S. Afr. J. Agric. Ext. Bontsa, Mushunje, Ngarava & Zhou
Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

Utilisation of Digital Technologies by Smallholder Farmers in South Africa

Bontsa, N.V.[1], Mushunje, A.[2], Ngarava, S.[3] and Zhou, L.[4]

Corresponding Author: N.V. Bontsa. Correspondence Email: bontsanv@gmail.com

ABSTRACT

The study's objective was to assess the utilisation of digital technologies by smallholder farmers, focusing on the types of digital technologies they use, their awareness and perceptions, and the constraints they face. The study used a systematic literature review design. The results show that there has been an increase in studies focussing on using digital technologies by smallholder farmers in South Africa. The focus has been on e-readiness, tools, and constraints in assisting smallholder farmers amongst extension workers, mainly from North West, KwaZulu-Natal, and Eastern Cape Provinces. Relevant topics have been smart farming, digital agriculture, adoption, and climate change. However, smallholder digital technology studies in South Africa have transitioned from small-scale agriculture and extension between 2012 and 2014 to transformation, food security and perception between 2014 and 2018, and innovations, communication technologies, and dissemination, more recently. Recent studies have focused on the productivity-enhanced adoption of ICTs, with various technologies used along the complexity spectrum. However, smallholder farmers have concentrated on low-tech digital technologies on the lower end of the complexity spectrum because they are more aware of them. End-user, service provider, and digital technology characteristics have constrained the use of digital technologies. In conclusion, smallholder farmers are aware of and use low-tech digital technologies limited by inherent internalised characteristics of the farmers themselves and the digital technologies.

[1] Department of Agricultural Economics and Extension, University of Fort Hare, PO. Bag X1314, 1 King William's Town Road, Alice, 5700

[2] Department of Agricultural Economics and Extension, University of Fort Hare, PO. Bag X1314, 1 King William's Town Road, Alice, 5700

[3] Copernicus Institute of Sustainable Development, Utrecht University, Princetonlaan 8a,3584CB, Utrecht, Netherlands.; email @s.ngarava@uu.nl

[4] Risk and Vulnerability Science Centre, University of Fort Hare, P. Bag X1314, 1 King William's Town Road, Alice, 5700

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

Keywords: Awareness, Constraints, Digital Technology, Perceptions.

1. INTRODUCTION

Smallholder agriculture digital technologies have become imperative in achieving the 2030 Sustainable Development Goals (SDGs) (Mabe *et al.*, 2021). Sustainable smallholder agriculture contributes to food security, influencing SDG 1 (ending poverty), SDG 2 (zero hunger and SDG 12 (sustainable consumption and production) (Smidt, 2021; UN, 2022a). Modernising the agricultural sector to increase productivity on the African continent was formalised through Agenda 2063 adopted by the African Union in 2013, with countries such as South Africa adopting its National Development Plan (NDP) to position agriculture for employment creation through facilitating commercialisation and expanding agricultural land (Smidt, 2021; DoP, 2012). Despite setting these goals, there were 278 million Africans who were affected by hunger in 2021, with the prevalence of malnutrition increasing by 5% between 2016 and 2021 (FAO, IFAD, UNICEF, WFP & WHO, 2022). Out of a population of 1373 billion in Africa, 759 million were moderately and severely food insecure, representing 55.28%. Severe food insecurity increased from 16.7% in Africa in 2014 to 23.4% in 2021. In Southern Africa, it increased from 8.9% to 11% during the same period, representing an increase of two million people (FAO, IFAD, UNICEF, WFP & WHO, 2022). The twinning effects of the COVID-19 pandemic and the war in Ukraine further strained the world food security concerns. For instance, people in poverty rose from 581 million pre-COVID-19 to 676 million in 2022. Ukraine and Russia supply global exports of 30% of wheat, 20% of maize and 80% of sunflower, with the war severely affecting the supply of these products (UN, 2022a). With the increasing population, food insecurity, war and conflict, agricultural digital technologies have been identified as a solution to transforming the smallholder sector and establishing resilient food systems (Mabaya & Porciello, 2022; UN, 2022b).

Digital agriculture technologies include big data and innovations in transforming agricultural value chains by improving productivity, market access, finances, supply chain management, and post-harvest handling (Born *et al.*, 2021). They are beneficial in enhancing resource use efficiency, reducing loss, increasing decision support, and decreasing costs. According to Mabaya and Porciello (2022), digital agricultural activities can be classified into 5 categories: supply chain management, market intelligence, farm tools, financial access, advisory services, and extension (Appendix 1).

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

Born *et al.* (2021) assert that a wide range of digital technologies are available in South Africa, which relate to data management, field management, decision support, input and market access, institutional resources, and credit application, even though some are combining. Some digital technology examples highlighted by Born *et al*. (2021) and summarised by Mabaya and Porciello (2022) are shown in Appendix 2. These digital technologies have been backed by a solid communication and power infrastructure providing 67% of the rural population with electricity, 56% of people with access to the internet, a 100% mobile phone penetration rate and an 80% smartphone penetration rate (Mabaya & Porciello, 2022). Some promising digital technologies in South Africa are shown in Table 1 (Born *et al.*, 2021).

TABLE 1: Digital Technologies That Have Been Identified in South Africa

	Promising technologies	Examples
Input hub	Online platforms, remote sensing, traceability, tracking	Bluetooth Smart (Bluetooth Low Energy) can be used for input asset tracking. This allows monitoring of the quality of inputs. It is set to overtake radio frequency identification (RFID) as an input-tracing technology.
		More efficient use of field inputs through drone imagery, remote sensing, and artificial intelligence as part of precision agriculture
		Better coordination through online platforms between farmers and agricultural departments
Production hub	Accessible networks and mobile platforms	Connecting farmers to service providers, input suppliers and markets through mobile platforms
		Integrated climate and weather services
		Online training in farm management, agri-processing, and agribusiness
		Low power, wide area (LoRa) network solutions allowing farmers to collect data from IoT sensors. This avoids prohibitive mobile data costs with high energy input.

Distribution hub	Tracking	Reduction of agricultural goods theft through vehicle tracking and improving route management, lowering the cost of transport.
		IoT solutions, barcoding and database technologies will enable traceability and tracking of agricultural products.
Consumer hub	Traceability	Simplification and accurate traceability of products through blockchains

Source: Born *et al.* (2021)

However, authors such as Mabaya and Porciello (2022) have identified that there is scarce literature on the use of digital technologies by smallholder farmers in South Africa. In addition, most of the digital technology studies in smallholder agriculture have focused on extension and advisory services, which is worrying given the low extension-farmer ratio (Mabaya & Porciello, 2022). The agricultural sector has been facing various challenges necessitating digital technologies, especially for smallholder farmers. These include increased natural disasters, climate change, the spread of parasites, loss of biodiversity and an increase in population (Mavilia and Pisani, 2022). Smidt (2021) avers that promising digital technologies have not been scaling up for smallholder farmers. South Africa's 2.5 million smallholder households have major inefficiencies in accessing value chains, climate change, low capacity and knowledge sharing, reliance on rainfed production and low access to basic services. The utilisation of digital technologies can contribute to overcoming some of these challenges. However, there has been an incomplete stock or inventory of the available digital technologies in South Africa. In addition, what has been the level of awareness of these digital technologies and the constraints faced by smallholder farmers (Akinsola, 2014). The study's objective was to assess the utilisation of digital technologies by smallholder farmers in South Africa by focussing on the types of digital technologies that were used, the awareness and perceptions as well as the constraints that are faced. Munyua (2007) indicates that there are limited baseline studies on the inventory of digital technologies used by smallholder farmers, as well as the usage of such technologies.

The Capabilities Approach (CA) conceptualises the understanding of the economic, political, and social circumstances affecting smallholder farmer's utilisation of digital technologies. This

is with the endeavour to improve choices that enhance their capabilities. On the other hand, CA systematically and holistically conceptualises individual freedoms. This distinguishes between the capabilities of an individual targeting a set of outcomes based on the impact of digital technologies (Smidt, 2021; Kleine, 2010). The study highlights the utilisation of digital technologies by focusing on the types of digital technologies that are used, the awareness and perceptions of the various digital technologies and the constraints that smallholder farmers in South Africa face. In the dimension of choice, digital technology choices exist based on the different attainable possibilities and their resources allowing it. However, a sense of choice indicates that even if individuals were aware of some new possibilities of digital technologies, they were also unaware of them. This was due to their economic, social, financial, human, and environmental circumstances. The choice dimension relates to individual choice of digital technology while the achievement of choice indicates the matching of the outcome to the preference expressed. The dimension of choice is influenced by the agency as informed by the resources endowments, the structure of institutions and governments, policies and programmes, and laws and regulations (Kleine, 2010; Smidt, 2021).

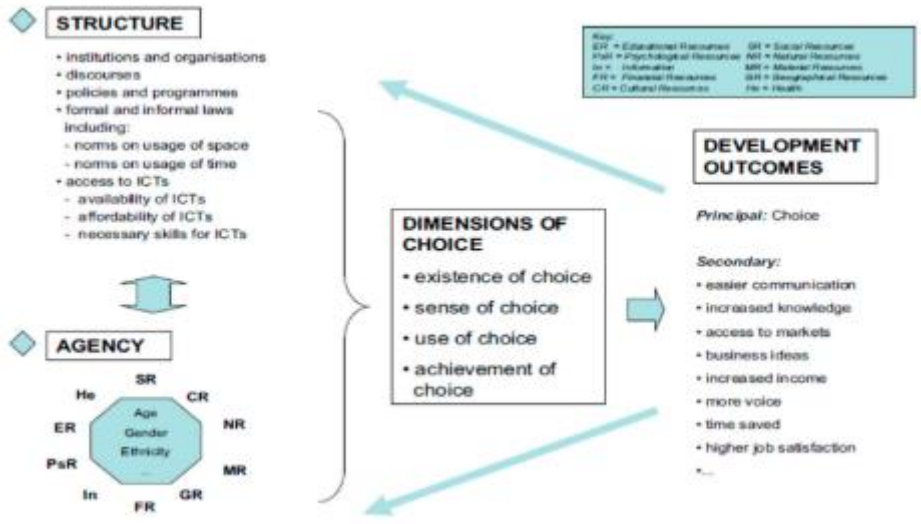


FIGURE 1: The Choice Framework (Source: Smidt, 2021; Kleine, 2010)

2. METHODS

2.1. Study Design

The study used a systematic literature review by making a systematic collection and analysis of relevant literature, endeavouring to advance knowledge and highlight any gaps to inform

future research (Smidt, 2021; Webster & Watson, 2002). A schematic presentation of the steps undertaken in the systematic literature review was those utilised by Smidt (2021) and Cooper (2010), shown in Figure 2.

