefficient = 4.261418, P ≤ 0.05), while Ease of use significantly influenced farmers' perceptions (coefficient = 0.36816, P ≤ 0.05). These findings underscore the need for targeted interventions to increase ICT adoption, focusing on education, gender equity, awareness, and the development of user-friendly technologies.

Keywords: Small-Scale Farmers, Perception, ICT Adoption, Agriculture.

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1. INTRODUCTION

1.1. Background

The adoption and integration of Information and Communication Technology (ICT) in agriculture has the potential to transform the agricultural sector, especially for small-scale farmers. ICT tools such as mobile phones, internet platforms, and radio broadcasts have been pivotal in improving access to agricultural information, increasing productivity, and enhancing market access for farmers worldwide (Mapiye *et al.*, 2023). Small-scale farmers in developing regions, such as sub-Saharan Africa, face unique challenges, including limited access to timely and relevant agricultural information (Misaki *et al.*, 2018). ICTs offer a way to overcome these barriers by providing real-time data, market prices, weather forecasts, and expert advice (Kumar *et al.*, 2021).

Small-scale farmers in Mahikeng, Northwest Province, South Africa, are a crucial segment of the agricultural workforce. These farmers typically operate on smaller plots of land, with limited resources and access to modern agricultural techniques. Despite these limitations, the increasing penetration of ICT devices, such as mobile phones, coupled with improved internet access, presents an opportunity to revolutionise how these farmers receive and utilise agricultural information. Studies have shown that when small-scale farmers adopt ICT tools, productivity and profitability often increase due to improved decision-making (Ndimbo *et al.*, 2023). However, the perception of ICT use among small-scale farmers in rural areas remains mixed, with factors such as education, income level, and technological infrastructure influencing adoption rates (Van Greunen & Fosu, 2022).

1.2. Statement of the Problem

In Mahikeng, there is limited empirical data on how small-scale farmers perceive the use of ICT for accessing agricultural information. Understanding their perceptions is crucial for designing targeted interventions that encourage the adoption of ICT and enhance agricultural outcomes. Previous research has highlighted that while some farmers view ICT as a valuable tool for enhancing farm productivity and market access, others face significant challenges, such as high device costs, poor network coverage, and a lack of technical expertise (Nyakudya *et al.*, 2024). These challenges are particularly prevalent in rural areas where infrastructure and literacy levels may limit the effective use of ICT tools.

1.3. Aim, Objectives and Hypothesis

This study aims to assess the perceptions of small-scale farmers in Mahikeng on the use of Information and Communication Technology (ICT) for accessing agricultural information. The key objectives include identifying the socioeconomic characteristics of small-scale farmers within Mahikeng Local Municipality and exploring how these characteristics influence their perceptions of ICT use for accessing agricultural information. To investigate the relationship between these variables, a null hypothesis was established, which states: "There is no significant relationship between the socioeconomic characteristics of small-scale farmers in Mahikeng and their perceptions of ICT use for accessing agricultural information."

2. METHODOLOGY AND PROCEDURES

2.1. Study Area

The study was conducted in the Mahikeng Local Municipality, located in the Northwest Province of South Africa. The region is characterised by agricultural activities, with small-scale farming playing a significant role in the local economy.

2.2. Research Design

A descriptive and quantitative research design was used for this study. Quantitative research designs are structured approaches used to systematically describe and analyse characteristics of a population using numerical data (Mohajan, 2020). This research design was selected because it allows a researcher to accurately and systematically describe the characteristics of a given population of interest, using numerical data (Dulock, 1993).

2.3. Population of the Study

The study population consisted of 1,449 small-scale farmers based in the Mahikeng Local Municipality, as recorded by the Rural Environment and Agricultural Development (READ).

2.4. Sampling Procedure and Sampling Size

Krecjie and Morgan's sample size table was used to draw a sample of 302 participants from the entire population of 1,449 small-scale farmers. Simple random sampling was used to recruit participants. However, only 121 respondents voluntarily participated in the study.

2.5. Data Collection

The study used a structured questionnaire to gather data on the socioeconomic characteristics of small-scale farmers. The first section focused on identifying socioeconomic characteristics and assessing farmers' awareness of ICT in extension service delivery, while the second section assessed farmers' perception of ICT use. The questionnaires were self-administered by the researcher.

2.6. Data Analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics summarised the socioeconomic characteristics of respondents and their perceptions of ICT use in accessing agricultural information. The data were presented in tables. To test the hypothesis, a binary logistic regression model was employed, which is suitable when a combination of continuous and discrete independent variables predicts a binary dependent variable. In this study, the Likert scale was collapsed, where "Strongly Agree" and "Agree" were combined as positive perceptions, and "Strongly Disagree" and "Disagree" were categorised as negative perceptions. "Undecided" was considered a non-response. Positive perceptions were coded as 1, and negative perceptions were coded as 0.

2.7. Ethical Clearance

This study obtained ethical clearance (NWU-0-3-2-3-1-8-A9) from the research ethics regulatory committee of Northwest University.

3. RESULTS AND DISCUSSIONS

3.1. Descriptive Statistics of Socioeconomic Characteristics of Small-Scale Farmers in Mahikeng Local Municipality.

As illustrated in *Table 1,* the study reveals that the majority of respondents in the study area are male, comprising 63% of the respondents, and 37% are female. This suggests that small-scale farmers in the area are predominantly male. The majority of respondents have a primary school education, with 31% having secondary education. Informal education is also prevalent, with 20% having it. The majority of respondents are married (51%), while 33% are single. The age range of respondents is 20 to 50 years and above, with 49% being over 50 years old.

The majority of respondents have a household size of 4-6 members, with 39.7% having a farming experience of 11-20 years. The majority of respondents have an estimated annual income of R10,000 to R30,000, with 32.2% having an income of R31,000 to R50,000. Only 10% have an income of R51,000 to R70,000, 4.1% have an income of R71,000 to R90,000, and 7.4% have an income of R91,000 and above.

The majority of respondents practice both animal and crop production, with only 16% practising animal production solely. The majority of respondents (36%) consider fellow farmers as the most prominent source of agricultural information, while another 35% use extension agents as their primary source. Radio is the least common source of agricultural information, with 29% using it.

The selection of agricultural information was based on multiple-choice questions, with 92% of respondents being aware of the use of ICT for extension service delivery. The majority of respondents use ICT to access extension services and agricultural information, while 14% do not. The majority of respondents use television (30.87%), radio (27.7%), and mobile phones (27.18%) as their major ICT tools for accessing agricultural information for farm management.

The selection of various ICT tools used was based on multiple choices, with the majority using television (30.87%), radio (27.7%), and mobile phones (27.18%) as their major ICT tools for accessing agricultural information for farm management. Only a few respondents use the internet (8.97%), personal computers (3.96%), DVD and CDS (0.53%), digital cameras (0.53%), and video conferencing (0.26%).

TABLE 1: Descriptive Statistics of Small-Scale Farmers Socioeconomic Characteristics (n=121)

Socioeconomic variable	Categories	Frequency	Percentage
Gender	Male	76	63%
	Female	45	37%
Level of education	Informal	24	20%
	Primary	40	33%
	Secondary	38	31%
	College	11	9%

	University	8	7%
Marital status	Single	40	31%
	Married	62	51%
	Divorced	19	16%
Age	21-30 years old	4	3%
	31-40 years old	10	8%
	41-50 years old	48	40%
	50 years and above	59	49%
Household Size	1-3 members	28	23%
	4-6 members	72	59.5%
	7-10 members	20	16.5%
	11-13 members	1	1%
	14 members and above	0	0
Farming Experience	2-10 years of experience	40	33.06%
	11-20 years of experience	28	39.67%
	21-30 years of experience	24	19.83%
	31-40 years of experience	6	4.96%
	41-50 years of experience	2	1.65%
	51 years or more of experience	1	0.83%
Farm size (ha)	0-2 hectares	57	47%
	3-6 hectares	47	39%
	7-10 hectares	11	9%
	11-15 hectares	2	2%
	16 and above	4	3%
Annual Income (ZAR)	10,000-30,000 rands	56	46.3%
	31,000-50,000 rands	39	32.2%
	51,000-70,000 rands	12	10%
	71,000-90,000 rands	5	4.1%
	91,000 rands and above	9	7.4%
Type of farm enterprise	Crop production	15	12%
	Livestock production	19	16%

	Both	87	72%
Information sources	Extension agents	111	35%
	Fellow farmers	114	36%
	Radio	92	29%
Awareness of the use of ICTs	Yes	111	92%
	No	10	8%
Use of ICTs for information access	Yes	104	86%
	No	17	14%
ICTs used by small-scale farmers	Radio	105	27.7
	Television	117	30.87
	Mobile phones	103	27.18
	Internet	34	8.97
	Video conferencing	1	0.26
	Personal computer	15	3.96
	DVDs and CDs	2	0.53
	Digital cameras	2	0.53
	Telecentres	0	0

3.2. Small-Scale Farmers' Perception of the Use of ICTs for Accessing Agricultural Information

In the study, respondents' perceptions were measured using a 5-point Likert scale, with the following response options: Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), and Strongly Disagree (SD), corresponding to values of 5, 4, 3, 2, and 1, respectively. The scale comprised 11 statements. The assigned values were used for analysing this section with the mathematical representation as follows: $\frac{5+4+3+2+1}{5} = \frac{15}{5} = 3$

Therefore, a mean of 3 and above was adjudged okay and accepted, while any value below Three were not accepted.

The study as depicted in *Table 2*, found that most respondents strongly agreed (65%) and agreed (29%) that Information and Communication Technology (ICT) is a valuable tool for implementing change in farming, this is buttressed by findings from Kante *et al.* (2017) and

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Singh and Khan (2020) that the majority of farmers view ICT as a valuable tool for implementing change, increasing access to agricultural information, and improving productivity. The majority (62.8%) agreed that ICT increases farmers' access to agricultural information, while 63.6% agreed that it increases farmers' productivity. The majority (61.1%) agreed that ICT reduces travel time and expenses, increases farmers' profitability through access to good markets and product prices, and leads to a broader network (70.2%) this is supported by findings from Naik and Navaneetham (2024) which affirms that ICT is perceived to reduce travel time and expenses, increase profitability through better market access, and broaden farmers' networks. However, 30.6% of respondents were undecided whether ICT helps farmers make good decisions during transactions, while 56.2% agreed that it does. The study also found that 36% of respondents found ICT easy to use, while 17% were undecided and 28% disagreed. However, 53% agreed that ICT improves the quality of services rendered to farmers. The results, as indicated in Table 2, suggest that the majority of respondents have a high perception of ICT for farm management, with none of the means being below 3.

TABLE 2: Perception on the Use of ICT for Farm Management of Respondents

STATMENTS	Strong agree Frq(%)	Agree Frq(%)	Undecided Frq(%)	Disagree Frq(%)	Strongly disagree Frq(%)	Mean	SD
ICT is a valuable tool to implement change in farming	79(65)	35(29)	5(4)	1(1)	1(1)	4.57	0.69
ICT increases farmers' access to agricultural information	37(30.6)	76(62.8)	7(5.8)	0(0)	1(0.8)	4.23	0.58
ICT is easily accessible to farmers	22(18)	43(36)	17(14)	30(25)	9(7)	3.15	1.46
ICT enables farmers to reach new markets	21(17)	77(64)	17(14)	5(4)	1(1)	3.91	0.83
ICT enhances agricultural productivity of farmers	20(16.5)	89(73.6)	9(7.4)	2(1.7)	1(0.8)	4.02	0.65

ICT reduces travel time and expenses	23(19)	74(61.1)	19(15.7)	3(2.5)	2(1.7)	3.93	0.79
ICT increases farmers' profitability through access to good markets and prices of products	22(18)	80(66)	16(13)	3(2.5)	0(0)	3.98	0.73
ICT leads to a broader network	15(12.4)	85(70.2)	17(14)	4(3.3)	0(0)	3.88	0.55
ICT helps farmers to make good decisions during transactions	15(12.4)	68(56)	37(31)	1(1)	0(0)	3.79	0.68
ICT are easy for farmers to use	14(11.57)	44(36)	20(17)	34(28)	9(7)	2.96	1.42
ICT improves the quality of services rendered to farmers	16(13.22)	64(53)	26(22)	11(9)	4(3)	3.58	1.06

3.3. Multicollinearity Test

Statistical anomalies must be examined prior to executing a binary logistic regression model. This is necessary to ensure that the statistical conclusions derived from the model are reliable and accurate. A prevalent issue in binary logistic models and other statistical models is multicollinearity (Senaviratna & Cooray, 2019). Multicollinearity occurs when significant linear intercorrelations and inter-associations exist among the variables, resulting in the formation of correlated variables (Shrestha, 2020). The presence of multicollinearity in the input data renders statistical inferences in the output inaccurate and unreliable (Kim, 2019).

In this study, Tolerance and Variance Inflation Factor (VIF) values were used to detect multicollinearity (Senaviratna & Cooray, 2019). These researchers assert that the Tolerance value must be greater than or equal to 0.1, and the VIF must be less than or equal to 10.VIF and Tolerance test for variables such as education, age, gender, farm experience, annual income, information sources, awareness of ICT use in extension service delivery, ICTs as a valuable tool to implement change, ICTs lead to broader network, ICTs help make good decisions, ICTs are easy to use, and ICTs improve the quality of extension services were run in the model. The collinearity statistics of variables are presented in Table 3.

TABLE 3: Multicollinearity Test of Variables

Variables	VIF	Tolerance	Eigenvalue
Educational level	1.69	0.5929	0.3226
Gender	1.15	0.8682	0.2426
Information sources	1.81	0.5515	0.0700
Awareness of ICT use in extension service delivery	2.15	0.4652	0.0593
Easy to use	1.57	0.6361	0.0142
Mean VIF	1.58		

3.4. Binary Logistic Regression and Model Results

The outcomes of the binary logistic regression model provide in-depth insight into the perception of small-scale farmers regarding the use of ICT. The model fit is demonstrated by the LR chi² (12) = 60.76 with a p-value of 0.0000, signifying statistical significance and rejecting the null hypothesis that all predictor variable coefficients are equal to zero. The Pseudo $R^2 = 0.3720$ indicates that the model is valid and has adequate explanatory power (Table 4).

A strong positive impact of education on ICT use was identified, with a significant positive correlation (coefficient = 1.190649, $p \leq 0.01$) (Table 4). This suggests that farmers with higher educational backgrounds are more likely to adopt ICT for agricultural activities. Education equips individuals with the necessary skills to navigate ICT tools effectively, suggesting that ICT literacy is closely tied to educational levels. Higher education enhances the understanding and usability of digital tools, making it easier for these farmers to access vital agricultural information. This is supported by (Ilić-Kosanović *et al.*, 2019), which found that small-scale farmers' perceptions of using ICT in agriculture are influenced by their level of education.

Gender is associated with a negative relationship with perception of ICT use, as indicated by the negative coefficient (-1.081679, $P \leq 0.10$) (Table 4). This suggests possible gender-related barriers in the use of ICTs, where male farmers appear less likely to engage with technology compared to female farmers. This could be influenced by various cultural, social, or access-related factors that need to be addressed to ensure gender equity in ICT adoption. Studies on gender and ICT adoption in agriculture present mixed findings. While some studies suggest that women farmers are less likely to adopt new technologies due to limited access to resources, education, and extension services (Aduwo *et al*., 2017), others indicate that women may be more receptive to ICT-enabled agricultural information (Mpiima *et al*., 2019).

The reliance on traditional information sources, such as word-of-mouth from fellow farmers or non-digital resources like extension training and visits, has a negative impact on small-scale farmers' perception of ICTs (coefficient = -0.4438458, $P \leq 0.10$) (Table 4). Small-scale farmers who continue to depend on non-ICT sources may find it challenging to integrate new technologies into their farming practices. This is supported by findings from Hoang and Tran (2023), which revealed that reliance on traditional information sources negatively impacts the perception and use of digital agricultural technologies among small-scale farmers in Vietnam. This suggests a need to transition farmers away from traditional sources and increase their trust and familiarity with digital platforms.

Awareness on the Use of ICTs for extension services was positively significant (coefficient = 4.261418, $P \leq 0.05$) (Table 4). This suggests that farmers who are more aware of the benefits and availability of ICTs for extension services are more likely to have a positive perception towards the use of ICTs. This underscores the importance of creating awareness campaigns and training programs to highlight how ICT can enhance farm productivity. This finding aligns with that of Obeng *et al*. (2019), who found that small-scale farmers' awareness of the benefits of ICT for extension services positively impacts their perception of ICT use.

Ease of use was a critical factor in farmers’ perceptions, with a positive and statistically significant coefficient (0.36816, $P \leq 0.05$) (Table 4). If ICT tools are perceived as user-friendly, small-scale farmers are more likely to adopt and utilise them regularly. Therefore, simplifying ICT interfaces and providing user support can significantly increase their accessibility and adoption among farmers. This finding aligns with Hendrawan *et al*. (2023), who found that ease of use is a critical factor in farmers' perceptions of ICT adoption, with a positive significance.

The null hypothesis that there is no significant relationship between the socioeconomic characteristics of small-scale farmers and their perceptions of ICT use can be rejected with confidence. The evaluation highlights key socioeconomic factors, including educational level, gender, reliance on traditional information sources, awareness, and ease of use, all of which show significant relationships with farmers' perceptions of ICT. Education level and awareness of ICT benefits positively influence ICT adoption, while reliance on traditional information sources and gender negatively affect adoption. These findings underscore the importance of targeting specific socioeconomic factors to enhance ICT adoption among small-scale farmers.

TABLE 4: Results of the Binary Logistic Regression Model

Variables	**Coefficient**	**Std error**	**Z**	**P>|z**	**Marginal effect**	**Tolerance**
Educational level	1.190649	0.3477275	3.42	0.001*	0.2717101	0.5929
Gender	-1.081679	0.5867735	-1.84	0.065***	-0.2468429	0.8682
Information sources	-.4438458	0.2641827	-1.68	0.093**	-0.1012872	0.5515
Awareness of ICT use in extension	4.261418	2.073414	2.06	0.040***	0.4254344	0.4652
Easy to use	0.36816	0.2114253	1.74	0.082***	0.0840154	0.6361
Constant	-7.084194	3.715509	-1.91	0.057		
Number of observations	121					
LR chi ^{2} (12) =	60.76					
Prob > chi ^{2}=	0.0000					
Psuedo R^2 =	0.3720					
Log likelihood =	-51.290358					
Marginal effects after logit=	0.35236353					

Note*, ** and * represents 1%, 5% and 10% levels of significance respectively**

4. SUMMARY

Small-scale farming in Mahikeng is predominantly male-driven, with most farmers engaged in both crop production and livestock farming. Their primary sources of agricultural information are fellow farmers and extension agents, reflecting a reliance on traditional networks. Notably, small-scale farmers in the region demonstrate considerable awareness of Information and

Communication Technology (ICT) and perceive it as highly beneficial for accessing agricultural information.

The findings reveal that education plays a statistically significant role, showing a positive relationship with farmers' perceptions of ICT, suggesting that higher levels of education enhance the likelihood of ICT adoption. Conversely, both gender and information sources are statistically significant but exhibit a negative relationship with ICT perceptions.

Additionally, awareness of ICTs and their ease of use are positively correlated with small-scale farmers' perceptions, indicating that greater awareness and perceived user-friendliness significantly promote the adoption of ICTs within this agricultural community.

5. CONCLUSION

The study confirms the significant role of Information and Communication Technology (ICT) in transforming small-scale farming. A substantial majority of respondents recognise ICT as a valuable tool for change, aligning with previous research (Kante *et al*., 2017; Singh & Khan, 2020). ICT's ability to enhance access to agricultural information, increase productivity, and reduce travel time and costs was widely acknowledged, with the majority agreeing on its positive impact on productivity and its role in expanding market networks. These findings reflect ICT’s capacity to improve farm profitability through better market access, as supported by Naik and Navaneetham (2024).

Educational attainment emerged as a key factor in perceptions of ICT usage, with a positive correlation between higher education levels and the likelihood of using ICT. This highlights the importance of educational initiatives to equip farmers with digital literacy skills. However, gender disparities suggest potential barriers to male farmers' perception of ICT use, a trend that requires further exploration to address equity in technology adoption.

Farmers’ reliance on traditional information sources negatively impacted their perception of ICT, underscoring the need to transition from traditional to digital platforms. Awareness of ICT's benefits and ease of use were positively significant, indicating that awareness campaigns and user-friendly technologies can positively impact the perception of ICT, which, in turn, can drive higher adoption rates.

In conclusion, the study emphasises that improving education, increasing awareness, and streamlining ICT tools are essential strategies for positively shaping farmers' perceptions of ICT. These factors play a crucial role in facilitating greater ICT adoption among small-scale farmers, which, in turn, can enhance agricultural productivity and profitability. By equipping farmers with the necessary knowledge and making ICT solutions more accessible and user-friendly, these interventions can foster a more technology-driven farming environment, ultimately leading to sustainable agricultural growth.

6. RECOMMENDATION

Based on the findings of this study, several recommendations are proposed to enhance positive perception and effective use of Information and Communication Technology (ICT) among small-scale farmers in Mahikeng:

- **Strengthen ICT Education and Training:** The study reveals a strong correlation between education and perception, underscoring the need to enhance digital literacy among farmers, particularly those with lower educational levels. Tailored training programs that focus on equipping small-scale farmers with the necessary skills to utilise ICT tools effectively will enable them to access agricultural information, enhance decision-making, and improve farm management.
- **Address Gender Barriers:** The negative association between gender and perception of ICT use highlights disparities in access and engagement with technology, with male farmers being less likely to adopt ICTs. Targeted gender-sensitive interventions are required to bridge this gap. Training programs must consider cultural and social factors and provide equal opportunities for both men and women to engage with digital farming tools.
- **Promote Awareness Campaigns on ICT Benefits:** Awareness is a key factor influencing the perception of ICT use. Increasing farmers' knowledge of the benefits of ICT for enhancing agricultural productivity, improving market access, and reducing costs is crucial. Governments and agricultural bodies should invest in large-scale awareness campaigns that demonstrate the practical advantages of ICT through success stories and accessible digital tools.
- **Transition Farmers Away from Traditional Information Sources:** Farmers' reliance on traditional information sources (e.g., word-of-mouth and non-digital resources)

hinders their adoption of ICT. To positively impact their perception and encourage a transition away from these practices, extension services must integrate digital platforms into their outreach. This shift requires building farmers' trust in ICT and familiarising them with its role in modern agriculture.

- **Simplify ICT Tools:** The user-friendliness of ICT tools is critical for how they are perceived. Simplifying interfaces, offering support in local languages, and providing ongoing technical assistance can enhance the user experience. These steps will increase farmers' comfort with ICT and encourage more frequent usage.
- **Expand ICT Infrastructure and Accessibility:** A reliable ICT infrastructure is crucial for maximising the potential of digital tools in agriculture. Investments in mobile networks, internet access, and affordable digital platforms will ensure that small-scale farmers, especially those in rural areas, have consistent access to critical agricultural information. Policymakers should prioritise the expansion of infrastructure to support the adoption of ICT at scale.

