

The use of IoT technologies to the small-scale cabbage farmers in South Africa

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Research Article

Keywords: Internet of Things, small-scale cabbage farmers, Free State, South Africa

Posted Date: July 17th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10148021/v1>

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Additional Declarations: No competing interests reported.

Abstract

IoT-based technologies possess the capacity to enhance the performance of small-scale agriculture business within the cabbage farmers. The objective of the study was to examine effects of IoT technology and assess its impact of IoT in the performance of small-scale cabbage farmers. A quantitative research methodology was utilised. Thus, this study utilised questionnaires for data collecting, involving 372 small-scale cabbage farmers from Free State, and employed Statistical Package for the Social Sciences (SPSS) and LISREL 8.80 software for data analysis. The findings indicated that IoT technologies possess the ability to enhance the cabbage industry by improving productivity and sustaining operations. The findings revealed that IoT poses considerable challenges concerning software complexity, data security, poor supporting infrastructure, and a lack of technical skills in small-scale cabbage farmers. Insufficient human capital and technology gaps in the South African cabbage farmers impede crop output, community food security, and governmental efforts to enhance agricultural productivity and the broader farming business. This study enhances the understanding of IoT technological dimensions both in South Africa and globally, hence contributing to the existing literature on the subject.

1. Introduction

IoT encompasses a variety of advanced technologies, including measurement devices, data transmission, data storage and analysis, feedback mechanisms, project organisation, and support systems (Antony et al.,2020). These technologies are innovative technology that enables farmers to make informed decisions concerning their soil, water, crops, and local climate. The adoption of IoT principally seeks to impose artificial control over climate change and land conditions in the agricultural sector (Myeko & Rambe,2024). IoT-based technologies as the integration of several current technologies that regulate climatic factors, including natural light and temperature. IoT has shown that it will offer significant benefits to small-scale agricultural businesses through its potential to deploy innovative technologies in diverse fields (Myeko, 2025). Myeko and Rambe (2024) averred that the IoT as a network that employs several sensors interconnected via information and communication infrastructure to provide superior services to clients and other stakeholders. IoT technology transforms traditional farming by changing the interactions between small-scale cabbage farmer owners or managers and their consumers, as well as the transmission of market activities and information (Hao et al., 2019). Fundamentally, IoT-technology enhances the cabbage productivity and fulfils market needs. IoT is changing traditional farming into a modern digital farming paradigm (He & He, 2021).

The study also addresses Sustainable Development Goal (SDG 2), referred to as "Zero Hunger." This objective seeks to eradicate hunger, attain food security, enhance nutrition, and foster sustainable agriculture by 2030. It involves guaranteeing access to safe and nutritious food for all, eradicating all types of malnutrition, and advocating for sustainable food production techniques. It is anticipated that over 600 million individuals globally would be confronted with hunger by 2030, underscoring the significant challenge of attaining the Zero hunger objective. Food security necessitates a

multidimensional strategy encompassing social protection. To address SDG2, some developed and developing countries would need to adopt IoT-based technologies to enhance productivity in their agriculture landscape. Kim et al., (2020) found that IoT-based technologies enhances automation within the agricultural sector, hence augmenting worldwide agricultural productivity. IoT-based technologies have the capacity to revolutionise the agricultural sector augmenting production, ensuring sustainable resource management and enhancing the profitability of small-scale cabbage farmers. IoT-based technologies have been hailed for its capacity to address numerous difficulties in the agricultural industry and fosters sustainable and effective farming methods (Antony et al., 2020).

The scientific literature is rich in contribution to the convergence of IoT-based technologies with the agriculture sector environment in particular in cabbage farmers. For example, Goedde et al. (2020a) asseverate that the IoT improve cabbage farmers performance through modern technology. Several studies investigated how small-scale cabbage farmers adopted IoT as tool to improve productivity and efficiency in agriculture sector (Rejeb et al., 2023; Chen, 2023). Yet, literature has emphasised the importance of exploring the links between IoT and agriculture to provide innovative insights into how this could improve performance of the small – scale cabbage farmers (Schoggl et al., 2023). Consequently, IoT technology entails many techniques that can be utilised by information communication technology to revolutionise traditional farming practices in terms of productivity and service delivery. Goedde et al., (2020a) contend that IoT significantly contributes to the agricultural industry by reducing labour costs, optimising inputs, enhancing yield, decreasing overheads, and improving machinery maintenance and operations. This argument recognises that the successful operation of the farming businesses depends on the deployment of various devices, networks, sensors, and actuators within the domain of IoT technology.

