Evaluating Applications of IoT and its Potential in South Africa's Agricultural Sector

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Abstract

The Internet of Things (IoT) has the potential of reshaping South Africa's agricultural industry, yet reservations about the sector's preparedness persist. Through a systematic literature review (SLR), this research endeavors to assess the implementation and prospects of IoT in the agricultural industry in South Africa. Among the research's key outcomes is that effective IoT use in the agricultural industry could boost production and profitability, although small-scale farmers find it exceedingly difficult to obtain substantial access to technologies owing to infrastructure and financial impediments. Furthermore, the government ought to engage in two tasks: 1) coordinating initiatives to garner funding and building infrastructure enabling smallholder farmers; 2) adopting data protection regulations. The research pinpoints a gap in previous literature covering the subject of the provision of resources for farmers in deploying IoT. It also offers valuable insight to farmers and investors, alongside proposals about investment and farming technologies. The most significant features in this research are firstly the aspect alluding to farmers' upskilling and training on incorporating IoT and other innovative technologies in their farming practices; and secondly that the revenue growth of the agricultural industrial base becomes prioritized for new farming approaches. These suggested practices are envisioned to aid farmers integrate the latest technologies into their farming activities

Keywords
Internet of Things (IoT); Agricultural Sector; Smart Farming; Automation.

1. Introduction
Food security for the world's expanding population depends on informed choices supporting farmers that are crucial for the world's food supply (Ramundo, Taisch & Terzi, 2016). To guarantee food security, the agricultural sector must balance demand alongside supply. Farmers might locate alternatives to fulfill their expectations with the use of the Internet of Things (IoT). Innovation using digital technology could boost agricultural output while lessening its adverse ecological effects (Ramudo et al., 2016). In certain areas globally, this might lessen prevailing food security threats (AIOTI, 2015). AIOTI (2015), argued that data collection, edge intelligence, data processing, analysis, and automation technologies can enhance food security and enable the improvement of management. Farmers must weigh their options and make trade-off decisions to maximize margins (Wen & Chen, 2014). Considering maize crops produced by thousands of smallholder farmers and 9 000 commercial maize producers within the Southern African Development Community (SADC) (Farming-Portal, 2020), research contrasts emerging and developed world contexts. South Africa's livestock business, comprising 13.8 million cattle and 28.8 million sheep, remains its largest agricultural sector (Farming-Portal, 2020).

The United States (US) Department of Agriculture (2017) discovered that breakthroughs in risk management, business approaches, and cultivation techniques optimized farmers' output without increasing input. The deployment of crucial inputs nevertheless plunged indefinitely. Between 1982 and 2007, the share of farming land in the US utilized declined from 54% to 51%, including 40% and 30% reductions in technician-based occupations and compensated labor. Through adopting technology, improved efficiency, and fertilizers, farmers managed to obtain over 50% of output (US Department of Agriculture, 2017).

Historically, agriculture has been an indispensable aspect of life from the inception of humanity, yielding food and beverages, among other vital supplies (Greyling & Vink, 2015). Presently, agriculture is bolstered by manual data involving soil quality, ecological variables, animal monitoring, and tracking, yet livestock could be prone to adverse events including relocation, severe starvation, or theft (Review, Von leoper, 2015; Corallo, Latino & Menegoli, 2018). This background summarizes four key areas: 1) the conceptualization of IoT; 2) a global overview of IoT in agriculture; 3) a local overview of IoT in agriculture; and 4) the potential impact of IoT on agriculture.

It is first and foremost imperative to understand IoT's conceptualisation. According to AIOTI (2015), IoT is a concept that includes a range of devices and communication channels used for information sharing. IoT includes the coding and networking of widely used items and things aimed at rendering each independently machine-readable while traceable through the Internet for multiple objectives (Wolfert, Verdouw & Bogaardt, 2017). It is seldom simple to clarify "IoT" due to perpetually developing technology and overwhelming data. Mouha (2021) noted that the Internet of Things (IoT) is conceptualized as a network of interconnected "things" that may interact with one another and with humans sophisticated capabilities by linking (physical and virtual) aspects based on progressing information and communication technologies". This remains the description that the researcher prefers to use.

