

# DETERMINANTS OF THE UTILIZATION OF DIGITAL TECHNOLOGIES BY SMALLHOLDER FARMERS IN EASTERN CAPE PROVINCE, SOUTH AFRICA

Nasiphi Vusokazi Bontsa<sup>✉</sup>, <https://orcid.org/0000-0002-6320-4559>

<sup>✉</sup>nbontsa@ufh.ac.za

Abbyssinia Mushunje, <https://orcid.org/0000-0002-2183-785X>

Department of Agricultural Economics and Extension, University of Fort Hare, Alice, South Africa

Saul Ngarava, <https://orcid.org/0000-0002-8462-0287>

Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, Netherlands

**Abstract.** The objective of the study was to assess the determinants of the utilization of digital technologies by smallholder farmers in South Africa. A cross-sectional survey of 250 smallholder farmers was purposively sampled from Port St Johns and Ingquza Hill Local Municipalities. Binary and ordered logistic regression were used to analyse the data. The results show that 55% of the smallholder farmers were using digital technologies. Out of these, 40% were using smartphones and radio. Close to 47% of the smallholder farmers who were using digital technologies were using them to some extent and 65% had been using digital technologies for a period of 1–4 years. 89% of the smallholder farmers using digital technologies indicated that they are beneficial and 83% had opted to continue using digital technologies to increase their skills and knowledge. However, 44% of the smallholder farmers who had opted to discontinue the use of digital technologies indicated that these technologies were not beneficial for them. Overall, 85% of the smallholder farmers would recommend the use of digital technologies to other farmers. Factors such as age, educational level, marital status, full-time farming, and land size affected the utilization of digital technologies while age, marital status, educational level, full-time farming, household size, non-crop producing, and tenure affected the extent of digital technology utilization. The study concludes that the partial utilization of low-tech digital technologies is a socio-economic driver. Recommendations include the promotion of digital technologies, especially high-tech technologies, taking into account the socio-economic circumstances of smallholder farmers.

**Keywords:** binary logistic regression; digital technology; ordered logistic regression; smallholder; South Africa; utilization

## INTRODUCTION

Digital technologies have been identified as one of the drivers of the Sustainable Development Goals (SDGs). They have been instrumental in biotechnology (SDGs 3, 12 and 13), farm management (SDGs 3, 12, 13, 15 and 17), indoor technologies and platforms (SDGs 3 and 8), food safety and traceability (SDGs 2, 6, 12 and 13),

supervision and stakeholder support (SDGs 3, 9, 12 and 13), indoor databases and analysis (SDGs 13 and 15), and training (SDG 4, 5, 9 and 10) (Secundo et al., 2022). In smallholder agricultural production systems, digital technologies are essential in poverty reduction (SDG 1) and ending hunger (SDG 2). Specifically, digital technologies for smallholder farmers can be a conduit to eradicate extreme poverty and reduce the number of people living

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in poverty (SDG Targets 1.1 and 1.2) as well as helping build resilience and reduce exposure to climate-related events (SDG Target 1.5) (Florey et al., 2020; Dayioğlu and Türker, 2021). This is achieved through empowering smallholder farmers with digital technologies that can meet these developmental standards. Furthermore, digital technologies improve income and livelihoods for smallholder farmers (Dietz and Drechsel, 2021). Digital technologies can also be used to achieve food security (SDG Target 2.1), increase smallholder production (SDG Target 2.3), and improve access to information (SDG Target 2.c) (Borodina et al., 2021; Raimi et al., 2021).

The agrarian sector is increasingly dynamic as well as information- and data-intensive, with the goal of reducing workloads, improving efficiency and improving livelihoods (Drewry et al., 2019; Monteleone et al., 2020; Carrer et al., 2022). According to Gangwar et al. (2022) there is a need for digital inclusion, especially for

smallholder farmers. This is in line with high production risks and resource planning. Various digital technologies have been adopted in South Africa's agricultural sector, and most are low-tech, such as TVs, radios, mobile phones, internet, email, etc. (Dlamini and Ocholla, 2018; Oladipo and Wynand, 2019; Makaula, 2021). The adoption of digital technologies in South Africa has been limited by factors such as cost, lack of integration of indigenous knowledge, complicated technology, and lack of awareness, among other things (Migiro and Kwake, 2007; Maumbe, 2010).

Digital technologies have offered an evolutionary change in agri-food systems which has occurred in tandem with socio-technical systems surrounding the large variety of digital technologies (Giua et al., 2022a). According to Giua et al. (2022a), there are variations in the adoption and use of digital technologies based on farm and farmer characteristics. As shown in Table 1, there

**Table 1.** Factors affecting the adoption and utilization of digital technologies

| Construct                  | Factors                                                    | Author(s)                                                                                                                                      |
|----------------------------|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Demographic                | Age                                                        | (Shang et al., 2021)(Michels, von Hobe and Musshoff, 2020) (Khan et al., 2022) (Groher, Heitkämper and Umstätter, 2020) (Michels et al., 2020) |
|                            | Gender                                                     | (Drewry et al., 2019) (Groher, Heitkämper and Umstätter, 2020)                                                                                 |
|                            | Marital status                                             | (Kaur, Walia and Singh, 2022) (Reisdorf, 2011) (Vimalkumar, Singh and Sharma, 2021)                                                            |
|                            | Educational levels (competences)                           | (Shang et al., 2021) (Drewry et al., 2019) (Carrer et al., 2022) (Khan et al., 2022) (Michels et al., 2020) (Giua, Materia and Camanzi, 2022a) |
|                            | Tenure                                                     | (Shang et al., 2021)                                                                                                                           |
|                            | Farming experience                                         | (Shang et al., 2021)(Carrer et al., 2022)                                                                                                      |
| Social                     | Social influence                                           | (Giua, Materia and Camanzi, 2022a) (Sood, Bhardwaj and Sharma, 2022)                                                                           |
|                            | Farm succession                                            | (Shang et al., 2021)                                                                                                                           |
| Economic                   | Employment status                                          | (Rodriguez Castelan et al., 2021)                                                                                                              |
|                            | Income                                                     | (Shang et al., 2021) (Drewry et al., 2019)                                                                                                     |
|                            | Source of income                                           | (Shang et al., 2021)                                                                                                                           |
| Farm characteristics       | Enterprise                                                 | (Shang et al., 2021)                                                                                                                           |
|                            | Farm size                                                  | (Drewry et al., 2019) (Carrer et al., 2022) (Khan et al., 2022) (Michels et al., 2020)                                                         |
|                            | Labour                                                     | (Shang et al., 2021)                                                                                                                           |
| Institutional              | Extension                                                  | (Musyoki et al., 2022)                                                                                                                         |
|                            | Farmer groups                                              | (Giua, Materia and Camanzi, 2022a)                                                                                                             |
|                            | Distance to market                                         | (Musyoki et al., 2022)                                                                                                                         |
| Technology characteristics | Technology attributes, performance expectation, complexity | (Giua, Materia and Camanzi, 2022a) (Shang et al., 2021)                                                                                        |

Source: produced by the authors, 2023.

are various factors that determine the adoption and use of digital technologies.

According to Giua et al. (2022a), young people are better at adopting and utilizing digital technologies. This is due to the complexity of digital technologies being a barrier to their adoption by older farmers. Furthermore, young people have longer planning horizons, are familiar with the technologies, are less risk averse, and can acquire relevant competencies. Giua et al. (2022b) highlight that competencies affect the diffusion of technology. Higher educational levels are associated with high adoption rates (Shang et al., 2021; Carrer et al., 2022). Some studies have found that there is greater adoption of digital technologies with an increase in farming experience (Shang et al., 2021). However, Carrer et al. (2022) found that there was less adoption of digital technology with an increase in experience. Experienced farmers are more risk-averse due to their lived experience. There are higher levels of adoption if farming is the main source of income (Shang et al., 2021). However, access to other sources of income can help increase the number of digital technologies that can be adopted. The type of land use influences the type of digital technologies that can be used (Shang et al., 2021). This invariably affects the adoption of digital technologies. Giua et al. (2022b) found that farm size was a significant factor in the adoption of digital technologies, especially for farmers intending to adopt them. This conclusion was supported by Shang et al. (2021), who found that farm size was associated with economies of scale. Extension training assists in providing knowledge about the utilization of digital technologies (Musyoki et al., 2022). Giua et al. (2022b) indicated that organisational support does not affect technology adoption. Increased distance to market is associated with transaction costs which hinder the adoption of digital technologies. However, digital technologies can offer a way to avoid transaction costs (Musyoki et al., 2022).

Using an ordinal logistic regression, Michels et al. (2020) demonstrated that socio-economic factors and the characteristics of digital technology play a role in the adoption and utilization process. This conclusion was supported by Gabriel and Gandorfer (2023), who found that factors such as farm and farmer characteristics were important. In South Africa, studies by Mdoda and Mdiya (2022) and Mabe and Oladele (2012) found various socio-economic and farm characteristics that affected the adoption of digital technologies. However,

Mabaya and Porciello (2022) acknowledge that few studies on digital technologies have been carried out in South Africa.