Hiroyuki and Kumar (2019) characterise shielded agriculture as a novel method utilised by farmers to supply plant coverings and control climatic conditions. These authors argue that this developing technology emphasises crop monitoring and the management of climatic effects on the agricultural environment. The current researcher contends that IoT technology transforms conventional traditional farming through the utilisation of current technology to improve agricultural product management. Moeti et al., (2024) accentuate that the revolutionary potential of IoT have garnered significant academic interest. As a result, the volume of publications has surged significantly in recent years, highlighting the necessity for studies that synthesise the current body of knowledge and identify future research directions. To researcher knowledge, no recent study has employed a quantitative research approach to thoroughly examine the entire interaction between the IoT and agriculture. Furthermore, it remains ambiguous which agricultural resources are most affected by the integrating IoT technology in agricultural sector. To address this knowledge gap, this study focusses on this research question: “What impact does IoT technology have on the performance of small-scale cabbage farmers? To address these deficiencies, the researcher work is founded on a quantitative research approach and is directed by the subsequent research objectives:

- To explore how IoT technology impact on the small- scale cabbage farmers performance, South Africa.
- To establish how small-scale cabbage farmers changed traditional farming approach to modern technology.

Secondly, the IoT technologies demonstrated potential in agriculture sector in particular in cabbage producers, therefore, have attracted academics and scholarly attention to how IoT can improve productivity in the small-scale agriculture businesses (Gatzweiler & Joachin, 2016). As such, the IoT literature demonstrated how disruptive innovation theory can leverage small-scale agricultural businesses(Myeko,2025).

The subsequent sections of this work are organised as follows. Section 2 elucidates the theoretical developments of this study and consolidates previous literature assessments about the Internet of Things and agriculture. Section 3 delineates the methodology, while Section 4 presents dimensions of IoT, Section 5 presents the principal findings and discussions, Section demonstrate study implications, section 7 present limitations of the stud. The last section conclusion of the study.

2. Theoretical Development

2.1 Disruptive innovation theory

The disruptive innovation theory (DIT) primarily concentrates on emerging technologies capable of fundamentally transforming entire sectors and redefining their competitive landscapes (Stromberg & Thorman, 2019). This suggests that small-scale agricultural businesses can harness IoT-based technologies as effective ways of disrupting existing technologies widely used in the agricultural sector to enhance the performance of their business. Therefore, disruptive innovation theory provides a useful theoretical lens that could assist small-scale agricultural businesses in adopting and implementing IoT-based technologies such as actuators, computers and sensors. In its original form, disruptive innovation theory provides an opportunity to improve products and services in the small-scale agricultural business. DIT explains how continual technology upgrades creates further opportunities for achieving a competitive advantage in all small-scale agricultural businesses.

Si and Chen (2020) examine the ramifications of DIT for small agricultural firms through DIT analysis. In his acclaimed work “The Innovator’s Dilemma”, Christensen (1997) made a concerted effort to explain concept of disruptive innovation theory. The disruptive innovation theory encourages the usage of the new modern technology by small-scale agriculture business in the agriculture sector. Furthermore, the disruptive innovation theory provides a clear picture on how to start the implementation of the new technology such as IoT technology in agriculture sector. Moreover, disruptive innovation theory provides an opportunity to improve performance of the small- scale agriculture businesses in agriculture sector. Organisations that proactively embrace emerging dominant technologies generally prosper, while those that reject such adoption are prone to failure (Nair and Ahlstrom, 2003).

DIT is especially relevant to small-scale agricultural businesses employing innovative technologies. IoT-based technologies are expected to enable machine-to-machine connectivity and employ IoT sensors to improve technical progress in crop production, animal breeding and milking and in horticulture. IoT-based technology enhances agricultural productivity through insights derived from past and current business scenarios. The disruptive innovation theory posits that small-scale agricultural businesses can implement IoT technology to enhance operations, seize opportunities while safeguarding themselves against external and internal threats (Adegbite & Govender, 2021). Moreover, the effective utilisation of latest innovations by small-scale agricultural businesses provides valuable insights into customer preferences, enhances processes, and improves efficiency, which can be advantageous in the development of products and services. Attracting and retaining consumers, as well as enhancing market share, are critical aspects that demonstrate a beneficial influence of drawing on latest innovations by small-scale agricultural businesses (Escalfoni & Oliveira, 2021). This supports the notion that disruptive innovation theory significantly enhances the dominant strategies of businesses, enabling small-scale agricultural businesses to engage effectively with their clients.