By addressing these key areas, farmers' perception and use of ICT in agriculture can be positively influenced, ultimately leading to higher adoption rates and improved agricultural productivity.

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Socio-economic Factors Influencing Marketing Practices and Opportunities for the Smallholder Pig Farming Enterprise in the Cape Metropole District, South Africa

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ABSTRACT

Urban smallholder pig production is one of the farming systems that dominate urban agriculture in South Africa. However, the challenges of urban smallholder pig farmers in adopting sustainable marketing practices have not been identified. Therefore, a survey was conducted amongst 160 pig farmers from five suburbs of the Cape Metropole District in South Africa to determine the impact of socio-economic factors on marketing practices and the accompanying challenges for urban smallholder farms. Data was collected using a convenience sampling technique and subjected to descriptive statistics, analysis of variance, and binomial logistic regression. The main challenges experienced by farmers were a slow growth rate in pigs (54% of respondents), scarcity of production inputs (25%), and difficulty in finding marketing information (20%). The main sustainable marketing practices adopted by smallholder pig farmers included the use of a farmgate marketing channel (82% of

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respondents), the sale of live pigs (52%), and affiliation with marketing organisations (16%). Logistic regression marginal effects revealed that farmers who were women, older, African traditional religion adherents, and had less farming experience, education, training, and access to extension services, relied on paid labour and one source of income, farmed extensively and off-plot, and owned small farms, one livestock type, indigenous breeds and small pig herds, were more likely to face challenges and fail to adopt sustainable marketing practices ($P \leq 0.05$). In conclusion, the identified socioeconomic factors have a significant impact on farmers' decision-making and should be incorporated in devising sustainable marketing strategies and policies to enhance market access and pig sales on smallholder urban farms in developing countries.

Keywords: Animal Slaughter, Farmgate, Formal Markets, Marketing Information, Pig Sales.

1. INTRODUCTION

Pig production plays a significant role in the agricultural industry, providing pork as a vital source of protein for human consumption (Roesel *et al*., 2019). The demand for pork in South Africa has increased gradually due to rising population, urbanisation, and per capita income (Davids *et al*., 2014). At the same time, the demand for high-quality and safe pork amongst consumers in urban areas has also been rising (Department of Agriculture, Land Reform and Rural Development [DALRRD], 2021; Davids *et al*., 2014; Levy *et al*., 2013). Such attributes include hygienic slaughtering standards and pork that is lean, flavoursome, healthful, free from diseases and harmful residues (Baltenweck *et al*., 2018; Magqupu *et al*., 2023). In this context, it is essential to comprehensively develop the smallholder urban pork value chain, identify sustainable pig marketing practices, and understand the socio-economic factors influencing the adoption of such practices, as well as their relationship to consumer preferences (Kimbi *et al.,* 2016; Mathobela *et al.*, 2024a). This could help to optimise the circular bioeconomy, enhance marketing efficiency, and address the diverse needs of different consumer segments of smallholder urban pig farmers (Mathobela *et al.*, 2024a; Magqupu *et al.*, 2024).

Smallholder pig farming is more convenient in urban areas, as it is practised on small landholdings compared to the larger tracts of land required for cattle, sheep, and goat farming (Mathobela *et al*., 2024b; Okello *et al*., 2021). Owing to its proximity to traders, slaughterhouses, high-quality markets, and efficient road networks, urban smallholder pig farming is more market-oriented than rural pig farming (Mathobela *et al*., 2024a; Ström *et al*., 2017). Effective marketing in the urban smallholder piggery enterprise is essential for economic growth and poverty reduction (Ajala & Adesehinwa, 2008; Levy *et al*., 2013). However, the marketing of pigs in the urban smallholder sector is subject to several challenges, including non-compliance with animal welfare, biosecurity, slaughter and waste management regulations (Kagira *et al*., 2010; Majunder & Cherala, 2021). Pork sold in these informal markets is perceived to be less safe compared to that from retail stores, due to a lack of efficient cooling systems and poor hygiene conditions (Deka *et al*., 2007; Dietze, 2011). In addition, the value chain is not sufficiently structured and informal markets are poorly organised with limited access to technology, production information, and services (Mugonya *et al*., 2021; Ouma *et al*., 2015). To create effective development strategies for the urban smallholder pig enterprise in developing countries, it is essential to identify the existing challenges and sustainable pig marketing practices, as well as the socio-economic factors influencing them.

Previous studies on urban smallholder pig marketing practices have been more concentrated on evaluating smallholder pig marketing systems to enhance farmers' access to high-value markets (Kimbi *et al*., 2016; Levy *et al*., 2013). However, there is a knowledge gap regarding the socio-economic variables influencing the challenges faced by urban smallholder pig farmers and the sustainable marketing practices they adopt. The socio-economic factors influencing smallholder farming practices and marketing decisions can be broadly categorised into farm (economic/financial), farmer (personal/demographic) and institutional characteristics (Mathobela *et al.*, 2024a, b). Understanding farmers' socio-economic factors may enable the development of effective interventions for the long-term growth of the urban smallholder pig industry. Therefore, the current study aimed to determine the socio-economic factors that have bearing on the challenges experienced by smallholder farmers and on the adoption of sustainable marketing practices by pig smallholder farms in the Cape Metropole District, South Africa.

2. RESEARCH METHODOLOGY

2.1. Ethical Clearance and Precautionary Measures

In accordance with the South African National Health Act No. 61 of 2003 (RSA, 2004), the Social, Behavioural, and Education Research (REC: SBE-17285) Ethics Committee at Stellenbosch University approved the current study. Since the study was conducted during the COVID-19 pandemic, in May 2021, all safety precautions, research guidelines, laws, and regulations, as emphasised by the Research Ethics Committee, were followed. The research team adhered to all the necessary COVID-19 Occupational Health and Safety protocols as a mitigating strategy, including the use of cloth face masks, sanitisers, boxes of tissues, non-contact infrared thermometers and record-keeping sheets. Furthermore, the five rules of good hygiene to prevent the spread of COVID-19 were observed. These included regular washing of hands with soap and water or disinfecting with a 70% alcohol-based hand sanitiser, the wearing of a cloth mask at all times to cover the mouth and nose, adhering to the social distancing rule of at least 1.5 m and avoiding meeting in groups, coughing or sneezing into a tissue or elbow, not touching the face with unwashed hands, and staying at home when feeling unwell. The South African Animal Diseases Act 35 of 1984 (RSA, 1984) was also enforced due to an outbreak of African swine fever (ASF) in the study area. All necessary mitigating strategies, biosecurity measures, and precautionary measures were followed during farm visits to prevent the spread of the disease. The study's objectives and potential benefits were explained to the participants prior to the interviews. Following this, each participant provided written informed consent, and they were assured of their privacy and anonymity. Participation was entirely optional, and individuals were informed that they could withdraw from the interview process at any moment.

2.2. Study Site and Selection of Farmers

The study was carried out in the low-income, high-density suburbs of Eerste River (GPS coordinates: -34.020630, 18.711254), Khayelitsha (-34.040539, 18.714261), Mfuleni (-34.008137, 18.675448), Penhill (-33.973532, 18.717577) and Strand (-34.129302, 18.881187), all located in the Cape Metropole District of South Africa’s Western Cape province. These five suburbs were selected because of the large population of smallholder farmers who raise pigs there, according to officials from the Western Cape Department of Agriculture. The sampling unit consisted of the head of household, who owned at least two adult pigs. A study sample of 160 pig farmers from Mfuleni (n = 31), Eerste River (n = 33), Penhill (n = 30), Khayelitsha (n = 36), and Strand (n = 30) was obtained using a convenience sampling technique. For convenience, the sampling technique involved selecting pig farmers based on their availability and willingness to participate in the study, with the assistance of extension officers and animal health professionals from the Western Cape Department of Agriculture. Slovin's formula (Yamane, 1967) was used to determine the acceptable sample size, as follows:

$$n = \frac{N}{1+N(e)^2} = \frac{383}{1+383(0.06)^2} = 161$$

where n = sample size required, N = the total number of small-scale pig farmers in the five surveyed suburbs, and e = the acceptable sampling error. Since participants were not selected randomly, the opportunistic (i.e., convenience) sampling technique may have introduced bias, making the results less representative of the larger population. Nevertheless, the technique enabled the researchers to conduct the interviews at a convenient time during the day, with close observations of the animals, infrastructure, production and marketing practices. This helped validate the data and enhance the accuracy of the results.

2.3. Data Collection

Data was collected through face-to-face personal interviews with pig farmers using pre-tested structured questionnaires administered in local languages (i.e., Afrikaans, isiXhosa, and English). The questionnaire was pre-tested on 15 April 2021 with 10 farmers in Kayamandi (GPS coordinates: -33.926706, 18.843263), using a prototype that had been developed. Kayamandi is a low-income, high-density suburb of Stellenbosch in the Western Cape province of South Africa, sharing similar socio-economic characteristics with the surveyed suburbs. Pretesting examined whether the survey was properly completed and whether respondents truly understood the questions, ensuring they would provide all the required data. Following the pre-test, changes were made to the questionnaire, including the rewording and rearranging of several questions to guarantee clarity, a logical question flow, and adequate guidance. The survey comprised 61 closed-ended, open-ended, and multiple-choice questions about household demographics (8 questions), farm characteristics (10), pig marketing practices (16), challenges (4), opportunities (4), and agricultural support services (19). The average interview time was approximately 45 minutes per respondent. Personal observations, physical examinations, reviews of pre-existing records, and, when appropriate, photos were used to supplement the data collected *via* questionnaires.

2.4. Statistical Analysis

The PROC FREQ of SAS 9.4 (SAS Institute Inc., Cary, NC, USA) was used to analyse descriptive statistics for demographics, pig marketing practices, and agricultural support services data. To evaluate the associations between suburbs and characteristics of general pig marketing practices, a Chi-square test was performed. The Shapiro-Wilk and Levene tests were used to determine the normality and homoscedasticity of this dataset, respectively. The PROC GLM of SAS was used to separate the means of the data on pig body weight, number of sales and slaughtered pigs, price, and distance to market at a 5% ($P \leq 0.05$) level of probability using Tukey's test.

Logistic regression analysis was employed to identify the variables influencing the key challenges faced by farmers and their adoption of key marketing practices. The PROC LOGISTIC model estimated the log chances of farmers choosing a specific marketing practice or facing a specific challenge. Socio-economic factors such as gender, age, religion, education level, farming experience, workforce, source of income, farm size, type of livestock, herd size, type of breeds kept, production system, location, agricultural advisory services, and pig management training were included in the model as independent variables (Table 1). The change in the likelihood that pig farmers could encounter a specific challenge or adopt a specific key marketing practice for a unit change in each socio-economic and ecological component was predicted using the marginal effects of logistic regression, based on the binomial logistic model. The binomial logistic regression model was selected based on its ability to accommodate numerous explanatory factors, account for the effects of confounding variables, facilitate the interpretation of dichotomous preference aspects, and ease data interpretation. However, if the differences in the independent variables are not verified, the projected values generated by the logistic regression may fall outside the range, and the relationship between the input and response may not be linear. Greene (2020) stated the model as follows:

$$\text{Prob}\left(Y_j = i\right) = P_{ji} = \frac{\text{expo}(X_j\beta_i)}{\sum\text{expo}(X_j\beta_k)} \text{ where } 0 < P_{ji} < 1 \text{ (1)}$$

Equation 1 was linearised into (2):

$$\text{Prob}\left(Y_j = i\right) = P_{ji}\ (\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \ldots \beta_k X_k) \text{ (2)}$$

where: Prob ($Yj = i$) is the the probability of a farmer to experience a key challenge or adopt key sustainable marketing practices with two response categories of either ‘yes’ or ‘no’ coded as 1 or 0; β_0 = Intercept; $\beta_1, \beta_2, \ldots, \beta_n$ = coefficients of independent variables; $\chi_1, \chi_2, \ldots, \chi_n$ = independent variables. Following the variables' fitting, the residual model was:

Y_i (key challenge or key sustainable marketing practices) = $\beta 0$ + $\beta 1$(gender) + $\beta 2$(age) + $\beta 3$(religion) + $\beta 4$(education) + $\beta 5$(farming experience) + $\beta 6$(workforce) + $\beta 7$(income source) + $\beta 8$(farm size) + $\beta 9$(type of livestock kept) + $\beta 10$(herd size) + $\beta 11$(type of pig breeds kept) + $\beta 12$(production system) + $\beta 13$(location) +

$\beta 14$(extension services) + $\beta 15$(pig marketing training) + ε, where; $\beta 0$ = Intercept, $\beta 1$, …, $\beta 15$ = Coefficients and ε = Error. Probability values were considered significant at 5% ($P \leq 0.05$).

TABLE 1: Description of Socio-Economic Factors Influencing Pork Marketing Practices and Challenges of Smallholder Farmers in the Cape Metropole District, South Africa

Independent variable	Description of independent variables
Gender	Gender of the farmer (1 = Male, 0 = Female)
Age	Age of the farmer [1 = Youth (40 years and younger) 0 = Elderly adults (older than 40)]
Religion	Religion of the farmer (1 = Christian, 0 = None/ Traditional)
Education level	Educational level of the farmer (1 = No formal education to primary education, 0 = Secondary to tertiary education)
Farming experience	Farming experience of the farmer (1 = 10 years and less, 0 = More than 10 years)
Workforce	Type of workforce used by the farmer (1 = None/ family labour, 0 = Paid labour)
Sources of income	Source of income [1 = Pig sales only (primary), 0 = Other sources of income (secondary)]
Farm size	Farm size [1 = Small (less than $500m^2$), 0 = Large ($500m^2$ and more)]
Type of livestock kept	Type of livestock kept by the farmer (1 = Pigs only/ monoculture, 0 = Other livestock/ /multispecies)
Herd size	Herd size [1 = Small (30 pigs and less), 0 = Large (More than 30 pigs)]
Type of breeds kept	Type of pig breeds kept by the farmer (1 = Exotic only, 0 = Indigenous and their crossbreds)
Production system	Production system practiced by the farmer (1 = Intensive, 0 = Extensive/ Semi-intensive)
Location	Location of the farm [1 = Township (on-plot), 0 = Farmland (off-plot)]
Extension services	Framer receiving agricultural extension services (1 = Yes, 0 = No)
Pig production training	Farmer receiving pig production training (1 = Yes, 0 = No)

3. RESULTS

3.1. Attributes of the Farmers and Pig Herds

Farmer and herd attributes were reported in a companion study by Mathobela *et al.* (2024b). Briefly, most participants were men, practised Christianity, aged 36-60 years, secondary school graduates, and had more than six years of experience in pig farming. In addition, the majority of the surveyed participants farmed on small, privately owned farms and relied primarily on unpaid family labour and income from the sale of live pigs and pork. Pigs were mainly raised for sale and consumption. In the surveyed suburbs, pig herd sizes ranged between 24 and 36. Participants in the surveyed suburbs also raised chickens, cattle, sheep and goats.

3.2. Pig Weighing Practices

Only 4% of the farmers weighed the pigs, and over 80% used visual body appearance to estimate pig weight, with more respondents from Khayelitsha, Mfuleni, and Penhill ($\chi^2 = 22.63$; $\varphi_c = 0.53$; $P \leq 0.05$) than the other suburbs. No differences ($P > 0.05$) were observed in the body weight of mature pigs across the five suburbs (Table 2).

TABLE 2: Mean (± standard error) for Pig and Pork Marketing Characteristics in Smallholder Farms in the Cape Metropole District, South Africa

Marketing performance	**Eerste River**	**Khayelitsha**	**Mfuleni**	**Penhill**	**Strand**	***P* value**
Pig body weight (kg)	110.0 ± 28.05	74.0 ± 7.02	126.3 ± 25.40	99.0 ± 13.01	87.5 ± 22.50	0.7547
Pig sales per year	33.4 ± 21.30	7.9 ± 1.06	13.2 ± 2.86	38.1 ± 9.23	7.1 ± 1.19	0.1887
Pig slaughtered per year	8.3 ± 2.19[ab]	5.8 ± 1.29[b]	10.8 ± 2.05[ab]	27.8 ± 14.5[a]	10.4 ± 3.97[ab]	0.0352
Price of mature pig (R)	2 494 ± 171	2 623 ± 218	2 903 ± 266	2 709 ± 164	2 229 ± 149	0.1980
Price of carcass (R)	2 000 ± 289[ab]	2 580 ± 314[ab]	3 236 ± 252[a]	2 167 ± 667[ab]	1 967 ± 260[b]	0.0373
Price of pork cuts (R)	85 ± 27.2	35 ± 10.9	93 ± 29.2	90 ± 60.0	30 ± 11.5	0.1535

Distance to market (km)	9.8 ± 2.27	6.8 ± 3.86	11.8 ± 3.84	17.1 ± 1.41	19.1 ± 4.02	0.0648

[a, b]: Least square means in the same row not sharing a common superscript are significantly different (P ≤ 0.05); kg: kilogram; R: rands; km: kilometre

Farmers who weighed pigs only did so prior to slaughter or selling. The likelihood of using visual weight estimation for pigs decreased (P ≤ 0.05) by 304, to 327%, with a unit increment in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 3).

TABLE 3: Socio-economic Factors Influencing Key Pork Marketing Practices Adopted by Smallholder Pig Farmers in the Cape Metropole District, South Africa

Variable	Margin	Standard Error	t Value	P>|t|	[95% Conf. Interval]	
Visual weight estimation						
Gender	-3.2658	0.4557	-7.17	<.0001	-4.1589	-2.3727
Age	-3.2581	0.4557	-7.15	<.0001	-4.1513	-2.3649
Religion	-3.2504	0.4558	-7.13	<.0001	-4.1437	-2.3570
Education level	-3.2504	0.4558	-7.13	<.0001	-4.1437	-2.3570
Farming experience	-3.2108	0.4561	-7.04	<.0001	-4.1049	-2.3168
Workforce	-3.2426	0.4559	-7.11	<.0001	-4.1361	-2.3491
Sources of income	-3.2734	0.4556	-7.18	<.0001	-4.1663	-2.3804
Farm size	-3.0350	0.4578	-6.63	<.0001	-3.9323	-2.1376
Type of livestock	-3.2734	0.4556	-7.18	<.0001	-4.1663	-2.3804
Herd size	-3.2734	0.4556	-7.18	<.0001	-4.1663	-2.3804
Type of breeds kept	-3.2581	0.4557	-7.15	<.0001	-4.1513	-2.3649
Production system	-3.2734	0.4556	-7.18	<.0001	-4.1663	-2.3804
Location	-3.2734	0.4556	-7.18	<.0001	-4.1663	-2.3804
Extension services	-3.2504	0.4558	-7.13	<.0001	-4.1437	-2.3570
Pig production training	-3.2658	0.4557	-7.17	<.0001	-4.1589	-2.3727

Marketing organization membership						
Gender	-1.6848	0.2270	-7.42	<.0001	-2.1298	-1.2398
Age	-1.7292	0.2313	-7.47	<.0001	-2.1827	-1.2758
Religion	-1.7047	0.2318	-7.36	<.0001	-2.1590	-1.2505
Education level	-1.7211	0.2315	-7.44	<.0001	-2.1748	-1.2674
Farming experience	-1.6796	0.2322	-7.23	<.0001	-2.1348	-1.2245
Workforce	-1.7130	0.2316	-7.40	<.0001	-2.1670	-1.2590
Sources of income	-1.6848	0.2270	-7.42	<.0001	-2.1298	-1.2398
Farm size	-1.4837	0.2361	-6.28	<.0001	-1.9465	-1.0208
Type of livestock	-1.6928	0.2269	-7.46	<.0001	-2.1375	-1.2481
Herd size	-1.6928	0.2269	-7.46	<.0001	-2.1375	-1.2481
Type of breeds kept	-1.6767	0.2272	-7.38	<.0001	-2.1219	-1.2314
Production system	-1.6928	0.2269	-7.46	<.0001	-2.1375	-1.2481
Location	-1.6928	0.2269	-7.46	<.0001	-2.1375	-1.2481
Extension services	-1.6767	0.2272	-7.38	<.0001	-2.1219	-1.2314
Pig production training	-1.6848	0.2270	-7.42	<.0001	-2.1298	-1.2398
Farmgate marketing channel usage						
Gender	1.5686	0.2458	6.38	<.0001	1.0869	2.0504
Age	1.4988	0.2414	6.21	<.0001	1.0257	1.9718
Religion	1.4773	0.2418	6.11	<.0001	1.0033	1.9513
Education level	1.5686	0.2458	6.38	<.0001	1.0869	2.0504
Farming experience	1.6205	0.2580	6.28	<.0001	1.1149	2.1261
Workforce	1.4773	0.2418	6.11	<.0001	1.0033	1.9513
Sources of income	1.5094	0.2411	6.26	<.0001	1.0367	1.9820
Farm size	1.5235	0.2677	5.69	<.0001	0.9989	2.0481
Type of livestock	1.5198	0.2409	6.31	<.0001	1.0477	1.9920
Herd size	1.5198	0.2409	6.31	<.0001	1.0477	1.9920
Type of breeds kept	1.5581	0.2460	6.33	<.0001	1.0760	2.0403
Production system	1.5198	0.2409	6.31	<.0001	1.0477	1.9920
Location	1.5198	0.2409	6.31	<.0001	1.0477	1.9920
Extension services	1.5476	0.2462	6.28	<.0001	1.0649	2.0302

Pig production training	1.5686	0.2458	6.38	<.0001	1.0869	2.0504
Seeking financial support						
Gender	-2.2882	0.2805	-8.16	<.0001	-2.8379	-1.7384
Age	-2.2809	0.2806	-8.13	<.0001	-2.8309	-1.7310
Religion	-2.2588	0.2809	-8.04	<.0001	-2.8093	-1.7083
Education level	-2.2809	0.2806	-8.13	<.0001	-2.8309	-1.7310
Farming experience	-2.2285	0.2813	-7.92	<.0001	-2.7798	-1.6772
Workforce	-2.2662	0.2808	-8.07	<.0001	-2.8165	-1.7159
Sources of income	-2.2882	0.2805	-8.16	<.0001	-2.8379	-1.7384
Farm size	-2.0523	0.2839	-7.23	<.0001	-2.6087	-1.4958
Type of livestock	-2.2954	0.2804	-8.19	<.0001	-2.8450	-1.7458
Herd size	-2.2954	0.2804	-8.19	<.0001	-2.8450	-1.7458
Type of breeds kept	-2.2809	0.2806	-8.13	<.0001	-2.8309	-1.7310
Production system	-2.2954	0.2804	-8.19	<.0001	-2.8450	-1.7458
Location	-2.2954	0.2804	-8.19	<.0001	-2.8450	-1.7458
Extension services	-2.3550	0.2902	-8.11	<.0001	-2.9238	-1.7862
Pig production training	-2.3695	0.2900	-8.17	<.0001	-2.9380	-1.8011

Poor pig growth rate (54% of respondents) was the most common challenge experienced by the farmers across all five suburbs. To avert this challenge, farmers suggested providing the pigs with supplementary feed (49% of respondents), adequate medicine (9%), minimising inbreeding (9%) and acquiring training on pig husbandry (9%) as solutions. The probability of pig farmers experiencing a slow growth rate in pigs was not influenced ($P > 0.05$) by any of the investigated predictor variables.