There are various digital technologies at the disposal of small-holder farmers (Gabriel and Gandorfer, 2023); however, Giua et al. (2022a) acknowledge that digital technology adoption studies have not considered individual dimensions. There is a need to understand the mechanisms of digital technology adoption and utilization (Shang et al., 2021). The interaction of digital technology with socio-economic characteristics determines its adoption, utilization, and diffusion. Even though various digital technology adoption studies have been conducted, Shang et al. (2021) acknowledge that socio-economic circumstances are dynamic across space and time. Furthermore, digital technologies keep improving, thereby necessitating constant re-evaluation of the factors determining their adoption. According to Michels et al. (2020), it is essential to understand the underlying drivers of digital technology utilization to improve its acceptance, with possible incorporation during the development process. This can also assist in the development of tailor-made digital technologies that meet the specific needs of smallholder farmers. Accordingly, the objective of this study was to assess the determinants of digital technology utilization by smallholder farmers in South Africa.

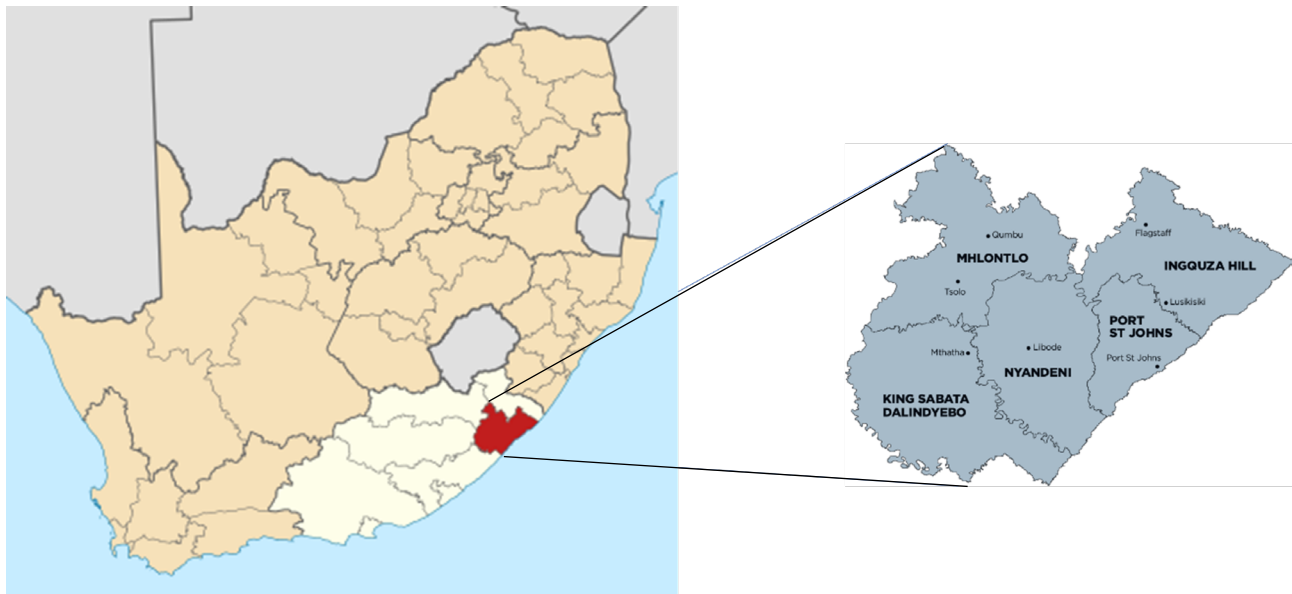
## METHODOLOGY

### Study area

The study was carried out in Port St Johns (PSJ) and Ingquza Hill (IH) Local Municipalities located in OR Tambo District Municipality of South Africa (Fig. 1). Both local municipalities are Category B rural, having high poverty levels with reliance on social grants (EC-SECC, 2017a, 2017b). Agriculture accounts for 2.0% of Gross Value Added (GVA) in IH Local Municipality compared to 1.4% in PSJ. 53.9% of households are engaged in agriculture in IH compared to 47.0% in PSJ, and PSJ also has a higher employment rate within agriculture at 5.4% compared to 4.1% in IH (ECSECC, 2017a, 2017b).

### Theoretical framework

The utility maximization model prescribes evaluating options and making the best choice amongst alternative decisions and choices, preferences, and judgments



**Fig. 1.** Study site  
Source: Municipalities of South Africa, 2023.

(Gamukama, 2015). The model is premised on an individual's preference-indifference relation (Liu et al., 2021; Du et al., 2022). Studies by Mdoda and Mdiya (2022) in Eastern Cape Province and by Migiro and Kwake (2007) countrywide reflect on the utilization of ICTs and the factors affecting such utilization. Digital technologies are not only utilized in agriculture but also in education, health, and social welfare, with various socio-economic and institutional factors affecting such use (Migiro and Kwake, 2007; Mdoda and Mdiya, 2022). A smallholder farmer is confronted with a choice of whether or not to use a digital technology  $D_T$ . For using the digital technology,  $U_{SDT}$ , the expected utility is  $E[U_{SDT}(\pi_{DT}^{USD_T})]$ , and the expected utility for not using it,  $NU_{SDT}$ , is  $E[U_{SDT}(\pi_{DT}^{NUSD_T})]$ .  $(\pi_{DT}^{USD_T})$  and  $(\pi_{DT}^{NUSD_T})$  are the benefits associated with using or not using the digital technology. Utility is defined as:

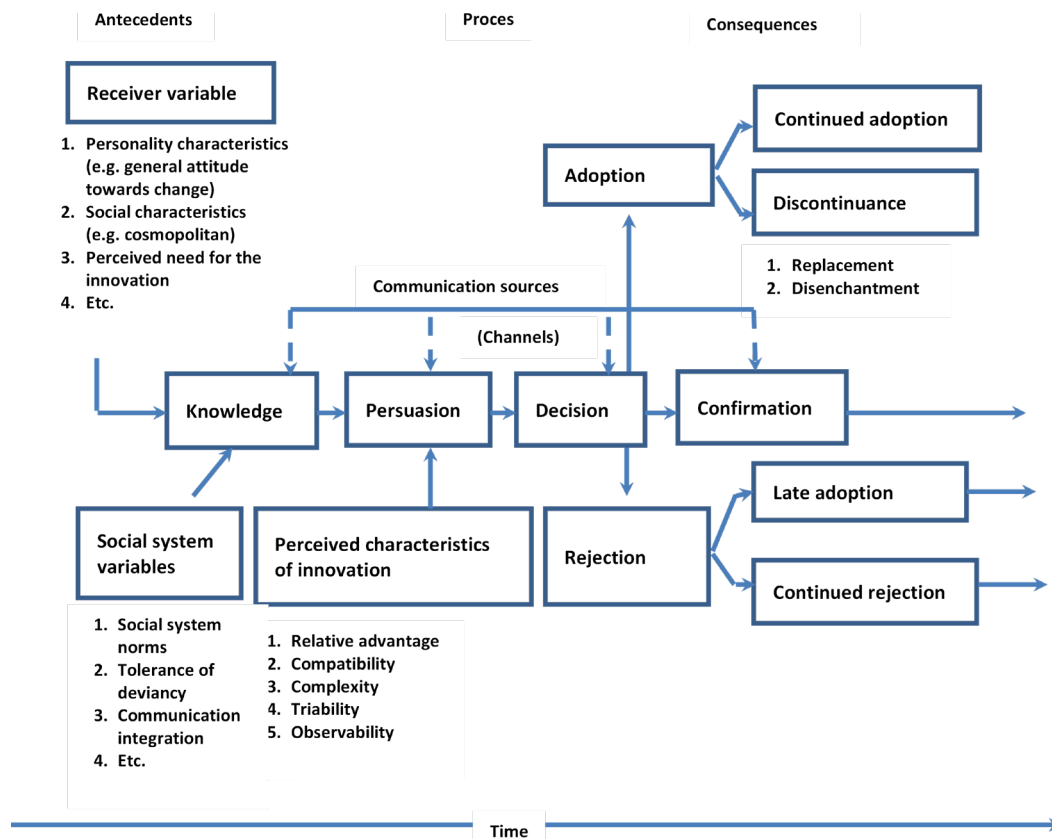
$$U_{iDT}^* = E[U_{SDT}(\pi_{DT}^{NUSD_T})] - [U_{SDT}(\pi_{DT}^{USD_T})]$$

where a smallholder farmer will use the digital technology  $D_T$  for agricultural purposes if  $U_{iDT}^* > 0$ .