3. Research Methodology

This study employed a quantitative research methodology, allowing the researcher to implement a deductive approach. According to Ghanad (2023), the quantitative approach entails the collection of numerical data to investigate deductive links among variables while preserving objectivity in the perception of reality. Bryman (2016) asserts that the quantitative approach is associated with the positivist research paradigm and posits that researcher maintain objectivity in examining phenomena.

The study executes a quantitative research approach to established research questions, collect data using structured questionnaires, select a suitable research design, analyse the data statistically and interpret finding of the study. This method proved effective in formulating broadly applicable conclusions regarding the nature and extent of the links among the variables studied. This deductive approach enables the shift of the study from the abstract theoretical realm to the tangible empirical examination of the research subject (Saunders et al., 2007).

Consequently, a structured questionnaire was employed as a quantitative instrument for data collection in this investigation. For the purpose of this study five points likert scale was selected to measure variables (Vagias, 2006). A five-point likert scale was chosen to measure accessible devices, network connectivity, advanced yield monitoring, optimal seeding, and optimal water usage variables. The five-point likert scale provides five response option. The respondents have an opportunity to select the option that best reflects their assessment of the item's significance. The current research used likert scale measure opinion, knowledge, perceptions about the variables. The research focusses on small-scale cabbage farmer owners and managers in the Free State province, specifically within the municipalities of Mangaung Metropolitan Municipality, Xhariep District, Thabo Mofutsanyane District Municipality, Lejweleputswa District Municipality, and Fezile Dabi District Municipality.

However, this study adopted probability sampling, in particular quota sampling. Probability sampling is often regarded as a best sampling method as it reduces the sampling error. Etika and Bala (2017) affirmed that with probability sampling, every member of the population has an equal chance of selection in a research study. This sample consists of small-scale cabbage farmers owners and managers in the Free State Province, South Africa. But, because these respondents are equally important to this study, the researcher decided to utilise quota sampling. Furthermore, data was analysed quantitatively using Statistical Package for Social Science version 28 (SPSS). The SPSS was used to generate descriptive statistics, whilst LISREL 8.80 analysis was used to conduct reliability and validate analysis through Cronbach alpha, composite reliability and average variance explained analysis

4. Literature Review

3.1. Examination of Prior Research

The impact of IoT technology on small-scale agricultural enterprises in South Africa remains insufficiently examined. This research study aims to address the knowledge gap due to the limited literature on such effects by integrating device accessibility, network connectivity, optimal seeding, and optimal water usage to ascertain the precise impacts of IoT applications on these variables in the agriculturally rich yet drought-prone Free State province of South Africa. IoT technology plays a significant role in the agricultural sector in the Free State, South Africa, and globally. Sharma et al. (2016) assert that the Internet of Things (IoT) constitutes a vast, globally interconnected network based on the internet. The Internet of Things (IoT) leverages the interconnected capabilities of sensors, computers, and other networked technology to enhance the profitability of small-scale agricultural enterprises. The IoT employs a system that connects all global internet networks, and the functionalities (e.g., connection, effective and timely utilization of resources) of these technologies are pertinent to drone-accessible regions with significant agricultural potential. This innovative method emphasizes crop surveillance and the regulation of climatic impacts on agricultural conditions. Plants require protection from climatic conditions to thrive well. The Internet of Things employs artificial intelligence methods to safeguard plants against climatic variables, including natural light, temperature, and humidity, thereby fostering an optimal growing environment (Shi et al., 2019). Consequently, IoT is recognized as a mechanism for managing crop agriculture against atypically adverse weather. The Internet of Things (IoT) is also referred to as open-field agriculture (Shi et al., 2019)

4.2 Small-scale agriculture business

The notion of small-scale agricultural businesses (SSABs) is expansive and varies in interpretation among different authors. The National Small Business Amendment Act 26 of 2003, along with Rambe and Agbotame (2018), characterizes small-scale agricultural enterprises as those employing 50 workers, with a total revenue of R3 million and total gross asset worth of R3 million. When individuals assess the magnitude of a firm, they examine many facets. Some assess the size of a corporation based on its workforce, while others evaluate it according to its performance and assets. Small-scale agricultural

enterprises differ from small agribusinesses (Rambe & Agbotame, 2018). Agribusiness primarily concentrates on specific elements, including marketplaces and private enterprise initiatives, which encompass the production, storage, supply of production inputs, and processing of agricultural goods.