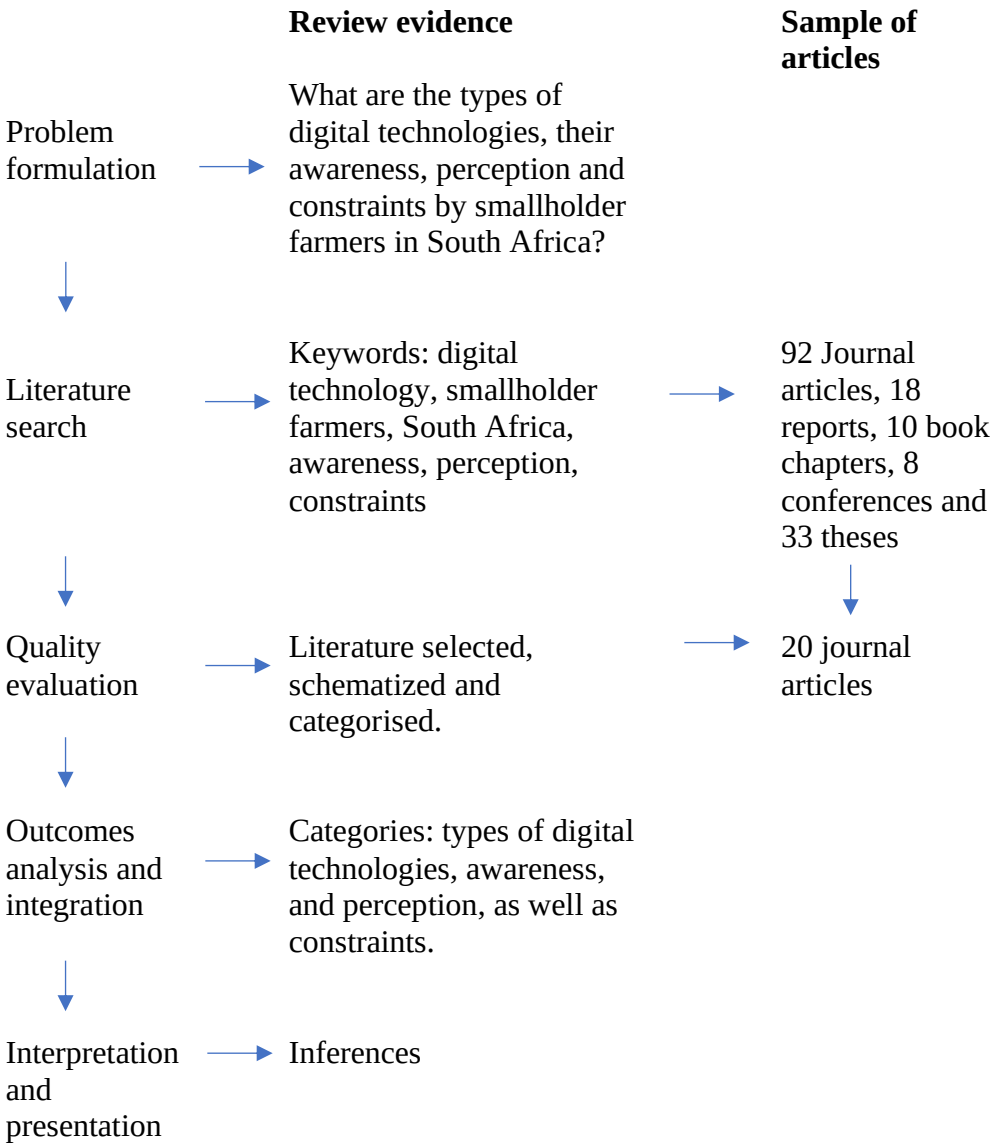


FIGURE 2: The Systematic Literature Review Framework (Source: Cooper, 2010; Smidt, 2021)

The study's objective was to assess the utilisation of digital technologies by smallholder farmers focusing on the types of digital technologies that were used, the farmer's awareness and perceptions, and the constraints that are faced. The literature search targeted all literature related to the topic from major online databases, i.e., Scopus, Taylor and Francis, Wiley Online

Library, Springer, Science Direct and Google Scholar. The keywords were predetermined to limit the study to the chosen specific areas. The following criteria were used:

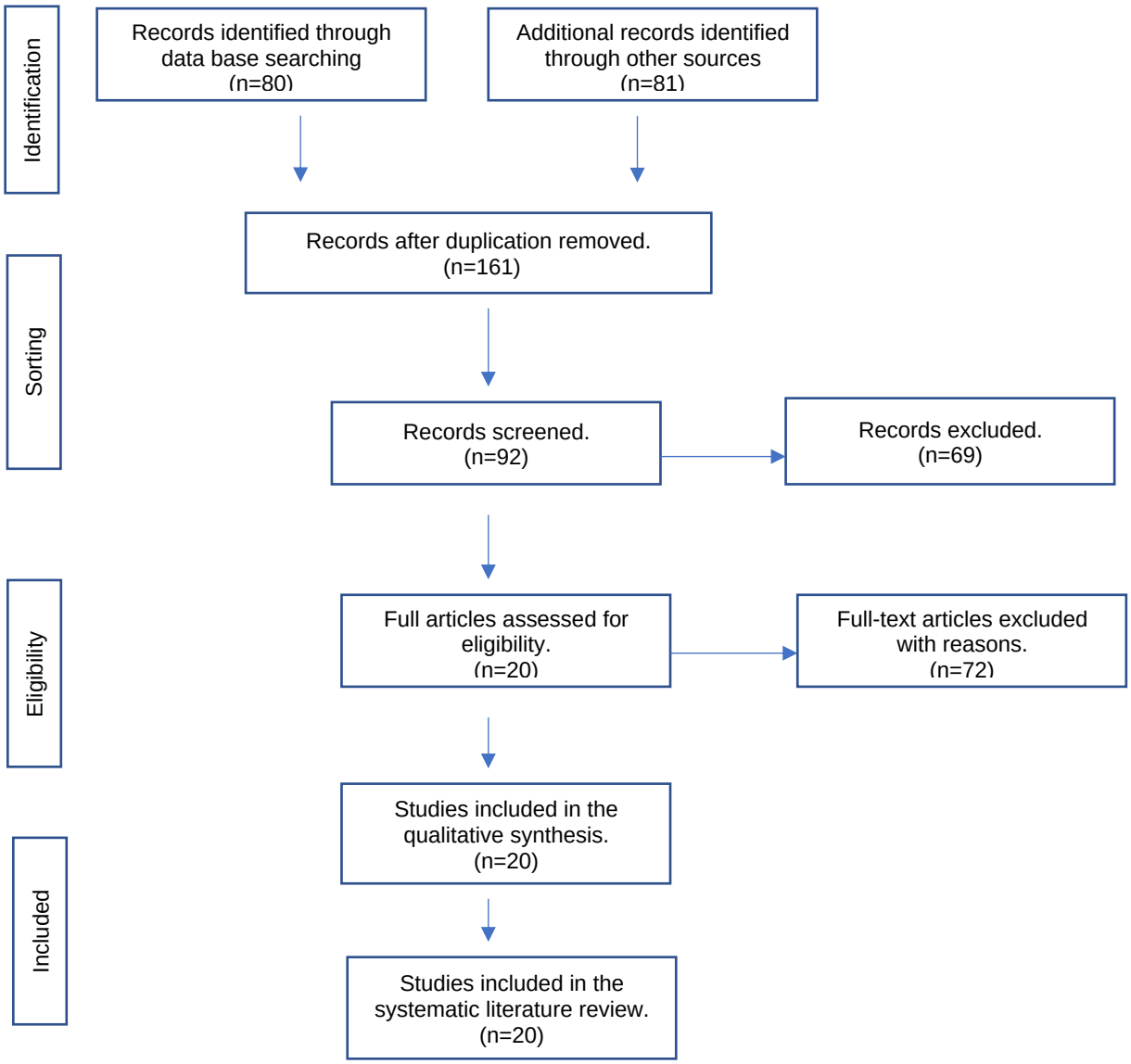
"digital technologies" AND "smallholder" AND "South Africa"

"digital technologies" AND "smallholder" AND "South Africa" AND "awareness"

"digital technologies" AND "smallholder" AND "South Africa" AND "perception"

"digital technologies" AND "smallholder" AND "South Africa" AND "constraint"

Other papers and reports were obtained from Google Scholar. The study identified 92 journal articles, 18 reports, 10 book chapters, eight conference papers and 33 theses. After cleaning, a total of 20 journal articles that were relevant to the study were used (Figure 2).



Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

FIGURE 3: Prisma Flow Diagram of the Decisions Made (Source: Adapted from Smidt, 2021)

2.2. Evaluating the Quality and Categorisation of the Studies

The studies were categorised to gain insights into the types of digital technologies used, the awareness and perception, and constraints faced by smallholder farmers in South Africa. The papers were classified into three categories: type of digital technologies used, awareness and perception of digital technologies, and constraints to utilising digital technologies. The literature was summarised as shown in Table 2 to identify consistencies and common patterns.

TABLE 2: Literature Used in the Study Focussing on the Type of Digital Technology Used, Whether There Was Focus On Awareness and Perception and Constraints in Using Digital Technologies

Articles	Type	Awareness and perception	Constraints
Woodburn, Ortmann and Levin (1994)	X		X
Migiro and Kwake (2007)	X	X	
Cloete and Doens (2010)	X		
Oladipo and Wynand (2019)	X	X	
Jere and Maharaj (2016)		X	X
Maumbe (2010)		X	X
Akinsola (2014)	X		X
Mdoda and Mdiya (2022)		X	X
Otiso and Moseley (2009)	X		
Mabe and Oladele (2015)	X		X
Dlamini and Ocholla (2018)	X		X
Mabaya and Porciello (2022)	X		X
Mavilia and Pisani (2022)	X		
L. Mabe and Oladele (2012)	X	X	
Makaula (2021)	X		X
Mabe (2012)			X

Munyua, Adera and Jensen (2009)	X	
L. K. Mabe and Oladele (2012)	X	
Zantsi and Nkunjana (2021)	X	
Smidt (2021)		X

3. RESULTS

Figure 4 shows that there has been a gradual increase in studies that focus on digital technologies in South Africa, from 1 in 1994 to 22 in 2022.