### Conceptual framework

Proposed by Rogers (1995), the diffusion of innovation model focuses on innovation communication methods through a bound channel over time. This is through the

transition from first learning about a source of innovation to the formation of enhanced perspectives on the innovation, with decisions to accept, reject and/or implement the new idea (Rogers, 1983; Miller and Mariola, 2009; Jemine and Guillaume, 2021; Byamukama et al., 2022). Biljon and Kotzé (2008) highlighted that culture was significant in the understanding of the adoption of technologies by particular groups of people as represented through the diffusion of innovation model. Jere and Maharaj (2016) found that ICT-based factors such as culture, perceived usefulness and ease of use have a bearing on adoption and diffusion amongst smallholder farmers in KwaZulu-Natal Province, even though no association between the perceived attributes of innovations and the nature of social systems was found. In addition, Dlamini and Ocholla (2018) also found that lack of awareness was a challenge in the availability of ICTs in KwaZulu-Natal. These studies depict the early stages of the diffusion of innovation model as having an effect on the knowledge of and persuasion of people to adopt digital technology. According to Rogers (2003), there are various stages that an individual goes through when making innovation decisions (Fig. 2). These include knowledge, persuasion, decision, implementation, and confirmation. In the context of the current study, at the knowledge stage, the smallholder farmers are exposed



**Fig. 2.** Innovation of diffusion model  
Source: Rogers, 1995.

to digital technologies and understanding of their use. The persuasion stage involves the creation of a positive or negative perception of digital technologies, which leads to the decision to adopt or not to adopt. The implementation stage involves the actual use of the digital technology by the smallholder farmer, while confirmation reinforces further use or rejection of the digital technology.

The current study addresses the confirmation stage of the innovation diffusion model, assessing the utilization of digital technologies and indicating which receiver and social system variables inform this utilization.

## STUDY DESIGN

A purposively selected sample of 250 small-holder farmers was obtained through a cross-sectional survey design. A binary logistic regression, as used by Groher

et al. (2020), was used to assess the factors affecting the utilization of digital technologies by smallholder farmers in Port St Johns and Ingquza Hill Local Municipalities. The logit model was specified as follows (Wooldrige, 2016; Greene, 2018):

$$P(y = 1 | x) = P(y = 1 | x_1, x_2, x_3, \dots, x_k) = G(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k) = G(\beta_0 + x\beta)$$

where  $y$  is the probability of utilising ( $y = 1$ ) or not utilising ( $y = 0$ ) digital technologies, the  $x$  values are the independent variables and  $0 < G(x'\beta) < 1$ . The logit model followed a logistic function:

$$G(x'\beta) = \frac{\exp(x'\beta)}{1 + \exp(x'\beta)} = \Lambda x'\beta$$

where  $\Lambda z$  is the cumulative logistic distribution function. The marginal effects were formulated using the following equation:

$$\frac{\partial E[y|x]}{\partial x} = A(x'\beta)[1 - A(x'\beta)]\beta$$

The variables used in the logistic regression are shown in Table 2.

An ordered logistic regression, as used by Michels et al. (2020), was used to analyse the extent of digital technology utilization by smallholder farmers in Port St Johns and Ingquza Hill Local Municipalities. The ordered logistic model followed (Greene, 2018):

$$y^* = x'\beta + \varepsilon$$

where  $y^*$  is unobserved. However, the following observations are made:

$$\begin{aligned} y &= 0 \text{ if } y^* \leq 0, \\ &= 1 \text{ if } 0 < y^* \leq \mu_1, \\ &= 2 \text{ if } \mu_1 < y^* \leq \mu_2 \end{aligned}$$

The model will estimate  $\mu$  and  $\beta$ . After normalizing the mean and variance of  $\varepsilon$ , we have the following probabilities:

$$\begin{aligned} \text{Prob}(y = 0 | x) &= \Phi(-x'\beta), \\ \text{Prob}(y = 1 | x) &= \Phi(\mu_1 - x'\beta) - \Phi(-x'\beta), \\ \text{Prob}(y = 2 | x) &= \Phi(\mu_2 - x'\beta) - \Phi(\mu_1 - x'\beta) \end{aligned}$$

For positive probabilities, the values of  $\mu$  should have the following property.

$$0 < \mu_1 < \mu_2$$

The variables in Table 2 were used in the ordered logistic regression, with the extent of utilization of digital technologies as the dependent variable.

**Table 2.** Variables used in the logistic and ordered logistic models

| Variable                                     | Explanation                              | Measurement                                                                             | Expected sign |
|----------------------------------------------|------------------------------------------|-----------------------------------------------------------------------------------------|---------------|
| <b>Dependent</b>                             |                                          |                                                                                         |               |
| <i>Y</i> (logistic regression model)         | Utilization of digital technologies      | Binary: 0 – utilisation, 1 – otherwise                                                  |               |
| <i>Y</i> (ordered logistic regression model) | Extent of utilizing digital technologies | Ordered: 0 – to some extent, 1 – large extent, 2 – very large extent                    |               |
| <b>Independent</b>                           |                                          |                                                                                         |               |
| <i>GEN</i>                                   | Gender                                   | Nominal: 0 – male, 1 – female                                                           | –             |
| <i>AGE</i>                                   | Age (years)                              | Ordinal: 0 – 30–39, 1 – 40–49, 2 – 50–59, 3 – 60–69, 4 – 70 and above                   | –             |
| <i>MARST</i>                                 | Marital status                           | Nominal: 0 – married, 1 – not married                                                   | –             |
| <i>EDU</i>                                   | Education level                          | Ordinal: 0 – none, 1 – primary, 2 – secondary, 3 – tertiary                             | +             |
| <i>EMPL</i>                                  | Employment status                        | Nominal: 0 – full-time farmer, 1 – part-time farmer                                     | –             |
| <i>SOUINC</i>                                | Source of income                         | Categorical: 0 – social grant, 1 – salary, 2 – agricultural activities, 4 – remittances | +/-           |
| <i>MI</i>                                    | Monthly income                           | Ordinal: 0 – less than R1000, 2 – R1001–R5000, 3 – R5001–R10000, 4 – more than R10000   | +             |
| <i>HHS</i>                                   | Household size                           | Ordinal: 0 – 1–5, 1 – 6–10, 2 – 11–15, 3 – 15 and above                                 | +/-           |
| <i>FEN</i>                                   | Farming enterprise                       | 0 – crop production, 1 – livestock production, 2 – mixed farming                        | +/-           |
| <i>TEN</i>                                   | Tenure                                   | Nominal: 0 – communal, 1 – leased                                                       | +             |
| <i>FZ</i>                                    | Farm size (ha)                           | Ordinal: 0 – 1–5, 1 – 6–10, 2 – 11–20                                                   | +             |

Source: field survey, 2022.

## RESULTS

Table 3 shows that 55.36% of the smallholder farmers in PSJ and IH Local Municipalities use digital technologies whereas 44.64% do not. Furthermore, 39.53% use smartphones and radio, while 31.01% utilize

smartphones only and 27.91% use radio only. A paltry 1.55% use digital sensors. Nearly half (47.29%) of the smallholder farmers use digital technologies to some extent, while 30.23% and 22.48% use them to a large extent and to a very large extent, respectively. Most of the smallholder farmers (65.12%) have been using digital

**Table 3.** Descriptive statistics

| Question                                           |                                                                                       | Answer | %     |
|----------------------------------------------------|---------------------------------------------------------------------------------------|--------|-------|
| 1                                                  |                                                                                       | 2      | 3     |
| Used any digital technologies                      | Yes                                                                                   |        | 55.36 |
|                                                    | No                                                                                    |        | 44.64 |
| Types digital technologies used                    | Digital sensors                                                                       |        | 1.55  |
|                                                    | ICT (smartphones)                                                                     |        | 31.01 |
|                                                    | Radio                                                                                 |        | 27.91 |
|                                                    | Smartphone and radio                                                                  |        | 39.53 |
| Extent of digital technologies use                 | To some extent                                                                        |        | 47.29 |
|                                                    | Large extent                                                                          |        | 22.48 |
|                                                    | Very large extent                                                                     |        | 30.23 |
| Duration of use (years)                            | 1–4s                                                                                  |        | 65.12 |
|                                                    | 5–10                                                                                  |        | 29.46 |
|                                                    | 11–15                                                                                 |        | 3.88  |
|                                                    | Above 15 years                                                                        |        | 1.55  |
| Are digital technologies beneficial                | Yes                                                                                   |        | 89.06 |
|                                                    | No                                                                                    |        | 10.94 |
| How are digital technologies beneficial            | Assists in accessing farming information                                              |        | 25.44 |
|                                                    | Assist in seeking farming advices                                                     |        | 20.18 |
|                                                    | Improve communication between farmers and extension officers                          |        | 16.67 |
|                                                    | Assist in tracking market prices                                                      |        | 4.39  |
|                                                    | Assist farmers in looking for market to sell the produce                              |        | 5.26  |
|                                                    | Help to get information related to climate change /follow daily weather reports       |        | 26.32 |
|                                                    | Communication between extension officers & farmers and also to look for market        |        | 1.75  |
| Would you continue to use digital technologies     | Yes                                                                                   |        | 83.59 |
|                                                    | No                                                                                    |        | 16.41 |
| Why would you continue to use digital technologies | Helps to track market and market prices                                               |        | 3.77  |
|                                                    | Helps to learn about improved seeds and get educated about different cropping systems |        | 30.19 |
|                                                    | Helps to get climate change information                                               |        | 27.36 |
|                                                    | Digital technologies improve farming skills and knowledge                             |        | 33.02 |
|                                                    | Promote better production and marketing                                               |        | 5.66  |