A consensus on the definition of SSABs is lacking. Different countries independently define SSABs based on their individual criteria for business size (Desta, 2015). The researcher aims to employ the terminology from the National Small Business Act 26 of 2003 to examine SSABs in the South African setting. The National Small Business Act of 1996 defines Small, Medium, and Micro Enterprises (SMMEs) as outlined in Section 1 of the Act, as amended by the National Small Business Amendment Acts of 2003 and 2004. Specifically, it describes SMMEs as a distinct business entity, encompassing cooperative enterprises and non-governmental organizations, managed by one or more owners, and predominantly operating within any sector or sub-sector of the economy specified in Column 1 of the schedule. The National Small Business Act classifies them into the following categories: survivalist, micro, very small, and medium.

4.3 Internet of Things in agricultural industry

This study defines IoT as an advanced farming method that utilises IoT technologies and tools, including sensors and computer-based techniques, to monitor and regulate environmental factors (e.g., water, moisture, humidity, temperature, soil acidity) to facilitate plant growth in controlled agricultural settings (Kaur & Kaur, 2019). Consequently, IoT automates irrigation systems, enabling cabbage farmers to check their crops remotely at any desired time. Cabbage producers can employ automatic drip irrigation that functions based on a predetermined soil moisture threshold to deliver the correct water quantity for the plants. The efficacy of IoT technology in many agricultural domains is mostly attributable to its integration of multiple devices with various platforms, standards, and network solutions (Stoce et al., 2016).

The IoT has evidently served as a mechanism for enhancing production, optimising management, reducing time, minimising costs, and lessening the human involvement required in the cultivation, monitoring, and harvesting of plant crops (Kaur & Kaur, 2019). Utilising IoT technologies, numerous cabbage farmers have enhanced production in both large-scale and small-scale agriculture. Cabbage farmers have diminished their time and personal engagement in production processes, exclusively due to the automation facilitated by IoT technology applications in their sector. Cabbage farmers have enhanced their profit margins with IoT by decreasing labour expenditures. IoT-based solutions concentrate on automating agricultural tasks, including crop growing and management globally (Stoce et al., 2016). These tools have been employed to safeguard items such as cabbages, tomatoes, spinach, cucumbers, and strawberries.

IoT-based technology is well situated to transform cabbage farming, allowing farmers to enhance both the number and quality of their harvests at a fair cost. The novel technological techniques enhance cabbage productivity and bolster the economies of small-scale farmers. Many cabbage producers are confronting environmental issues, including increased water scarcity and climate change in various

places (Rayes & Salam, 2019). IoT-based technologies employ sensors to monitor soil moisture, crop growth, feed levels, and irrigation systems. The new technologies employ analytics to evaluate operational data alongside weather and additional information to enhance decision-making. Most cabbage farming machinery is being outfitted with sensors and actuators.

Accessibility to devices in IoT-based technology encompasses numerous gadgets and smart things, facilitating the expansion of the internet and enabling unique identification. Device accessibility can be assessed through numerous dimensions, including sensors, smartphones, and mobile computers. Notably, the focus of ICT innovation and economic development has shifted towards IoT-related technologies, which are regarded as a crucial infrastructure that may be advocated for cabbage farmers.

Network connectivity refers to the interconnection of heterogeneous and intelligent devices (Rayes & Salam, 2019). IoT-based technology facilitates interoperability, machine-to-machine connection, information sharing, and data transfer, enhancing the efficacy of service delivery for cabbage producers. Network connectivity can be assessed through several mediums, including gateways, routers, switches, Bluetooth, Wi-Fi, and Zigbee. Connectivity occurs at any time, from any location, for anyone, and for any purpose (Rayens & Salam, 2019). Essentially, an IoT-based technological sensing device requires at least three components: sensors, a microcontroller, and connectivity to transmit filtered data to the IoT gateway. The sensor gathers substantial data continuously and from any location, transmitting it in real time across an IoT network(Rayes&Salam,2019).

The IoT-based technology employed an enhanced yield monitoring tool as a component of the created system, enabling the monitoring and control of various cabbage crops to enhance output outcomes for cabbage farmers. It also employs sensors to monitor soil moisture and manage water by detecting the necessary water levels in the soil to promote green initiatives (Rayes & Salam, 2019).

Optimal seeding offers a technique that identifies the most suitable seeds for specific soil types and provides guidance on the optimal arrangement of row spacing for cabbage cultivation. Cabbage producers can determine the appropriate fertilisers for certain soils and the necessary quantities to enhance the quality of cabbage crops in those soils (Rayes & Salam, 2019). The IoT-based system can optimise water usage to monitor and regulate environmental factors impacting cabbage cultivation.