3.3. Pig Slaughtering Practices

Across the five suburbs, 61% of the farmers slaughtered pigs on-farm, with more respondents ($\chi2 = 23.56$; $\varphi c = 0.39$; $P \leq 0.05$) coming from Mfuleni compared to the other suburbs. Penhill had a greater ($P \leq 0.05$) number of pigs slaughtered annually than Khayelitsha (Table 2). Porkers (56%), baconers (37%), and weaners (18%) were the most slaughtered pig classes. Sixty percent of the farmers did not experience slaughter-related challenges. The remaining

40% faced several slaughter challenges, including unavailability of slaughtering facilities (13%), high slaughter costs (7%), restraint bars (6%) and stunning equipment (5%), insufficient energy to boil scalding water (5%) and lack of refrigerators for carcass preservation (4%). Most (74%) of the farmers proposed building a proper slaughtering facility as one of the slaughter solutions. However, 5% suggested access to information on recommended slaughter practices, use of offal as a payment method to reduce slaughter costs, selling live pigs only, storage of wood for boiling scalding water in a dry place, and provision of electricity for operating the refrigerator as possible solutions that they could implement to counteract challenges associated with pig slaughter. The likelihood of lacking slaughter facilities decreased ($P \leq 0.05$) by 190 to 215%, with a unit increase in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 4).

TABLE 4: Socio-economic Factors Influencing Key Pork Marketing Constraints Experienced by Smallholder Pig Farmers in the Cape Metropole District, South Africa

Variable	Margin	Standard Error	t Value	P>|t|	[95% Conf. Interval]	
Absence of slaughtering facilities						
Gender	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Age	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Religion	-1.9042	0.4051	-4.70	<.0001	-2.6983	-1.1102
Education level	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Farming experience	-2.1001	0.4325	-4.86	<.0001	-2.9478	-1.2523
Workforce	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Sources of income	-1.9253	0.4046	-4.76	<.0001	-2.7183	-1.1323
Farm size	-2.1518	0.4725	-4.55	<.0001	-3.0778	-1.2257
Type of livestock	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Herd size	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Type of breeds kept	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Production system	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Location	-1.9459	0.4041	-4.82	<.0001	-2.7379	-1.1540
Extension services	-2.0794	0.4330	-4.80	<.0001	-2.9281	-1.2308

Pig production training	-1.9253	0.4046	-4.76	<.0001	-2.7183	-1.1323
Shortage of customers						
Gender	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Age	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Religion	-1.7391	0.3007	-5.78	<.0001	-2.3285	-1.1497
Education level	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Farming experience	-1.6977	0.3017	-5.63	<.0001	-2.2890	-1.1065
Workforce	-1.7391	0.3007	-5.78	<.0001	-2.3285	-1.1497
Sources of income	-1.7391	0.3007	-5.78	<.0001	-2.3285	-1.1497
Farm size	-1.9459	0.3563	-5.46	<.0001	-2.6443	-1.2475
Type of livestock	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Herd size	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Type of breeds kept	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Production system	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Location	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Extension services	-1.7391	0.3007	-5.78	<.0001	-2.3285	-1.1497
Pig production training	-1.7525	0.3004	-5.83	<.0001	-2.3414	-1.1637
Difficulties in finding information						
Gender	-1.4078	0.2326	-6.05	<.0001	-1.8637	-0.9519
Age	-1.3545	0.2290	-5.92	<.0001	-1.8033	-0.9058
Religion	-1.3106	0.2300	-5.70	<.0001	-1.7614	-0.8598
Education level	-1.3971	0.2329	-6.00	<.0001	-1.8535	-0.9407
Farming experience	-1.3754	0.2334	-5.89	<.0001	-1.8328	-0.9179
Workforce	-1.3652	0.2287	-5.97	<.0001	-1.8135	-0.9170
Sources of income	-1.3545	0.2290	-5.92	<.0001	-1.8033	-0.9058
Farm size	-1.8659	0.2980	-6.26	<.0001	-2.4500	-1.2817
Type of livestock	-1.3652	0.2287	-5.97	<.0001	-1.8135	-0.9170
Herd size	-1.3652	0.2287	-5.97	<.0001	-1.8135	-0.9170
Type of breeds kept	-1.3545	0.2290	-5.92	<.0001	-1.8033	-0.9058

Production system	-1.3652	0.2287	-5.97	<.0001	-1.8135	-0.9170
Location	-1.3652	0.2287	-5.97	<.0001	-1.8135	-0.9170
Extension services	-1.3437	0.2292	-5.86	<.0001	-1.7930	-0.8945
Pig production training	-1.4078	0.2326	-6.05	<.0001	-1.8637	-0.9519
Scarcity of production inputs						
Gender	-1.1100	0.2141	-5.18	<.0001	-1.5297	-0.6904
Age	-1.1100	0.2141	-5.18	<.0001	-1.5297	-0.6904
Religion	-1.1585	0.2206	-5.25	<.0001	-1.5909	-0.7261
Education level	-1.0986	0.2144	-5.12	<.0001	-1.5189	-0.6784
Farming experience	-1.1221	0.2176	-5.16	<.0001	-1.5486	-0.6957
Workforce	-1.1213	0.2138	-5.24	<.0001	-1.5404	-0.7023
Sources of income	-1.1100	0.2141	-5.18	<.0001	-1.5297	-0.6904
Farm size	-0.9527	0.2265	-4.21	<.0001	-1.3967	-0.5086
Type of livestock	-1.1213	0.2138	-5.24	<.0001	-1.5404	-0.7023
Herd size	-1.1213	0.2138	-5.24	<.0001	-1.5404	-0.7023
Type of breeds kept	-1.1100	0.2141	-5.18	<.0001	-1.5297	-0.6904
Production system	-1.1213	0.2138	-5.24	<.0001	-1.5404	-0.7023
Location	-1.1213	0.2138	-5.24	<.0001	-1.5404	-0.7023
Extension services	-1.1451	0.2170	-5.28	<.0001	-1.5704	-0.7199
Pig production training	-1.1100	0.2141	-5.18	<.0001	-1.5297	-0.6904

3.4. Pig and Pork Marketing Practices

Across all five suburbs, income was primarily generated by selling live pigs (52% of respondents), carcasses (18%), or a combination of both (29%). Eerste River had more (χ^2 = 34.03; φ_c = 0.34; P ≤ 0.05) respondents who sold live pigs than the other suburbs. There were no differences (P > 0.05) in annual pig sales, price of mature live pigs, retail cuts, and distance to the market across the five suburbs (Table 2). However, Mfuleni had higher (P ≤ 0.05) prices for whole/half carcasses than Strand (Table 2). The likelihood of pig farmers selling live pigs was not influenced (P > 0.05) by any of the investigated predictor variables. About two-thirds of farmers sold whole carcasses and retail cuts of pork. The class of pigs commonly sold were porkers (56% of respondents), baconers (40%), and weaners (35%). Pigs were mainly sold to the local community (73% of respondents), with Khayelitsha having more (χ^2 = 37.75; φ_c = 0.34; P ≤ 0.05) sales than the other suburbs. Only 18% and 6% of the pigs were sold to informal traders and family members, respectively. A total of 54% of pigs were transported to the market in small trucks and 13% by trailers. The transport was arranged either by the buyers (69% of respondents), farmers (28%), or middlemen (3%). About 85% of the farmers belonged to a marketing organisation that largely provided information on pig production (55% of respondents), neighbourhood watch (14%), pig sales (9%), and access to land (9%). Farmers who did not participate in any organisations cited lack of representation (36%), provision of inadequate information (20%), and perceived no value in joining (19%) as the main reasons. The probability of a farmer to be a member of a marketing organisation decreased (P ≤ 0.05) by 148 to 173%, with a unit rise in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 3).

Farmgate (82% of respondents) was the dominant marketing channel used by the farmers, followed by the use of middlemen (9%), abattoirs (8%), and auctions (3%). Farmgate markets were primarily used due to convenience (71% of respondents), the lack of alternatives (9%), and limited funds (9%). The likelihood of farmers to adopt the farmgate marketing channel increased (P ≤ 0.05) by 148 to 162%, with a unit increment in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 3). Farmers who opted to work with middlemen for marketing purposes did so based on network referrals (57% of respondents) or convenience (43%). Four-fifths of the farmers used the formal market for convenience, while 13% and 7% benefited from better management and competitive prices for the product, respectively. Most farmers (79% of respondents) preferred to sell their pigs throughout the year, whereas 8% and 13% sold pigs in the wet and dry seasons, respectively. A large flock size (67% of respondents) and regular cash flow (20%) were the main reasons why farmers preferred to sell pigs all year round. Two-fifths of farmers did not encounter pork marketing challenges. However, some farmers reported a lack of clientele (15%), absence of formal markets (9%), non-payments from clients who purchase on credit (7%), negative perceptions of pork healthfulness (7%), limited marketing exposure (6%), inadequate marketing tools (6%) and unreliable markets (5%) as other challenges. Farmers offered a variety of marketing solutions including marketing training

(23%), access to formal markets (15%), assistance in advertising (13%), producing high-quality pigs (10%), using reliable markets (5%), selling pigs or pork for cash (5%), maintaining stable selling prices (5%) and growing herd size (5%). The probability of farmers experiencing customer shortage decreased ($P \leq 0.05$) by 170 to 195%, with a unit increase in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 4).

3.5. Agricultural Support Services

An overview of the extension and veterinary services received by smallholder pig farmers in the Cape Metropole District, South Africa, is presented in Table 5. Two-fifths of the farmers received information about pig marketing from the other farmers, while 17% accessed it from social media, 13% from customers, and 10% from elders. Only 18% of the farmers received extension services, and 82% of these services came from government departments. Mfuleni had more ($\chi^2 = 16.75$; $\varphi_c = 0.33$; $P \leq 0.05$) respondents who received extension services than other suburbs. The extension services were provided to nearly 40% of the farmers on a need-to-know basis, while the rest received the services on either a quarterly (30%) or annual basis (17%). Only 28% of the farmers received veterinary care, with more respondents ($\chi2 = 26.63$; $\varphi c = 0.42$; $P \leq 0.05$) coming from Penhill than from the other suburbs. The government provided nearly three-quarters of the veterinary services, with Khayelitsha receiving more ($\chi^2 = 15.97$; $\varphi_c = 0.43$; $P \leq 0.05$) services compared to other suburbs. The frequency of farmers receiving veterinary services was mainly quarterly (41%) or as needed (34%).

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TABLE 5: Extension and Veterinary Services Received by Smallholder Pig Farmers in the Cape Metropole District, South Africa

Data variable	**Class**	**Eerste River (%)**	**Khayelitsha (%)**	**Mfuleni (%)**	**Penhill (%)**	**Strand (%)**	**Total (%)**	φ_c	χ^2	***P* value**
Extension and advisory services										
Receiving extension services?	Yes	25.0	2.8	39.3	14.3	10.7	17.8	0.3319	16.7445	0.0022
	No	75.0	97.2	60.7	85.7	89.3	82.2			
Veterinary services										
Receiving veterinary services?	Yes	42.4	5.6	37.9	50.0	7.1	27.9	0.4158	26.6291	<.0001
	No	57.6	94.4	62.1	50.0	92.9	72.1			
Veterinary services sector	Government	84.6	100	90.9	64.3	0	74.4	0.4309	15.9703	0.0428
	Private	7.7	0	9.1	28.6	100	20.9			
	NGO	7.7	0	0	7.1	0	4.7			
Training services										
Receiving training services?	Yes	37.5	13.9	37.9	28.6	0	23.4	0.3426	18.0717	0.0012
	No	62.5	86.1	62.1	71.4	100	76.6			

φ_c: Cramer's V; χ^2: Chi-square

One-fifth of the farmers in each of the five surveyed suburbs acquired training services, with government officials providing 74% of them (Table 5). Eerste River and Mfuleni had more respondents ($\chi2 = 18.07$; $\varphi c = 0.34$; $P \leq 0.05$) who received training services than other suburbs. Two-fifths of the farmers received need-based training when necessary, while one-third received training on an annual basis. According to respondents, the training received covered the pig value chain (36% of respondents), pig production (27%), and animal health (15%), with Eerste River having the highest number of respondents who received training ($\chi^2 = 44.57$; $\varphi_c = 0.67$; $P \leq 0.05$). Only 9% of the farmers received financial support once, and the support was mainly from the government (83%). The probability of seeking financial support decreased ($P \leq 0.05$) by 205 to 237%, with a unit rise in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 3).

Farmers across all five suburbs reported experiencing a scarcity of production inputs (25%), limited access to information on pig production and marketing (20%), lack of service delivery (18%), not receiving feedback after farm visits from extension officers (6%), farming on illegal communal land (5%), lack of training and advice (4%) and no farm visits by extension officers (3%). According to the farmers, possible solutions proposed included the provision of production inputs (30%), delivering need-based training (23%), advocating for more site visits by extension officials (15%), establishing proper communication channels (15%), employing more government extension personnel (6%) and acquiring title deeds to land (4%). The likelihood of encountering difficulties in finding information and scarcity of production inputs decreased ($P \leq 0.05$) by 131 to 187% and 100 to 120%, respectively, with a unit rise in males, youths, Christians, level of education, farming experience, family labour, sources of income, farm size, type of livestock kept, herd size, use of exotic breeds, intensive and on-plot farming, extension services, and training in pig production (Table 4).

4. DISCUSSION

The information obtained from this study provides insight into the pig marketing practices and agricultural support services adopted by urban smallholder pig farmers, as well as the accompanying challenges in the Cape Metropole District, South Africa. In agreement with the current study, most smallholder pig farmers used visual appraisal to determine the weight of pigs before slaughter and sale (Berihu & Tamir, 2016; Mulindwa *et al*., 2016; Mutua *et al*., 2020). As a result, farmers are often exploited by buyers who undervalue and underpay for their pigs (Mugonya *et al*., 2021; Mulindwa *et al*., 2016; Ouma *et al*., 2015). The use of the visual weight estimation method could be related to the unavailability of farm resources such as weighing scales, which are costly (Kimbi *et al*., 2016). Due to its drawbacks, the visual weight estimation method offers a more suitable alternative, providing a comparatively precise, reliable, and affordable method for estimating the live weight of pigs for resource-limited farmers (Kabululu, 2023). The decline in farmers' probability of visually estimating pig weight, given a unit increase in farming experience, education level, extension services, and production training, was expected. This could be explained by the fact that resourceful and knowledgeable farmers often utilise technology, which may include weighing scales, rather than the visual weight estimation method. The decrease in the likelihood of using the visual weight estimation method among more educated farmers agrees with Mulindwa *et al*. (2016), who reported that knowledge and information on pig husbandry positively influence farmers' ability to weigh their pigs.

The majority of respondents in the survey practised on-farm pig slaughtering, confirming earlier reports by Qekwana and Oguttu (2014). The decreased likelihood of lacking slaughtering facilities, with a unit increase in the number of Christians, could be attributed to Christianity's humane animal welfare practices (Adam *et al*., 2019). The decline in the probability of not having slaughter facilities, with a unit increase in males, could be related to the observation that men have greater access to resources and are frequently in charge of tasks requiring strength, expertise, and abilities such as slaughtering. At the same time, women have limited access to resources and are primarily responsible for mundane household tasks (Nguyen-Thi-Duong *et al*., 2022). The observed positive influence of extension services and training on ownership of slaughtering facilities may have been attributed to farmers being more knowledgeable about on-farm informal pig slaughter, meat safety regulations, and inappropriate meat handling that can pose a health risk to customers (Dietze, 2011; Mutua *et al*., 2020). Additionally, farmers who sell slaughtered pigs typically pay substantial transaction expenses, including expensive fees for slaughter, cold storage and transportation (Antwi & Seahlodi, 2011).

Farmers sold live pigs more frequently than carcasses or meat, confirming previous findings by Shongwe *et al*. (2020), who reported that 68% of farmers sold live pigs, while 57%

slaughtered for household consumption. The high sales of live pigs may be attributed to several factors, primarily driven by farmers' preference due to convenience or the absence of slaughter facilities among smallholder farmers (Atherstone et al., 2019; Mathobela et al., 2024a, 2025; Ndwandwe & Weng, 2018). To ensure the efficient marketing of pork, the provision of low-cost slaughterhouses or mobile abattoirs, along with information about formal markets, is recommended (Atherstone *et al*., 2019; Ndwandwe & Weng, 2018). Despite a high number of live pig sales, socio-economic factors had no influence on the mode of sale. This study found that price differentials between suburbs may be linked to a lack of market information, differences in pig live weight estimation skills and price bargaining power among urban smallholder pig farmers (Le *et al*., 2016).

Informal slaughter without proper meat inspection was a common practice among urban smallholder pig farmers. Such a practice poses health risks to consumers (Mutua *et al*., 2020). As a result, this could lower pork sales from the informal market and reduce profit for the urban smallholder pig producers (Dietze, 2011). The influence of age on the shortage of customers agrees with the study by Madzimure *et al*. (2014), who reported that young farmers (<30 years) had better chances of selling pigs than older farmers. The age of pig farmers is directly related to their condition as human resources, who manage the day-to-day production and marketing of pigs, and have a direct impact on working productivity (Ajala & Adesehinwa, 2008; Manese *et al.*, 2016).

Regarding education and training, similar findings were reported where farmers with more knowledge of pig husbandry and marketing practices sold more pigs than those without such knowledge (Madzimure *et al*., 2014). Educated farmers with access to updated market information possess stronger market networking, negotiating power, and enterprise management skills, and are more likely to adopt new technological advances in farming, thereby increasing their market access (Tilahun *et al*., 2023). The finding that herd size positively influences the customer base aligns with the study by Antwi and Seahlodi (2011), who reported that smallholder pig farmers who produce on a reasonably large and effective scale have access to high-value markets and higher profit margins. Additionally, they may utilise crossbreeding systems to expand the breeding herd, as this strategy has been proven beneficial for commercial pork producers.

The shortage of customers experienced by the pig farmers in the current study is not surprising. It is possible that some people in the community may not accept pigs due to cultural, spiritual, and religious reasons (Weka *et al*., 2021). Additionally, some individuals refrain from consuming pork due to financial constraints and personal taste preferences (Roesel *et al*., 2019). Some consumers perceive pork as being less healthy and more oily than beef and lamb, which is contrary to its high proportion of health-beneficial polyunsaturated fatty acids (Roesel *et al*., 2019).

The finding that non-membership in farmers' associations or organisations is one of the major constraints faced by urban smallholder pig farmers concurs with previous reports (Kirima *et al*., 2017). The active participation of farmers in agribusiness associations serves as a source of empowerment, facilitating access to the market and the sharing of technical knowledge and information (Mugonya *et al*., 2021; Nwachukwu & Udegbunam, 2020; Ouma *et al*., 2015). In this regard, farmers have been recommended to leverage the opportunities offered by such agribusiness organisations to enhance production efficiency, herd size, value-added, and market share (Ndwandwe & Weng, 2018).

The finding that socio-economic factors influence the likelihood of farmers having a marketing organisation has been reported previously (Dietze, 2011; Ouma *et al*., 2015). Gender had an influence on market organisation in the current study, and the dominance of men reduced the likelihood of farmers adopting such associations. The decrease in the likelihood of men's affiliation with farmer organisations can be attributed to the gender-sensitive and women's empowerment policies of urban farmers' organisations, which specifically target women (Ouma *et al*., 2015). However, it has also been observed that women in the pig farming sector tend to frequently face social obstacles that limit their ability to take the lead in marketing sectors (Dietze, 2011). Regarding knowledge transfer, some marketing programmes are based on membership, and smallholder farmers who do not operate in organised groups seldom receive agricultural advisory services (Tatwangire, 2013). This explains the effect of extension services on adopting marketing organisation in the current study. Thus, farmers operating in isolation and who have limited exposure to extension services tend to inadvertently limit their production performance due to the difficulties of collectively sourcing funding, accessing markets, and controlling market prices (Ndwandwe & Weng, 2018).

The identification of farmgate and middlemen as the dominant marketing channels used by the farmers agrees with previous research (Abu *et al*., 2016; Berihu & Tamir, 2015; Levy *et al.*, 2013). On the one hand, although farmgate sales are less remunerative, they are convenient, reduce transportation costs, and mitigate stress-related losses in pigs (Berihu & Tamir, 2015).

On the other hand, sales through middlemen play a crucial role by linking farmers to end markets, reducing the costs and risks associated with maintaining a market, and often offering better prices (Mutua *et al*., 2020). However, middlemen can take a large share of the profits in the value chain, thereby limiting smallholder farmers' opportunities for upgrading (Abebe *et al*., 2016).

The influence of education level, training, and extension services on pig and pork marketing channels was expected. The less knowledgeable and informed smallholder pig farmers often lack animal husbandry skills and the ability to network, resulting in struggles with increasing production and securing reliable markets (Madzimure *et al.,* 2014). Similarly, location influenced farmers' adoption of the market channel, with on-plot farmgate sales being the preferred choice over off-plot sales. This is because on-plot farmers are located near urban areas, away from farmlands, which renders their pig sales easily accessible (Madzimure *et al*., 2014). Besides these factors, breed choice also influenced pig production, with farmers having a higher preference for exotic breeds due to their larger body size and faster growth rates compared to indigenous breeds (Ouma *et al*., 2015). As expected, farmers who rear exotic breeds had greater sales and marketing options. Thus, even though some farmers raised and valued indigenous breeds for their meat in the current study, no effort had been made to improve the local breeds into the niche market due to their small body size, slow growth rate and perceivably inferior carcass quality (Halimani *et al*., 2010; Madzimure *et al.,* 2014).

The lack of agricultural support services, including access to extension, training, agribusiness, and financial services reported in the present survey corresponds with previous reports (Atherstone *et al*., 2019; Nwachukwu & Udegbunam, 2020). The lack of agricultural support services may result in inadequate information, poor skill development, and ineffective farm management (Nwachukwu & Udegbunam, 2020). Most of the agricultural support services in the surveyed areas were provided by government-affiliated organisations; however, challenges remain concerning the capacity of the personnel responsible for disseminating these services. Therefore, training government extension officers on how to disseminate knowledge to farmers could improve the production capacity and market access of urban smallholder pig farmers (Mathobela *et al*., 2024a; Ndwandwe & Weng, 2018). Financing is a critical barrier for urban smallholder farmers to transform into market-oriented production (Dietze, 2011). Smallholder farmers are often overlooked by financial institutions because they lack the collateral to secure loans or other forms of financial support. Additionally, cultural barriers among farmers influence their reluctance to acquire loans (Okello *et al*., 2021). Therefore, it is essential for governments, donors, and other development actors to develop innovative models that provide a comprehensive package of inputs, support, and financing for urban smallholder pig farmers (Okello *et al*., 2021).