**Table 3 – cont.**

| 1                                                            | 2                                                                                                              | 3     |
|--------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|-------|
| Extent of willingness to continue using digital technologies | Not at all                                                                                                     | 5.36  |
|                                                              | To some extent                                                                                                 | 25.89 |
|                                                              | Large extent                                                                                                   | 41.07 |
|                                                              | To a very large extent                                                                                         | 27.68 |
| Why would you not continue to use digital technologies       | Not beneficial to farmers' need                                                                                | 44.44 |
|                                                              | Expensive                                                                                                      | 11.11 |
|                                                              | Poor network coverage                                                                                          | 5.56  |
|                                                              | Expensive data and poor network coverage                                                                       | 33.33 |
|                                                              | Expensive data bundles                                                                                         | 5.56  |
| Do you recommend digital technologies                        | yes                                                                                                            | 85.04 |
|                                                              | No                                                                                                             | 14.96 |
| Reason for recommending digital technologies                 | Digital technologies improve and make farming activities easy and interesting                                  | 17.39 |
|                                                              | Digital technologies bridge the gap between extension officers & farmers and promote information dissemination | 25.22 |
|                                                              | Helps to access farm loans                                                                                     | 5.22  |
|                                                              | Provide farmers with knowledge and information about agriculture                                               | 43.48 |
|                                                              | Not recommending it because it is expensive                                                                    | 6.96  |
|                                                              | Improve farmers' marketing skills                                                                              | 1.74  |

Source: field survey, 2022.

technologies for 1–4 years, while 29.46% have using them for 5–10 years. About 89.06% indicated that digital technologies were beneficial, with 26.32% indicating that digital technologies assist in getting climate and weather-related information. This was relative to 25.44% of the smallholder farmers who indicated that they aid in getting farming information and 20.18% who noted that they assist in getting farming advice. Up to 83.59% of smallholder farmers from PSJ and IH had opted to continue using digital technologies because they improve their farming skills and knowledge (33.02%), assist in learning about new farming techniques and methods (30.19%), and help provide access to climate-related information (27.36%). Around 41.07% of the smallholder farmers indicated that they would continue to use digital technologies to a large extent, 27.68% to a very large extent, 25.89% to some extent, and 5.68% not at all. About 44.44% of the smallholder farmers who said they would discontinue using digital technologies indicated that they were not beneficial to farmers, 33.33% indicated that they would stop using them due to expensive

data and poor network coverage, and 11.11% indicated that the technologies themselves were expensive. 85% of smallholder farmers from PSJ and IH Local Municipalities would recommend the use of digital technologies to other farmers, due to the provision of knowledge and information about farming (43.38%), their capacity to bridge the gap between extension officers and farmers (25.22%) and their potential to improve farming and make it easy and interesting (17.39%).

Table 4 shows the factors affecting the utilization of digital technologies by smallholder farmers in PSJ and IH Local Municipalities. The model was significant at the 1% level with a Nagelkerke of 0.31. This indicates a model fit of 31.00%, with the same amount of variance explained by the variables used. Table 4 shows that the utilization of digital technologies by smallholder farmers is affected by educational level, source of income, land size (1% level), age and marital status (10%) level. The results show that there is a 76.00% chance that as age increases, smallholder farmers will utilise digital technologies. Furthermore, there is 1.45% chance that

**Table 4.** Factors affecting the utilization of digital technologies by smallholder farmers in Port St Johns and Ingquza Hill Local Municipalities

| Variable          | $\beta$ | Std. Error | $P_{value}$ | $Exp(B)$ |
|-------------------|---------|------------|-------------|----------|
| Gender            | 0.05    | 0.34       | 0.89        | 1.05     |
| Age               | −0.28   | 0.16       | 0.09        | 0.76     |
| Marital status    | 0.37    | 0.20       | 0.06        | 1.45     |
| Education         | −0.91   | 0.25       | 0.00        | 0.40     |
| Employment status | −0.11   | 0.15       | 0.44        | 0.89     |
| Income source     | −0.29   | 0.11       | 0.01        | 0.75     |
| Monthly income    | −0.28   | 0.25       | 0.25        | 0.75     |
| Household size    | −0.29   | 0.24       | 0.23        | 0.75     |
| Farming activity  | −0.10   | 0.17       | 0.54        | 0.90     |
| Tenure            | −0.49   | 0.69       | 0.48        | 0.61     |
| Land size         | 1.14    | 0.30       | 0.00        | 3.13     |
| Constant          | 2.41    | 1.02       | 0.02        | 11.19    |
| Model summary     |         |            |             |          |
| $\chi^2$          | 60.38   |            | 0.00        |          |
| −2 Log Likelihood | 259.94  |            |             |          |
| Nagelkerke $R^2$  | 0.31    |            |             |          |

Source: field survey, 2022.

smallholder farmers will not use digital technologies if they are single/unmarried, while there is a 40.00% chance that an increase in education level will be associated with the utilization of digital technologies. The results also show that if a farmer's income is derived from full-time farming, they is a 75.00% chance that they will use digital technologies, and there a 3.13% chance that as land size increases, they will not use digital technologies.

Table 5 shows the factors affecting the extent of digital technology utilization by smallholder farmers in PSJ and IH Local Municipalities. The model was also significant at the 1% level with a higher Nagelkerke of 0.68. Thus 68.00% of the variance in the extent of digital technology utilization was explained by the variables that were included in the model. The results show that gender, age, marital status, employment status, household size, farming enterprise, and land tenure were significant factors at the 1% level. A decrease in age was associated with a reduction in digital technology utilization, with both married and single smallholder farmers indicating that they would use digital technologies to a larger extent. A decrease in educational level was associated with an increase in the use of digital technologies,

**Table 5.** Factors affecting the extent of digital technology utilization by smallholder farmers in Port St Johns and Ingquza Hill Local Municipalities

|                | Variable            | $\beta$ | Std. Error | $P_{value}$ |
|----------------|---------------------|---------|------------|-------------|
| 1              | 2                   | 3       | 4          | 5           |
| Gender         | Male                | 1.37    | 0.78       | 0.08        |
|                | Female*             |         |            |             |
| Age            | 30–39               | 6.01    | 1.83       | 0.00        |
|                | 40–49               | 4.98    | 1.85       | 0.01        |
|                | 50–59               | 5.12    | 1.80       | 0.00        |
|                | 60–69               | 6.81    | 1.69       | 0.00        |
|                | 70 and above*       |         |            |             |
| Marital status | Single              | −2.64   | 1.52       | 0.08        |
|                | Married             | −2.83   | 1.54       | 0.07        |
|                | Divorced            | −24.33  | 0.00       |             |
|                | Widower/widow*      |         |            |             |
| Education      | No formal education | −9.03   | 2.48       | 0.00        |
|                | Primary education   | −2.33   | 1.36       | 0.09        |
|                | Secondary education | −2.83   | 1.39       | 0.04        |
|                | Tertiary education* |         |            |             |

**Table 5 – cont.**

| 1                  | 2                                        | 3      | 4       | 5    |
|--------------------|------------------------------------------|--------|---------|------|
| Employment status  | Unemployed                               | 12.39  | 4.98    | 0.01 |
|                    | Formal employed                          | 11.04  | 5.38    | 0.04 |
|                    | Self-employed                            | 9.24   | 5.44    | 0.09 |
|                    | Full-time farmer                         | 12.16  | 5.23    | 0.02 |
|                    | Part-time farmer                         | 12.00  | 5.82    | 0.04 |
|                    | Retiree*                                 |        |         |      |
| Source of income   | Social grants                            | –0.81  | 2.46    | 0.74 |
|                    | Salary/wages                             | –2.35  | 3.56    | 0.51 |
|                    | Agricultural activities                  | –2.05  | 2.89    | 0.48 |
|                    | Remittances                              | –18.37 | 9203.61 | 1.00 |
|                    | Social grant and Agricultural activities | –3.72  | 2.81    | 0.19 |
|                    | Retirement pension funds*                |        |         |      |
|                    | Social grant and remittances*            |        |         |      |
| Income level       | R500–R1000                               | –2.28  | 3.04    | 0.45 |
|                    | R1001–R5000                              | –0.91  | 2.71    | 0.74 |
|                    | R5001–10000                              | 0.45   | 2.60    | 0.86 |
|                    | More than R10000 <sup>a</sup>            |        |         |      |
| Household size     | 1–5 people                               | –20.59 | 1.23    | 0.00 |
|                    | 6–10 people                              | –19.35 | 1.18    | 0.00 |
|                    | 11–15 people                             | –14.35 | 0.00    |      |
|                    | Above 15 people*                         |        |         |      |
| Farming enterprise | Crop production only                     | 2.06   | 0.67    | 0.00 |
|                    | Livestock production only                | –0.08  | 1.31    | 0.95 |
|                    | Mixed farming*                           |        |         |      |
| Land tenure        | Communal land                            | –2.81  | 1.38    | 0.04 |
|                    | Leased*                                  |        |         |      |
| Land size (ha)     | 1–5                                      | –2.96  | 2.02    | 0.14 |
|                    | 6–10                                     | 0.71   | 2.33    | 0.76 |
|                    | 11–20*                                   |        |         |      |
| Model summary      |                                          |        |         |      |
|                    | $\chi^2$                                 | 397.95 |         | 0.00 |
|                    | –2 Log Likelihood                        | 150.85 |         |      |
|                    | Nagelkerke $R^2$                         | 0.68   |         |      |

\*Referral category.