Efficient water utilisation dictates the quantity of water necessary to enhance cabbage crop yield under specific soil conditions (Rayes & Salam, 2019). It also offers weather forecast data to enable cabbage producers to avert potential damage from ice, severe rain, drought, snow, and strong winds. Optimal water usage aids in regulating humidity levels for monitoring crops like hay and alfalfa to minimize fungal and bacterial contamination (Rayes&Salam,2019).

5. Results and Discussions

5.1 THE RELIABILITY OUTPUT FOR THE ACCESSIBLE TO THE DEVICE SUBSCALE

A Cronbach's alpha of 0.513 was achieved for the accessible reliability output. This fell below the acceptable Cronbach's alpha threshold of $\alpha = 0.70$ (Nunnally & Bernstein, 1994). The adjusted item-total correlation values in the Item-Total Statistics table indicate the extent to which each item correlates with the overall score. Values below 0.30 suggest that the item is assessing a construct distinct from the overall scale (Pallant, 2016). All corrected item-total correlations above 0.30, except for items B1_11 and B1_12, as indicated in Table 1. These items were thereafter omitted from the analyses. Cohen (1988) recommends the following rules for assessing the strength of the relationship between variables: $r = .10$ to $.29$ indicates a modest relationship; $r = .30$ to $.49$ signifies a medium link; and $r = .50$ to 1.0 denotes a big relationship. The inter-item correlation matrix values of the revised accessibility to the device subscale range from 0.286 to 0.664, indicating a small to large link among the items.

Table.1

The reliability analysis output for the accessible to the device subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.513	.606	6

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B1_11	18.37	4.278	.122	.058	.523
B1_12	19.08	3.031	.078	.038	.662
B1_13	18.50	3.528	.408	.475	.426
B1_14	18.50	3.604	.384	.461	.438
B1_15	18.82	2.565	.452	.348	.345
B1_16	18.62	3.175	.435	.345	.389

B1_11	Mean	Std. Deviation	N
	4.01	.194	372
B1_12	3.30	1.048	372
B1_13	3.88	.448	372
B1_14	3.88	.429	372
B1_15	3.56	.817	372
B1_16	3.76	.581	372

THE RELIABILITY OUTPUT FOR REVISED ACCESSIBLE TO THE DEVICE SUBSCALE

Following the removal of items B1_11 and B1_12, deemed inadequate in the preliminary item analysis shown in Table 1, the Cronbach alpha of the scale increased to $\alpha = .701$, which is considered satisfactory (Nunnally & Bernstein, 1994). The adjusted item-total correlation values in the Item-Total Statistics table exceed 0.30 (Pallant, 2016) (refer to Table 2). The inter-item correlation matrix values for the updated accessibility to the device subscale range from 0.286 to 0.664, indicating a small to large link among the items.

Table 2

The revised reliability analysis output for the accessible to the device subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.701	.737	4

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B1_13	11.20	2.086	.497	.461	.645
B1_14	11.20	2.113	.507	.459	.644
B1_15	11.52	1.312	.507	.323	.675
B1_16	11.31	1.736	.559	.339	.591

B1_13	Mean	Std. Deviation	N
	3.88	.448	372
B1_14	3.88	.429	372
B1_15	3.56	.817	372
B1_16	3.76	.581	372

THE RELIABILITY OUTPUT FOR THE NETWORK CONNECTIVITY SUBSCALE

A Cronbach's alpha of 0.622 was derived for the network connection subscale. This fell below the acceptable Cronbach's alpha threshold of $\alpha = 0.70$ (Nunnally & Bernstein, 1994). The adjusted item-total correlation values in the Item-Total Statistics table reveal that item B2_21 exhibited a low value (below 0.30), and its removal will enhance the scale reliability coefficient to $\alpha = 0.691$, which is just below the 0.70 threshold. The item was eliminated from all the subsequent analyses (see Table.3). Table 4 presents the updated output for network connectivity reliability. The item total correlation loadings for item B2_20 fell below the 0.30 threshold, and its exclusion would elevate the scale's Cronbach alpha to $\alpha = 0.752$. The item was likewise omitted. The inter-item correlation matrix values of the modified network connection subscale vary from 0.480 to 0.571, indicating substantial relationships among the items.