All the investigated socio-economic factors influenced the provision of financial support, but sources of income and herd size were the most prominent. The influence of income source and herd size on the provision of financial support was expected, as smallholder farmers with multiple income sources tend to maintain large herd sizes because they can afford the necessary production inputs (Dietze, 2011). Key production inputs in pig farming (i.e., feed, medicines and slaughter equipment) are costly but essential for efficient pig production and marketing (Dietze, 2011), warranting government support. It was not surprising that pig farmers with small herd sizes, due to a lack of finance, were unable to restructure their production into a market-driven model.

5. CONCLUSIONS AND RECOMMENDATIONS

The main challenges faced by urban smallholder farmers in the studied low-income suburbs were slow pig growth rates, scarcity of production inputs, and difficulties in accessing marketing information. The use of the farmgate marketing channel and sales of live pigs were the key sustainable marketing practices adopted by smallholder pig farmers in the surveyed areas. The likelihood of farmers to encounter marketing challenges and not to adopt sustainable marketing practices was high among the women, older, African traditional religion adherents, and those with less farming experience, education, training, and access to extension services, as well as those that relied on paid labour and on only one source of income, farmed extensively and off-plot, owned small farms, one livestock type, indigenous breeds, and small pig herds. Considering these farmers' socio-economic factors can guide the creation of effective pig marketing strategies, ultimately increasing market access and the sustainability of small urban pig farming enterprises in developing countries. To ensure consistency of supply and sustainable access to high-value markets, urban smallholder farmers are encouraged to network with key value chain actors, identify markets and understand their specifications prior to production.

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Agricultural Shocks and Constraints Encountered by Independent Smallholder Irrigators in Msinga Local Municipality, KwaZulu-Natal Province of South Africa

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ABSTRACT

Smallholder farmers' market participation is an effective vehicle for securing better incomes, reducing poverty, and enhancing household food security, especially in rural areas. However, smallholders face various challenges that prevent them from benefiting from the opportunities in agricultural output markets. This article aimed to identify the agricultural-related shocks and constraints that independent smallholder irrigators in the Msinga local municipality faced and recommend several techniques to help tackle these challenges, improving their livelihoods. The 101 survey participants were selected using snowball sampling, while the four participants in the Focus Group Discussion were purposively selected. The findings suggest that the primary issues facing Msinga irrigators were drought, inadequate access to production inputs and the infestation of pests and diseases. As a result, crop failure affecting nine out of ten irrigators was unavoidable among these smallholders. If smallholder farmers can access comprehensive agricultural support services, they may be able to tackle these issues and boost farm production and market participation. Creating an enabling environment to improve irrigation water access can help mitigate drought difficulties. Including independent irrigators in the government's existing extension support services could provide irrigators with assistance from agricultural advisors who are knowledgeable in pest and disease awareness and control.

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Keywords: Agricultural Extension, Crop Production, Droughts, Market Participation, Production Inputs.

1. INTRODUCTION

In 2016, the number of agricultural households in South Africa was 2.3 million, with over two-thirds residing in KwaZulu-Natal, the Eastern Cape, and Limpopo (Statistics South Africa, 2016). According to the 2016 South African national community survey, KwaZulu-Natal recorded the country's highest number of agricultural households (23.0%) (Statistics South Africa, 2016). Within KwaZulu-Natal, slightly over two-fifths (44.0 %) practised agriculture as a secondary source of income, while two-fifths (40.8%) practised agriculture as a primary source of income. In the study area, Msinga Local Municipality, agriculture is still primarily used for subsistence (Dearlove, 2007; Sinyolo *et al*., 2014) due to unfavourable climatic conditions and poor soil quality (Msinga Local Municipality, 2020).

Hence, most farm produce is for domestic consumption rather than the output market. Generally, smallholders' market participation enables them to combat rural poverty and food insecurity (Jagwe *et al*., 2010; Zanella *et al*., 2012). Producing for the market requires the use of resources such as land, water, on-farm and off-farm infrastructure, labour force, capital, and effective resource management (Baloyi, 2010). Meanwhile, rural smallholder farmers' ability to benefit from opportunities in agricultural markets is hindered by a lack of access to these resources, particularly in terms of the quality and quantity of these assets. As a result, they cannot meet the high-quality standards set by fresh produce marketplaces, retailers, and food processors (Bienabe *et al*., 2004). Therefore, smallholders' poor participation in the crop market leads to low incomes, exposing them to food insecurity and a vicious cycle of poverty. Smallholders face several additional challenges in addition to a lack of access to essential resources, and these resources are vital for them to address or overcome these difficulties. The external environment in which people live presents these challenges, referred to as the vulnerability context within the Sustainable Livelihood Framework (DFID, 1999; Devereux, 2001). Shocks, trends, and seasonality are all part of the external environment, which affects the asset base (Erenstein, Hellin & Chandna, 2007). Human, livestock, or crop health shocks; natural disasters such as floods or earthquakes; economic shocks; conflicts, including national or foreign wars; and agricultural challenges, such as pests and diseases, are examples of shocks. Demographic trends, resource trends, trends in governance at national and international levels of economics, politics, and technology, decreasing farm sizes, and growing pest and disease levels are all thought to have a detrimental impact on livelihoods and are examples of trends (DFID, 1999; Chambers & Conway, 1991; Erenstein, Hellin & Chandna, 2000). Seasonality can be observed in pricing, goods, job opportunities, and the impact of weather patterns on agricultural production, livestock nutrition, and disease (DFID, 1999; Erenstein, Hellin, & Chandna, 2000).

In South Africa, agricultural extension is a potential tool for combating food insecurity and poverty. However, this has focused chiefly on smallholder irrigated schemes for decades, giving limited to no attention to the other smallholder categories, including independent irrigators, home or backyard gardeners and community gardens. South African independent irrigators lack an institutional home to administer agricultural extension and advisory services. As elsewhere in Africa, South African independent irrigators have not received government or formal institutional support (De Lange, 1994; Crosby *et al*., 2000). Vaughan (1997) concluded that there was limited to nonexistent support for independent irrigators. In the former Transkei, factors of production, assistance, and farmer support, as well as appropriate and sufficient land, capital, inputs, and labour, technical advice on irrigation systems, and information on crop water requirements and scheduling, were all inadequate (Vaughan, 1997). In a livelihood study of independent irrigators in Limpopo, only 38.8% reported receiving some production advice, while 28.6% received irrigation advice (Denison *et al*., 2016). Similar to the Greater Tzaneen Local Municipality, only 27.6% had received some production advice, and 24.1% received irrigation training. Grant assistance was nonexistent in both studies (Denison *et al*., 2016). The main question now is how smallholders can be supported to overcome these challenges and become market-driven. However, before one can respond to this and offer potential solutions, it is essential to assess the difficulties and limitations that independent irrigators face. Therefore, this paper aimed to identify the farming shocks and constraints encountered by independent smallholder irrigators in the Msinga Local Municipality. Policymakers are advised to consider various strategies when designing bottom-up intervention approaches to address the challenges faced by independent irrigators.

2. MATERIALS AND METHODS

2.1. Study Area Description

Msinga, a local municipality in South Africa's KwaZulu-Natal province, served as the research site. It measures 2,500 km² and has a population of 184,494 (Statistics South Africa, 2016). In most portions of the region, the climate is subtropical. Msinga receives an average rainfall of 600 mm, ranging from 400 mm to 900 mm yearly (Mkhabela, 2005; Sinyolo *et al*., 2018). Msinga temperatures are scorching, reaching 45 °C (Mthembu, 2014). Msinga is one of the province's poorest municipalities, having significant unemployment and poverty rates. Agriculture is critical to the livelihoods of Msinga inhabitants, although most remain impoverished. Statistics South Africa (2016) indicate that 55% of the 38,372 Msinga households practised agriculture in 2016.

However, agriculture in the area is highly subsistent and subject to the limited capacity of the land due to low soil quality, climatic conditions, and overstocking (Msinga Local Municipality, 2020).

2.2. Study Population and Selection

Survey participants included independent smallholder irrigators operating within the boundaries of Msinga's Local Municipality. The study participants were chosen using a snowball sampling technique. In the initial survey round, the researcher and field assistants were guided to other respondents with similar characteristics by agricultural advisors from the local office of the Department of Agriculture, resulting in 101 respondents. Of the 101 survey respondents, 41 were invited to participate in four Focus Group Discussions (FGDs). The grouping characteristics were the method of extracting irrigation water from the source and the location of the irrigators. This was more convenient in terms of cost and practicality. Additionally, the research aims to help irrigators feel more comfortable, as they share similar experiences. The irrigator's willingness to reflect and share their experiences prompted inclusion, as well as their availability on the phone and for the planned date of the scheduled FGD.

2.3. Data Collection and Analysis

Survey data were collected between November and December 2019 using a standardised questionnaire. The questionnaire gathered data on the household's shocks experienced in their irrigation during the last two years and other challenges and constraints in their irrigated enterprise. The face-to-face interviews with the respondents were conducted in isiZulu and documented on the interview schedule. After the survey data had been coded, it was entered into Microsoft Excel and the Statistical Package for the Social Sciences (SPSS) v27. The data was then examined using descriptive statistics using SPSS. The four groupings, designed to facilitate manageable discussions, were held at Mashunka and Paraffin villages between July 29 and 30, 2020. In-depth interaction included four focus groups, each with nine to twelve participants selected from the survey. Interview transcripts and voice recordings collected during the focus group interaction were subjected to Thematic Content Analysis. This information began with themes, and codes for variables of interest were grouped under these themes. Codes identified responses from the discussions. The coded responses were collated from all four groups.

3. RESULTS AND DISCUSSION

3.1. Shocks Faced by Independent Irrigators

Independent irrigators in Msinga faced various external shocks that hindered their agricultural production. The relative distribution of independent smallholder irrigators facing several shock events is shown in Figure 1. The common shock to agricultural production irrigators experienced two years before 2019 (data collection period) in Msinga was the problematic access to production inputs, the infestation of pests and diseases and droughts, resulting in crop failure. Irrigators in Msinga reported high prices for agricultural inputs as one of their significant shocks since they cannot afford to purchase them. Figure 1 shows that 80% of the 101 survey respondents in this study have experienced difficulties accessing production inputs, particularly seedlings. Their inadequate financial stability exacerbated this problem. In Msinga, 96% of the respondent group received income from the state through disability grants, child support, foster care, and old-age pensions.

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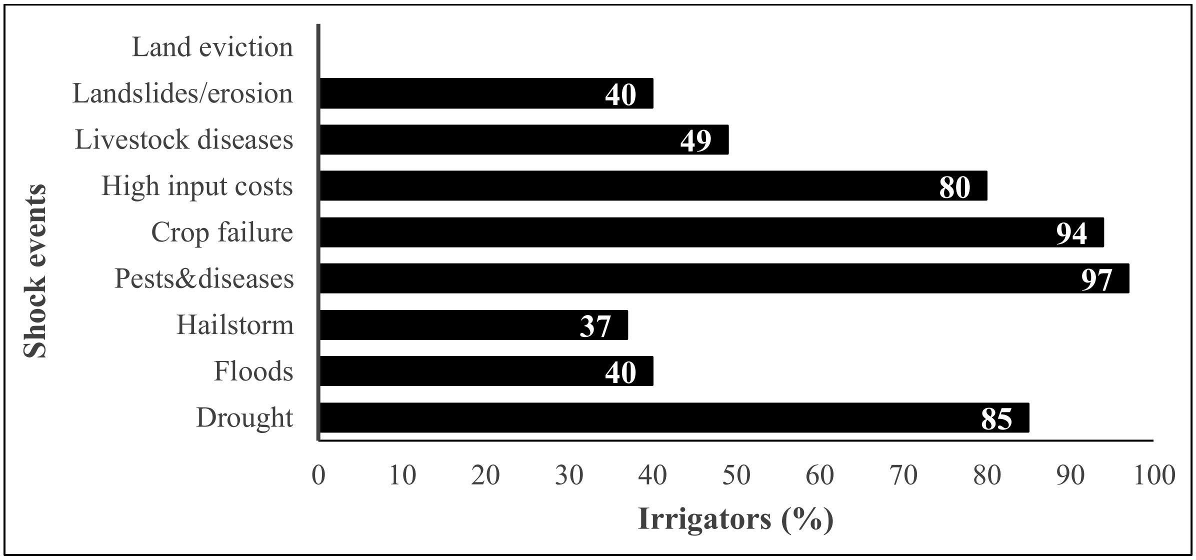

FIGURE 1: Relative Distribution of Irrigators That Experienced Shocks

This is typical of Msinga, as Zaca (2018) found that in Tugela Ferry, smallholder households claimed 92% of their income from the state social grant. In South Africa, the government has primarily assisted irrigation schemes and projects to enhance smallholder agricultural productivity through inputs, mechanisation, and other forms of support (Mudhara, 2010; Sinyolo, Mudhara, & Wale, 2014; Denison *et al*., 2016; Wale & Chipfupa, 2018). In their study, Wale and Chipfupa (2018) argued that smallholder "scheme" farmers in Ndumo-B indicated that although they receive support from the government regarding seeds and fertilisers, this support is inappropriate since they are never consulted on what they need. Farmers report receiving inputs they have already purchased, while others indicate that the inputs they are given have a limited shelf life with approaching expiry dates (Wale & Chipfupa, 2018). Also, they cannot use them before the expiry date due to seasonality issues. The survey observations show that this kind of support was a rare to nonexistent gesture to the Msinga "independent" irrigators, as none have received such support in recent years. The 20.8% who had contact with the Msinga local office agricultural advisor indicated that they only received some agricultural advisory services. The focus of agricultural extension support on smallholder irrigation schemes, while ignoring independent smallholder irrigators, is not just a South African issue, but a global phenomenon. For example, according to Giordano *et al*. (2012), in Asia, independent irrigators do not receive institutional support and have no financial support, as irrigation Departments tend to oversee large-scale irrigation schemes, while agricultural Departments are mainly concerned with rain-fed farming. Namara *et al*. (2011) reported that independent irrigators in Ghana received inadequate public support. According to Giordano and De Fraiture (2014), just 10% of male irrigators received visits from extension officers, while only 1% of their female counterparts did. In Tanzania, farmers claimed that they had never received any extension support or seen an agricultural extension worker during their farming years (Giordano & De Fraiture, 2014). The FGD participants confirmed the survey data on limited support for independent irrigators. The second and fourth focus groups reported having previously met with an agriculture advisor or extension officer. They were given hand hoes on both occasions, and FGD three was given spinach seeds. However, they could not recall the year because it happened many years ago.

Concerning the input access challenge, the distance to the input market fuelled independent irrigators' difficulty accessing inputs. Input purchases are made in small shops in Tugela Ferry (e.g. Mike's Agric). Some farmers indicated that they purchased in Grey Town, approximately 47.7 km from the Tugela Ferry town. At least in Grey Town, there are various shops, including CPS (seedlings), TWK, and farmers' Agri care. Again, the limited financial base poses a travel limit to accessing these various shops for production inputs. Travelling to Grey Town requires two taxis: one from the village to Tugela Ferry and another from Tugela Ferry to Grey Town. Pests and diseases have been reported by almost all independent irrigators in Msinga (97%) as one of the biggest shocks they have previously encountered in their farming operations. Most of the time, these outbreaks result in crop failure. The primary issue was a lack of knowledge about precautions, such as which agrochemicals to use. Additionally, agrochemicals are very expensive, and their limited financial resources made footing the bill challenging. According to these irrigators, when they bought the inexpensive ones from Tugela Ferry town, they were ineffective because they permanently damaged the produce, which could not be sold.

Droughts are another common problem for irrigators, which have been detrimental to their production. Over eight out of ten (85%) irrigators reported that droughts have affected them. The drought in the area significantly impacted their crops, and irrigators ultimately received no return on their investment. The Northern region of KwaZulu-Natal, including Msinga, usually experiences dry conditions. Droughts strike Msinga regularly, with the most recent officially reported drought occurring from 2015 to 2016 (Vetter, Goodall, & Alcock, 2020). Formally recognised or not, villages in Msinga continue to be affected by drought, and the effects are severe. In 2015-2016, cattle farmers in the study area lost 43% of their herd, while goat farmers lost 29%. Cattle numbers remained low three years after the drought, whereas goat numbers recovered (Vetter, Goodall & Alcock, 2020). Larger herds had lower mortality rates, implying that herd owners had better resources to support their herds.

Droughts have, without a doubt, had complex socio-economic implications for residents of Msinga communities, generating vulnerability in these communities' livelihoods (Rumeki & Umubyeyi, 2019). Independent irrigators have lost crops due to drought, and their livelihoods have suffered as a result. Irrigators sourcing water from springs, which comprised over half of the respondent group, were significantly affected, as their water source frequently dries out. Aside from the drought, independent irrigators who participated in the focus groups (FGDs one and four) expressed concerns about irrigation water. These two groups were non-pumpers. Non-pumpers are irrigators who do not use pumps; they extract irrigation water in buckets or cans. These irrigators stated that it was difficult to carry water on their heads from the source to the irrigation land, especially since they were old. According to Howley, Donoghue and Heanue (2012) and Ramoroka (2011), age and gender influence labour quality, particularly in physical activities, where older people and females are less capable of performing physical activities than young people and males. This finding suggests that age affected irrigation activity since it limited their physical capability to irrigate their independent land. Also, due to groundwater/spring water scarcity, participants from FDG described how they must take turns irrigating and alternate days so everyone can access water. These patterns indicate intense competition for accessing this water source. As a result, irrigators occasionally use water intended for domestic use, which they purchase from vendors. Since the river is seldom dry, the researcher enquired why irrigators do not use a petrol pump. Participants stated that they could not afford a pump due to financial constraints. One of the participants in the second FGD describes her failure to keep the pump running. She stated that she used to have one, but it broke and could not be repaired, so she now relies on buckets to extract irrigation water. Irrigators were requested to rate the adequacy of their water sources during the period when they planted. Most (48.5%) of the irrigators rated their water adequacy as 'rarely enough' or 'never enough' (8.9%). Less than half of the sampled irrigators in Msinga rated water adequacy as mostly enough (29.7%) and consistently enough (12.9%). These findings indicate a substantial need to consider water access to improve the production of independently irrigated land and assist them in dealing with the dry season.

3.2. Independent Irrigator's Farming Constraints

Irrigators face a variety of other challenges and constraints in their farming operations. Table 1 presents the respondents' relative distribution (%) of constraints, using a five-point Likert scale ranking. In this paper, Table 1 supports the initial findings (Figure 1), indicating that high input prices were a barrier to irrigator production. According to the survey data, independent irrigators see a lack of capital (74%) as a significant limitation, followed by a lack of inputs due to high prices (71%) and a lack of support services (84%). In South Africa, smallholder agricultural advisors or extension officers assist farmers (Denison *et al*., 2016; Wale & Chipfupa, 2018), highlighting the need for additional support in the study area. This assistance tends to focus on group projects, such as irrigation schemes and cooperatives (Sinyolo, Mudhara & Wale, 2014). Due to this bias, independent irrigation farmers are often overlooked. Irrigators pointed out that new pests and diseases are one of the most severe shocks to their farming operations.

TABLE 1: Relative Frequency Distribution (%) of Constraints Faced by Irrigators (N=101)

	Never	**Rarely**	**Sometimes**	**Most of the time**	**Always**
	Irrigators (%)				
Lack of capital	3	1	23	54	20
Insufficient land	38	21	23	19	0
Lack of access to inputs	8	14	41	36	2
High increase in input prices	4	6	19	67	4

Production below normal	4	4	53	39	1
Declining output market prices	8	26	55	11	0
Land tenure is not secure	92	6	2	0	0
Local and political conflict	89	10	1	0	0
Lack of support services	8	3	6	47	37
High pump and maintenance cost	81	1	5	13	0
Water availability	8	7	54	25	6

There is a limited understanding of how to manage them, and agricultural advisors may be the best people to help irrigators control them. However, there is little or no interaction between the two. There appear to be two components that underlie all these shocks and constraints: a lack of cash and agricultural extension services. Regarding agrarian extension officers as people responsible for implementing agricultural extension services, most (64%) independent irrigators rated agricultural extension officers (or advisers) as an unimportant source of information when rating information sources (Figure 2).

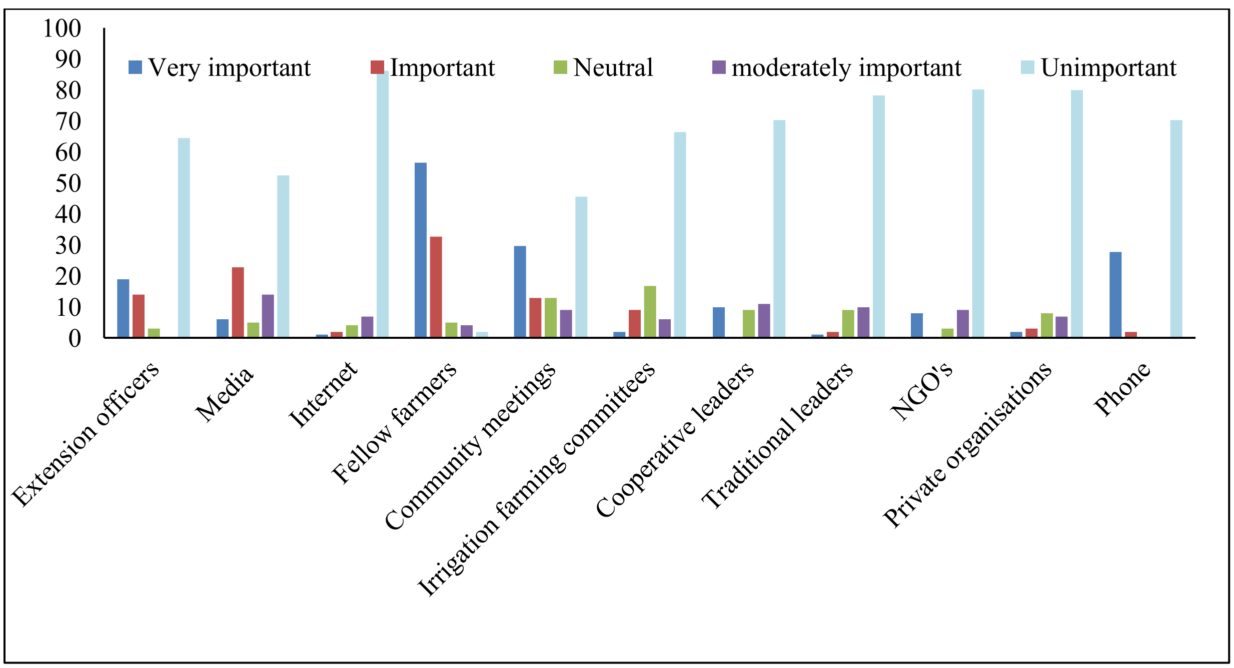

FIGURE 2: Importance of Sources of Information Among Msinga Independent Irrigators

Limited independent irrigators had either interacted with or received support, which explains this rating. Irrigators also regard fellow counterparts (56%) as essential sources of knowledge. There are lots of reasons why farmer-to-farmer transmission is sound. There is legitimacy, familiar language, and contextualisation of information into the spreader's experience, as in 'I tried it this way'. Creative thinking and problem-solving emerge from discussions among individuals who have equal power in the conversation.