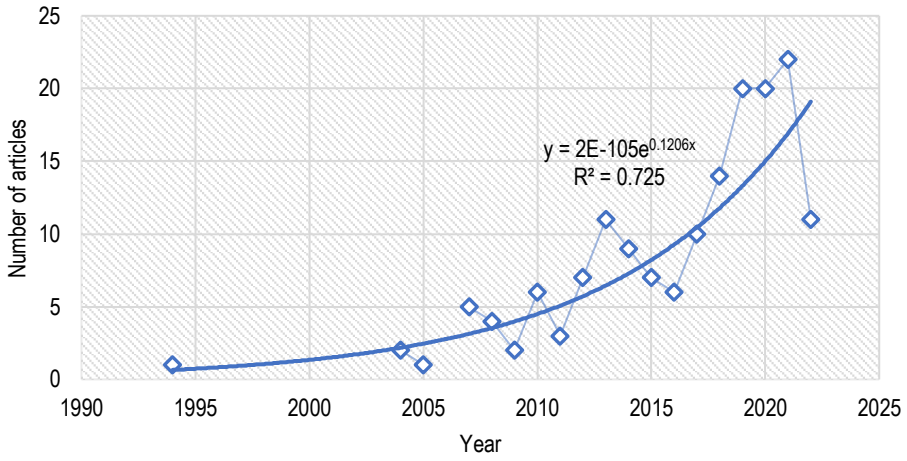


FIGURE 4: Trend in the Number of Articles That Were Used in the Study

Close to 57% of the studies on smallholder farmer digital technologies in South Africa have been journal articles, while 21%, 11%, 6% and 5% have been theses, reports, book chapters and conference presentations, respectively (Figure 5).

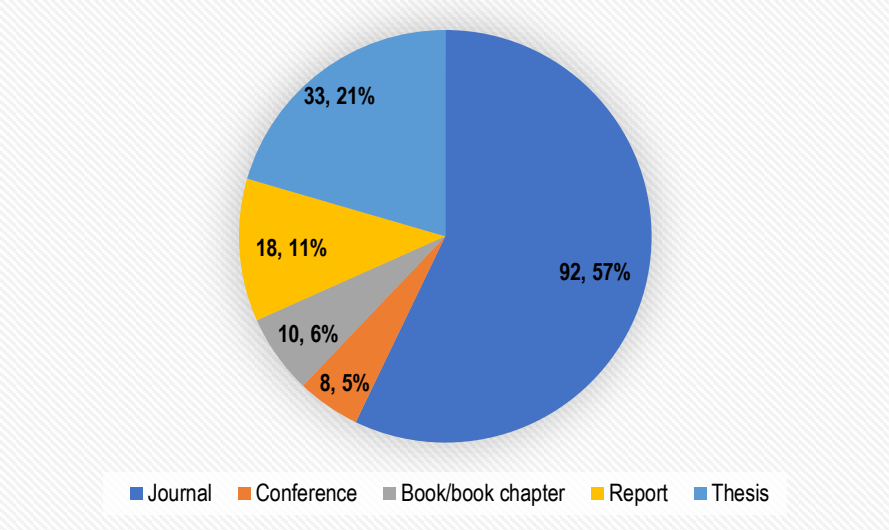


FIGURE 5: Types of Articles with Research on Smallholder Digital Technologies in South Africa

There has been a gradual increase in journal articles since 2004, with a peak of 16 articles in 2021 (Figure 6). The number of theses has also increased from one in 2004 to a height of eight in 2019. Technical reports on digital technologies in South Africa have also been minimal, with a maximum of four in 2020.

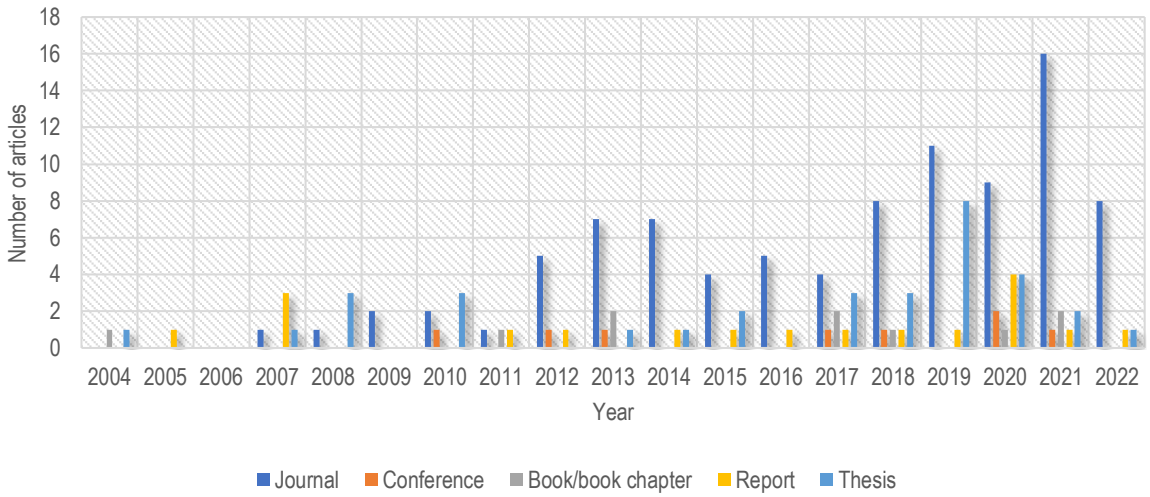


FIGURE 6: Trend in Type of Articles with Research on Smallholder Digital Technologies in South Africa

Mabe, Maumbe, Oladele, and Tembo. have been the leading authors of studies that reflect on the utilisation of digital technologies amongst smallholder farmers in South Africa (Figure 7).

Their work has concentrated on e-readiness, tools, and constraints in executing assistance to smallholder farmers amongst extension workers mainly in North West Province (Mabe & Oladele, 2015; Maumbe & Okello, 2013; Mabe, 2012; Mabe & Oladele, 2012; Tembo & Maumbe, 2011; Maumbe, 2010).

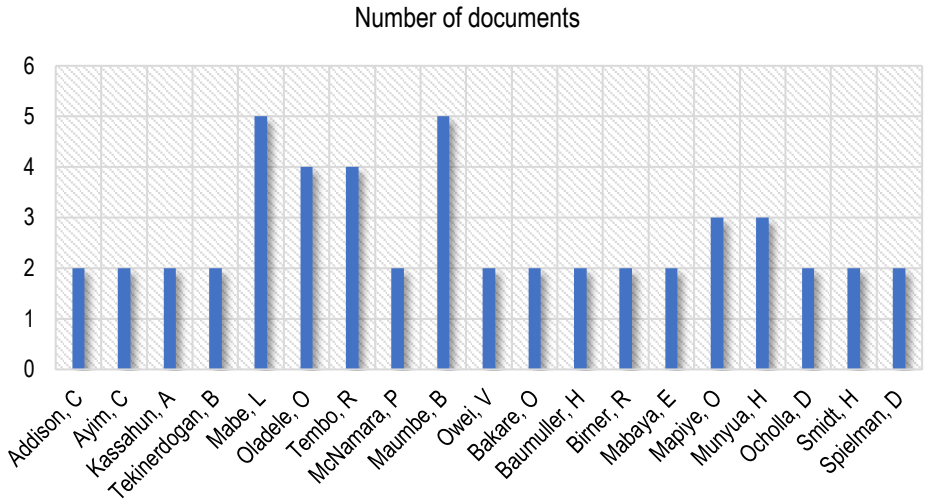


FIGURE 7: Authors Involved in Smallholder Agriculture Digital Technology Research in South Africa

Figure 8 shows that recent literature on the utilisation of digital technologies by smallholder farmers in South Africa has been conducted by Ayim *et al*., 2022; Mabaya and Porciello, 2022; Alanta and Bakare, 2021; Birner *et al*., 2021; and Mapiye *et al*., 2021. The studies have mainly focussed on smallholder farmer adoption of ICTs to enhance productivity.

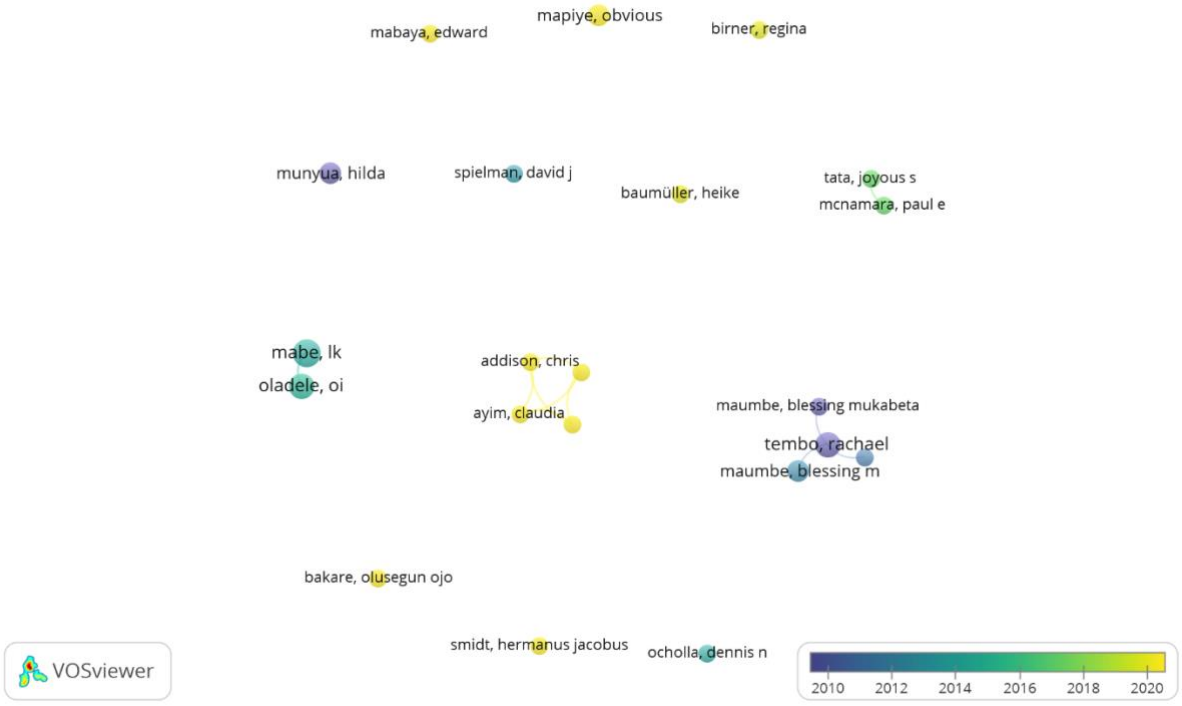


FIGURE 1: Collaborative Work on Digital Technology Research in South Africa

Smallholder digital agriculture studies conducted in South Africa have focused mainly on farmers and transformation (Figure 9). However, the most relevant topics were related to smart farming, digital agriculture, adoption, and climate change (Born *et al.*, 2021; Smidt, 2021; Popoola, Yusuf & Monde, 2020; Basdew, Jiri & Mafongoya, 2017).