Table .3

The reliability analysis output for the network connectivity subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.622	.660	5

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B2_17	15.58	1.069	.465	.391	.531
B2_18	15.62	.970	.503	.338	.501
B2_19	15.57	1.108	.473	.385	.535
B2_20	15.59	1.142	.338	.145	.587
B2_21	15.68	1.006	.221	.082	.691

B2_17	Mean	Std. Deviation	N
	3.93	.341	372
B2_18	3.90	.392	372
B2_19	3.94	.310	372
B2_20	3.92	.346	372
B2_21	3.83	.523	372

THE REVISED NETWORK CONNECTIVITY RELIABILITY OUTPUT

Table 4

The reliability analysis output for the revised network connectivity subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.691	.693	4

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B2_17	11.75	.608	.530	.387	.590
B2_18	11.78	.527	.574	.336	.555
B2_19	11.74	.630	.570	.384	.573
B2_20	11.76	.732	.260	.094	.752

B2_17	Mean	Std. Deviation	N
	3.93	.341	372
B2_18	3.90	.392	372
B2_19	3.94	.310	372
B2_20	3.92	.346	372

THE ADVANCE YIELD MONITORING RELIABILITY OUTPUT

A Cronbach's alpha of 0.528 was recorded for the Advance yield monitoring subscale. This fell below the acceptable Cronbach alpha threshold of $\alpha = 0.70$ (Nunnally & Bernstein, 1994). The adjusted item-total

correlation values in the Item-Total Statistics table indicate that the loadings for all items above the 0.30 threshold (Pallant, 2016). Excluding any of the elements would not enhance the scale reliability coefficient. Consequently, all elements were preserved (see to Table 5). The inter-item correlation matrix values of the Advanced Yield Monitoring subscale range from 0.23 to 0.34, indicating a small to medium link among the items.

Table .5

The reliability analysis output for the advanced yield monitoring subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.528	.539	3

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B3_22	7.69	.512	.305	.093	.485
B3_23	7.75	.393	.381	.155	.367
B3_24	7.64	.581	.365	.139	.417

B3_22	Mean	Std. Deviation	N
	3.85	.443	372
B3_23	3.79	.513	372
B3_24	3.90	.353	372

THE OPTIMAL SEEDING RELIABILITY OUTPUT

The Optimal seeding subscale yielded a Cronbach alpha of 0.478. This fell below the acceptable Cronbach's alpha threshold of $\alpha = 0.70$ (Nunnally & Bernstein, 1994). All corrected item-total correlation values in the Item-Total Statistics exceed the 0.30 threshold (refer to Table 6). Consequently, all things were retained. The inter-item correlation matrix for the two items of the optimal seeding subscale indicates a correlation coefficient of $r = 0.326$, showing a moderate association between the items.

Table 6
The reliability analysis output for the optimal seeding subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.478	.492	2

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B4_25	3.88	.112	.326	.106	.
B4_26	3.82	.193	.326	.106	.

B4_25	Mean	Std. Deviation	N
	3.82	.439	372
B4_26	3.88	.335	372

OPTIMAL WATER USAGE RELIABILITY OUTPUT

The Optimal water usage subscale yielded a Cronbach alpha of 0.547. This fell below the acceptable Cronbach alpha threshold of $\alpha = 0.70$ (Nunnally & Bernstein, 1994). Two of the adjusted item-total correlation values in the Item-Total Statistics exceed the 0.30 threshold, while two fall below this threshold (refer to Table 7). Excluding item B5_28 would enhance the reliability coefficient of the scale. A determination was reached to eliminate the item. The elimination led to an enhancement in the corrected item total correlation (refer to Table 7). The inter-item correlation matrix values for the optimal water usage subscale range from 0.231 to 0.393, indicating a small to medium association among the items.

Table. 7

The reliability analysis output for the optimal water usage subscale

Reliability Statistics					
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items			
.547	.591	4			
Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B5_27	11.32	1.290	.423	.211	.399
B5_28	11.47	1.058	.276	.115	.596
B5_29	11.26	1.387	.476	.240	.383
B5_30	11.23	1.688	.259	.138	.533

B5_27	Mean	Std. Deviation	N
	3.77	.537	372
B5_28	3.62	.773	372
B5_29	3.84	.450	372
B5_30	3.86	.384	372

The revised reliability analysis output for the optimal water usage subscale

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.596	.600	3

Item-Total Statistics					
Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B5_27	7.70	.455	.435	.192	.462
B5_29	7.63	.561	.438	.192	.447
B5_30	7.61	.681	.364	.133	.558

B5_27	Mean	Std. Deviation	N
	3.77	.537	372
B5_29	3.84	.450	372
B5_30	3.86	.384	372

6. Discussions

This study analyses input from small-scale cabbage farmers in South Africa who utilise IoT devices. The researcher gathered data from 372 small-scale cabbage farmers in South Africa and performed a statistical analysis. Interestingly, the results indicate that small-scale cabbage farmers heavily rely on IoT technologies to enhance cabbage production and performance. IoT technologies improve accessibility to devices through connecting smart devices, sensors and apps (Anshu, 2025).