3.3. Produce Output Markets

The output market distribution of Msinga independent smallholder irrigators is shown in Figure 3. Smallholder farmers typically participate in lower-value markets, such as farmgate and local markets, due to the high transaction costs associated with reaching high-value food markets (World Bank, 2007). In Msinga, independent irrigators face a similar predicament, with market access as a significant barrier. Over half of the Msinga irrigators (58.4%) had some of their produce sold. Most independent irrigators in the studied area sell their produce to local community consumers off-farm (52%), local consumers at the farm gate (39%), and street traders (39%) in bakkies.

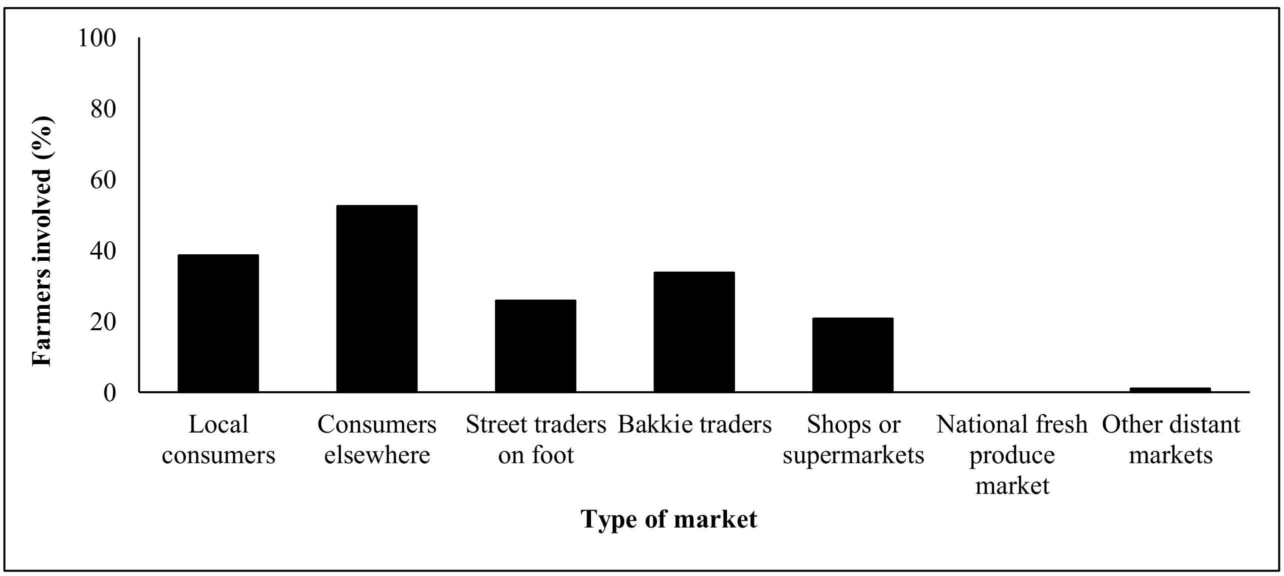

FIGURE 3: Relative Frequency Distribution for Independent Irrigators' Output Markets

It was challenging to sell to any formal market (1%) due to the high quality and quantity required in these product markets. Additionally, other growers in the area, including smallholders from the irrigation project and commercial producers, compete fiercely (Cousins, 2012). Irrigators also confirmed the high competition among producers in FGD two, indicating that at some point, they return home with produce that was not sold and, once it is spoiled, feed it to livestock.

4. CONCLUSIONS AND RECOMMENDATIONS

The objective of this paper was to identify the agricultural shocks and constraints faced by independent irrigators in the Msinga local municipality, as well as to explore intervention strategies that could help them overcome these obstacles. The findings revealed that a significant challenge was access to inputs, exacerbated by a lack of financial capital. Irrigators faced pests and diseases, and a lack of funds and knowledge about dealing with them resulted in crop loss. Access to water was also a significant issue for these irrigators. Irrigators in the area lacked adequate irrigation infrastructure, so they mainly used buckets, which limited their ability to perform at their best due to the physical requirement of carrying a bucket from the source to the household. The lack of this infrastructure also stems from the shortage of capital necessary to purchase or procure the required equipment. Drought was another concern for irrigators, particularly those relying on spring water. Droughts in Msinga caused water sources to dry up, limiting productivity, and some irrigators chose not to plant. The South African government and other stakeholders could prioritise providing appropriate systems, services, and support to independent irrigators from the existing farmer support services they already provide to group projects, including irrigation schemes and cooperatives. This could include innovating with supportive services rather than production supplies and shifting to appropriate technology rather than glamorous, unsuitable technology (like big tractors). Increase the extension-to-farmer ratio to shift the emphasis from cooperative production to cooperative supplies, and market and inputs from suppliers. This involves ensuring that farmers have access to resources while also maintaining the necessary connections for them to utilise these resources. This includes establishing supply and value chains to link the micro and macro levels, taking advantage of market-oriented production. Generally, we examine the micro and macro context links for transformation, including value chains, supply chains, scaled financing, and affordable (even if initially subsidised) incentives that result in transformation. The fallacy is that the public/government extension thinks farmers must be helped to produce. Suppose farmers have an opportunity to make a change. In that case, they will adapt their traditional knowledge to commercially relevant knowledge, and if the knowledge and incentive are there, they can access it. However, when the focus is on handing out seeds, lime, and fencing poles, farmers view this as "getting something for free," rather than as incentives for production.

The study recommends that the government collaborate with other stakeholders on water harvesting and savings techniques to address drought and water access issues. In other countries, a pump is one of the initiatives adopted to assist independent irrigators with water access issues. However, among Msinga irrigators who participated in this study, support in the form of petrol or diesel pumps does not appear to be sustainable. There are numerous financial responsibilities associated with owning a petrol or diesel pump, and most irrigators in these areas lack adequate financial capabilities to purchase, operate, and maintain these pumps. Another option to reduce running costs is the use of solar pumps. Solar pumps could be a low-cost alternative for supplying irrigation water. Especially when combined with a storage tank that fills up during sunny days, ensuring constant drip irrigation during production. Solar irrigation eliminates the hassles associated with intermittent electricity access or the expense of fuel and labour for water delivery. However, maintenance is still an issue. The applicability of solar pumps on a larger scale requires rigorous research to test whether they can work with less resourceful irrigators, such as those in Msinga.

The findings presented here shed new light on the challenges independent smallholder irrigators face in South Africa. They also contribute an emic perspective to the discussion around resource-constrained independent irrigating. This paper provides the groundwork for future research into issues faced by these overlooked irrigators. More information on these constraints from a larger sample would help us establish a higher level of accuracy on this subject. This information can help identify entry points and develop targeted interventions to remove the constraints that independent irrigators face, thereby improving their participation in formal markets and positively impacting their livelihoods.

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Barriers to the Adoption of Information and Communication Technology (ICT) for Accessing Agricultural Information by Small-Scale Farmers in Mahikeng, Northwest Province

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ABSTRACT

Small-scale farmers in Mahikeng, South Africa, face significant challenges in leveraging Information and Communication Technology (ICT) for agricultural information. This study examined how socio-economic characteristics and perceived barriers influence the adoption of ICT. A cross-sectional survey of 121 farmers was conducted using a structured, pre-tested questionnaire, and data were analysed using descriptive statistics and binary logistic regression. Findings showed that while 92% of respondents were aware of ICT-based agricultural services, actual adoption was uneven. Approximately 86% used ICT, primarily radios and mobile phones, while internet-based platforms were relatively rare. Barriers were multifaceted, with unreliable electricity and poor connectivity being the most frequently cited (85%), followed by high device costs (71%) and unaffordable data (73%). The absence of local ICT hubs (79%) and socio-cultural constraints such as low literacy and language mismatches further limited uptake. Regression analysis revealed that larger farm sizes significantly increased the likelihood of adoption, while high perceived costs and poor internet access reduced it. Overall, despite high awareness, ICT adoption is constrained by intersecting infrastructural, economic, and socio-cultural barriers. Addressing these issues requires a holistic strategy that combines infrastructure investment, affordability interventions, and targeted digital literacy support.

Keywords: ICT Adoption, Small-Scale Farmers, Barriers.

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1. INTRODUCTION

In the modern agricultural landscape, access to timely and relevant information plays a crucial role in enhancing productivity and sustainability, particularly for small-scale farmers. Information and Communication Technology (ICT) has the potential to bridge knowledge gaps by providing access to vital agricultural information on weather patterns, market prices, pest management, and improved farming techniques (Choruma, 2024; Domguia, 2025). For small-scale farmers who often face resource constraints, ICT offers opportunities to enhance yields, mitigate risks, and increase profitability (Ngulube, 2025; Onyeneke *et al.*, 2023). In the context of this study, ICT refers to technologies such as mobile phones, radio, television, computers, and internet services that facilitate the dissemination and exchange of information. The term agricultural information encompasses any knowledge that supports farming decision-making, including data on weather forecasts, input and output market trends, pest and disease management, and improved farming practices.

However, despite its potential, many small-scale farmers in Mahikeng Local Municipality (like those in other regions of sub-Saharan Africa) face significant barriers to adopting ICT. These challenges include limited access to digital infrastructure, low levels of digital literacy, language and educational constraints, and economic hardships, all of which hinder farmers' ability to fully benefit from agricultural information systems (Nxumalo, 2025; Smidt & Jokonya, 2022; Oki & Agbeyangi, 2024). Previous studies have revealed such constraints in broader contexts, but there remains a need to understand the specific severity and interplay of these barriers in Mahikeng. In other words, although it is recognised that inadequate infrastructure, restricted device access, low digital skills, and high internet costs impede ICT uptake (Ayim et al., 2020; Fox & Signe, 2022), the extent of these problems and how they relate to farmers' characteristics in this area have not been thoroughly documented. This represents a critical knowledge gap. Consequently, small-scale farmers in Mahikeng continue to struggle with accessing important agricultural information, making them more vulnerable to climate shocks, price fluctuations, and pest outbreaks. There is a clear problem: ICT-based services that could mitigate these risks are underutilised, and the local farming community remains less informed and less resilient than it could be. Addressing these obstacles is crucial for improving ICT adoption, promoting informed agricultural practices, and bolstering the livelihoods of small-scale farmers in the area.

1.2. Research Aim, Objectives and Hypothesis

Considering the persistent challenges faced by small-scale farmers in accessing critical agricultural information, this study seeks to explore the factors influencing their adoption of ICT tools in the Mahikeng Local Municipality. While ICT has the potential to bridge information gaps and improve farming outcomes, its uptake remains limited, often constrained by infrastructural, educational, and economic barriers. To better understand this underutilisation, the study focuses on how socio-economic characteristics and perceived barriers shape farmers' likelihood of adopting ICT for agricultural purposes.

The overall aim of this research is to examine how the socio-economic profiles of small-scale farmers and their perceived barriers influence their adoption of ICT tools for accessing agricultural information. Specifically, the study identifies whether farmers have adopted ICT (based on a binary yes/no response), identifies the types of barriers they face, and assesses how these barriers, together with socio-economic characteristics, predict ICT adoption. A binary logistic regression model is used to determine which factors are significantly associated with ICT uptake, providing insights to guide future policy and support interventions aimed at increasing digital inclusion in the agricultural sector.

The following hypotheses were tested in this study:
Null Hypothesis (H_0): There is no significant relationship between small-scale farmers' socio-economic characteristics and perceived barriers, and their adoption of ICT for accessing agricultural information.
Alternative Hypothesis (H_1): There is a significant relationship between the socio-economic characteristics of small-scale farmers and their perceived barriers to adoption, as well as their use of ICT for accessing agricultural information.

2. METHODOLOGY

2.1. Study Area

Located in South Africa's Northwest Province, Mahikeng Local Municipality spans approximately 3,703 km² and comprises 28 wards and over 100 villages, accommodating a population estimated between 270,000 and 350,000 (Mahikeng Local Municipality, 2024; Municipalities of South Africa, 2024). Approximately 70% of the municipality is classified as rural, with over 40 scattered villages situated as far as 120 km from the urban core

(Municipalities of South Africa, 2024). Despite a high rate of household electrification (97%), access to essential services such as piped water and flush sanitation remains limited, reaching only about half of the population (Municipalities of South Africa, 2024). The municipality also faces significant socio-economic challenges, including a 35.7% unemployment rate and a predominantly young population with modest educational attainment levels. Only 26% hold a matric certificate, while 7% have received no formal education (Municipalities of South Africa, 2024).

Agriculture remains a cornerstone of Mahikeng's economy, with a focus on livestock, particularly cattle, sheep, and goats, as well as crops such as maize and sunflowers. However, the sector is highly susceptible to drought (Setshedi & Modirwa, 2020). While Mahikeng, alongside its main suburb Mmabatho, functions as the administrative and commercial nucleus, many peripheral villages still lack adequate infrastructure and service delivery (Mahikeng Local Municipality, 2024). Strategically situated near the Botswana border and key transportation routes leading to Gauteng, the municipality holds untapped potential for enhanced market access and digital connectivity.

Mahikeng was chosen as the focus of this study owing to its substantial population of smallholder farmers facing socio-economic hardship, coupled with recent governmental agricultural initiatives. For instance, the Northwest Department of Agriculture and Rural Development (DARD) has constructed a modern livestock-handling facility in Ditshilo village and supported community gardening efforts in Ottoshoop as part of the Thuntsha Lerole food security initiative. Additionally, a farmer in Setlopo was provided with Boer goat breeding stock through departmental support (Food for Mzansi, 2024; Northwest DARD, 2024).

2.2. Research Design

This study employed a descriptive quantitative research design to investigate the barriers to the adoption of Information and Communication Technology (ICT) for accessing agricultural information by small-scale farmers in Mahikeng Local Municipality, Northwest Province. A descriptive design was considered appropriate as it facilitates an in-depth understanding of prevailing conditions and the identification of key trends among a specific population (Creswell & Creswell, 2018). Quantitative methodology was applied to systematically collect and analyse numerical data related to socio-economic characteristics, ICT usage, and perceived barriers. This approach allowed for objectivity, replicability, and the use of inferential statistics to test the relationships between variables (Mohajan, 2021). The design further enabled the evaluation of farmers' ICT adoption patterns, supported by structured and standardised data collection and analysis processes.

Given the aim of determining the influence of socio-economic characteristics and barriers on ICT adoption, the study applied a cross-sectional survey design, capturing data from a sample of small-scale farmers at a single point in time. This approach ensured a representative snapshot of current ICT adoption behaviours and constraints within the study area.

A binary logistic regression model was selected as the core statistical method to test the null hypothesis: There is no significant relationship between the socio-economic characteristics of small-scale farmers and their barriers to adopting ICT for accessing agricultural information. This model was suitable because the dependent variable, ICT adoption, was binary (1 = adopter, 0 = non-adopter), and the predictor variables included both continuous (e.g., farm size) and categorical factors (e.g., cost of ICT tools, digital infrastructure, literacy level). To ensure the validity of the model, multicollinearity was assessed using the Variance Inflation Factor (VIF) and Tolerance values. All tested variables met the acceptable thresholds (VIF < 10, Tolerance > 0.1), confirming the reliability of the regression outputs. The model's goodness-of-fit was confirmed with a statistically significant LR chi^2 value ($p < 0.0000$) and a strong Pseudo R^2 of 0.6568, indicating that the model explained a substantial proportion of variance in ICT adoption.

2.3. Population of the Study

The target population for this study consisted of all small-scale farmers residing within the designated area of the Mahikeng Local Municipality. Based on official records provided by the Mahikeng Agricultural Office under the Northwest Department of Agriculture and Rural Development (NWDARD), the total number of registered smallholder farmers, encompassing both livestock and crop producers, was 1,449. This figure was adopted as the definitive population frame for the research. A random sampling technique was subsequently employed to select participants from this population. The use of a comprehensive, government-verified registry ensured that the sampling frame was both accurate and representative of the broader smallholder farming community, thereby aligning with the study's descriptive and quantitative research design.

2.4. Sampling Procedure and Sample Size

The sample size was determined using a standard sample size table by Krejcie and Morgan (1970). For a population of around 1,449, this table recommends a sample of about 302 respondents for a 95% confidence level and a 5% margin of error (assuming a proportion of 0.5). In line with this guidance, a target sample of 302 small-scale farmers was considered sufficient to yield statistically meaningful results. In line with this guidance, a target sample of 302 small-scale farmers was considered sufficient to yield statistically meaningful results. A simple random sampling technique was then employed to select participants, ensuring that every farmer in the population had an equal chance of being included. Ultimately, due to practical considerations and voluntary participation, 121 respondents were successfully reached and agreed to participate in the survey. Although the realised sample size is smaller than the initial target, it still provides valuable insights. Bartlett *et al*. (2001) emphasise the importance of considering expected response rates when determining adequate sample sizes in voluntary survey research. Considering this, the 40% response rate achieved in the present study falls within generally acceptable thresholds.

2.5. Data Collection

Data were collected using a structured questionnaire administered in person. The instrument was designed in two sections. The first section gathered data on the socio-economic characteristics of the farmers (e.g., age, gender, education level, farm size, farming experience, household income) and assessed farmers' awareness of ICT in agricultural extension service delivery. The second section focused on the barriers faced by farmers in utilising ICT for agricultural purposes. Respondents were asked about various potential barriers (such as cost, infrastructure, skills, etc.), usually by rating each factor as a "major barrier," "minor barrier," or "not a barrier" in their farming activities. The questionnaires were distributed and self-administered by the researcher, and an extension officer was present to clarify any questions. This approach helped ensure clarity and consistency in data collection. Farmers' responses about barriers were later categorised based on the severity of the barrier (major vs. minor) for analysis.

TABLE 1: Descriptions of Variable, Measurement and Expected Outcomes

Variable	**Type**	**Coding / Measurement**	**Expected Effect on ICT Adoption**
ICT Adoption (DV)	Binary	1 = Yes, 0 = No	Outcome variable
Age	Categorical/ordinal	Farmer's age in years	Negative or neutral
Education Level	Ordinal	1 = No schooling to 5 = Tertiary	Positive
Farm Size	Continuous	In hectares	Positive
Income Level	Ordinal / categorical	Grouped Annual income (e.g., R10,000–R30,000, etc.)	Positive
Gender	Binary	1 = Male, 0 = Female	Neutral or slightly positive
Barrier: Cost of ICT	Binary	1 = Major barrier, 0 = Not major	Negative
Barrier: Poor Network Access	Binary	1 = Major barrier, 0 = Not major	Negative
Barrier: Low Digital Skills	Binary	1 = Major barrier, 0 = Not major	Negative
Barrier: Language or Literacy	Binary	1 = Major barrier, 0 = Not major	Negative

2.6. Justification for the Selection of Variables

The choice of variables for this study is informed by both theoretical and empirical literature rooted in agricultural extension, particularly the Diffusion of Innovations (DOI) theory and the Technology Acceptance Model (TAM). DOI suggests that socio-economic characteristics, such as age, education, and income, significantly influence the rate of innovation uptake by affecting the perceived advantages, compatibility, and complexity of the innovation (Rogers, 2003). TAM further emphasises that perceived usefulness and ease of use determine

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technology acceptance (Davis, 1989), both of which can be shaped by the farmer's resources, skills, and contextual barriers.

Age was included because younger farmers tend to adopt digital innovations more readily than older counterparts, who may perceive such tools as complex or less relevant (Hoang & Tran, 2023). Education level was considered due to its role in enhancing digital literacy and the ability to engage with new technologies, which is well-supported in the literature (Fharaz *et al*., 2022). Similarly, income level and farm size were included based on their positive association with adoption; farmers with greater financial resources or larger operations are often better positioned to invest in ICT tools and data costs (Singh & Aryal, 2023).

Gender was included to account for structural disparities in access to training and digital tools, although evidence on its effect remains mixed and context-dependent (Peterman *et al*., 2014). In addition to these socio-economic factors, the model includes key barriers identified in prior research. High ICT costs, poor network access, low digital skills, and language or literacy constraints are well-documented inhibitors of adoption in African farming contexts (Mhlanga & Ndhlovu, 2023; Awuor & Rambim, 2022). These barriers reduce both the perceived ease of use and usefulness of ICTs, aligning closely with TAM's conceptual framework. Including them as binary variables allows the model to capture their marginal effects on ICT adoption.

2.7. Validity and Reliability

To ensure the content validity of the questionnaire, a face validation process was conducted by a panel of subject-matter experts in Agricultural Extension and Development Studies. The panel comprised a Senior Lecturer in Agricultural Extension, senior officials from the Northwest Department of Agriculture and Rural Development (NWDRAD), as well as experienced researchers with relevant domain expertise. Following this, the instrument was piloted with a purposive sample of 12 small-scale farmers from Mahikeng, selected based on their availability and willingness to participate. These participants were excluded from the main study to prevent bias. Feedback from the pilot exercise informed several revisions, including the rephrasing of ambiguous items, restructuring certain questions, and standardising response scales. These modifications enhanced the clarity, internal coherence, and contextual appropriateness of the instrument for the target population. The reliability of the 9-item Likert scale measuring barriers to ICT adoption was assessed using Cronbach's alpha, which yielded a value of 0.89, indicating high internal consistency. The mean total scale score was 22.85 (SD = 4.38). Inter-item correlations ranged from 0.13 to 0.83, and item-total correlations ranged from 0.32 to 0.73. Deleting any single item reduced Cronbach's alpha to a minimum of 0.87, suggesting that all items contributed meaningfully to the scale.

TABLE 2: Cronbach's Alpha Reliability Statistics for the Barriers Scale

Statistic	Value
Number of items	9
Cronbach's alpha (α)	0.886
Mean of total scale score	22.85
Standard deviation of the total scale score	4.38
Inter-item correlation (range)	0.13 to 0.83
Item-total correlation (range)	0.41 to 0.75
Lowest alpha if item deleted	0.863

2.8. Data Analysis

The collected data were coded and analysed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics (frequencies, percentages, means, and standard deviations) were used to summarise the socio-economic characteristics of the respondents and the prevalence of each barrier to ICT use. The results of these descriptive analyses are presented in tabular form (see Tables 1 and 2) for clarity and ease of interpretation.

To address the hypothesis concerning relationships between farmer characteristics and ICT adoption barriers, a binary logistic regression model was employed. In this model, the dependent variable was ICT adoption status, defined as whether a farmer was actively using any ICT tools to access agricultural information (adopter = 1 if the farmer used at least one ICT platform such as a mobile phone, radio, or internet for farm information; non-adopter = 0 if the farmer did not use any ICT for this purpose). The independent variables included key socio-economic factors (such as farm size, age, education, and income) and the presence of major constraints (e.g., whether the farmer indicated that high costs and lack of internet were a major barrier for them). We coded each potential barrier as 1 if the respondent perceived it as a major constraint and 0 if it was a minor or no constraint. This coding collapses the original three-category constraint scale into a binary indicator focusing on major hindrances (while excluding the "no constraint" category from the analysis as a baseline). The logistic regression thus allowed us to assess which factors significantly influenced the likelihood of a farmer adopting ICT.