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

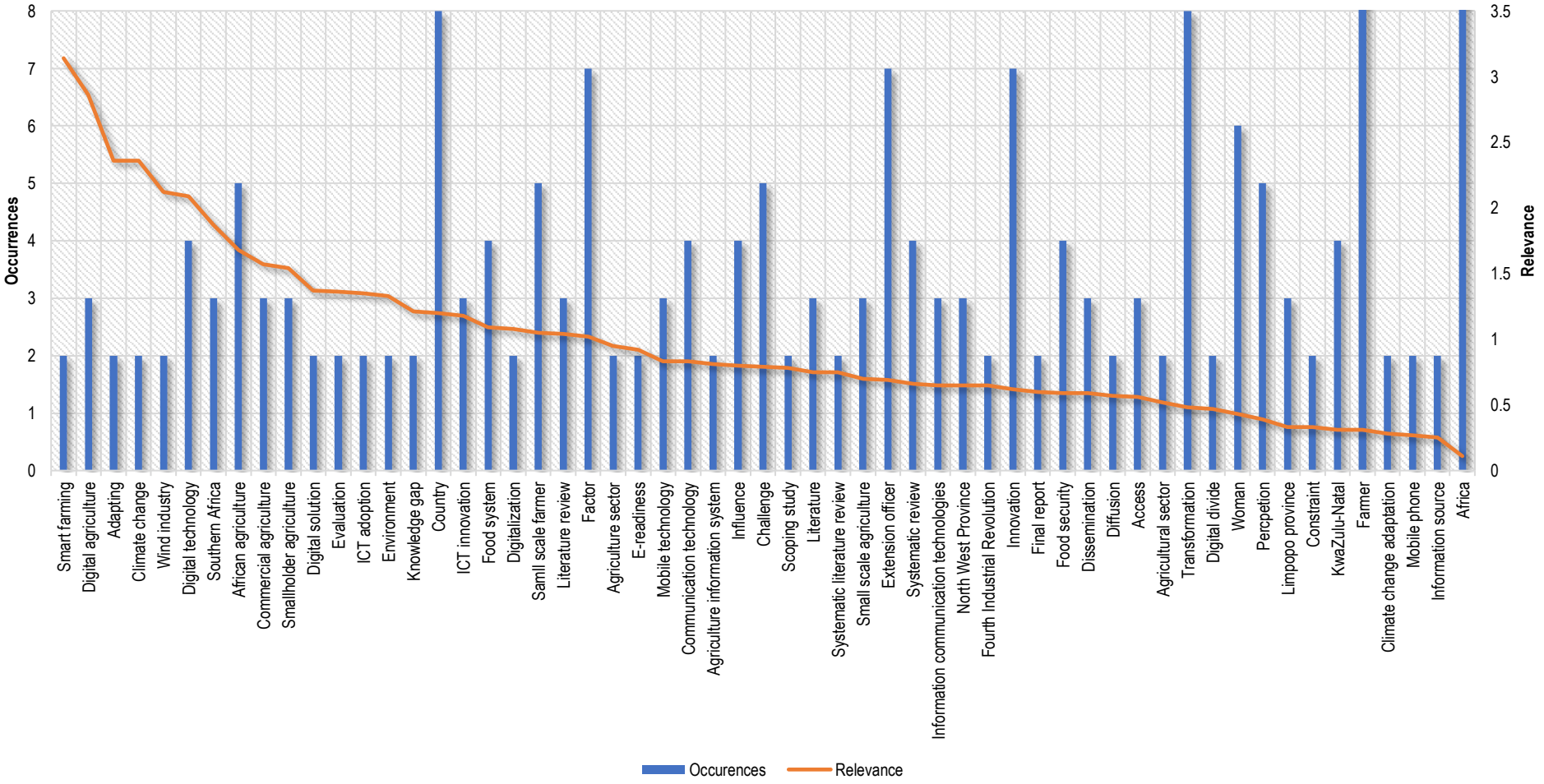


FIGURE 2: Occurrences and Relevance of Key Words in Digital Technology Research in South Africa

Figure 10 shows the progression of topics relating to studies on digital technologies in South Africa, the most recent focusing on innovations, communication technologies and dissemination. This is through a transition from focusing on small-scale agriculture and extension between 2012 and 2014 to transformation, food security and perception between 2014 and 2018.

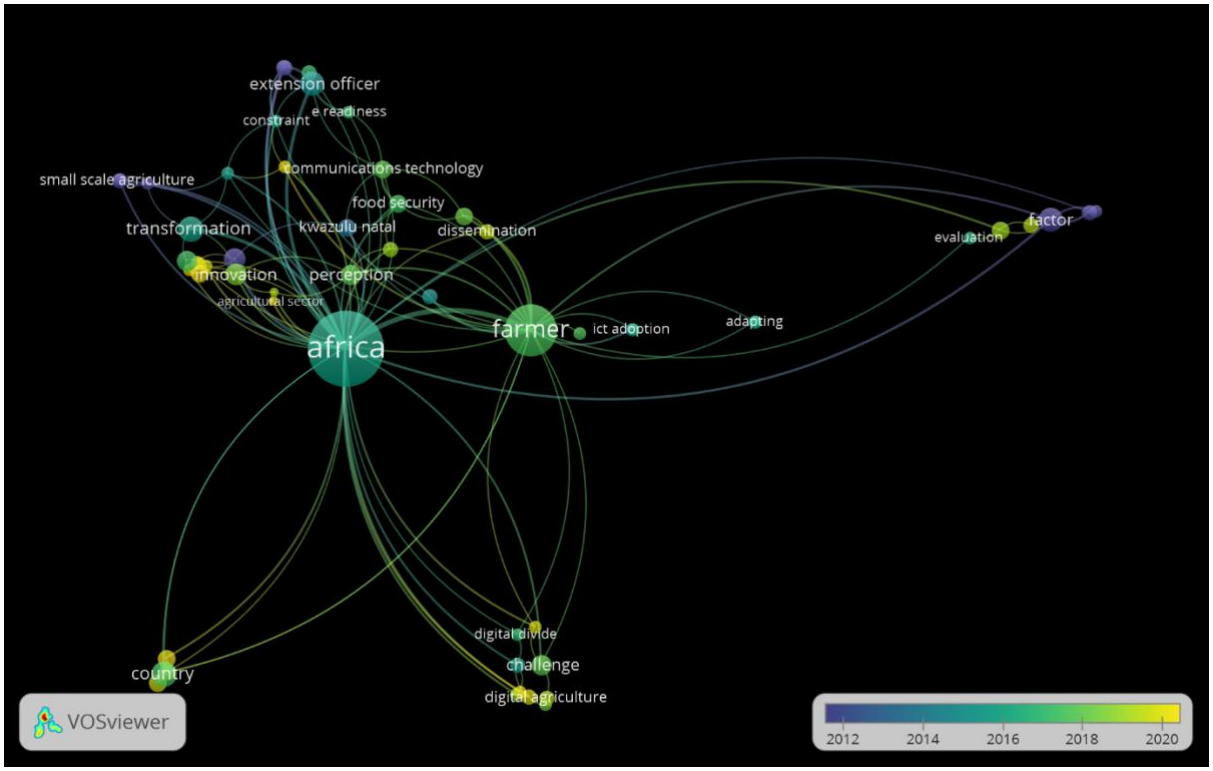


FIGURE 3: Topics on Smallholder Digital Technologies in South Africa

The selected literature of 20 journal articles included 10 survey articles, seven review articles, two key informant interview articles and one that used secondary data (Table 3). The survey studies were concentrated in KwaZulu-Natal (KZN), North West (NW) and Eastern Cape (EC) Provinces, while the review, key informant interview and secondary data studies were national.

TABLE 3: Location and Designs of Primary Studies Selected for Review

Design	Number of articles	Areas	Authors
Survey	10	KZN, EC, NW	Woodburn, Ortmann and Levin (1994); Migiro and Kwake (2007); Jere and Maharaj (2016); Mdoda and

			Mdiya (2022); Mabe and Oladele (2015); Dlamini and Ocholla (2018); Mabe and Oladele (2012); Makaula (2021); Mabe (2012); Mabe and Oladele (2012)
Review	7	National	Maumbe (2010); Otiso and Moseley (2009); Mabaya and Porciello (2022); Mavilia and Pisani (2022); Munyua, Adera and Jensen (2009); Zantsi and Nkunjana (2021); Smidt (2021)
Key informant interviews	2	National	Cloete and Doens (2010); Akinsola (2014)
Secondary data	1	National	Oladipo and Wynand (2019)

The list of studies used for the systematic literature review is shown in Appendix 3.

3.1. Types of Digital Technologies That Are Being Used in South Africa

The types of digital technologies that smallholder farmers in South Africa are utilising are shown in Table 4. Most authors identified the use of mobile phones, TV and radio by smallholder farmers in South Africa (Makaula, 2021; Oladipo & Wynand, 2019; Dlamini & Ocholla, 2018; Maumbe, 2010; Otiso & Moseley, 2009). Other authors such as Zantsi & Nkunjana (2021) and Munyua *et al*. (2009) highlighted the use of more sophisticated digital technologies such as GIS, Radio Frequency Identification (RFID), Precision Agriculture and GPS. However, there was no indication that such technology was being extensively utilised in the smallholder sector. Other digital technologies included personal computers, internet, videos, and emails, amongst others (Akinsola, 2014; Migiro & Kwake, 2007; Woodburn *et al*., 1994).