Source: field survey, 2022.

while unemployment was associated with a decrease in the use of digital technologies for smallholder farmers in PSJ and IH Local Municipalities. A smaller household size was associated with an increase in digital technology utilization. Producing crops only and the use of communal land for farming were associated with a decrease in the use of digital technologies.

## DISCUSSION

The results show that most smallholder farmers have been using smartphone and radio digital technologies to some extent for 1–4 years. Furthermore, they indicate that digital technologies are beneficial, especially in assisting with climate and weather-related information, with most smallholder farmers indicating that they would continue using digital technologies to a large extent, as they improved their farming skills and knowledge. However, some smallholder farmers indicated that they would discontinue the use of digital technologies, as they are not beneficial to farmers. Most of the farmers would recommend the use of digital technologies to other smallholder farmers due to the provision of farming information. The use of mobile phone and radio digital technologies in South Africa has been confirmed by various authors, such as Migiro and Kwake (2007), Akinsola (2014), Dlamini and Ocholla (2018), Makaula (2021), Oladipo and Wynand (2019), Maumbe (2010) and Otiso and Moseley (2009). The reason radio and mobile phones are prominent is cost, as these technologies are relatively inexpensive, but the disadvantage of using them is that they are used instead of advanced technologies. However, the use of mobile phones offers an entry point to the use of other high-tech digital technologies – for example, the use of the internet, email, cameras and GPS, which can be integrated into mobile phone designs. Omulo and Kumeh (2020) and Caine et al. (2018) indicated that the use of digital technologies was beneficial to obtain climate and weather-related information as well as providing a platform for energy exchange, while Makinde et al. (2022) found unsuitable and prohibitively expensive digital technologies in Canada. Alant and Bakare (2021) confirmed the use of digital technologies for climate and weather-related agricultural practices by smallholder farmers. This is because farmers require historical, current, and forecast weather information to sustain their production and market prospects.

The results also show that older, educated, and married smallholder farmers who practice full-time farming on small pieces of land make more extensive use of digital technologies. Furthermore, older, single, less educated, and full-time smallholder farmers with small household sizes on leased farmland who did not concentrate on crop production used digital technologies to a greater extent. Groher et al. (2020) highlighted that the use of digital technologies varies according to the type of technology and the characteristics of the agricultural enterprise in addition to the farmer's socio-economic characteristics. Factors such as age (Shang et al., 2021; Giua et al., 2022a; Khan et al., 2022), gender (Drewry et al., 2019; Michels et al., 2020), marital status (Vimal-kumar et al., 2021; Melaine and Nonvide, 2023), education (Ashwini et al., 2022; Carrer et al., 2022), source of income (Shang et al., 2021; Musyoki et al., 2022), employment status (Rodriguez Castelan et al., 2021), household size (Musyoki et al., 2022), land size (Kerneck et al., 2020; Giu et al., 2022a) and enterprise type (Groher et al., 2020; Giua et al., 2022a) have also been identified in the literature as affecting the adoption and use of digital technologies.

Four factors were significant in both the propensity to use and the extent of utilization of digital technologies. These were age, marital status, educational level, and full-time farming. Groher et al. (2020) found that there was less likelihood of using new technologies as age increased in Switzerland, which is contrary to the study findings. This was supported by Michels et al. (2020) in Kenya and Michels et al. (2020) in Australia, where there is lower adoption of digital technologies as age increases. This is because the younger the farmer, the more affinity they have for the adoption of digital technologies. This effect is compounded by their lower agricultural production experience, and thus they rely more heavily on digital technologies. The findings in the study can be explained by the type of digital technologies being used, which are mostly low-tech mobile phones and radios, everyday household and personal appliances. This was compounded by the contextual underpinnings of the region where the study was carried out, with over 63% of the respondents from both study sites having an age greater than 50 years. These results reinforce the emerging cyclical process of an affinity for low-tech and easy-to-use technologies by the older generations being perpetuated by even lower-tech and older smallholder farmers.

Melaine and Nonvide (2023) found that marital status was a significant determinant of digital technology utilization in Benin. This was supported by Kaur et al. (2022) in India and Vimalkumar et al. (2021), who indicated that it was a significant factor in the digital divide. However, Reisdorf (2011) was of the view that marital status was a less important factor in the use of digital technologies. These studies, however, do not provide any insights into the significance or lack of significance of marital status. Puzzlingly, the results show that married smallholder farmers have a propensity to utilize digital technologies, but the extent of utilization is largest amongst unmarried smallholder farmers. Therefore, even though there is low utilization of digital technologies amongst unmarried smallholder farmers, once they are utilized, they are exploited to a larger extent than they are by other groups. It seems logical to conclude that spousal influence affects the utilization of digital technologies by smallholder farmers. This can be tied in with co-decision-making in married households, with the associated high opportunity cost of using digital technologies relative to other family or spousal obligations. Thus, the more responsibilities there are due to extended family, the less important the use of digital technologies for agricultural practices becomes. The reverse is true for unmarried smallholder farmers.

Authors such as Carrer et al. (2022), Michels et al. (2020) and Drewry et al. (2019) found that higher educational levels were associated with greater use of digital technologies. Educational levels were significant in Brazil, mainly due to the technological and managerial demands of digital technologies which require higher levels of education (Carrer et al., 2022). According to Michels et al. (2020), higher educational levels are associated with the ability to process information on new technologies. Furthermore, they enhance knowledge and skills in technology adoption. However, Giua et al. (2022b) found that education was not a significant factor in the decision to adopt digital technologies. The authors attributed this finding to the contextual underpinnings of the study, which was carried out in an area of Italy with a fairly high level of education. The study findings indicate that high educational levels were significant in deciding whether to utilize, and low educational levels were significant in the extent of utilization. The results reflect a belief or perception barrier in the utilization of digital technology, especially in the initial stages of utilization. The decision to utilize is informed

by exposure. This can be through different media and forums, requiring higher levels of education. However, once that hurdle has been overcome, those with lower educational levels have a higher affinity for digital technologies. This is due to the benefits that they enjoy from the technologies.

Gabriel and Gandorfer (2023) indicate that part-time farming among smallholder farmers is associated with economic risks, especially in using digital technologies that they are not certain about. Part-time smallholder farming is associated with reduced time and capital investment with reduced motivation (Gabriel and Gandorfer, 2023). Contrary to the study findings, Groher et al. (2020) found that whether the farmer was part-time or full-time did not affect decisions to utilize digital technologies in Switzerland. In Bavaria, Gabriel (2023) indicated that segmentation into part-time or full-time farming was associated with awareness and protection in using digital technologies. It was particularly highly educated part-time smallholder farmers who had confidence in using digital technologies. However, the same study highlighted that full-time smallholder farmers with small farm sizes also showed awareness and confidence in using digital technologies, mainly due to intensive investment in new technologies, which required them to familiarize themselves with the technology. In Germany, Michels and Mußhoff (2022) found that the extent of digital technology utilization was positively affected by full-time farming. This is due to the high opportunity cost and huge benefits of utilizing digital technology for welfare gains. The study findings showed that full-time farming was associated with both the propensity to use and the extent of utilization of digital technologies. This was in line with Gabriel (2023) and Michels and Mußhoff (2022), and the reasons given for this were high investment, opportunity cost, and welfare gains from income and food security.

According to Kernecker et al. (2020) and Tagarakis et al. (2018), the utilization of digital technologies depends on larger farm sizes, contrary to the study findings. This was supported by Groher et al. (2020), who found that there was less likelihood of using new technologies as farm size decreased. This was due to the lowering of perceived investment risks as the farm increased in size, increasing access to capital (Gabriel and Gandorfer, 2023). However, the study by Kernecker et al. (2020) was carried out in Europe, where there is less smallholder subsistence agriculture, or there are differentiated

characteristics at most. Different land sizes require different types of digital technologies (Bronson and Knezevic, 2019). Kos and Kloppenburg (2019) indicate that use of digital technologies is inherently connected to land size, as there is higher utility, for instance, in optimal input utilization and supply. The findings from the study show the dynamic relationship between low-tech digital technologies and farm size. In this instance, because the digital technologies are low tech, limiting their applications in the farming enterprise, their utilization is associated with small-holder production systems which are less sophisticated.