Rochford (2019) asserts that IoT technologies have garnered interest in the agricultural industry due to their capability to enhance smart and connected communities. IoT technologies have introduced novel network connectivity to farming communities in many regions of South Africa and internationally. Network connectivity enhances the operations and performance of small-scale cabbage farmers across various regions. Small-scale cabbage farmers frequently encountered network connectivity issues due to the distribution of their enterprises; nevertheless, IoT technologies endeavoured to address these concerns in several aspects of their operations. The findings indicated that certain small-scale cabbage farmers opted to employ IoT applications alongside app interfaces to enhance their business communications (Rochford, 2019). It is essential to note that IoT apps and app interfaces link numerous small-scale cabbage farmers with individuals both within and beyond the agriculture sector. Bhuiyan et al. (2021) emphasised that IoT applications and interfaces are predominantly built for accessibility to encourage widespread adoption in corporate contexts. Notably, network connectivity can be achieved with minimal financial investment and at a reduced scale (Patel et al., 2021). The IoT technologies established a compact network among IoT devices. Moreover, network connectivity enhances consumer engagement and pleasure, optimises user experience, facilitates data collecting, and empowers individuals to advance their business through IoT Technology

The study results indicate that network connectivity has been employed in Internet Bluetooth, radio frequency identification, and ZigBee. This network connectivity has been crucial for managing device connections and information exchange. This internet protocol enables small-scale cabbage farmers to interact with others, exchange information, and acquire insights from various individuals (Bello & Zeadally, 2016). IoT technologies established connectivity via IoT devices. Certain devices are interconnected autonomously. IoT devices may autonomously gather data from diverse surroundings and report it without human intervention. Sensors and actuators are devices that operate autonomously, without human intervention (Patel et al., 2021).

The study results indicate that small-scale cabbage farmers employed various sensors, data analytics, and automated systems to execute advanced yield monitoring (Alsalamiet et al., 2025). Evidence indicates that advanced yield monitoring improves efficiency and fosters sustainable farming practices. The results indicate that advanced yield monitoring facilitates the assessment of moisture levels, temperature, humidity, rainfall, and wind speed. Apart from the advanced yield monitoring mentioned above.

The findings indicate that optimal seeding was achieved among small-scale cabbage farmers utilising IoT technologies. Many small-scale cabbage farmers employed IoT technologies to prioritise quality and yield production (Liu et al., 2024). Additionally, the implementation of seeding rate control technology can lower costs by minimising double-sown fields, thereby eliminating the need for seed-metering devices. Small-scale cabbage farmers lack the technical expertise to utilise advanced technologies, including sophisticated electrical sensors and control systems. Some choose to employ service provider manufacturing. Evidence indicates that proper sowing can enhance the performance and profitability of small-scale cabbage farmers with IoT technologies.

The results indicate that the IoT technology system reduces water resource consumption among small-scale cabbage farmers. Evidence indicates that IoT technology systems automate meter readings, facilitating real-time exchange of collected data (Slany et al. 2020). Furthermore, the IoT employs a range of technologies, including low-power wide-area networks, GSM, GPRS, Wi-Fi, Zigbee, 3G, 4G, and long-term evolution (LTE). The IoT technology has been essential in optimising water usage for small-scale cabbage farmers on numerous occasions. The method assists small-scale cabbage farmers in identifying potential water leaks by sending an alarm notification, enabling immediate response and minimising financial loss (Andric et al. 2022). The results indicate that IoT technology furnish weather forecast information to mitigate potential damage to enterprises. Additionally, certain small-scale cabbage farmers employ the software system to track water consumption (Andric et al. 2022). IoT solutions assist small-scale cabbage farmers in obtaining weather forecasts through the capabilities and potentials of IoT technologies. Evidence show that IoT systems reduce water usage in the small-scale cabbage farmers through smart meters.