TABLE 4: Digital Technologies Identified from Primary Studies

Digital technologies	**Studies**
Personal computer	Woodburn, Ortmann and Levin (1994); Akinsola (2014); Dlamini and Ocholla (2018);

TV	Migiro and Kwake (2007); Akinsola (2014); Dlamini and Ocholla (2018); Makaula (2021);
Radio	Migiro and Kwake (2007); Akinsola (2014); Dlamini and Ocholla (2018); Makaula (2021);
Mobile phone	Oladipo and Wynand (2019); Maumbe (2010); Otiso and Moseley (2009); Dlamini and Ocholla (2018); Makaula (2021);
Internet/world wide web	Migiro and Kwake (2007); Akinsola (2014); Dlamini and Ocholla (2018); Makaula (2021);
Video/Video camera/Video recording	Migiro and Kwake (2007); Akinsola (2014); Dlamini and Ocholla (2018); Makaula (2021);
Agro-portal	Maumbe (2010)
CD/DVD	Akinsola (2014); Dlamini and Ocholla (2018);
Tape recording	Dlamini and Ocholla (2018)
USB	Dlamini and Ocholla (2018)
E-mail	Dlamini and Ocholla (2018)
Digital camera	Dlamini and Ocholla (2018)
Telephone	Dlamini and Ocholla (2018)
Photocopying	Makaula (2021);
GIS	Munyua, Adera and Jensen (2009);
Radio Frequency Identification (RFID)	Munyua, Adera and Jensen (2009);
Precision agriculture	Munyua, Adera and Jensen (2009);
GPS	Zantsi and Nkunjana (2021)

3.2. Awareness and Perception of Smallholder Farmers in the Utilisation of Digital Technologies

Table 5 shows the theoretical constructs showing awareness and perceptions towards digital technologies by smallholder farmers in South Africa. Theoretical models that can be singled out from the literature pertain to the Diffusion of Innovation, Digital Acceptance, AIDA (Attention, Interest, Desire, and Action), Unified Theory of Acceptance and Use of Technology (UTAUT) and Utility Maximisation.

TABLE 5: Awareness and Perceptions Theoretical Frameworks Identified from the Primary Studies

Type of Theory	Focus	Studies
Diffusion of innovation model	Culture	Jere & Maharaj (2016)
	Perception of ease of use	Jere & Maharaj (2016)
	Awareness	Dlamini & Ocholla (2018); Mabaya & Porciello (2022); Maumbe (2010)
Digital acceptance model	Perception of ease of use	Jere & Maharaj (2016)
	Awareness	Dlamini & Ocholla (2018); Mabaya & Porciello (2022); Maumbe (2010)
AIDA (Attention, Interest, Desire, and Action) model	Perception of ease of use	Jere & Maharaj (2016)
	Awareness	Dlamini & Ocholla (2018); Mabaya & Porciello (2022); Maumbe (2010)
Unified Theory of Acceptance and Use of Technology (UTAUT) model	Perception of ease of use	Jere & Maharaj (2016)
	Awareness	Dlamini & Ocholla (2018); Mabaya & Porciello (2022); Maumbe (2010)
	Constraints	Smidt (2021); Jere & Maharaj (2016); Makaula (2021); Mabaya & Porciello (2022); Dlamini & Ocholla (2018); Mdoda & Mdiya (2022)
Utility maximisation	Adoption	Mdoda & Mdiya (2022); Migiro & Kwake (2007);
	Utilisation	Mdoda & Mdiya (2022); Migiro & Kwake (2007);

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

3.3. Diffusion of Innovation

Proposed by Rogers (1995), the diffusion of innovation model focuses on the innovation communication methods through a bound channel over time. This is through the transition from a source of innovation to forming enhanced perspectives of the innovation, with decisions to accept, reject and implement the new idea (Rogers, 1983; Miller & Mariola, 2009; Jemine & Guillaume, 2021; Byamukama, Kalibwami & Mbabazi, 2022). Biljon & Kotzé (2008) highlighted that culture was significant in understanding the adoption of technologies by particular groups of people as represented through the diffusion of innovation model. Jere & 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 perceived attributes of innovations and the nature of social systems was found. In addition, Dlamini & Ocholla (2018) also found that lack of awareness was a challenge in the unavailability of ICTs in KwaZulu-Natal. These studies depict the early stages of the diffusion of innovation model by having an effect on the knowledge and persuasion of digital technology adoption.

3.4. Digital Acceptance Model

Established by Davis (1989), the Digital Acceptance Model focuses on determining factors influencing the acceptance or rejection of a technology (Hanafizadeh, Khosravi & Tabatabaeian, 2020; Byamukama, Kalibwami & Mbabazi, 2022). Perceived usefulness and ease of use are the foremost vital beliefs. They relate to the belief that employing a certain system will improve adoption and free them from the effort. These will result in individual behaviour intention and actual behaviour (Biljon & Kotzé, 2008). Studies by Jere & Maharaj (2016) & Dlamini & Ocholla (2018) also ascribe to the Digital Acceptance Model, focusing on awareness and perceptive factors influencing adoption.

3.5. AIDA (Attention, Interest, Desire, and Action) Model

The AIDA model is one of the information-based rational choice models which show that digital technology users go through a series of cognitive and emotional steps in making a purchase and adoption decision or in a behaviour change process (Erdogdu, 2021). The steps involve attracting attention by creating interest (cognitive level), with the second step turning this interest into a strong desire (affective level). The final step is taking action to move to that behaviour (behavioural level) (Rawal, 2013; Le, Liaw & Bui, 2020). The AIDA model

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

prescribes agricultural digital technology provider behaviour in promoting their use by smallholder farmers. Greater competition amongst service providers, utilisation of multi-lingual, customised value-added services and integration of Indigenous Knowledge were some of the service provider activities advocated by Maumbe (2010) to enhance adoption of digital technologies by smallholder farmers in South Africa.

3.6. Utility Maximisation Model

The utility maximisation model prescribes evaluating and making the best choice amongst alternative decisions and choices, preferences and judgements on preferability (Gamukama, 2015). The model is premised on an individual's preference-indifference relation (Liu, Liu & Zhou, 2021; Du *et al.*, 2022). Studies by Mdoda and Mdiya (2022) in the Eastern Cape Province and Migiro and Kwake (2007), countrywide, reflect on the utilisation of ICTs and the factors affecting such utilisation. Digital technologies were utilised in agriculture, education, health and social welfare, with various socio-economic and institutional factors affecting such use (Migiro & Kwake, 2007; Mdoda & Mdiya, 2022).

3.7. Unified Theory of Acceptance and Use of Technology (UTAUT) Model

The UTAUT model is premised on four constructs, namely performance expectation, effort expectation, social influence and facilitating conditions (Srinuan & Seangnoree, 2014; Omulo & Kumeh, 2020; Byamukama, Kalibwami & Mbabazi, 2022). Performance expectation believes in the model improving performance, while effort expectancy is the comfort of using the technology. Social influence is the societal pressure to utilise technology while facilitating conditions relate to the belief of existing infrastructure to support the use of the technology (Byamukama *et al.*, 2022; Chang, Chiu & Lai, 2020; Venkatesh *et al.*, 2003). According to Mabaya and Porciello (2022), although South Africa has vast communication and power infrastructure, there are challenges and constraints related to mobile data cost. In the Eastern Cape Province, Makaula (2021) identified challenges such as unpredictable broadcasting time, poor signal, language barriers and lack of electricity as impediments in the utilisation of digital technologies by smallholder farmers. Some of the constraints and challenges as reflected in the UTAUT model are reflected in the next section.

3.8. Constraints in the Utilisation of Digital Technologies

Constraints or challenges that smallholder farmers face in utilising digital technologies are shown in Table 6. These constraints can be classified under end user, service provider and digital technology characteristics.

TABLE 6: Identified Constraints and Challenges from Primary Studies

Challenge/Constraint	Description of challenge/ constraint	Studies
Cost of ICTs	The cost of ICTs is prohibitive, reducing usage.	Migiro & Kwake (2007); Dlamini & Ocholla (2018)
Access to land	Lack of access to land is prohibitive to the utilisation of digital technologies, reducing the possible positive spillovers.	Oladipo & Wynand (2019)
Inadequate infrastructure and spare parts	Poor internet connectivity	Maumbe (2010); Dlamini & Ocholla (2018)
Monopoly by service providers	There is a lack of competition amongst service providers, thereby limiting innovativeness.	Maumbe (2010)
Language	Language is a barrier to utilising some of these digital technologies.	Maumbe (2010); Makaula (2021)
Lack of integration with indigenous knowledge	Digital technologies do not account for inherent indigenous knowledge	Maumbe (2010)
Abstract value-added services	Digital technologies are not context-specific to the needs of the end user.	Maumbe (2010); Akinsola (2014)
Inefficiency in time delivery	Knowledge is not delivered in a timely fashion.	Akinsola (2014)
Lost information	Knowledge is lost through compression to accommodate for space and time	Akinsola (2014); Dlamini & Ocholla (2018)
Myopia	Technologies and knowledge do not account for change and are treated as static.	Akinsola (2014)

Expert-oriented and lack of digital skills	Technologies and knowledge require expertise in both utilising and interpreting, with smallholder farmers lacking digital skills.	Akinsola (2014); Dlamini & Ocholla (2018)
Difficulty in verifying knowledge	There is difficulty in verifying information and knowledge provided by some of these digital technologies.	Akinsola (2014)
Low battery	Prohibitive battery life on some of the technologies.	Dlamini & Ocholla (2018)
Small memories	Restrictive memory sizes on some digital technologies.	Dlamini and Ocholla (2018)
Sensitivity of some tools	Digital technologies are easily breakable and, therefore, not sustainable.	Dlamini & Ocholla (2018)
Complicated devices and manuals	Digital technologies are too complicated for lowly educated smallholder farmers.	Dlamini & Ocholla (2018)
Lack of money	Lack of funds or no money or budget for digital technologies	Dlamini & Ocholla (2018)
Lack of electricity	Lack and disrupted electricity supply is prohibitive in using digital technologies.	Dlamini & Ocholla (2018); Makaula (2021)
Lack of awareness	Digital technologies are not utilised because of a lack of awareness.	Dlamini & Ocholla (2018)
Cost of mobile data	The prohibitive cost of data reduced utilisation of digital technologies.	Mabaya & Porciello (2022)
Economies of scale	The utilisation of digital technologies is dependent on economies of scale.	Makaula (2021)
Inconsistent broadcasting time	Lack of knowledge of broadcasting time in TV and Radio programmes.	Makaula (2021)
Poor signal	Remote areas have poor cellphone, radio, and TV signals.	Makaula (2021)

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

3.8.1. End User Constraints

End-user constraints/challenges faced by smallholder farmers in South Africa include lack of access to land, lack of money, lack of electricity, lack of awareness, lack of digital skills and lack of economies of scale in agricultural activities.