Musyoki et al. (2022), Rodriguez Castelan et al. (2021) and Huang et al. (2023) indicate that household size significantly affects the decision to adopt digital technologies. This can be advantageous in providing family labour and access to a wide variety of digital technologies from different family members (Musyoki et al., 2022). However, Kiarie (2020) found that household size was insignificant in the utilization of digital technologies in Kenya. The findings from the study highlight that household size was significant, but there was increased utilization of digital technologies for smaller households, contrary to Musyoki et al. (2022), Rodriguez Castelan et al. (2021) and Huang et al. (2023). The use of low-tech digital technologies may also help explain why there is increased utilization when households are small. There is a negligible increase in utility when there are more individuals in households, likely with similar technologies, such as smart phones and radios, which is characteristic of African households. In fact, one radio can service the needs of the entire family. Therefore, the likely increase in family size will not affect the number of radios and the information obtained from the radio, which is standardised across all receivers.

The study findings further showed that concentrating on non-crop agricultural activities increases the utilization of digital technologies for smallholder farmers. Smallholder crop and animal production, especially in Africa, is associated with rainfed, low-technology systems (Kuivanen et al., 2016). High value agricultural practices such as horticulture and dairy production require high-tech digital technologies related to precision agriculture, aquaponics, and irrigation, etc. (Munyua et al., 2009; Singh et al., 2022; Gabriel and Gandorfer, 2023). The findings are peculiar, though, given that small-holder farmers in the study region rely on grain

crops for their food security needs. The study findings confirm that the farming enterprises being pursued by small-holder farmers, i.e. crop production, are not particularly suited for the utilization of digital technologies. They are generally small-holder farming systems that are low-input and environment-reliant.

The findings from the study also show that tenure (particularly leasing) was a significant factor in the utilization of digital technologies. Elsafty and Atallah (2022) found that land tenure was not a significant factor in the utilization of digital technologies in Egypt. Gardezi and Bronson (2020) found that in the US, farmers were less likely to use digital technologies when they rented more land than they owned. According to Sudan (2020) tenure security affects the incentives for long-term investment in an agricultural enterprise. Lack of ownership translates into compromised expansion, and prevents land from being used as an asset in the farming enterprise (Sudan, 2020). However, Gardezi and Bronson (2020) indicated that farmers who leased their land had a propensity for short-term, high-return investments. In the context of the current study, small-holder farmers had a propensity to use digital technologies even when they were leasing. The particular technologies used (i.e. mobile phone and radio) did not have much effect on capital expenditure and investment in their enterprises, hence the propensity to use low-tech digital technologies.

## CONCLUSION

The study sought to understand the determinants of digital technology utilization by smallholder farmers in South Africa. A cross-sectional survey and a purposively selected sample of 250 smallholder farmers in Port St Johns and Ingquza Hill Local Municipalities were used. Binary and ordered logistic regressions were employed to assess the determinants of (i) utilization and (ii) the extent of utilization, respectively. The results show that more than half of the smallholder farmers were using digital technologies. Furthermore, most of the smallholder farmers were using smart phones and radios. Close to half of the smallholder farmers had been using digital technologies to some extent for between 1 and 4 years. Close to 90% of the smallholder farmers indicated that digital technologies were beneficial, especially for providing climate and weather-related information. Close to 80% of the smallholder farmers had opted to continue

using digital technologies, with 41% highlighting they would do so to a large extent, as it improved their skills and knowledge. However, 44% of the smallholder farmers who indicated that they would discontinue the use of digital technologies highlighted that they are not beneficial to farmers. Overall, four of every five smallholder farmers indicated that they would recommend the use of digital technologies to other farmers, especially in the provision of knowledge and information. The results also show that older, educated and married smallholder farmers who practice full-time farming on small pieces of land are more likely to utilize digital technologies. Furthermore, older, single, less educated and full-time smallholder farmers who had small household sizes and did not concentrate on crop production on leased farm land utilized digital technologies to a greater extent.

The study concludes that there is partial utilization of digital technologies in Port St Johns and Ingquza Hill Local Municipalities. However, the smallholder farmers there were using low-tech digital technologies and had only recently started using them. This relatively small-scale and recent adoption was mainly informed by the cost of such digital technologies. Their main use was in the provision of weather and climate information, especially to sustain production and marketing activities. There were various socio-economic factors that affected the utilization and extent of utilization of digital technologies amongst the smallholder farmers. Chief among them were age, marital status, educational level and full-time farming, which affected both the decision to utilize and the extent of utilization. Conclusions drawn from the study include the socio-economic determinants that play a part in the utilization of low tech digital technologies, and conversely, how low tech technologies shape the influence of socio-economic factors on the use of digital technologies. Furthermore, socio-economic factors appear to have differentiated effects on the use and extent of use of digital technologies.

## RECOMMENDATION

The study recommends the promotion of digital technologies for smallholder farmers. This is, however, more effective when it is carried out by means of other information-related digital technologies such as the electronic and print media. Extension officers offer a tangible way to disseminate digital technology information. This can be augmented by involving the developers of the

technologies (especially high-tech technologies) in the training of farmers. Farmer groups and cooperatives can also be used as conduits to inform and train smallholder farmers in the awareness and utilization of digital technologies. The design of digital technologies and training in their use should take account of the socio-economic circumstances of the target audience. The study recommends that the design of the new digital technologies and associated training programmes should be appealing to older, educated and married smallholder farmers who practice full-time farming on small pieces of land. Furthermore, the continued use of existing digital technologies should target older, single, less educated and full-time smallholder farmers who have small household sizes and do not concentrate on crop production on leased farm land.

## REFERENCES

- Akinsola, O.S. (2014). ICT adoption for bridging South African black farmers' knowledge gap'. *Int. J. Agric. Sci. Technol.*, 2(1), pp. 39–47. <http://dx.doi.org/10.14355/ijast.2014.0301.06>
- Alant, B.P., Bakare, O.O. (2021). 'A case study of the relationship between smallholder farmers' ICT literacy levels and demographic data w.r.t. their use and adoption of ICT for weather forecasting'. *Heliyon*, 7(3). <https://doi.org/10.1016/j.heliyon.2021.e06403>
- Ashwini, P., Janaiah, A., Sunandini, G.P., Radhika, P., Meena, A. (2022). Farmers' awareness and its determinants of digital technologies in agriculture – Evidence from rural Telangana. *J. Res. PJTSAU*, 50(3), 130–134. <https://epubs.icar.org.in/index.php/TJRP/article/view/136000>
- Biljon, J. Van, Kotzé, P. (2008). Cultural factors in a mobile phone adoption and usage model. *J. Univ. Comp. Sci.*, 14(16), 2650–2679. Retrieved from: <https://epubs.icar.org.in/index.php/TJRP/article/view/136000>
- Borodina, O., Rykovska, O., Mykhailenko, O., Fraier, O. (2021). Digital transformations in agri-food systems: Innovation drivers and new threats to sustainable rural development. *SHS Web of Conferences*, 100, 03002. <https://doi.org/10.1051/shsconf/202110003002>
- Bronson, K., Knezevic, I. (2019). The digital divide and how it matters for Canadian food system equity. *Canad. J. Commun.*, 44(2), 63–68. <https://doi.org/10.22230/cjc.2019v44n2a3489>
- Byamukama, W., Kalibwami, M.R., Mbabazi, B.P. (2022). Information system (Is) models: Technology as a service for agricultural information dissemination in developing