Before running the logistic regression, multicollinearity diagnostics were performed to ensure that the predictor variables were not excessively correlated with each other, which could distort the regression results. Variance Inflation Factors (VIF) and tolerance values were examined for all independent variables. All VIF values were below the commonly accepted threshold (e.g., VIF < 5), indicating that multicollinearity was not an issue in the model. After confirming the validity of the predictors, the logistic model was implemented, and the results (coefficients, standard errors, and significance levels) were interpreted in relation to the study objectives**.**

2.9. Binary Logistic Regression Model and Assumptions

The binary logistic regression model used to estimate the probability of ICT adoption among small-scale farmers can be expressed as follows:

$\log(P(Y=1) / (1 - P(Y=1))) = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \cdots + \beta_kX_k$

Where:

$\log(P(Y=1) / (1 - P(Y=1)))$ is the log-odds of being an ICT adopter (i.e., using at least one ICT tool for agricultural information).

$Y = 1$ indicates an ICT adopter, and $Y = 0$ indicates a non-adopter.

β_0 is the intercept.

$\beta_1, \beta_2, ..., \beta_k$ are the coefficients of the independent variables.

$X_1, X_2, ..., X_k$ are the predictor variables.

2.10. Model Fit and Limitations

The overall fit of the logistic regression model was assessed using several standard indicators. The Likelihood Ratio Chi-Square test yielded a statistically significant result (LR $\chi^2 = 64.51$, $p < 0.001$), indicating that the model was statistically meaningful in predicting ICT adoption among small-scale farmers. The log-likelihood value was -16.85, suggesting good model convergence. Additionally, the pseudo-R^2 (McFadden's R^2) value was 0.6568, indicating that approximately 65.7% of the variation in ICT adoption could be explained by the independent variables included in the model. The final model included 121 observations. These results suggest a reasonably strong model fit for binary logistic regression in the context of socio-economic and barrier-related predictors.

While the logistic regression model provided a good fit and yielded meaningful results, a few limitations should be acknowledged. First, the use of a cross-sectional design restricts the ability to infer causality; the model identifies associations rather than temporal cause-and-effect relationships. Second, although the pseudo-R^2 value was relatively high, pseudo-R-squared metrics in logistic regression do not have a direct interpretation equivalent to R^2 in linear regression and should be interpreted with caution. Third, several barrier variables were dichotomised, which may have resulted in the loss of nuanced responses originally captured on ordinal scales. Lastly, while multicollinearity was checked using tolerance values (all > 0.3), some moderate correlations may still exist, which could potentially influence the stability of coefficient estimates.

2.11. Ethical Considerations

This study obtained ethical clearance (Approval No. NWU-00323-18-A9) from the Research Ethics Regulatory Committee of Northwest University. All participants were informed about the purpose of the research and participated voluntarily, understanding that they could withdraw from completing the questionnaire at any point without consequences. The confidentiality of respondents' information was strictly maintained, and data were used solely for academic purposes.

3. RESULTS AND DISCUSSION

3.1. Socio-Economic Characteristics of Respondents

A total of 121 small-scale farmers participated in the survey. *Table 2* presents the socio-economic profile of these respondents. The sample was predominantly male (63%), with females making up (37%). This male majority reflects the gender distribution often observed in small-scale farming in the region, where men tend to have more access to land and farming resources, although women also play significant roles.

In terms of education, about one-third of the farmers (33%) had only primary education, 31% had reached secondary school, and 20% had no formal schooling (informal education). A smaller segment had post-secondary education: 9% had a college-level qualification, and 7%

had a university degree. This generally low level of formal education among the farmers suggests potential challenges in dealing with complex technologies and information, and it underscores the importance of delivering ICT solutions that are accessible to users with limited literacy or educational background.

Regarding marital status, just over half of the respondents (51%) were married, while about one-third (31%) were single. The remaining (16%) were divorced or separated. There were few widowed respondents recorded (if any, they were included in the "divorced/other" category). Marital status can sometimes influence farm decision-making dynamics and openness to new practices; for instance, married farmers might have larger households that could either support or constrain ICT adoption through labour availability or competing financial priorities.

The age distribution was skewed towards older farmers, with nearly half (49%) of the respondents being above 50 years old. (40%) The majority were in the 41–50 years age bracket (8%), followed by those in the 31–40 years age group (8%), and only 3% were in their twenties (21–30 years old). The predominance of older farmers (with almost 90% being over 40) is notable. Older age can be associated with lower technology adoption rates in agriculture, as younger farmers are often more open to trying new ICT tools. The ageing farming population in Mahikeng may therefore contribute to a slower uptake of ICT, as also observed in other rural communities.

Household sizes among respondents were moderate to large. Most farming households (around 60%) consisted of 4–6 members. About 23% had only 1–3 members, and roughly 17% had 7–10 members. Only a few households were very large: less than 2% had more than 10 members. The average household size falling in the 4–6 range suggests that many farmers have families or dependents who could both contribute to farm labour and benefit from farm incomes. A larger household might mean more labour available to assist with farming, but it can also mean more financial pressure, which might limit funds available for investing in ICT tools.

Farmers in the study were generally experienced. A plurality (about 40%) reported 11–20 years of farming experience, and roughly one-third (33%) had 2–10 years of experience. About 20% had 21–30 years of farming experience, and nearly 5% had 31–40 years of farming experience. A small number (approximately 2%) had over 40 years of experience in farming. This suggests that many respondents possess long-standing knowledge and farming practices, which could influence their perception of new technologies. Experienced farmers may be accustomed to traditional ways, or conversely, they may recognise how information access has evolved over the decades. The high proportion with over a decade of farming suggests that interventions to introduce ICT need to account for entrenched habits and possibly provide clear demonstrations of added value to convince older farmers.

The farm sizes operated by respondents were relatively small, as expected for small-scale farmers. Nearly half (47%) of the farmers cultivated land ranging from 0 to 2 hectares, and 39% had landholdings of 3 to 6 hectares. Only 9% had mid-sized farms of 7–10 hectares, and an even smaller fraction (about 5% combined) had farms larger than 10 hectares. These small farm sizes imply limited financial margins and capital, which can constrain the ability to purchase ICT devices or pay for services. On the other hand, smaller farms might greatly benefit from precise and timely information, for instance, to maximise output on limited land, so affordable ICT solutions could have a high impact if barriers are overcome.

Annual household income from farming was modest for most respondents. Nearly half (46.3%) reported an annual income between R10,000 and R30,000 (South African Rand), and about one-third (32.2%) earned between R31,000 and R50,000 per year. About 10% had incomes in the R51,000–R70,000 range, and 4% incomes in the R71,000–R90,000 range. Only about 7% earned more than R91,000 annually from their farming activities. This finding, that nearly half of small-scale farmers in Mahikeng earned between R10,000 and R30,000 annually, is consistent with evidence from the Eastern Cape, where smallholder farmers reported an average annual income of R26,600 (Zantsi *et al.*, 2019). These figures, though from different provinces, highlight a common trend of modest farm incomes among small-scale producers in South Africa, underlining a critical economic constraint. With such limited financial resources, it is understandable that many farmers would be hesitant or unable to invest in ICT hardware, such as smartphones or computers, or incur recurring costs like internet data plans. The affordability of technology emerges as a likely significant barrier, given this income profile.

In terms of farming enterprises, the respondents were not exclusively specialised. About 16% of the farmers engaged solely in livestock production, while the majority practised mixed farming (72%). It was observed that very few (12%) were strictly crop-only farmers; instead, many smallholders diversify to spread risk. Mixed farming can influence the types of information needed, for instance, market prices for both crops and livestock, weather for crops, and veterinary information for animals.

When asked about their primary sources of agricultural information, 36% of the farmers cited fellow farmers, i.e. peer networks, as their most significant source, and 35% relied on agricultural extension agents provided by government or NGOs. This leaves radio and other traditional media as the least-cited primary source at 29%. These percentages suggest that interpersonal communication remains crucial as farmers trust advice from peers and extension officers, while radio, although used by nearly one-third, is comparatively less dominant as the first choice. The reliance on fellow farmers and extension workers indicates that any ICT interventions might be more readily accepted if they are integrated with these existing information networks. For example, using radio programs or mobile messaging that involve extension advice or farmer discussion forums.

Awareness of ICT for accessing agricultural information was found to be very high: 92% of respondents stated that they were aware that ICT can be used to support the delivery of agricultural information. This is an encouraging finding, implying that a lack of awareness is not the primary issue, as most farmers are aware that technologies such as phones or the internet can serve agricultural purposes. The remaining (8%) who were not aware are a small minority, possibly very isolated or older farmers who have had little exposure to new communication tools.

Despite high awareness, actual usage of ICT tools for farming information was concentrated in a few traditional media. Most farmers reported using television (30.9%), radio (27.7%), and mobile phones (27.2%) as their primary ICT-based tools to access agricultural information. These three media collectively account for the dominant share of usage, suggesting that many farmers stick to relatively accessible and familiar technologies. For instance, TV and radio have long been present in rural communities, and basic mobile phones are now widely available. A much smaller share of farmers uses the internet (9%) or personal computers (4%) for agricultural information, indicating that advanced digital platforms, such as online resources, smartphone apps, or computer databases, are not yet widely adopted in this community.

Additionally, about 1–2% of respondents mentioned “other” ICT tools (such as DVDs, digital cameras, or video conferencing. The low uptake of internet and computers underscores infrastructural and skill barriers: many rural areas lack broadband access or have expensive data plans, and farmers may not have the necessary training to use computer-based tools. Moreover, smartphones, which are capable of internet use, might not be affordable for many; hence, only a small minority leverages the full capabilities of the internet for farming needs.

Overall, the socio-economic characteristics paint a picture of an older, predominantly male farming population with limited education and income, operating small farms. These factors help contextualise the subsequent findings on ICT adoption barriers. For instance, lower literacy and education levels are associated with the latter finding that digital literacy is a problem for over half of the farmers. Similarly, the low-income levels correspond with the finding that cost is a major barrier. The following section discusses these barriers in detail, linking them with both the quantitative results from the survey and comparable findings from other studies.

TABLE 2: Socio-Economic Characteristics and ICT Use Among Respondents

Socio-economic Variable	**Categories**	**Frequency**	**Percentage (%)**
Gender	Male	76	63
	Female	45	37
Level of Education	Informal	24	20
	Primary	40	33
	Secondary	38	31
	College	11	9
	University	8	7
Marital Status	Single	40	31
	Married	62	51
	Divorced	19	16
Age	21–30 years	4	3
	31–40 years	10	8
	41–50 years	48	40
	51 years and above	59	49
Household Size	1–3 members	28	23

	4–6 members	72	59.5
	7–10 members	20	16.5
	11–13 members	1	1
	14 members and above	0	0
Farming Experience	2–10 years	40	33.06
	11–20 years	28	39.67
	21–30 years	24	19.83
	31–40 years	6	4.96
	41–50 years	2	1.65
	51+ years	1	0.83
Farm Size (ha)	0–2 hectares	57	47
	3–6 hectares	47	39
	7–10 hectares	11	9
	11–15 hectares	2	2
	16 hectares and above	4	3
Annual Income (ZAR)	10,000–30,000	56	46.3
	31,000–50,000	39	32.2
	51,000–70,000	12	10
	71,000–90,000	5	4.1
	91,000 and above	9	7.4
Type of Farm Enterprise	Crop production	15	12
	Livestock production	19	16
	Both	87	72
Information Sources	Extension agents	111	35
	Fellow farmers	114	36

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	Radio	92	29
Awareness of the Use of ICTs	Yes	111	92
	No	10	8
Use of ICTs for Information Access	Yes	104	86
	No	17	14
ICTs Used by Small-scale Farmers	Radio	105	27.7
	Television	117	30.87
	Mobile phones	103	27.18
	Internet	34	8.97
	Video conferencing	1	0.26
	Personal computer	15	3.96
	DVDs and CDs	2	0.53
	Digital cameras	2	0.53
	Telecentres	0	0

***Note**: Respondents could select more than one option for "Information Sources" and "ICTs Used by Small-scale Farmers". Percentages are based on the total number of respondents (n = 121) and may therefore exceed 100%. Additionally, currency is in South African Rand (ZAR).*

3.2. Barriers to ICT Adoption for Accessing Agricultural Information

The study identified a range of barriers that small-scale farmers face when using ICT to access agricultural information. *Table 3* summarises the surveyed barriers, showing the proportion of farmers who rated each as a "major constraint" versus a "minor or not a constraint." The discussion below highlights the most significant barriers and provides context by comparing with findings from other studies.

3.2.1. Major Barriers

The most cited barrier was the poor infrastructure in rural areas, reported as a major constraint by 85% of the respondents. The rural environment in which these farmers operate often lacks essential technological infrastructure, such as reliable electricity, telephone lines, and broadband internet coverage, which is critical for effectively accessing and using ICT. Many farming communities in Mahikeng experience frequent power outages (Loadshedding) or have no grid connection at all, and network signal coverage can be weak or non-existent outside of town centres. This finding aligns with widespread challenges in many rural parts of South Africa and sub-Saharan Africa as a whole, where infrastructure development has lagged behind in urban areas. For instance, Makaula and Yusuf (2021) note that inadequate infrastructure, such as electricity and telecom networks, remains a primary barrier to ICT uptake in rural Eastern Cape communities. In the context of our study, without improvements in basic infrastructure, farmers have a limited ability to charge devices, maintain internet connectivity, or even receive radio/TV signals consistently. Thus, poor infrastructure undercuts nearly all other efforts to leverage ICT and must be addressed as a foundational step.

The second most prevalent barrier was the lack of ICT-related facilities such as telecentres, identified by 79% of respondents as a major challenge. Telecentres are community venues equipped with computers, internet access, and other communication services, intended to provide public access to those who cannot afford private devices or connections. In Mahikeng's rural villages, such facilities are largely absent. Their absence means that if a farmer does not personally own an ICT device or cannot afford internet data, there are few alternatives for them to access the internet or use digital services. Even those who own basic phones might benefit from telecentre services, such as printing information, accessing advanced applications, or receiving training. The importance of telecentres and similar shared facilities is echoed in another research. Mishra *et al*. (2020) found that farmers in rural India faced various constraints in ICT utilisation, including a lack of awareness, insufficient training, and the absence of infrastructure such as telecentres, internet kiosks, and a reliable power supply. Our findings support this, indicating that establishing community ICT hubs could significantly alleviate some barriers, particularly for resource-poor farmers who cannot afford to invest in expensive ICT resources individually.

Data bundle costs were highlighted as a major constraint by 73% of the farmers. South Africa is known to have relatively high mobile data costs compared to many other countries, which is particularly burdensome for low-income users in rural areas. For small-scale farmers operating on tight profit margins, spending money on internet data competes with other essential needs. A majority indicated that even if they have a phone that can access the internet, they often cannot afford to purchase enough data to regularly use services like online markets, weather apps, or agricultural extension WhatsApp groups. This finding is well-documented by other studies; for example, Fosu and Van Greunen (2021) report that in rural Eastern Cape, the expense of internet access is a significant barrier to ICT use. High data costs, combined with low household incomes, create a situation where digital connectivity is viewed as a luxury. The implication is that interventions to reduce data costs, such as subsidised data for farmers or community Wi-Fi hotspots, could make a meaningful difference in ICT adoption.

Compounding the cost issue is poor network connectivity, which was noted by about 55% of the farmers as a major problem, either standalone or related to data usage. Even when farmers purchase data, they may still struggle with slow speeds, dropped connections, or a weak network signal in their fields or homes. Such unreliable connectivity reduces the perceived value of using internet-based ICT tools. Our findings here align with those of Mehrabi *et al.* (2021), who noted that a "digital divide" in agriculture often arises from high data costs and inadequate network infrastructure, leaving small-scale farmers at a disadvantage in accessing data-driven farming technologies. Thus, improving the telecommunications network, i.e., adding more cell towers or enhancing coverage, is just as important as making data affordable; both complement each other in enabling farmers to have online access when needed.

Another 71% of respondents identified the high cost of ICT tools, such as smartphones and computers, as a major barrier. Many small-scale farmers cannot afford the upfront cost of purchasing modern ICT devices. For example, smartphones that can run agricultural apps or connect to the internet may be priced beyond what an average farmer earns in a month or even a year. Additionally, the cost of maintaining devices, including repairs, charging, and accessories, adds to the burden. This result highlights the financial limitations of farmers and reflects a broader issue of digital affordability. As Parvathy and Dolli (2019) found in India, the high cost of gadgets was a top-ranked barrier for farmers, with more than half of their respondents unable to keep up with modern agricultural technologies due to these expenses.

Our study's context is similar: without external support or cheaper device options, many farmers continue farming without digital tools, prioritising immediate farm inputs and household needs over technology purchases.

It is interesting to note that while 71% said the cost of devices is a major issue, a similar proportion (71%) also reported internet connectivity challenges as a major barrier, which includes aspects of both coverage and perhaps quality of connection. The overlap of these groups likely indicates that the same farmers suffering device poverty are also those in poorly connected areas; they face a dual hurdle of not having the right device, and even if they did, not having reliable internet. This combined barrier creates a significant digital exclusion.

A significant portion of farmers (55%) admitted that a lack of technical know-how or low digital literacy is a major challenge for them. This refers to the skills and confidence needed to operate ICT devices and navigate information platforms. Many small-scale farmers, particularly the older ones and those with limited formal education, are unfamiliar with using smartphones, computers, or even basic phone functions beyond making calls and sending SMS messages. They may have difficulty with tasks such as searching for information on the internet, using mobile apps, or interpreting the information they find. This highlights an important human capacity gap: even if infrastructure and cost barriers are overcome, farmers will not benefit from ICT unless they also possess the necessary skills to use the technology effectively. Barbier (2023) emphasises that bridging the digital divide in rural areas requires not just technology deployment but also investments in improving digital literacy among users. Our findings concur that over half of the respondents require training or assistance to use ICT tools comfortably. The implication is that programs aiming to promote ICT in agriculture should incorporate training sessions, demonstrations, and user-friendly interfaces tailored for farmers with little prior exposure to technology. Without building this capacity, ICT tools might remain underutilised even if they are available and affordable.

3.2.2. Other Noteworthy Barriers

Beyond the above major issues, the study also identified other barriers that, although less frequently cited as "major," are still noteworthy due to their impact on a substantial subset of farmers and often are interrelated with the primary barriers.

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Exactly 50% of respondents indicated that language is a barrier to their use of ICT for agricultural information. Many ICT platforms, applications, and even devices operate in English, which is not the first language of most small-scale farmers in Mahikeng, who often speak Setswana. When agricultural information, such as weather updates, farming tips, and market news, is provided through ICT channels in a language that farmers are not fully comfortable with, the utility of that information decreases significantly. Even literate farmers may struggle with technical terminology if it's not in their mother tongue. This challenge was similarly observed by Matsenjwa *et al.* (2019), who noted that the complexity of ICT tools and content, often delivered in non-native languages, poses a significant hurdle for farmer engagement with these technologies. The result is that even if a farmer has a smartphone and internet access, they might not use an agricultural app if it is written in English, or they might misinterpret critical information. Addressing this requires more localised content, such as providing interfaces and information in local languages, employing audio/video content for those who cannot read English, or offering translation support through extension services.

Closely tied to language and digital skills are general education and literacy barriers, which 50% of respondents also cited as a barrier to ICT adoption. Low formal education can limit a farmer’s ability to effectively use ICT in multiple ways: it may reduce their confidence in trying new technologies, make it harder to troubleshoot issues, and hinder their understanding of written information. The fact that half viewed their education level as a barrier corresponds with the earlier demographic data, which shows that a significant share had only primary schooling or less. This highlights the need for straightforward, user-friendly ICT solutions, as well as potential intermediary support. As Awan *et al.* (2019) found in rural Pakistan, low literacy levels among farmers restricted their ability to use ICT tools effectively, and they recommended targeted literacy programs and training as a remedy. In Mahikeng, adult education programs or ICT literacy workshops tailored to farmers could empower them to better utilise digital resources effectively. Moreover, designing ICT interfaces that use more visuals, symbols, or voice commands could also help bypass some literacy limitations.

In summary, the results revealed that the key barriers to ICT adoption for agricultural information access in Mahikeng are infrastructural (lack of electricity, network, facilities), economic (high costs of devices and data), and personal (low digital literacy, language and education limitations). These barriers are interlinked and often reinforce one another. For example, an older farmer with limited formal education (personal barrier) who lives in a village with an unreliable electricity supply (infrastructure barrier) and earns under R30,000 per year (economic barrier) is extremely unlikely to adopt ICT, even if they are aware of its potential benefits. The implication for policy and development interventions is that a holistic approach is needed. Efforts must be made simultaneously to improve rural infrastructure (electricity and internet coverage), make ICT access more affordable (through subsidies or low-cost options for devices and data), and build human capacity (by training farmers to use technology, providing content in local languages, and integrating extension support). Addressing only one barrier in isolation, for instance, handing out smartphones without providing network coverage and training would yield limited success.

The findings of this study align with the broader literature on digital inclusion in agriculture, y*et al*so provide localised evidence for Mahikeng. By quantifying the number of farmers affected by each barrier, we can prioritise interventions. Clearly, infrastructure and cost factors stand out, suggesting that any ICT adoption program should coordinate with government infrastructure projects and possibly establish public-private partnerships with telecom providers. Additionally, the significant role of literacy and language means extension services and NGOs must continue to act as intermediaries, translating and simplifying digital information for farmers until such time that farmers themselves are equipped to handle ICT independently.

TABLE 3: Barriers to Small-Scale Farmers' Use of ICT in Accessing Agricultural Information (n = 121)

Barrier	Major Barrier (Frq %)	Minor Barrier (Frq %)	Not a Barrier (Frq %)	Mean	SD
ICT tools are expensive to purchase	86 (71%)	27 (22%)	8 (7%)	2.64	0.60
Language is a barrier to using ICT	61 (50%)	37 (31%)	23 (19%)	2.31	0.77
Low educational level/illiteracy	61 (50%)	37 (31%)	23 (19%)	2.31	0.77

Lack of internet connectivity (no access)	86 (71%)	19 (16%)	16 (13%)	2.58	0.71
Poor network coverage (unstable signal)	67 (55.4%)	44 (36.4%)	10 (8.2%)	2.47	0.64
Lack of technical know-how (digital skills)	66 (55%)	28 (23%)	27 (22%)	2.32	0.81
Data bundles are expensive	88 (73%)	22 (18%)	11 (9%)	2.64	0.65
Poor rural infrastructure (electricity, etc.)	103 (85%)	14 (12%)	4 (3%)	2.82	0.46
Lack of ICT-related facilities (e.g., telecentres)	96 (79%)	20 (17%)	5 (4%)	2.75	0.52

Note: *Mean values are based on a three-point scale for each item: 3 = major barrier, 2 = minor barrier, 1 = not a barrier. Higher means indicate more severe overall constraint perception.*

3.3. Multicollinearity Test

Before interpreting the logistic regression results, it is essential to verify that the independent variables included in the model do not exhibit multicollinearity, i.e., a situation where predictor variables are highly correlated with one another. High multicollinearity can distort the regression coefficients and lead to misleading conclusions (Shrestha, 2020). In this study, a multicollinearity diagnostic was performed using the Variance Inflation Factor (VIF) and Tolerance values for each predictor. According to standard guidelines, a tolerance value below 0.1 or a VIF above 10 would indicate problematic multicollinearity (Shrestha, 2020; Senaviratna & Cooray, 2019).