3.8.2. Service Provider Constraints

Service providers have also conferred constraints/challenges to digital technology utilisation by smallholder farmers in South Africa through inadequate infrastructure and spare parts, monopolies, abstract value-added services, inefficiency in time delivery, inconsistent broadcasting time and high cost of mobile data.

3.8.3. Digital Technology Characteristic Constraints

Cost of digital technologies, language, lack of integration with indigenous knowledge, inefficiency in time delivery, lost information, and myopia were some of the technology characteristics that were constraints/challenges in digital technology utilisation by smallholder farmers in South Africa. This was augmented by technologies with low batteries, small memories, sensitivity, complicated manuals, and difficulty verifying knowledge.

4. DISCUSSION

There has been a gradual increase in studies focusing on digital technologies in South Africa, even though the studies have been minimal. A recent review study by & Porciello (2022) showed less than 10 studies focussing on digital technologies for smallholder farmers in South Africa. In addition, most studies have been journal publications; however, there is also a large number of theses which have not been extensively peer-reviewed to inform policy. The lack of reports and policy documents regarding smallholder farmer use of digital technology in South Africa is also alarming, raising questions about how smallholder digital technology policy is developed. Smallholder digital technology utilisation in South Africa has also not been extensively communicated, as indicated by low conference presentations.

Literature on the utilisation of digital technologies by smallholder farmers in South Africa has mainly concentrated on e-readiness, tools and constraints in executing assistance to smallholder farmers amongst extension workers mainly in North West Province, with minimal in KwaZulu-Natal and Eastern Cape Provinces (Maumbe, 2010; Tembo & Maumbe, 2011; Mabe & Oladele,

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

2012; Mabe & Oladele, 2012; Mabe, 2012; Maumbe & Okello, 2013; Mabe & Oladele, 2015). Relevant topics have focussed on smart farming, digital agriculture, adoption and climate change (Basdew, Jiri & Mafongoya, 2017; Popoola, Yusuf & Monde, 2020; Born *et al.*, 2021; Smidt, 2021). However, there has been a transition from focusing on small-scale agriculture and extension between 2012 and 2014 to transformation, food security and perception between 2014 and 2018, and innovations, communication technologies and dissemination more recently. Recent studies have concentrated on smallholder farmer adoption of ICTs to enhance productivity (Ayim *et al.*, 2022; Mabaya & Porciello, 2022; Alant & Bakare, 2021; Alant & Bakare, 2021; Birner, Daum & Pray, 2021; Mapiye *et al.*, 2021).

Various digital technologies are being used by smallholder farmers in South Africa, the prominent being mobile phones, TV, and radio, with other high-end technologies, such as GIS, Radio Frequency Identification (RFID), Precision Agriculture and GPS, being used (Makaula, 2021; Zantsi & Nkunjana, 2021; Oladipo & Wynand, 2019; Dlamini & Ocholla, 2018; Maumbe, 2010; Munyua *et al.*, 2009; Otiso & Moseley, 2009). A study by Mabaya and Porciello (2022) indicated that South Africa has a dynamic and thriving digital agriculture ecosystem with many innovations driven by solid infrastructure providing 67% of people with electricity, 56% with internet access, 100% mobile phone penetration rate and 80% smartphone penetration. This was supported by Born *et al.* (2021), indicating that the most promising digital technologies were weather forecasting, artificial intelligence, Bluetooth Low Energy, blockchain technology, database technology, vehicle tracking, mobile platforms, drone imagery and remote sensing. However, on the ground, such technologies are utilised less than the less complicated digital technologies. This raises the question of whether the smallholder farmers know these more complicated digital technologies.

Furthermore, what could be the constraints or challenges faced by these smallholder farmers if they are aware and not utilising these promising digital technologies, or if they are unaware at all. Munyua (2007) found that digital technologies for smallholder farmers in Africa included GIS, decision support systems, mobile mapping, personal digital assistants, precision agriculture, mobile phone applications, community radios, radio frequency identification, WorldSpace satellite radio, internet and web-based applications, distance learning, telecentres, knowledge centres, CD-ROMs, and DVDs. According to Buchana, Sithole and Mjokweni (2022), there has been a 52.9% increase in precision agriculture digital technology utilisation in South Africa's agriculture sector between 2016 and 2018. This was followed by air and soil

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

sensors (40%), crop sensors (34%), smart plant/animal breeding (30%), drones/robotics (15.9%), biometric (4.7%) and other types of digital technologies (0.7%) (Buchana *et al*., 2022). Even though Simpson and Calitz (2014) found various digital technologies being utilised by farmers in South Africa, they used applications related to weather, banking, type of productivity, news, social media and finances. However, the study focused on commercial farmers, with use likely to be different from smallholder farmers. Akinsola and Dehinbo (2013) advocate for an integrated and internet-enabled knowledge support platform providing a one-point access and interaction of the various digital technologies available to smallholder farmers.

The literature shows that smallholder farmers in South Africa know digital technologies (Dlamini & Ocholla, 2018; Jere & Maharaj, 2016;). However, culture was a significant factor over and above the utility obtained from utilising digital technologies (Mdoda & Mdiya, 2022; Biljon & Kotzé, 2008; Migiro & Kwake, 2007). In addition, service provider behaviour can also affect the awareness and perception towards digital technologies by smallholder farmers in South Africa. This is through the provision of greater competition amongst service providers, utilisation of multi-lingual, customised value-added services, and integration of Indigenous Knowledge. Awareness and utilisation of digital technology are not abstract and are context-specific. That is why Born *et al.* (2021) advocate for digital technologies tailor-made for communities, especially at differing scales of agriculture, such as smallholder, small, medium and large scale that is characterised in South Africa.

Various constraints and challenges have inundated smallholder farmers' utilisation of digital technologies in South Africa. These can be classified under end user, service provider and digital technology characteristics. End-user constraints have included lack of access to land, lack of money, lack of electricity, lack of awareness, lack of digital skills and lack of economies of scale in agricultural activities. For service providers, the constraints identified were inadequate infrastructure and spare parts, monopolies, abstract value-added services, inefficiency in time delivery, inconsistent broadcasting time and high cost of mobile data. The digital technology characteristics have impeded utilisation by smallholder farmers in South Africa through cost, language, lack of integration with indigenous knowledge, inefficiency in time delivery, lost information, and myopia. Even though there are various constraints, these are not homogenous throughout South Africa, requiring tailormade and context-specific solutions (Born *et al.*, 2021). Munyua (2007) found similar results, indicating that challenges to digital technology utilisation by smallholder farmers in Africa were limited by inadequate

and poor infrastructure, high cost of digital technologies, low bandwidth, inadequate digital technology policy, illiteracy, skills gap, weak institutions, inappropriate local content, inadequate involvement of women and youth as well as poor awareness of digital technologies.

5. CONCLUSION

There has been an increase in studies focussing on utilising digital technologies by smallholder farmers in South Africa concentrating on e-readiness, tools, and constraints in assisting smallholder farmers amongst extension workers in North West, KwaZulu-Natal, and Eastern Cape Provinces. Relevant topics have been smart farming, digital agriculture, adoption, and climate change. There has, however, been a transition of the smallholder digital technology studies in South Africa from those focussing on small-scale agriculture and extension between 2012 and 2014 to transformation, food security and perception between 2014 and 2018, and innovations, communication technologies and dissemination, more recently. Recent studies have concentrated on smallholder farmer adoption of ICTs to enhance productivity. Smallholder farmers in South Africa have utilised various digital technologies, ranging from mobile phones, TV, and radio, with other high-end technologies such as GIS, Radio Frequency Identification (RFID), Precision Agriculture and GPS. However, most smallholder farmers have been using low-tech digital technologies. Smallholder farmers are thus aware and positively perceive low-tech digital technologies. Various constraints to the utilisation of digital technologies by smallholder farmers were identified from the literature, summarised as end user, service provider and digital technology characteristics. The study concludes that various digital technologies are available to smallholder farmers in South Africa. However, they are aware of low-tech digital technologies and face various constraints in utilising digital technologies.

REFERENCES

AKINSOLA, O.S., 2014. ICT adoption for bridging South African black farmers ' knowledge gap. *JAST*., 2(1): 39–47.

AKINSOLA, O.S. & DEHINBO, J.O., 2013. Internet-enabled platform for bridging South African emerging farmers' knowledge gap. Paper presented in *Proceedings of the International MultiConference of Engineers and Computer Scientists* (IMECS), 13-15 March, Hong Kong.

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).

AYIM, C., KASSAHUN, A., ADDISON, C. & TEKINERDOGAN, B., 2022. Adoption of ICT innovations in the agriculture sector in Africa: A review of the literature. *Agric. Food Sec.*, 11(1): 1-16.

BASDEW, M., JIRI, O. & MAFONGOYA, P.L., 2017. Integration of indigenous and scientific knowledge in climate adaptation in KwaZulu-Natal, South Africa. *Change Adapt. Socio-Ecol. Syst.*, 3(1): 56–67.

BILJON VAN, J. & KOTZÉ, P., 2008. Cultural factors in a mobile phone adoption and usage model. *J Univers. Comput Sci.*, 14(16): 2650–2679.

BIRNER, R., DAUM, T. & PRAY, C., 2021. Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. *Appl Econ Perspect Policy.*, 43(4): 1260–1285.

BORN, L., CHIRINDA, N., MABAYA, E., AFUN-OGIDAN, O., GIRVETZ, E.H., JARVIS, A. & KROPFF, W., 2021. *Digital Agriculture Profile: South Africa*. Available from https://www.fao.org/3/cb2506en/cb2506en.pdf.