7. Study implications

This research holds considerable significance for marketers as it investigates agricultural competencies and the application of agricultural performance to guide marketing strategy. The enhancement of agricultural capabilities, including marketing skills, can be achieved through widespread social awareness campaigns that demonstrate the advantages of IoT-based technologies to owners and managers of small-scale cabbage farmers, which generally influence employment prospects in South Africa. Marketers can showcase case studies that delineate the advantages and benefits of IoT-based solutions in the agriculture sector of African nations, thereby illustrating the efficacy of this novel method.

The agricultural skills, encompassing technological expertise and perceptual obstacles, can be alleviated for small-scale cabbage farmers through the establishment of continuous awareness and training programs about the utilisation of IoT-based technologies. Companies offering IoT-based technology services can create an information and training centre in the Free State region to promote the extensive adoption of IoT technologies among small-scale cabbage farmers, thereby improving crop yields and bolstering the livelihoods of these businesses in the Free State Province and South Africa. This research offers substantial implications for policymakers and governmental bodies, facilitating the formulation of plans that promote the deployment of IoT systems while considering agricultural performance. The government, in partnership with the South Africa Business Council, the South African Business Association, and NGOs in the Free State province, should play a crucial role in educating small-scale cabbage farmers owners and managers about the capabilities of IoT-based technologies, as barriers related to new technological advancements present substantial challenges for these enterprises. Consequently, the government should establish initiatives to subsidize service providers of IoT-based technology, thereby reducing prices to a more accessible level for small-scale cabbage farmers.

IoT technology developers and designers can provide uncomplicated IoT solutions for the agricultural industry, efficiently addressing technological challenges and perceptual hurdles encountered by small-scale cabbage farmers owners and managers. The government, NGOs, and IoT service providers can collaborate to develop cost-effective IoT technology solutions for the agriculture sector, reducing financial burdens on small-scale agricultural enterprises and promoting their use of IoT-based technology. Marketers must offer continuous support and training to small-scale cabbage farmers to alleviate these challenges. Marketers must also convince the owners and managers of small-scale cabbage farmers regarding the security of their farm data to alleviate any perceived risks linked to the adoption of IoT-based technology in the agriculture sector.

8. Limitations of the study

The generalisability of this research is constrained by multiple factors. The research focused exclusively on the Free State province in South Africa, which may exhibit a unique landscape for SMMEs compared to other provinces within the agricultural sector's small-scale enterprises. Conclusions on small-scale cabbage farmers may not be generalized outside the Free State province. Nevertheless, the study integrated the data with prior research across other industries to augment the significance and breadth of the conclusions.

The modest sample size may compromise its representativeness of the broader South African small-scale cabbage farmers. The inquiry was confined to a quantitative approach, allowing the researcher to employ a deductive methodology. Quantitative studies frequently neglect the intricate nuances and complexity associated with individual context and subjective experience, which qualitative research more effectively captures. Nevertheless, this encapsulates the core of positivism, which prioritises generalisability over specificity. Although self-administered surveys are highly advantageous for

acquiring precise information and achieving elevated response rates, questionnaires frequently face criticism for their issues related to social desirability.

9. Conclusion

The research explored how IoT based technologies influence the performance of small-scale agricultural businesses in the Free State Province, South Africa. The study first re-evaluated the research questions to offer a comprehensive understanding of the investigation. Moreover, the empirical data was synthesised to draw major findings on the assessment of accessible devices, Network connectivity, advanced yield monitoring, optimal seeding and optimal water usage. The results demonstrate the critical need to implement IoT-based technologies in the small-scale agricultural businesses operations and efficiency in crop farming. Furthermore, the study elucidated its contributions to knowledge, particularly highlighting advancements in theory and technique within the domains of accessible devices, Network connectivity, Advanced yield monitoring, optimal seedings and optimal water usage research.

Declarations

Funding Declaration

This research was supported by the Masters and Doctoral Grants of Central University of Technology. The funding provided financial support for the conduct of the study. The funder had no role in the study design, data collection, data analysis, interpretation of the data, manuscript preparation, or the decision to submit the manuscript for publication.

Clinical Trial Number

Not Applicable

Ethic, consent to participate

This study was conducted with ethical approval from Faculty Research and Innovation committee at Central University of Technology, approval number FMSE05/20, in 29/03/2022. Informed consent was obtained from all participants. The study respected participant rights, privacy, and confidentiality. No identifiable information is disclosed without authorization.

Author Contribution

The author of this manuscript wrote whole manuscript text

Acknowledgement

I am acknowledge Prof Patient Rambe from Central University of Technology

Data availability:

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

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