- countries (Uganda ). A systematic literature review. *Int. J. Sci. Manag. Res.*, 5(4), pp. 42–54. <https://doi.org/10.37502/IJSMR.2022.5404>
- Caine, A., Clarke, C., Clarkson, G., Dorward, P. (2018). Mobile phone applications for weather and climate information for smallholder farmer decision making, Digital technologies for agricultural and rural development in the global south, pp. 1–13. <https://doi.org/10.1079/9781786393364.0001>
- Carrer, M.J., Souza Filho, H.M., Vinholis, M.M.B., Mozambani, C.I. (2022). Precision agriculture adoption and technical efficiency: An analysis of sugarcane farms in Brazil. *Technol. Forecast. Soc. Change*, 177, 121510. <https://doi.org/10.1016/j.techfore.2022.121510>
- Dayioğlu, M.A., Türker, U. (2021). Digital transformation for sustainable future-agriculture 4.0: A review. *Tarim Bilim. Derg.*, 27(4), 373–399. <https://doi.org/10.15832/ankutbd.986431>
- Dietz, K., Drechsel, F. (2021). Digital agriculture. *Int. J. Trend Res. Dev.*, 8(5), 568–580. [https://doi.org/10.1007/978-3-030-89123-7\\_13-1](https://doi.org/10.1007/978-3-030-89123-7_13-1)
- Dlamini, P., Ocholla, D.N. (2018). Information and communication technology tools for managing indigenous knowledge in KwaZulu-Natal Province, South Africa. *Afr. J. Lib. Arch. Inf. Sci.*, 28(2), 137–153. Retrieved from: [https://www.researchgate.net/profile/Dennis-Ocholla/publication/329359896\\_Information\\_and\\_Communication\\_Technology\\_Tools\\_for\\_Managing\\_Indigenous\\_Knowledge\\_in\\_KwaZulu-Natal\\_Province\\_South\\_Africa/links/5c0421e092851c63cab5cb99/Information-and-Communication-Technology-Tools-for-Managing-Indigenous-Knowledge-in-KwaZulu-Natal-Province-South-Africa.pdf](https://www.researchgate.net/profile/Dennis-Ocholla/publication/329359896_Information_and_Communication_Technology_Tools_for_Managing_Indigenous_Knowledge_in_KwaZulu-Natal_Province_South_Africa/links/5c0421e092851c63cab5cb99/Information-and-Communication-Technology-Tools-for-Managing-Indigenous-Knowledge-in-KwaZulu-Natal-Province-South-Africa.pdf)
- Drewry, J.L., Shutske, J.M., Trechter, D., Luck, B.D., Pitman, L. (2019). Assessment of digital technology adoption and access barriers among crop, dairy and livestock producers in Wisconsin. *Comp. Elect. Agric.*, 165(104960). <https://doi.org/10.1016/j.compag.2019.104960>
- Du, X., Tejada, H., Yang, Z., Lu, L. (2022). A general-equilibrium model of labor-saving technology adoption : Theory and evidences from robotic milking systems in Idaho. *Sustainability*, 14(7683). <https://doi.org/10.3390/su14137683>
- ECSECC (2017a). Ingquza Hill Local Municipality socio economic review and outlook, 2017. East London, South Africa. Retrieved from: [https://www.ecsecc.org/documentrepository/informationcentre/ngquza-hill-local-municipality\\_35291.pdf](https://www.ecsecc.org/documentrepository/informationcentre/ngquza-hill-local-municipality_35291.pdf)
- ECSECC (2017b). Port St Johns municipality socio-economic review and outlook. East London, South Africa. Retrieved from: [https://www.ecsecc.org/documentrepository/informationcentre/port-st-jonhs-local-municipality\\_82667.pdf](https://www.ecsecc.org/documentrepository/informationcentre/port-st-jonhs-local-municipality_82667.pdf)
- Elsafty, A., Atallah, A. (2022). Factors influencing precision agriculture tools or technologies adoption in Egypt. *Bus. Manag. Stud.*, 8(2), p. 1. Retrieved from: <https://doi.org/10.11114/bms.v8i2.5598>
- Florey, C., Jon, H., Jean, B. (2020). Digital agriculture and pathways out of poverty: The need for appropriate design, targeting, and scaling. *Enterp. Dev. Microfin.*, 31(2), 126–140. <http://dx.doi.org/10.3362/1755-1986.20-00007%3E>
- Gabriel, A. (2023). Farmers ’ attitudes towards data security in agriculture when using digital technologies: Farmers’ attitudes towards data protection guidelines. Bonn, Germany. Retrieved from: [https://dl.gi.de/bitstream/handle/20.500.12116/40278/GIL\\_2023\\_Gabriel\\_65-76.pdf?sequence=1&isAllowed=y](https://dl.gi.de/bitstream/handle/20.500.12116/40278/GIL_2023_Gabriel_65-76.pdf?sequence=1&isAllowed=y)
- Gabriel, A., Gandorfer, M. (2023). Adoption of digital technologies in agriculture — an inventory in a european small-scale farming region. *Prec. Agric.*, 24(1), 68–91. <https://doi.org/10.1007/s11119-022-09931-1>
- Gamukama, E.A. (2015). Analytical modelling of Internet provision and usage in context of development through a utility based framework. No. 15-018. Stockholm, Sweden.
- Gangwar, D.S., Tyagi, S., Soni, S.K. (2022). A techno-economic analysis of digital agriculture services: an ecological approach toward green growth. *Int. J. Env. Sci. Technol.*, 19(5), 3859–3870. <https://doi.org/10.1007/s13762-021-03300-7>
- Gardezi, M., Bronson, K. (2020). Examining the social and biophysical determinants of U.S. Midwestern corn farmers’ adoption of precision agriculture. *Prec. Agric.*, 21(3), 549–568. <https://doi.org/10.1007/s11119-019-09681-7>
- Giua, C., Materia, V.C., Camanzi, L. (2022a). Smart farming technologies adoption: Which factors play a role in the digital transition? *Technol. Soc.*, 68, 101869. <https://doi.org/10.1016/j.techsoc.2022.101869>
- Greene, W.H. (2018). Econometric analysis. Contributions to management science. [https://doi.org/10.1007/3-7908-1599-3\\_5](https://doi.org/10.1007/3-7908-1599-3_5)
- Groher, T., Heitkämper, K., Umstätter, C. (2020). Digital technology adoption in livestock production with a special focus on ruminant farming. *Animal*, 14(11), 2404–2413. <https://doi.org/10.1017/S1751731120001391>
- Huang, J., Su, L., Liu, X. (2023). Facilitating inclusive use of ICTs in rural China, in: J.P. Estudillo, Y. Kijima, T. Sonobe (eds.), *Agricultural development in Asia and Africa: Essays in honor of Keijiro Otsuka* (pp. 197–212). Singapore: Springer.
- Jemine, G., Guillaume, K. (2021). Lifting the veil on HRIS adoption: The role of vendors and consultants in the diffusion of HR innovations. *Information Technology and People* [Preprint]. <https://doi.org/10.1108/ITP-02-2021-0114>

- Jere, N., Maharaj, M.S. (2016). Evaluating the influence of information and communications technology on food security. *South Afr. J. Inform. Manag.*, 19(1), 1–7. <https://doi.org/10.4102/sajim.v19i1.745>
- Kaur, A., Walia, G.S., Singh, R. (2022). Leveraging social media platforms for valuing agri-entrepreneurship in Punjab, India. *Indian J. Exten. Edu.*, 58(3), 70–73. <https://doi.org/10.48165/ijee.2022.58315>
- Kernecker, M., Knierim, A., Wurbs, A., Kraus, T., Borges, F. (2020). Experience versus expectation: farmers' perceptions of smart farming technologies for cropping systems across Europe. *Prec. Agric.*, 21(1), 34–50. <https://doi.org/10.1007/s11119-019-09651-z>
- Khan, N., Ray, R.L., Kassem, H.S., Zhang, S. (2022). Mobile Internet Technology Adoption for Sustainable Agriculture: Evidence from Wheat Farmers. *Appl. Sci. (Switz.)*, 12(10). <https://doi.org/10.3390/app12104902>
- Kiarie, H. (2020). Determinants of digital technologies adoption among small scale farmers in Kenya-a case of Embu and Kirinyaga Counties. Strathmore University. Retrieved from: <http://hdl.handle.net/11071/10422Followthisandadditionalworksat:http://hdl.handle.net/11071/10422>
- Kos, D., Kloppenburg, S. (2019). Digital technologies, hyper-transparency and smallholder farmer inclusion in global value chains. *Curr. Opin. Env. Sust.*, 41, 56–63. <https://doi.org/10.1016/j.cosust.2019.10.011>
- Kuivanen, K.S., Kuivanen, K.S., Alvarez, S., Michalscheck, M., Adjei-Nsiah, S., Descheemaeker, K., Mellon-Bedi, S., Groot, J.C.J. (2016). Characterising the diversity of smallholder farming systems and their constraints and opportunities for innovation: A case study from the Northern Region, Ghana. *NJAS – Wagen. J. Life Sci.*, 78, 153–166. <https://doi.org/10.1016/j.njas.2016.04.003>
- Liu, Y., Liu, C., Zhou, M. (2021). Does digital inclusive finance promote agricultural production for rural households in China? Research based on the Chinese family database (CFD). *China Agric. Econ. Rev.*, 13(2), 475–494. <https://doi.org/10.1108/CAER-06-2020-0141>
- Mabaya, E., Porciello, J. (2022). Can digital solutions transform agri-food systems in Africa? *Agrekon*, 61(1), 67–79. <https://doi.org/10.1080/03031853.2022.2032223>
- Mabe, L.K., Oladele, I. (2012). Use of Information Communication Technologies tools among Extension officers in the North-West Province, South Africa. *Life Sci. J.*, 9(4), 3275–3279. Retrieved from: [https://www.researchgate.net/publication/290542152\\_Use\\_of\\_information\\_communication\\_technologies\\_tools\\_among\\_extension\\_officers\\_in\\_the\\_North-West\\_Province\\_South\\_Africa](https://www.researchgate.net/publication/290542152_Use_of_information_communication_technologies_tools_among_extension_officers_in_the_North-West_Province_South_Africa)
- Makaula, Z. (2021). Information and communication technologies (ICT) towards agricultural development in rural areas: case of smallholder farmers in Umzimvubu local municipality of the Eastern Cape Province in South Africa. *South Afr. J. Agric. Exten.*, 49(1), 81–90. <https://doi.org/10.17159/2413-3221/2021/v49n1a10779>
- Makinde, A., Islam, M.M., Wood, K.M., Conlin, E., Williams, M., Scott, S.D. (2022). Investigating perceptions, adoption, and use of digital technologies in the Canadian beef industry. *Comp. Elect. Agric.*, 198, 107095. <https://doi.org/10.1016/j.compag.2022.107095>
- Maumbe, B. (2010). Mobile agriculture in South Africa: Implementation framework, value-added services and policy implication. *Int. J. ICT Res. Dev. Afr.*, 1(2), 35–59. Available at: <https://doi.org/10.4018/jictda.2010040103>
- Mdoda, L., Mdiya, L. (2022). Factors affecting the using information and communication technologies (ICTs) by livestock farmers in the Eastern Cape Province. *Cogent Soc. Sci.*, 8(1). <https://doi.org/10.1080/23311886.2022.2026017>
- Michels, M., Fecke, W., Feil, J.H., Musshoff, O., Pigisch, J., Krone, S. (2020). Smartphone adoption and use in agriculture: empirical evidence from Germany. *Prec. Agric.*, 21(2), 403–425. <https://doi.org/10.1007/s11119-019-09675-5>
- Michels, M., von Hobe, C.F., Musshoff, O. (2020). A trans-theoretical model for the adoption of drones by large-scale German farmers. *J. Rural Stud.*, 75, 80–88. <https://doi.org/10.1016/j.jrurstud.2020.01.005>
- Michels, M., Mußhoff, O. (2022). Understanding the adoption timing of smart phones oin agriculture. In: H. Grethe (ed.), *Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues*. Münster: Landwirtschaftsverlag GmbH, pp. 3–11.
- Migiyo, S.O., Kwake, A. (2007). Information needs and communication technology adoption in Africa: a comparative study of rural women in Kenya and South Africa. *J. Soc. Dev. Afr.*, 22(1), 109–141. Retrieved from: [https://www.researchgate.net/publication/290125153\\_Information\\_needs\\_and\\_communication\\_technology\\_adoption\\_in\\_Africa\\_A\\_comparative\\_study\\_of\\_rural\\_women\\_in\\_Kenya\\_and\\_South\\_Africa](https://www.researchgate.net/publication/290125153_Information_needs_and_communication_technology_adoption_in_Africa_A_comparative_study_of_rural_women_in_Kenya_and_South_Africa)
- Miller, M., Mariola, M.J. (2009). The discontinuance of environmental technologies in the humid yropics of Costa Rica: Results from a qualitative survey. *J. Int. Agric. Exten. Edu.*, 16(1), 31–42. <http://dx.doi.org/10.5191/jiaee.2009.16103>
- Monteleone, S., Moraes, E.A.S., Tondato de Faria, B., Aquino Junior, P.T., Maia, R.F., Neto, A.T., Toscano, A. (2020). Exploring the adoption of precision agriculture for irrigation in the context of agriculture 4.0: The key role of internet of things. *Sensors (Switz.)*, 20(24), 1–32. <https://doi.org/10.3390/s20247091>