Table 4 shows the VIF and Tolerance for key variables like farm size, cost of ICT tools, lack of internet connectivity, high data cost, and lack of ICT facilities (these were the variables entered into the regression model as predictors). All variables had VIF values well below 5 and

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Tolerance values well above 0.2, suggesting that multicollinearity is not a concern in the dataset. For example, "lack of internet connectivity" had the highest VIF (~2.55) and lowest Tolerance (~0.392) among the predictors, which is still within acceptable limits. This indicates that while some predictors are correlated (as expected, e.g., poor infrastructure might correlate with lack of facilities), the correlations are not strong enough to inflate variances unduly. We can thus proceed to examine the logistic regression outcomes with confidence that the relationships identified are not artefacts of multicollinearity.

TABLE 4: Multicollinearity Test of Variables

Variables	VIF	Tolerance	Eigenvalue
Farm size	1.43	0.6992	0.1702
ICT tools are expensive to purchase	1.60	0.6237	0.1044
Lack of internet connectivity	2.55	0.3915	0.0826
Data bundles are expensive to purchase	1.16	0.4635	0.0724
Lack of ICT-related facilities	2.41	0.4154	0.0351
Mean VIF	2.19		

3.4. Logistic Regression Results: Factors Influencing ICT Adoption

Table 5 presents the estimated coefficients (log-odds) for each predictor, along with their standard errors and significance levels. The key findings from the model are summarised below:

3.4.1. Farm Size

The coefficient for farm size was positive ($\beta \approx 0.9062$) and statistically significant at the 10% level ($p \leq 0.10$). This positive coefficient indicates that farmers with larger farm holdings were more likely to adopt ICT, holding other factors constant. In practical terms, managing more hectares is associated with increased odds of using ICT tools. One possible interpretation is that larger-scale smallholders have greater financial capacity and an incentive to invest in technology, as the potential returns (e.g., improved productivity, access to markets) are greater when spread over a larger area or output. Larger farms might generate slightly more income or might be more commercially oriented, making their operators more open to innovations like ICT. This finding is consistent with the idea that farm commercialisation and scale can drive technology adoption. If a farmer sees ICT to optimise a large operation, they may be willing to allocate resources to it. Our result aligns with observations in similar contexts, such as those made by Balgah *et al*. (2022), who noted that better-resourced farmers tend to adopt ICT to improve farm management.

3.4.2. Cost of ICT Tools

The coefficient for the variable "ICT tools is expensive to purchase" was negative ($\beta \approx -0.1326$) and significant at the 10% level ($p \leq 0.10$). This means that farmers who regarded the cost of devices as a major constraint were less likely to be ICT adopters. It confirms the straightforward expectation that high device costs deter adoption: those who cannot afford or are strained by the cost of buying phones, radios, or computers generally do not use them for agricultural purposes. This factor essentially captures a financial barrier on the personal level. The negative impact of device costs on adoption echoes findings by Nyakudya *et al*. (2024) in Zimbabwe, where limited financial resources were associated with a lower likelihood of using advanced farming technologies. The policy implication is that reducing the effective cost of devices through subsidies, financing schemes, or promoting second-hand and low-cost technologies could help increase ICT uptake among farmers.

3.4.3. Poor Internet Connectivity

"Lack of internet connectivity" (representing inadequate internet services or coverage) had a substantial negative coefficient ($\beta \approx -2.9721$) and was highly significant ($p \leq 0.01$). This suggests that farmers who face poor internet connectivity are far less likely to use ICT for information. This is intuitive: if a farmer's area has no signal or extremely unreliable connectivity, many ICT tools, especially modern ones like smartphones or internet-based services, become practically unusable; thus, those farmers remain non-adopters. The magnitude of this effect in the model is significant, indicating that connectivity is a critical prerequisite. This finding underscores the urgency of improving rural network infrastructure: as long as entire communities lack connectivity, interventions focusing on training or subsidising devices may have limited impact because the basic utility of ICT is compromised. It reinforces the argument made by Poudel and Ghadei (2024) that infrastructure deficiencies, such as poor internet connectivity, severely restrict technology usage in agriculture.

3.4.4. High Data Cost

The variable for “expensive data bundles” also showed a positive coefficient ($\beta \approx 1.3170$) that was significant at the 5% level ($p \leq 0.05$). This result might initially seem counterintuitive, since we would expect high data costs to discourage adoption. However, the positive coefficient here likely reflects how the model was coded: a higher value on this variable corresponds to perceiving data cost as a major constraint (value 1 for major constraint). A positive coefficient indicates that, controlling for other factors, individuals who use ICT (adopters) are more likely to report that data costs are a major issue. In other words, active ICT users acutely feel the pinch of data expenses (since they buy data regularly), whereas non-users might not cite it as a personal constraint simply because they are not even attempting to use data. This interpretation aligns with our descriptive finding that data cost is a widely recognised barrier; even adopters may struggle to maintain their usage due to cost. Thus, the positive coefficient does not imply that high data costs encourage adoption; instead, it highlights that current ICT users identify cost as a significant pain point. This nuance aside, the broader understanding remains that data affordability is a key barrier that needs to be addressed to both encourage non-users to start using services and prevent current users from dropping out. As Wani (2021) observed in Kashmir, even when farmers adopt ICT, the ongoing high cost of internet can limit their continued usage or the extent to which they leverage the technology.

3.4.5. Lack of ICT Facilities

The variable representing the lack of ICT facilities, such as telecentres, had a positive coefficient ($\beta \approx 2.1239$) that was significant at the 5% level ($p \leq 0.05$). Interpreting this, farmers who reported the absence of ICT support facilities as a major issue were actually more likely to be ICT adopters. This might appear contradictory at first glance, but it could mean that the more tech-progressive farmers (those who have started using ICT) are the ones who strongly notice and complain about the lack of support facilities, because they would benefit from them. Non-adopters might not yet realise what they are missing in terms of support, whereas adopters know that if telecentres or ICT training were available, it would greatly enhance their usage. So, rather than implying that lack of facilities somehow pushes farmers to adopt (which is unlikely), the positive association here indicates that current ICT users feel hindered by the absence of local ICT resource centres. This highlights a need expressed by the more ICT-engaged farmers for support infrastructure, such as community internet access points, repair workshops, or digital training centres. This aligns with the findings of Akintelu *et al*. (2021) in

Nigeria: even when farmers begin using ICT, the sustainability and expansion of their use depend on having institutional support and infrastructure in place.

In summary, the logistic regression analysis provides evidence for the factors influencing ICT adoption among small-scale farmers, affirming many of the intuitive relationships and shedding light on the relative importance of each. Larger farm sizes (a proxy for better resources) increase the likelihood of adoption, while key barriers, such as device cost and poor connectivity, significantly decrease it. The analysis also uncovered that current ICT users highlight ongoing barriers (data cost, lack of facilities) that, if resolved, could further increase ICT utilisation.

These results confirm the study's hypothesis in a nuanced way: there is a significant relationship between the socio-economic characteristics of small-scale farmers and their perceived barriers, as well as their adoption of ICT for accessing agricultural information. For instance, farm size (a socio-economic characteristic) is significantly related to adoption status. Similarly, experiencing major barriers (like high costs or poor infrastructure) is strongly related to not adopting ICT. Therefore, we reject the null hypothesis of "no significant relationship"; instead, we accept that certain socio-economic factors and barrier experiences do influence ICT adoption among the farmers.

The findings here are instructive for stakeholders aiming to promote digital tools in agriculture. To increase adoption rates, strategies should focus on mitigating the key deterrents identified, including reducing costs through subsidies or cooperative purchasing of equipment and group data plans, expanding rural network infrastructure through government and private sector telecom investments, and providing training and support facilities via extension services or public telecentres. Additionally, since farm size and possibly income influence adoption, interventions might also need to be pro-poor, ensuring that even farmers with minimal operations can find value in ICT and are supported in using it. Otherwise, we risk ICT widening the gap between larger, better-off farmers and the smaller, poorer ones, with only the former adopting and benefiting from technology.

Although this study employed a strictly quantitative design, some respondents provided informal feedback during the survey administration. While not systematically analysed, these comments offer useful context. Several farmers expressed interest in using ICT if it became more affordable, noting that they had observed younger farmers using smartphones for weather updates and market prices. Such remarks reinforce the quantitative finding that cost is a major barrier, while also suggesting a latent demand that could translate into higher adoption if supportive measures were implemented.

TABLE 5: Binary Logistic Regression of the Significant Variables

Variables	Coefficient	Std. Error	Z	P>|z	Marginal effects	Tolerance
Farm size	.9062135	0.4906695	1.85	0.065***	.0477443	0.6992
ICT tools are expensive to purchase	-.1325804	0.71667	-1.85	0.064***	-.0698506	0.6237
Lack of internet connectivity	-2.972073	1.0706	-2.78	0.006*	-.156585	0.3915
Data bundles are expensive to purchase	1.316974	0.5119009	2.57	0.010**	.0693854	0.4635
Lack of ICT related facilities	2.123933	0.8608678	2.47	0.014 **	.1119003	0.4154
Constant	-.2202614	3.715509	-1.91	0.057		
Number of observations	121					
LR $chi^2(14)$ =	64.51					
Prob > chi ^{2}=	0.0000					
Psuedo R^2 =	0.6568					
Log likelihood =	-16.852644					
Marginal effect after logit=	0.97790065					

Note: *, ** and * means1%, 5% and 10% levels of significant respectively**

4. CONCLUSION AND RECOMMENDATIONS

In conclusion, the adoption of ICT among small-scale farmers in Mahikeng is significantly constrained by a combination of infrastructural, economic, and socio-cultural barriers. While awareness of ICT's potential is relatively high, practical use remains limited due to poor connectivity, high costs, low digital literacy, and limited access to locally relevant information. These challenges are further compounded by the demographic profile of the farmers, including low levels of education and income.

To address these barriers effectively, efforts should focus on expanding rural infrastructure, enhancing the affordability and accessibility of ICT tools, and integrating digital support into existing agricultural extension services. Tailored training initiatives, local-language content, and community-based access points can further improve uptake. Encouraging youth participation in agriculture may also help drive broader digital inclusion. A coordinated, context-specific approach that aligns technology with farmers' realities is essential for unlocking the full benefits of ICT in rural agricultural development.

5. FUTURE RESEARCH DIRECTIONS

Building on the findings of this study, future research should prioritise in-depth, context-sensitive investigations into the social and cultural factors influencing ICT adoption among small-scale farmers in Mahikeng. Comparative studies across other municipalities could reveal whether these barriers are widespread or locally specific, helping tailor regional or national interventions. Researchers should also evaluate how infrastructure improvements, such as reliable internet access or solar energy, impact ICT uptake over time. Affordability remains a key concern; therefore, trials involving subsidised devices, shared resources, or community-based cost models are worth exploring. Additionally, the role of digital literacy should be further studied, particularly in terms of training methods tailored to local languages and formats suitable for low-literacy users. Engaging youth as ICT ambassadors and integrating digital tools into agricultural extension services also presents promising areas for enhancing uptake. Lastly, longitudinal and mixed-methods research can help establish causal links and track the long-term effectiveness of such interventions.

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Factors Influencing Farmers' Adoption of Crop Biotechnology to Mitigate Climate Change: Case of Eastern Cape, South Africa

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ABSTRACT

This study examined the adoption of crop biotechnology among smallholder farmers in the Eastern Cape as a strategy to mitigate the impacts of climate change, focusing on the barriers, socioeconomic factors, and current adoption status. Despite the increasing relevance of biotechnology in climate resilience, there is a lack of research on the specific challenges and drivers influencing its adoption in rural South Africa. The study aims to examine the barriers to biotechnology adoption, assess the socioeconomic factors influencing adoption, and highlight the status of crop biotechnology in climate change adaptation. A multi-stage sampling method was employed to conduct interviews with 350 smallholder maize farmers across three district municipalities in the Eastern Cape, with data collected through structured interviews. The Multinomial regression model and descriptive statistics were used in the analyses of the study. Key findings reveal that financial constraints, lack of knowledge, and limited access to climate information and credit are significant barriers, while education, income, and farm size have a positive influence on adoption. The study further recommends that targeted interventions be implemented to address these barriers, including financial, informational, and educational barriers, in order to enhance biotechnology adoption and improve the resilience and productivity of smallholder farmers in the face of climate change.

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1. INTRODUCTION AND BACKGROUND

South Africa faces significant challenges from climate change, which impacts critical sectors such as social welfare, infrastructure, and agriculture. Rising temperatures and altered rainfall patterns pose a threat to the country's ecosystems and economic stability. Extreme weather events have also become increasingly common. In KwaZulu-Natal and the Eastern Cape, the frequency and intensity of storms and flooding have escalated. These events are mainly driven by climate change and environmental mismanagement (Busayo *et al*., 2022; Gqalindaba *et al*., 2024). These climate variations result in severe rainfall and extreme temperatures. They pose considerable risks to low-lying coastal areas and contribute to flood disasters and sea level rise (Griggs & Reguero, 2021; Laino *et al*., 2023). Extreme temperatures have made socioeconomic challenges worse for families in coastal cities. Climate impacts in these regions are intensified by tropical cyclones, heavy rainfall, frequent coastal flooding, storm surges, and tidal shifts (Dube *et al*., 2022). Farmers are responding by adjusting planting schedules and diversifying crops to adapt to climate variability (Adlina & Oktari, 2024). Agroforestry and conservation agriculture are also gaining traction, enhancing resilience by promoting ecosystem health (Chauhan, 2024).

To combat these challenges, smallholder farmers are adopting agricultural biotechnology solutions. These solutions are vital for adapting productivity to climate change. Agricultural biotechnology increases crop yields and strengthens plants' resistance to pests and diseases. It can also reduce energy use (Andualem & Seid, 2021). Furthermore, agricultural biotechnology offers solutions for lowering the impact of climate change and mitigating its effects. South Africa is among the few African nations that have embraced biotechnology. It has adopted genetically modified (GM) crops, including cotton, soybeans, and maize. The South African government has supported GMOs for over a decade. It recognises their role in boosting productivity, especially in combating challenges such as stalk-boring insects, a major threat to maize production (Choudhary & Gaur, 2022). Despite these promising advances, some farmers remain wary of GMOs because of concerns about safety and market acceptance. This highlights the importance of education and support for adoption (Mutiga *et al*., 2023). By leveraging biotechnological tools and promoting awareness, South Africa aims to enhance its agricultural resilience in the face of climate challenges.

Farmers in the Eastern Cape, South Africa, are facing severe impacts from climate change. These include declining crop yields and agricultural productivity (Amoah & Simatele, 2021). While crop biotechnology offers a viable solution, its adoption remains low. Limited awareness, socioeconomic barriers, and cultural perception are key factors (Lemarié *et al.*, 2022). These challenges hinder farmers' ability to leverage biotechnology for climate resilience. Understanding these factors is crucial to promoting adoption and improving agricultural sustainability in the region. The objectives of the article are:

- To highlight the current status of crop biotechnology adoption as a strategy to mitigate climate change impacts in smallholder farming systems.
- To highlight the contribution of Agricultural Extension in the adoption of agricultural biotechnology.
- To investigate the barriers smallholder farmers face in adopting crop biotechnology, with a particular focus on the challenges that limit their ability to embrace climate-smart agricultural practices.
- To identify the socioeconomic factors influencing the adoption of crop biotechnology.

2. THEORETICAL ASPECT OF ADOPTION

The adoption of crop biotechnology by smallholder farmers is a complex phenomenon driven by several interconnected factors. By adopting a systems thinking approach, these variables can be examined as components of a larger, interconnected ecosystem rather than separately (Sarkar *et al.*, 2024). This framework posits that the adoption process is influenced by three primary dimensions: individual farmer characteristics, socioeconomic factors, and environmental conditions, all of which interact dynamically within the agricultural system.

2.1. Individual Farmer Characteristics

The characteristics of smallholder farmers, such as education level, risk perception, and technological literacy, play a vital role in influencing their propensity to accept biotechnology. Farmers with higher educational attainment are more likely to recognise the benefits and risks associated with biotechnology breakthroughs (Harfouche *et al.*, 2021). Furthermore, according to Saleh *et al.* (2021), farmers' willingness to adopt new technologies is influenced by their perception of risk, as individuals who believe biotechnology will be advantageous are more likely to incorporate it into their farming methods.

2.2. Socioeconomic Factors

The socioeconomic context comprises access to resources, financial capital, and social networks. Smallholder farmers often face constraints such as limited access to credit, which can hinder their ability to invest in biotechnology. Farmers' views on the adoption of biotechnology are also greatly influenced by social networks and local norms. Implementation success can be enhanced by promoting collective adoption and facilitating knowledge transfer through peer and agricultural extension services (Beumer & Swart, 2021).

2.3. Environmental Conditions

The physical and regulatory elements of the agricultural environment contribute to the adoption of biotechnology. Factors such as soil fertility, climate variability, and pest pressures affect the perceived need and effectiveness of biotechnological solutions. Additionally, government policies and regulatory frameworks play a crucial role in shaping the adoption landscape. Policies that support biotechnology research, development, and dissemination can foster an environment conducive to smallholder farmers adopting these innovations (Yongabo, 2021; Feleke *et al*., 2021).

3. RESEARCH METHODOLOGY

The research methods used in the study are quantitative. The study utilised a multi-stage sampling method to select smallholder farmers in the Eastern Cape, explicitly targeting the districts of Alfred Nzo and Amathole, which have the largest populations of maize farmers, as these farmers were the largest group growing Genetically Modified (GM) maize, hence the motivation for this study to adopt GM maize. From these districts, two local municipalities were randomly selected, and a snowball sampling technique was used to identify individual maize farmers for participation. The initial target sample size was 400, calculated using the following probability sampling formula:

$$n = \frac{N}{1 + N\ (e^2)}$$

Where:

- n = sample size
- N = total population of maize-producing smallholder farmers in Eastern Cape (596,573 as per Stats SA, 2021)
- e = margin of error (0.05, representing a 95% confidence level)

Using the formula, the required sample size was determined to be 400. However, due to budget constraints, only 350 smallholder farmers were selected for the interview. The study ensured that participants were equally distributed across the three selected district municipalities and were fully informed about the study's objectives and confidentiality, thereby ensuring voluntary participation. The final sample represents a cross-section of maize-producing smallholder farmers in the region. The data collected through a survey questionnaire was encoded and recorded in Microsoft Excel. Primary data was collected using a questionnaire. Personal information (such as age, gender, level of education, and marital status) was required for this study, as well as general demographic data (income levels, household size). The study used descriptive statistics and a multinomial regression model.

3.1. Multinomial Regression Model (Analytical Framework)

The multinomial logit regression model (MNL) was employed to analyse the socioeconomic and environmental factors influencing the choice of biotechnological adoption by smallholder farmers in this study. Socioeconomic constraints can become significant factors that slow or hinder the mitigation of climate change and variability. Multinomial logit regression is used to analyse an individual's choice among a set of J alternatives (Hoffman & Duncan, 1988; Damtew *et al*., 2024). According to Bayaga (2010), multinomial logistic regression is used when the dependent variable has more than two nominal or unordered categories, in which dummy coding 3 of three independent variables is quite common. Furthermore, Shongwe *et al*. (2014) and Shongwe *et al*. (2021) argue that the MNL model for the choice of adaptation strategies specifies the relationship between the probability of choosing an adaptation option and the set of explanatory variables.

To further describe the multinomial logit regression model, P represents the probability that an individual chooses alternative J, and Y is the polychotomic dependent variable, while J denotes the number of unordered alternatives and x represents the set of explanatory variables

(Hoffman & Duncan, 1988). In this study, the Y represents the alternative adaptation trait to mitigate the effects of climate variability on crop production. Therefore, the set of explanatory variables includes the characteristics of the smallholder farmers who choose adaptation strategies. Additionally, the P in this study presents the likelihood of the smallholder farmers being in each adaptation trait. Shongwe *et al.* (2014) argue that the MNL model for the choice of adaptation strategies specifies the relationship between the probability of choosing an adaptation option and the set of explanatory variables. Gbetibouo (2009) stated that the multinomial logit model analyses how the elements of x would affect the response probabilities.

$$P\left(Y = \frac{j}{x}\right), j = 1,\ 2, \dots J.$$

Also, the probability that a farmer i will choose an adaptation alternative j among the set of adaptation options could be defined as:

$$P\left(Y = \frac{1}{X}\right) = P(Uij > \frac{Uik}{X})$$

The above-defined probability equation is adopted from Armah *et al.* (2013), where Uij and Uik are the perceived utilities by farmer i of adaptation options j and k, respectively with Xi being the vector of explanatory variables influencing the choice of the adaptation option. Since the probabilities must sum to unity, $P(Y = \frac{j}{X})$ would be determined once the probabilities for $j = 2, \dots J$ are known. Furthermore, the adaptation strategies will be grouped into three categories, as farmers may have employed more than one strategy. The following multinomial logit model is adopted, as used by Armah *et al.* (2013) and Obayelu *et al.* (2014).

$$P\left(y = \frac{j}{x}\right) = exp\ exp\ (x\beta j)\ / \left[1 + \sum_{K=1}^{J} \quad (exp \times \beta j) + e, j = 1, \dots J\right]$$

In the above MNL equation, βj is the parameter to be estimated and e is the error term. The parameter estimates of the multinomial logit regression only offer the direction of the effect of the independent variables on the dependent variable but do not represent the actual magnitude of change or probabilities (Deressa *et al.*, 2010; Armah *et al.,* 2013). Dependent and independent variables are shown in Table 1.