BUCHANA, Y., SITHOLE, M.M. & MJOKWENI, P., 2022. *Adoption and diffusion of advanced ICTs in South Africa's agricultural sector: Policy issues and implications*. Pretoria, South Africa.

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. *IJSRM.*, 5(4): 42–54.

CHANG, J., CHIU, P. & LAI, C., 2020. Implementation and evaluation of cloud-based e-learning in agricultural course. *Interact. Learn. Environ.*, 31(2): 908-923.

CLOETE, E. & DOENS, M., 2010. B2B e-marketplace adoption in South African agriculture. *Inf. Technol. Dev.*, 14(3): 184–196.

COOPER, H., 2010. *Research synthesis and meta-analysis: A step-by-step approach*. 5th edn. Sage.

DAVIS, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly.*, 13(3): 319–340.

DLAMINI, P. & OCHOLLA, D.N., 2018. Information and communication technology tools for managing indigenous knowledge in KwaZulu-Natal Province, South Africa. *Afr. J. Libr. Arch. Inf. Sci.*, 28(2): 137–153.

DOP., 2012. *National Development Plan 2030. Our future – make it work*. Pretoria, South Africa.

DU, X., TEJEDA, 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*(13): 7683.

ERDOGDU, A.I., 2021. *Social marketing of post-pandemic teleworking to improve the well-being of white-collar workers in Instanbul*. Middle East Technical University.

FAO, IFAD, UNICEF, WFP & WHO., 2022. *The state of food security and nutrition in the world: Repurposing food and agricultural policies to make healthy diets more affordable*. Rome, Italy: FAO.

GAMUKAMA, E.A., 2015. *Analytical modelling of Internet provision and usage in context of development through a utility based framework*. Stockholm, Sweden.

HANAFIZADEH, P., KHOSRAVI, B. & TABATABAEIAN, S.H., 2020. Rethinking dominant theories used in information systems fi eld in the digital platform era. *Digit. Policy, Regul. Gov.*, 22(4): 363–384.

JEMINE, G. & GUILLAUME, K., 2021. Lifting the veil on HRIS adoption : The role of vendors and consultants in the diffusion of HR innovations. *Inf. Technol. People.*, 35(7): 2418-2440.

JERE, N. & MAHARAJ, M.S., 2016. Evaluating the influence of information and communications technology on food security. *S. Afr. J. Inf. Manag.*, 19(1): 1–7.

KLEINE, D., 2010. ICT4WHAT?—Using the choice framework to operationalise the capability approach to development. *J. Int. Dev.*, 22(5): 674–692.

LE, T.M., LIAW, S. & BUI, T., 2020. The role of perceived risk and trust propensity in the relationship between negative perceptions of applying big data analytics and consumers ' responses'. *WSEAS Trans. Bus. Econ.*, 17: 426–435.

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.

MABAYA, E. & PORCIELLO, J., 2022. Can digital solutions transform agri-food systems in Africa ? Can digital solutions transform agri-food systems in Africa ? *Agrekon.*, 61(1): 67–79.

MABE, L.K., 2012. Constraints related to use of Information Communication Technologies tools among extension officers in the North- West Province, South Africa. *Life Sci. J.*, 9(3): 1616–1619.

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.

MABE, L.K. & OLADELE, I., 2015. E-Readiness among male and female extension officers in North-West Province, South Africa. *J. Agric. Food Inf.*, 16(4): 315–325.

MABE, L. & OLADELE, O., 2012. Awareness level of use of Information Communication Technologies tools among Extension officers in the North- West Province, South Africa. *Life Sci. J.*, 9(3): 440–444.

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. *S. Afr. J. Agric. Ext.*, 49(1): 81–90.

MAPIYE, O., MAKOMBE, G., MOLOTSI, A., DZAMA, K. & MAPIYE, C., 2021.

Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-Saharan Africa. *Info. Dev.*, p.02666669211064847.

MAUMBE, B., 2010. Mobile agriculture in South Africa: Implementation framework , value-added services and policy implication. *IJICTRDA.*, 1(2): 35–59.

MAUMBE, B.M. & OKELLO, J., 2013. Uses of information and communication technology (ICT) in agriculture and rural development in sub-saharan Africa: Experiences from South Africa and Kenya. *Tech. Sustain. Rur. Dev. Afr.*, 1(1): 113–134.

MAVILIA, R. & PISANI, R., 2022. Blockchain for agricultural sector: The case of South Africa. *Afr. J. Sci. Tech. Innov. Dev.*, 14(3): 845–851.

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). doi: 10.1080/23311886.2022.2026017.

MIGIRO, 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.

MILLER, M. & MARIOLA, M.J., 2009. The discontinuance of environmental technologies in the humid yropics of Costa Rica: Results from a qualitative survey. *Springer.*, 16(1): 31–42.

MUNYUA, H., 2007. *ICTs and small-scale agriculture in Africa: A scoping study*.

MUNYUA, H., ADERA, E. & JENSEN, M., 2009. Emerging ICTs and their potential in revitalizing small-scale agriculture in Africa. *Agric. Inf. Worldw.*, 2(1): 3–9.

OLADIPO, O.D. & WYNAND, G., 2019. Agricultural production in South Africa: information and communication technology (ICT) spillover. *Int. J. eBus. eGovernment Stud.*, 11(q): 166–190.

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: 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.

POPOOLA, O.O., YUSUF, S.F.G. & MONDE, N., 2020. Information sources ad constrainyts in climate change adoptation amongst smallholder farmers in Amathole District Municipality, Eastern Cape Province. *Sustainability (Switzerland).*, 12(7): 20–24.

RAWAL, P., 2013. AIDA Marketing Communication Model: Stimulating a Purchase. *IRC's Int. J. Multidis. Res. Insoc. Manag. Sci.*, 1(1): 37–44.

ROGERS, E.M., 1983. *Diffusion of innovation*. 3rd edn. New York: The Free Press.

ROGERS, E.M., 1995. *Diffusion of innovations*. 4th edn. New York: The Free Press.

SIMPSON, A.P. & CALITZ, A.P., 2014. The use of mobile technologies amongst South African commercial farmers. *S. Afr. J. Agric. Ext.*, 42: 98–107.

SMIDT, H.J., 2021. Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa. *Inf. Technol. Dev.*, 28(3): 558–584.

SRINUAN, C. & SEANGNOREE, A., 2014. Adoption of Thai rubber smallholders' household on the use of ICT: A case of Southern Thailand. Presented at the *The Asian Conference on Technology, Information & Society*.

TEMBO, R. & MAUMBE, B.M., 2011. E-Agriculture Development in South Africa. *Green Technologies: Concepts, Methodologies, Tools and Applications*. IGI Global.

UN., 2022a. *The Sustainable Development Goals report*. Geneva, Switzerland.

UN., 2022b. *World population prospects*. New York, USA: United Nations.

VENKATESH, V., MORRIS, M.G., DAVIS, G.B. & DAVIS, F.D., 2003. User acceptance of information technology: Toward a unified view. *MIS quarterly.*, 27(3): 425-478.

WEBSTER, J. & WATSON, R.T., 2002. Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly.*, 26(2): xiii–xxiii.

WOODBURN, M.R., ORTMANN, G.F. & LEVIN, J.B., 1994. Computer use and factors influencing computer adoption among commercial farmers in Natal Province, South Africa. *Comput Electron Agric.*, 11(2–3): 183–194.

ZANTSI, S. & NKUNJANA, T., 2021. A review of possibilities for using animal tracking devices to mitigate stock theft in smallholder livestock farming systems in rural South Africa. *S. Afr. J. Agric. Ext.,* 49(1): 162–182.

APPENDIX 1: Agricultural Digital Technology Classification in Africa

Category	Description	Examples
Market intelligence	Technologies involved in the facilitation of sharing information, improve coordination, and minimize value chain transaction costs	Supply chain management, traceability, traceability solutions certification, e-commerce, service provider linkages, online inputs and output markets
Farm tools	Technologies involved in the optimization of production and management	Internet of Things (IoT), irrigation, pay-as-you-go, mechanisation, remote sensing, robotics, drones, precision agriculture tools, farm management software

10.17159/2413-3221/2023/v51n4a15337

Financial access	Technologies that deliver financial products and solutions (financial technologies)	Crowdfunding platforms, credit risk profiling, index-based insurance products, warehouse receipt systems, mobile payments, e-wallet
Advisory services	Technologies that provide timely and cheap extension and advisory services	Predictive analysis, early warning tools for pest/disease control or weather/climate, market information system, customised extension services

Source: Mabaya and Porciello (2022)

APPENDIX 2: Examples of Digital Technologies and their Providers in South Africa

Service area	Key provides
Certification and tracing	South African Organic Sector Organisation
Input and market linkage	AgriProtein, Farmer2Farmer
Extension services	National Emergent Red Meat Producers, ARC
Input service aggregation	Khula
Crowd farming	Livestock Wealth, Impact farming
Precision farming	Massey Fergusson and John Deere tractors, Monsanto's Climate Field View, Aerobotics
Online agronomy	Collaboration between ARC, AgriColleges and University of Stellenbosch

Source: Born *et al.* (2021) and Mabaya and Porciello (2022)

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337

APPENDIX 3: List of Primary Studies Used in the Review.