- Municipalities of South Africa (2023). OR Tambo District Municipality. Retrieved Nov 5<sup>th</sup> 2022 from: <https://municipalities.co.za/map/106/or-tambo-district-municipality>
- Munyua, H., Adera, E., Jensen, M. (2009). Emerging ICTs and Their Potential in Revitalizing Small-Scale Agriculture in Africa. *Agric. Inf. World.*, 2(1), 3–9. Retrieved from: <https://eds.p.ebscohost.com/eds/detail/detail?vid=0&sid=24fb7e97-7514-40a4-b78d-c673910441c7%40redis&bdata=Jmxhbm9cGwmc2l0ZT1lZHMtbGl2ZQ%3d%3d#AN=43248412&db=lxh>
- Musyoki, M.E., Busienei, J.R., Gathiaka, J.K., Karuku, G.N. (2022). Linking farmers' risk attitudes, livelihood diversification and adoption of climate smart agriculture technologies in the Nyando basin, South-Western Kenya. *Heliyon*, 8(4), e09305. <https://doi.org/10.1016/j.heliyon.2022.e09305>
- Nonvide, G.M.A. (2023). Impact of information and communication technologies on agricultural households' welfare in Benin. *Telecomm. Pol.*, 47(6), 102570. <https://doi.org/10.1016/j.telpol.2023.102570>
- Ochoa, R.G., Lach, S., Masaki, T., Rodríguez-Castelán, C. (2021). Mobile internet adoption in West Africa. Discussion Paper No. 14151. Bonn, Germany. <https://doi.org/10.1016/j.techsoc.2021.101845>
- Oladipo, O.D., Wynand, G. (2019). Agricultural production in South Africa: information and communication technology (ICT) spillover. *Int. J. eBus. eGov. Stud.*, 11(q), 166–190. <https://doi.org/10.34111/ijebe.20191126>
- Omulo, G., Kumeh, E.M. (2020). Technological Forecasting & Social Change Farmer-to-farmer digital network as a strategy to strengthen agricultural performance in Kenya : A research note on “Wefarm” platform. *Technol. Forecast. Soc. Change*, 158(May), 120120. <https://doi.org/10.1016/j.techfore.2020.120120>
- Otiso, K.M., Moseley, W.G. (2009). Examining Claims for Information and Communication Technology-Led Development in Africa. *Afr. Geogr. Rev.*, 28(1), 99–116. <https://doi.org/10.1080/19376812.2009.9756219>
- Raimi, L., Mirela, P., Ramotu, S. (2021). Leveraging precision agriculture for sustainable food security in Sub-Saharan Africa: A theoretical discourse. In: V. Erokhin, T. Gao, J.V. Andrei (eds.), *Shifting Patterns of Agricultural Trade: The Protectionism Outbreak and Food Security* (pp. 491–509). Singapore: Springer Singapore.
- Reisdorf, B.C. (2011). Non-adoption of the internet in Great Britain and Sweden: A cross-national comparison. *Inf. Comm. Soc.*, 14(3), 400–420. <https://doi.org/10.1080/1369118X.2010.543141>
- Rogers, E.M. (1983). *Diffusion of innovation* (3<sup>rd</sup> ed.). New York: The Free Press.
- Rogers, E.M. (1995). *Diffusion of innovations* (4<sup>th</sup> ed.) New York: The Free Press.
- Rogers, E.M. (2003). *Diffusion of innovations theory* (5<sup>th</sup> ed.). New York: Free Press. <https://doi.org/10.1111/j.1467-9523.1970.tb00071.x>
- Secundo, G., Schena, R., Russo, A., Schiavone, F., Shams, R. (2022). The impact of digital technologies on the achievement of the Sustainable Development Goals: evidence from the agri-food sector. *Tot. Qual. Manag. Bus. Excell.*, 1–17. <https://doi.org/10.1080/14783363.2022.2065981>
- Shang, L., Heckelee, T., Gerullis, M.K., Börner, J., Rasch, S. (2021). Adoption and diffusion of digital farming technologies – integrating farm-level evidence and system interaction. *Agric. Syst.*, 190. <https://doi.org/10.1016/j.agsy.2021.103074>
- Singh, R., Singh, R., Gehlot, A., Akram, S.V., Priyadarshi, N., Twala, B. (2022). Horticulture 4.0: Adoption of Industry 4.0 Technologies in Horticulture for Meeting Sustainable Farming. *Appl. Sci. (Switz.)*, 12(12557). <https://doi.org/10.3390/app122412557>
- Sood, A., Bhardwaj, A.K., Sharma, R.K. (2022). Towards sustainable agriculture: key determinants of adopting artificial intelligence in agriculture. *J. Dec. Syst.*, 00(00), pp. 1–45. <https://doi.org/10.1080/12460125.2022.2154419>
- Sudan, F.K. (2020). Addressing market inefficiencies through agricultural market information systems and digital technologies in Punjab. *Int. J. Appl. Bus. Manag. Sci.*, 1(2), 211–227. Retrieved from: <https://arjournals.com/image/catalog/Falendra/5-Falendra%20Sudan-IJABMS.pdf>
- Tagarakis, A.C., Evert, F.K. van, Kempenaar, C., Ljubicic, N., Milic, D., Crnojevic-Bengin, V., Crnojevic, V. (2018). Opportunities for precision agriculture in Serbia. In: 14<sup>th</sup> International Conference on Precision Agriculture. Montreal, Quebec, Canada, June 24 – June 27 (pp. 1–12). Retrieved from: <https://library.wur.nl/WebQuery/wurpubs/539550>
- Vimalkumar, M., Singh, J.B., Sharma, S.K. (2021). Exploring the multi-level digital divide in mobile phone adoption: A comparison of developing nations. *Inf. Syst. Front.*, 23(4), 1057–1076. <https://doi.org/10.1007/s10796-020-10032-5>
- Wooldridge, J.M. (2016). *Introductory econometrics* (6<sup>th</sup> ed.). Cengage Learning. Retrieved from: [www.cengage.com/highered](http://www.cengage.com/highered)