TABLE 1: Dependent and Independent Variables for the Multinomial Regression Model

Variables	**Type of variables and description**
Dependent variables(Y)-Maize variety adopted.	Polychotomic variables
Bt maize (Insect resistant) RR maize (Herbicide-tolerant) Drought-TEGO (Drought-tolerant) CAP 9001 maize (Disease resistant) Non-genetically modified maize varieties (landrace)	
Independent variables (x):Socio-economic	
Age of the farmer	Discrete= Age of household head
Educational level	Discrete=Years
Marital status	Dummy-1=Married, 0 otherwise
Household size	Dummy-1=Yes, 0 otherwise
Land size	Discrete-Size
Gender	Dummy-1=Male, 0=Female
Reason for Farming	Dummy-1=Profit, 0= Subsistence
Source of Capital	Polychotomic variables
Farming years	Discrete= number of years
Household monthly income	Continuous
Farming Method	Polychotomic variables
Employment status	Polychotomic variables
Other Income Source	Polychotomic variables

4. RESULTS AND DISCUSSION

4.1. Adoption of Crop Biotechnology to Adapt to Climate Change and Variability

Adaptation to climate change is imperative for the resilience of smallholder agriculture. The resilience of smallholder farmers to climate change can be directly linked to various adaptation strategies and their adaptive capacity, as documented in the literature (Ogundeji, 2022; Gebre *et al.*, 2023). According to Verma and Sudan (2021), farmers who respond to climate change through various adaptation measures are more likely to enhance agricultural productivity and improve their livelihoods. Adaptation to climate change contributes to improved household food security and, in general, farm household welfare. Adaptation strategies, such as improved crop varieties, are the adaptation strategies that farmers are adopting most frequently lately. According to the results of this study, approximately 96.9% of the respondents have adapted to climate change and its associated variability. The results showed that 76.6% of the respondents were familiar with crop biotechnology, which involved a variety of GM maize crops adopted to mitigate the effects of climate change.

4.1.1. Maize Variety Adopted by Smallholder Farmers

According to Ala-Kokko *et al*. (2021), genetically modified (GM) maize has significantly improved food security in South Africa, reduced environmental damage, and helped smallholder farmers achieve substantial gains in earnings over the past two decades. The respondents were asked about the maize varieties they had previously adopted and about the current maize variety they were using during the planting season. The maize variety they adopted from November 2023 to August 2024. This was done as it is essential when examining the adoption status of crop biotechnology for mitigating climate change.

The results from the last planting season showed that respondents reported the following varieties: 41.43% planted Bt maize, 29.57% planted drought-resistant maize, 11.71% non-GM/Landrace maize, 10.57% RR maize, and 9.14% Cap009 maize. This aligns with findings from Ala-Kokko *et al*. (2021) and Muzhinji and Ntuli (2021), which highlight that GM maize has contributed to improvements in food security, increased farmer incomes, and reduced environmental damage in South Africa.

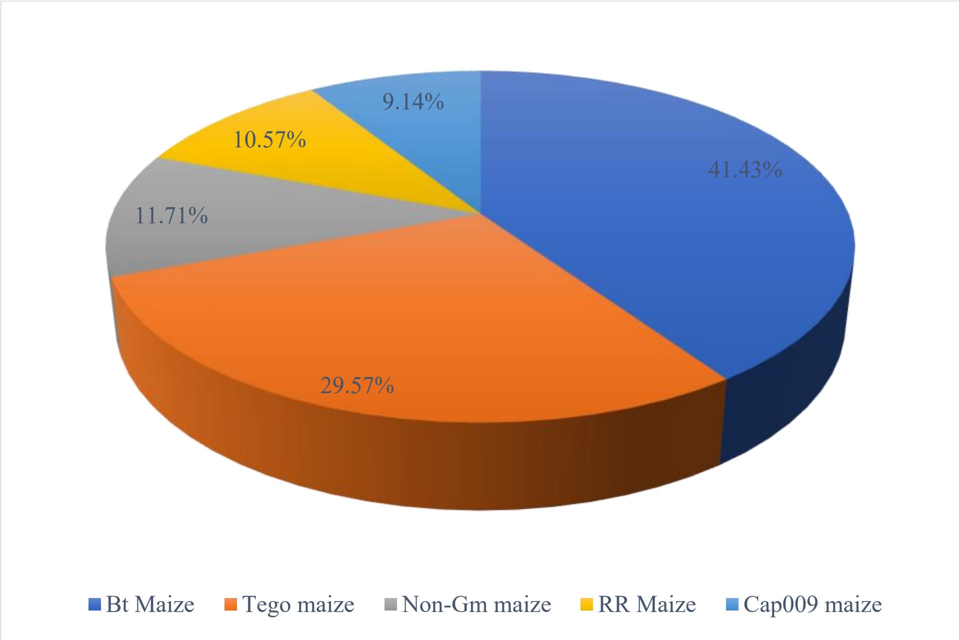

FIGURE 1: Showing Currently Adopted Maize Varieties by the Respondents

The study examined the adoption of various maize varieties among smallholder farmers, with a focus on their use in past planting seasons. Results showed that Bt maize, with its pest resistance, was the most widely adopted variety, used by 46.28% of respondents (n = 350). This was followed by drought-resistant maize, adopted by 34.29% (n = 350), highlighting the importance of crops that can withstand climate variability. Non-GM maize and RR maize were also adopted, at 32.29% and 29.14% (n = 350), respectively, suggesting that farmers are balancing biotechnology with traditional practices. These findings reflect a growing trend among smallholder farmers to select maize varieties that help address critical climate challenges, such as pests and drought. The high adoption of Bt and drought-resistant varieties suggests that farmers recognise the need for resilient crops to cope with the increasing unpredictability of weather patterns associated with climate change.

The results also emphasise the potential of crop biotechnology in climate change adaptation. By adopting genetically modified (GM) and drought-tolerant varieties, farmers can enhance their resilience to climate stressors, including insect infestations and water scarcity. However, this also highlights the importance of providing access to affordable and sustainable seed varieties, ensuring that all farmers, regardless of their economic status, can benefit from these innovations. As climate change continues to impact agricultural productivity, the adoption of climate-resilient crops will be crucial in ensuring food security for smallholder farmers. The maize varieties are shown in Figure 2.

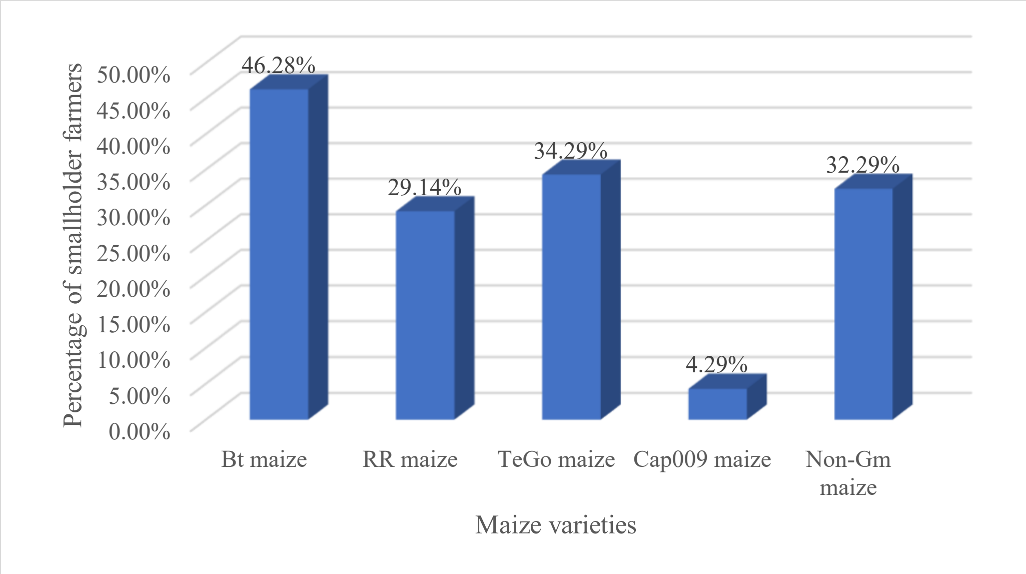

FIGURE 2: Showing the Maize Varieties Adopted in Past Planting Seasons

The study found that 59.14% of respondents had no issues with paying for GM seeds, indicating a positive attitude toward the adoption of genetically modified crops. However, 19.14% of respondents reported that GM seeds were not affordable for them, highlighting a significant barrier to wider adoption. A small portion (2%) of farmers were uncertain about their willingness to pay for GM seeds, suggesting some indecision or lack of information. The respondents who had previously and currently bought GM maize seeds were then asked how they paid for the seeds. Forty percent (n=350) of the overall sample reported using loans, 60% personal savings, 17.71% (n=350) received support from the government, and 12.51% (n=350) used other means. These results offer a glimmer of hope, as previous studies have reported that farmers in the Eastern Cape are not willing to pay for their farming services and are dependent on government support (Loki, 2022; Ruzhani & Mushunje, 2022). However, a willingness and desire to do something do not always mean the ability to do so. These respondents face challenges in accessing credit facilities, which also hinders their advancement in farming. When observing the respondents who are more inclined to adopt GM maize. Smallholder farmers are still sceptical about adopting advanced crop varieties and still face barriers in the adoption of new technology, including biotechnology

4.2. Contribution of Agriculture Extension in the Adoption of Agricultural Biotechnology

Agricultural extension is crucial in providing small-scale farmers with the knowledge and resources they need to adopt agricultural biotechnology and mitigate the effects of climate change (Wahyuni, 2025). The findings demonstrate that extension services serve as a vital link between research and agriculture by raising awareness about climate change, offering technical assistance, and providing training. More than half of the farmers (58.9%) reported participating in extension services, and many stated that they had observed improvements in their farming methods, such as using higher-quality seeds and managing climate variability more effectively. Farmers have found it crucial to adapt to climate change with the aid of technical assistance, which includes soil analysis (39.4%), training (50.9%), crop insurance advice (29.1%), and the dissemination of climate information (50.9%) to face difficulties such as increasing temperatures, drought, and changes in precipitation patterns.

However, there are still notable failings. The effectiveness of services is hampered by the scarcity of extension officers, inconsistent contact (59%), and inadequate specialised training. Additionally, government incentives such as seed distribution, mechanisation assistance, and soil testing are not being provided to farmers regularly, with the majority of respondents stating that they received little or no assistance. These gaps undermine farmers' ability to embrace climate-smart strategies and biotechnology.

4.3. Barrier to Adoption of Agricultural Biotechnology

Solutions to reduce the yield gap must meet the requirements of smallholder farmers. According to Alemu (2020) and Kabisa *et al*. (2020), biotechnology in agriculture provides some solutions. However, there are several obstacles in the way of creating, implementing, and embracing biotechnology, as with any other technology. When examining the barriers to the adoption of crop biotechnology, the results indicated that a lack of adequate finances (92%) is the leading cause of slow adoption or use of GM varieties accessible to their financial brackets, with no consideration of the solutions offered. This is consistent with Alemu and Grebitus (2020), Kabisa *et al* (2020), Alemu (2020), Langyintuo (2020), and Kedisso *et al*. (2022), who identify financing as a major barrier to the uptake of biotechnology and who assert that access to credit and financial support is vital for the uptake of biotechnology.

Furthermore, while GM maize adoption is relatively high, other crop varieties, including non-GM maize, are still widely used, signalling hesitance or resistance to biotechnology in some farming communities. This suggests that factors such as access to knowledge, affordability, and trust in the technology continue to be significant barriers to full adoption. The respondents reported a lack of knowledge as a barrier to their adoption, with 60.57% of the farmers responding that they need more knowledge in the aspect of new crop varieties. A percentage of 39.43% of respondents are well-informed and connected to information sources, whose knowledge was not a barrier for them.

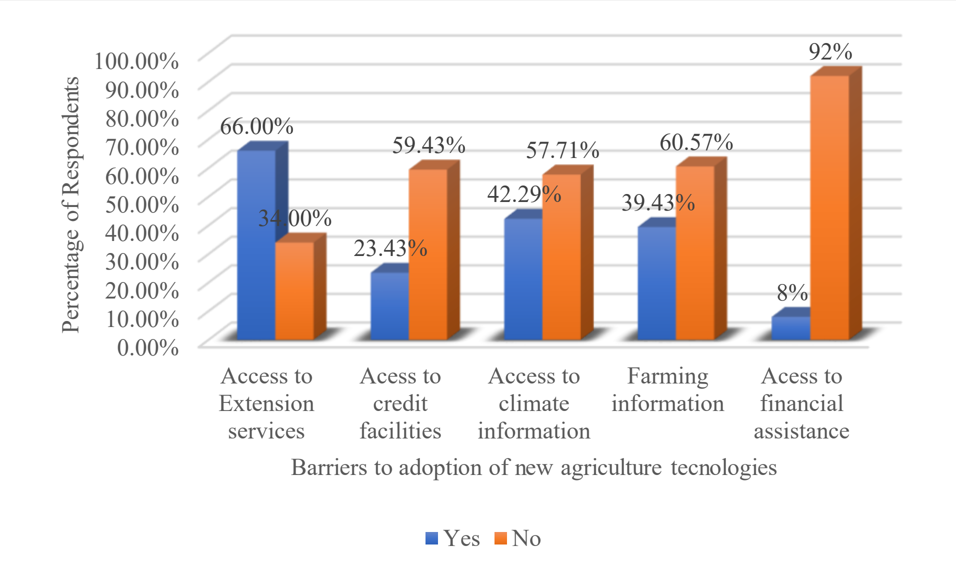

FIGURE 3: Challenges Faced by Smallholders in Their General Farming Practices

To enhance agricultural resilience and production in the face of climate change, smallholder farmers implementing crop biotechnology must have access to accurate climatic information. Farmers can use this knowledge to make informed decisions about biotechnology applications that mitigate negative effects by understanding climatic trends. When asked about their level of climate-informedness, 57.71% of respondents reported being climate-informed and having access to climate information, while 42.29% reported having no access to climate information.

Fifty-eight percent may seem like a significant percentage, but 42.29% is still a larger number of smallholder farmers with no access to climate information, which can alter the goal of climate resilience and self-reliance among smallholder farmers in Rural areas. This can put a stumbling block to food security. This gap in access to critical information could undermine efforts to improve resilience through biotechnology, as farmers may struggle to align their crop choices with current climatic conditions. This lack of access is particularly concerning in rural areas, where the infrastructure for disseminating information is often limited. As noted by Hallegatte (2016) and Schattman *et al*. (2021), the effectiveness of GM crop adoption in mitigating climate impacts is significantly reduced when climate-informed decision-making is not employed.

Access to credit is crucial for smallholder farmers to adopt green biotechnology, as it alleviates financial constraints and enables investment in innovative agricultural practices; however, looking at the results, a high percentage of 59,43% of the respondents reported they had no access to credit, which stems as a barrier to their adoption of crop biotechnology. Only 23.43% of the population had access to credit, and this was not a major barrier. Access to credit is crucial for smallholder farmers to adopt crop biotechnology, as it enables them to invest in advanced seed varieties, technology, and infrastructure needed to mitigate the impacts of climate change. Financial support enables farmers to afford genetically modified (GM) crops or drought-resistant varieties that enhance yield and resilience against climate-related stressors, thereby fostering sustainable agricultural practices in the face of environmental uncertainty.

Access to agricultural extension services is also crucial for smallholder farmers to effectively adopt green biotechnology and other technologies. These services facilitate the dissemination of knowledge and innovations, enabling farmers to make informed decisions about new technologies. A percentage of 66.3% of respondents reported having access to agricultural extension services; however, some reported this for different reasons. These include livestock production and other activities. They reported that they were not part of the maize-producing farmers' groups. A percentage of 33,7% of the farmers reported that access to agricultural extension was a barrier for them. This finding is supported by Shankar *et al*. (2018) and Maulu *et al*. (2021), who note that access to extension services and educational programs is critical for overcoming knowledge gaps. However, even when extension services are available, they are often limited in reach, with some farmers not having access due to geographic or logistical challenges.

4.4. Socioeconomic Factors Influencing the Adoption of Crop Biotechnology

4.4.1. Multinomial Model Results

The multinomial regression model was used to analyse factors influencing smallholder farmers' adoption of various maize varieties, particularly genetically modified (GM) crops. The model fitting criteria show that the -2 Log Likelihood statistic decreased from 993.289 in the intercept-only model to 873.770 in the final model, with a Chi-Square of 119.519 (df = 60, p < .001). This significant reduction indicates that the inclusion of predictor variables meaningfully improves the model's ability to predict maize adoption categories compared to a model with only the intercept.

The goodness-of-fit tests, including the Pearson and Deviance chi-square tests, both display high p-values (Pearson: .245, Deviance: 1.000), suggesting that the model fits the data well and that the observed frequencies in each category are consistent with those predicted by the model. However, the pseudo-R-square values Cox and Snell (.291), Nagelkerke (.308), and McFadden (.120) indicate a moderate amount of explained variance. These values highlight the model's effectiveness, but also suggest that additional, unexplained factors influence maize adoption decisions that are not currently included in the model. A key focus of the analysis is identifying significant predictors of maize adoption levels. The likelihood ratio tests reveal that several predictors are statistically significant, specifically age (p = .036), employment status (p = .005), education level (p < .001), monthly income (p = .013), other source of income (p = .033), and years farming (p =.020).

4.4.2. Education Level

The education level, with the highest Chi-Square value (21.852), emerges as a particularly influential predictor, suggesting that increased education is strongly correlated with maize variety adoption decisions. This implies that farmers with higher educational attainment are more likely to adopt new or GM maize varieties. The parameter estimates give further insight into the direction and magnitude of these relationships. Education level shows a particularly strong effect across multiple adoption levels. For example, in category 2, education has a positive coefficient of B = 1.610 (p < .001), with an Exp(B) of 5.001, indicating that farmers with higher levels of education are five times more likely to adopt this maize type than those with lower levels of education.

This result highlights the critical influence of educational attainment in shaping farmers' openness to genetically modified or advanced crop varieties, likely due to increased knowledge about the benefits of GM technology and a reduction in misconceptions or fears about GM crops. This trend aligns with the literature, which suggests that educated farmers are more open to adopting innovative agricultural technologies due to a better understanding and fewer misconceptions about biotechnology (Asfaw *et al*., 2021; Mulugeta *et al*., 2024). In the study, education has a particularly strong correlation with the adoption of GM crops, as evidenced by the high Chi-square value for education level in the regression analysis.

4.4.3. Age of Farmers

Age consistently shows a negative coefficient across adoption levels, meaning younger farmers are more likely than older ones to adopt various maize varieties. This trend is especially notable in adoption category 2, where age has a coefficient of -0.066 ($p = .003$), indicating that younger farmers have a significantly higher likelihood of adopting this maize type. These findings suggest that younger farmers may be more open to innovations, potentially due to greater familiarity with or openness to agricultural technologies.

4.4.4. Employment Status

Employment status is another important predictor. In the adoption category 0, employment status has a positive coefficient ($B = 0.676$, $p = .034$), indicating that farmers with stable employment are more likely to adopt specific maize varieties than those without employment. This finding highlights the importance of economic stability in influencing adoption decisions, as employed farmers may have greater financial security to invest in GM seeds. This finding is consistent with that of Teye and Quarshie (2022), who argue that access to financial resources plays a crucial role in enabling farmers to invest in new technologies. Employment provides the necessary economic stability to absorb the costs associated with GM seeds, which may be prohibitive for farmers without stable incomes. Conversely, farmers with lower monthly incomes or those without employment face challenges in adopting GM maize, as they prioritise cost-effective agricultural practices.

4.4.5. Farm Size

Farm size also plays a significant role in determining adoption levels. In category 3, farm size has a positive coefficient ($B = 0.385$, $p = 0.011$), indicating that larger farms are more likely to adopt specific types of GM maize. This aligns with the notion that larger farms, which often benefit from economies of scale, may be better equipped to absorb the costs associated with GM seed technology and may also have greater access to resources to support new crop varieties. Monthly income and other income sources are also significant predictors. This supports the findings of Zewde (2020) and Kedisso *et al*. (2023), who suggest that farm size directly influences the ability of farmers to adopt and implement high-cost technologies, such as GM crops. However, smallholder farmers with limited land may struggle to adopt GM maize due to the upfront costs, despite potential long-term benefits.

4.4.6. Farmer's Diverse Income

Farmers with diverse income streams (p = .033 in likelihood ratio tests) are more likely to adopt GM varieties, possibly due to increased financial flexibility that enables them to invest in newer or more resilient maize types. However, income effects vary slightly across adoption levels, reflecting that different financial structures may influence adoption in unique ways. Notably, in category 3, monthly income has a negative coefficient of -0.594 (p = .020), which could indicate that lower-income farmers in this group may prioritise cost-effective crops over GM varieties or that the cost of GM seeds may be a limiting factor.

4.4.7. Years of Farming Experience

Years of farming experience (Years F) also shows significance (p = 0.020 in likelihood ratio tests), particularly at adoption level 1, where it has a negative association with adoption (B = -0.068, p = 0.008). This suggests that farmers with less farming experience may be more inclined to adopt GM varieties, possibly because they may be more adaptable to new practices or less entrenched in traditional farming methods. The acceptance of genetically modified (GM) crops and farming experience has a complex relationship; some research indicates that farmers with less expertise may be more likely to embrace GM crops. In the context of GM acceptance, Mueller and Flachs (2022) stated that this pattern is observed, with less experienced farmers possibly being less devoted to conventional methods or more flexible in adopting new ones. The simplicity of farming methods and the potential for greater production improvements associated with genetically modified crops are two reasons for this trend.

4.4.8. Farming Method

The influence of farming methods is evident in adoption category 3, where farming methods have a negative impact on adoption (B = -1.152, p = .077). Although this effect is not statistically significant across all categories, it suggests that specific farming practices may affect openness to GM maize. In line with the findings of Tobaben and Kwade's 2024 study, farmers' perceptions of the hazards associated with adopting GM technology significantly influence their attitudes towards it. The association between perceived advantages and adoption readiness is mediated by negative views rooted in health and environmental dangers (Tobaben & Kwade, 2024). According to Patil & Padaria (2018) and Sendhil *et al*. (2022), this is similar to the finding that farmers' willingness to adopt Bt-brinjal was negatively impacted by socioeconomic and health risk perceptions, suggesting that risk perception is a critical factor in adoption decisions.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

In conclusion, smallholder farmers in the Eastern Cape are increasingly adopting crop biotechnology, with Bt maize and drought-tolerant varieties being the most favoured since they are resistant to climate stress and pests. Despite affordability, lack of credit, and little government assistance remaining significant challenges, the majority of farmers indicated a willingness to pay for GM seeds. Despite the crucial role that agricultural extension services play in providing training, technical advice, and climate data, their effectiveness is hindered by a shortage of extension officers, inadequate specialised support and sporadic contact. Due to these gaps, farmers' capacity to adopt biotechnology for climate change adaptation is limited.

Additionally, socioeconomic variables influence adoption choices. Older farmers with limited resources are still hesitant to use GM types, while younger, more educated farmers with steady incomes and larger farms are more likely to do so. Additionally, adoption is slowed by insufficient access to climate data and knowledge gaps. In general, biotechnology has a clear capacity to enhance resilience, increase productivity, and promote food security among smallholder farmers. However, maximising its impact necessitates addressing financial limitations, increasing extension support, and ensuring consistent government incentives to foster a conducive environment for broader and more equitable uptake.

5.2. Recommendations

It is recommended that policymakers and development agencies should focus on improving access to credit, providing targeted educational programs, and enhancing information dissemination systems to support smallholder farmers in adopting GM crops and other climate-smart technologies. Extension services should educate farmers about the benefits of GM varieties to promote food security.

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