Author	Title	Approach	Main Findings
Woodburn, Ortmann and Levin (1994)	Computer use and factors influencing computer adoption among commercial farmers in Natal Province, South Africa	✓ Survey of 199 commercial farmers in Natal Province ✓ Used multivariate logit to assess determinants of adoption	✓ 48% own personal computers and were using them as decision-aids in farm management. ✓ Computers were used for record keeping, business planning and payroll preparation. ✓ Rated computers high for saving time and producing up to date, more usable and easy access information. ✓ Reasons for not owning personal computers include cost of computer system, lack of confidence to operate a computer, insufficient time to operate a computer. ✓ Educational levels, gross farm income (size of business), proportion of farmland rented, financial management skills and off-farm employment were significant determinants of adoption computer adoption
Migiro and Kwake (2007)	Information needs and communication technology adoption in Africa: a comparative study of rural women in Kenya and South Africa	✓ Survey	✓ Radio and TV most used ICTs for information needs in health, education, social welfare, and agriculture. ✓ Internet and video and exclusion of women was still significant. This was explained by low literacy levels, inadequate computer skills. ✓ Felt that ICTs were too costly

Author	Title	Approach	Main Findings
Cloete and Doens (2010)	B2B e-marketplace adoption in South African agriculture	✓ Key informant interview	✓ Majority of decision-makers are already using e-commerce of some form
Oladipo and Wynand (2019)	Agricultural production in South Africa: information and communication technology (ICT) spill over	✓ Used the General Household Survey to obtain information on 21 601 households ✓ Used logit regression of factors affecting food production	✓ 80% of households have at least one form of ICT i.e. mobile phone ✓ internet connection has significant positive impact on household agricultural production ✓ positive spill over impacts of ICT not possible due to lack of access to land for agriculture
Jere and Maharaj (2016)	Evaluating the influence of information and communications technology on food security	✓ Survey of 517 smallholder farmers in KZN ✓ Used structural equation modelling	✓ ICT influence food security based on culture, perceived usefulness and perceived ease of use. ✓ Perceived ease of use has most significant effect on ICT adoption and diffusion among smallholder farmers ✓ No association was found between perceived attributes of innovation and nature of social systems
Maumbe (2010)	Mobile agriculture in South Africa: Implementation	Review	✓ Rural e-government has been hampered by poor internet connection. ✓ Proposed a multi-functional agro-portal and mobile agriculture services. ✓ Advocated for development of “value-based” and “demand-driven” mobile agriculture.

Author	Title	Approach	Main Findings
	framework, value-added services and policy implication		✓ Advocated for greater competition amongst service providers, utilisation of multi-lingual, integration of IKS and customised value-added services
Akinsola (2014)	ICT Adoption for Bridging South African Black Farmers' Knowledge Gap	Qualitative interviews	✓ Traditional agricultural knowledge support strategies are inadequate and inefficient. This is through dual nature of South Africa's agricultural sector. ✓ Black farmers require a platform of dynamic knowledge support where interactions with other stakeholders could be accomplished. ✓ Bridging smallholder farmer's agricultural knowledge gap has benefits such as sustainable employment, food security, poverty alleviation. ✓ Existing information technology was from radio, television, computers, video tapes, CD/DVD, worldwide web. ✓ There is however lack of interaction amongst knowledge providers, extension, and users. ✓ Some of the challenges include: -knowledge not delivered when required -compression to accommodate space and time -knowledge treated as static -knowledge is expert oriented -knowledge not contextualised -difficulty in verifying source of knowledge

Author	Title	Approach	Main Findings
Mdoda and Mdiya (2022)	Factors affecting the using information and communication technologies (ICTs) by livestock farmers in the Eastern Cape province	✓ Survey of 170 livestock farmers ✓ Used binary logistic regression	✓ Found that ICTs increase information availability, knowledge on farming activities, quality of marketing information and access to markets, improve access to inputs, disease control and recording, awareness of agricultural events, encourages information sharing, dissemination, enhances productivity. ✓ gender, age, educational levels, marital status, access to extension, household size, membership to farmer organisation, load shedding, network coverage and access to credit were significant factors in the utilisation of ICTs
Otiso and Moseley (2009)	Examining Claims for Information and Communication Technology-Led Development in Africa	✓ Review but was focussed on Africa as a whole, and only partly mentioned South Africa	✓ In 2009, South Africa had 4.6 million internet users, ranked 4th in Africa. This was at 9.4% of the population. ✓ In 2008, South Africa was ranked 3rd in Africa on cell phone penetration, at 92 per 100
Mabe and Oladele (2015)	E-Readiness Among Male and Female Extension Officers in North-	✓ Survey of 169 extension officers ✓ Conceptualised e-readiness as	✓ Found residing in the job area, means of mobility, educational levels, number of farmers covered, working experience and age being significant determinants of e-readiness ✓ Had an extensive evaluation of ICT tools, which included mobile phone, internet, cable TV, fax machine, computer graphics, image technology, VCD, computer visuals, data

Author	Title	Approach	Main Findings
	West Province, South Africa	awareness, availability, accessibility, competencies, and importance of ICT tools ✓ Used multiple linear regression	processors, DVD, wireless radio, TV, overhead projector, radio, cinema, multimedia projector, newspaper, fixed telephone, computer, organisational email, organisational website, personal email, personal website, video, CD-ROM, blackberry/3 G card, world wide web, e-mail, electronic spreadsheet, word processing, chat room, intranet, extension suite online
Dlamini and Ocholla (2018)	Information and Communication Technology Tools for Managing Indigenous Knowledge in KwaZulu-Natal Province, South Africa	✓ Survey of 57 ICT users/beneficiaries ✓ Survey of 196 owners/custodians of IK	✓ ICT provides a good platform for managing IK ✓ Problems identified included access to relevant ICT infrastructure and resources, lack of digital skills. ✓ ICT users/beneficiaries mostly used video camera, video recording, tape recording and cellphone recordings, while owns/custodians of IK use video cameras and cellphone recordings. ✓ In terms of ICT tools for storing/preserving IK, ICT users/beneficiaries were using computer, internet, USB, DVD, email, cellphone, tape/video recorder, video/digital camera. However, owners/custodians of IK were using DVDs, CD and cellphone

Author	Title	Approach	Main Findings
			✓ In terms of disseminating IK, ICT users/beneficiaries were using internet, cellphone, telephone, radio, TV, and emails. The owners/custodians of IK were using cellphone, DVDs, CDs, telephone, and laptop. ✓ Most of the respondents indicated that the ICTs were effective tools in recording, storing and disseminating IKS. ✓ Challenges in use identified by users/beneficiaries included low battery, lack of digital skills, losing data, small memories of some ICT tool, sensitivity of some ICT tools, viruses in some ICTs. ✓ Challenges in use identified by owners/custodians include lack of digital skills, small memories of ICTs, low battery, complicated devices, and manuals written in English. ✓ Challenges in unavailability of ICT tools by users/beneficiaries include being expensive, tools are short supply, batteries are few and no budget for ICTs. ✓ Challenges in unavailability of ICTs for owners/custodians of ICT include being expensive, poor networks, lack of electricity, lack of awareness of proper tools, poor infrastructure, and few batteries
Mabaya and Porciello (2022)	Can digital solutions transform agri-food systems in Africa?	Review	✓ Various digital technologies are available in South Africa, which relate to certification and trading; input and market linkage; extension services; input service aggregation; crowd farming; precision farming and online agronomy. ✓ Digital technologies backed by a solid communication and power infrastructure.

Author	Title	Approach	Main Findings
			✓ Challenges include mobile data cost. ✓ Found less than 10 studies that have been carried out in South Africa
Mavilia and Pisani (2022)	Blockchain for agricultural sector: The case of South Africa	Review of a case for tracking grapes in South Africa	✓ Blockchain can potentially reshape the entire agricultural sector
L. Mabe and Oladele (2012)	Awareness level of use of Information Communication Technologies tools among Extension officers in the North- West Province, South Africa	✓ Survey of 169 extension officers ✓ Use multiple regression	✓ There was high awareness of mobile phones, computer, internet, overhead projector, fax machines, organisation email, fixed telephone, personal email and organisational website. ✓ Determinants of awareness were religion, constraints to ICT use, importance of ICT tool, competence on ICT use,
Makaula (2021)	Information and communication technologies (ICT) towards agricultural	✓ Survey of 138 smallholder farmers ✓ Correlation analysis	✓ There was correlation between ICT usage and the economies of scale in agricultural development. ✓ Smallholder farmers mostly using mobile phones, radio, TV, internet, photocopying, videos and cameras.

Author	Title	Approach	Main Findings
	development in rural areas: case of smallholder farmers in Umzimvubu local municipality of the Eastern Cape Province in South Africa		✓ Challenges faced include not knowing exact broadcasting time, poor signal, language barrier and no electricity
Mabe (2012)	Constraints related to use of Information Communication Technologies tools among extension officers in the North- West Province, South Africa	✓ Survey of 169 extension officers ✓ Use multiple regression	✓ Constraints to using ICTs include failure of service, poor basic infrastructure that encourages ICT, inability to maintain the ICT, too costly as well as non-availability of technical personnel. ✓ Determinants of constraints include working experience, awareness of ICT, effect of ICT on information access, officers e-readiness and use of ICT

Author	Title	Approach	Main Findings
Munyua, Adera and Jensen (2009)	Emerging ICTs and Their Potential in Revitalizing Small-Scale Agriculture in Africa (did not focus on South Africa, but made reference and cases to it)	✓ Desktop study, field observation and individual and group interviews in Botswana, Ghana, Kenya and Uganda	✓ GIS technology has been used in South Africa to map fences in the International Livestock Research Institute (ILRI) livestock-wildlife ecosystem initiative. ✓ GIS was also used in natural resource management in the Roiboos tea land by the Gender, Agriculture and Rural Development in the Information Society (GenARDIS) ✓ Radio Frequency Identification (RFID) has been used in South Africa for livestock identification purposes under the livestock information trace back system. ✓ Precision Agriculture has been adopted in South Africa for irrigation using ground water
L. K. Mabe and Oladele (2012)	Use of Information Communication Technologies tools among Extension officers in the North- West Province, South Africa.	✓ Survey of 169 extension officers ✓ Use multiple regression	✓ ICTs were used to gain access to information on marketing produce, obtaining new information on technologies, new prices of farm produce, new animal breeds, preservation of farm produce, viewing how to practice new techniques, presenting seminars to farmers, obtain information on crop protection, information about new variety of crops/seeds, project level of production, feed information, time of planting crops. ✓ Determinants of use of ICTs were education levels, importance of ICT, constraints to ICT use, effect of ICT on information access

Author	Title	Approach	Main Findings
Zantsi and Nkunjana (2021)	A review of possibilities for using animal tracking devices to mitigate stock theft in smallholder livestock farming systems in rural South Africa	Review	✓ Few studies have a made a case for GPS animal tracking in South Africa's smallholder sector. ✓ Adoption of GPS animal tracking device adoption depends on the awareness about the device, the acuteness of stock theft and income level, access to mobile phone and risk behaviour
Smidt (2021)	Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa	Review	✓ Role of government and institutional support is essential to facilitate collaboration of different actors. ✓ Development of comprehensive localized developmental implementation framework

Vol. 51 No. 4, 2023: 104-146
10.17159/2413-3221/2023/v51n4a15337