Globally, IoT in agriculture began with robotics, synthetic protein, nanotechnology, gene editing technology, cellular agriculture, blockchain, machine learning, and artificial intelligence (Klerkx & Rose, 2020). These technologies have the potential to transform future food and agricultural systems, such as aquaponic systems, bioeconomy, digital agriculture, circular agriculture, and vertical farming (Klerkx & Rose, 2020). In this research, emphasis was placed on the connections between mission-driven innovation systems and pathways into sustainable food and agribusiness networks. Applications built on the IoT are being used to improve data accuracy, agility, reliability, distribution, traceability, product commercialization, and other areas (BusinessTech, 2018; de Villiers, 2018; Campos & Cugnasca, 2015; Botha, Malekian & Ijiga, 2019). Elsewhere in research, some authors recalled that the implementation of IoT systems in South Africa has ensured that resources are utilized as effectively as possible by managing the utilization of energy, water, and pesticides. Moreover, irrigation may be improved to utilize the limited water supply as effectively as possible (Smiljkovikj & Gavrilovska, 2014; Cravero, Lagos & Espinosa, 2018). The ripening of products has also changed due to climate change, allowing for more efficient and sustainable resource usage (Medela, Cendon, Gonzalez, Crespo & Nevares, 2013; Cravero et al., 2018). Overall, the output of agricultural products has increased in both quantity and quality, which supports sustainable development (Cravero et al., 2018; Smiljkovikj & Gavrilovska, 2014; Botha et al., 2019).

In terms of the potential impact that IoT has on agriculture, it is already proven that it can maximize and enhance the production of agricultural produce while also bringing in money (Viajedor, 2019). This is made possible by using cameras, sensors to measure soil humidity, and trackers to monitor animal movement and activity. Solar radiation data may also be collected following any climate change (Donca, 2018). IoT may allow farmers to save money on inputs including water and fertilizer, which decreases the price of the final output. Farmers are capable of predicting results and optimal conditions, which saves time, money, and labor (Viajedor, 2019). Given that farmers can now predict results and ideal conditions using IoT, they can support and have a positive impact on all agricultural activities while saving time, money, and effort.

1.1 Problem Statement and Objectives

Providing for a sustainable population while tackling significant crises like climate change, financial loss, and resource shortages is a problem that the agricultural industry must overcome on a global basis (Firbank, Attwood, Eory, Gadanakis, Lynch, Sonnino & Takahashi, 2018). This issue is not unique to South Africa which frequently encounters similar hurdles. The government and businesses are collaborating to find an approach to respond proactively to the growing food demand. In light of such approaches and responses devised, as well as efforts to combat environmental difficulties, farmers use production methods that are not eco-friendly, and climate change and global warming additionally leave an adverse effect on soil (Review et al., 2015; Kruger, Mathews & Wentink, 2018). Consequently, agricultural output has decreased, and income has dropped. To address all of these challenges and guarantee food security, agriculturalists, IT specialists, and economists have stated arguments in favor of integrating agronomic technologies into all of the farming across South Africa. The innovative advances and technologies that might have an enormous effect on food production, preparation, commerce, and consumption are the most vital details in this research. De Wilde (2016) further highlights that gene editing, 3D food printing, robots, drones, nanotechnology, sensors, microalgae bioreactors, artificial food production, cultured meat or cellular agriculture, machine learning, blockchain, and artificial intelligence are among the possibilities. Klerkx and Rose (2020) note that technology such as "agriculture 4.0" has the power to disrupt and transform society in several ways. It could alter how agriculture is interwoven into ecosystems and landscapes, as well as how food security and nutrition are impacted on a biophysical,

social, and economic level. Moreover, it could influence how agricultural supply chains work, as well as how food producers produce their goods and how sellers distribute and promote such goods (Klerkx & Rose, 2020). Given the complexity accompanying the interplay of technology, this study on agriculture and the IoT is conducted to explore and clarify its influence on food security. This is because new ideas and technologies do not usually spread quickly, and major changes generally take many decades or longer to materialize.
The objectives of the present research covered in this article are:

- To investigate IoT in agriculture in preventing losses when it comes to farming using new agricultural technologies.
- To ascertain how IoT will assist in meeting the food production demand in South Africa.
- To explore if there is cheaper labor and lower cost of production and products, at the same time using methods that are not harmful to the environment.
- •To recommend what application technologies farmers should adopt in South Africa to meet the above technological, agricultural, economic, health, nutritional and environmental objectives.

2. Literature Review

Key themes that were taken into consideration for inclusion in this article's literature are arranged to complement the findings and answer the questions presented by the research and the identified problems. There are only three key themes worth mentioning: 1) challenges of implementing IoT in the agricultural sector; 2) opportunities or benefits of adopting IoT in the agricultural sector; and 3) technology applications that may be implemented within the agricultural sector.

In either the global or African or South African contexts, a common feature that prefaces the challenges of implementing IoT within the agricultural sector is that of food security. Accessibility to sufficient quantities of nutritious food for regular human growth and development is commonly referred to as food security (Review, Leopar, Blignaut & Wit, 2015; Food and Agriculture Organisation [FAO], 2019; Klerkx & Rose, 2020). Food must be regularly accessible and available in sufficient amounts diversely for favorable nutritional value before being deemed secure (FAO, 2019).

Over the years, the World Health Organisation (WHO) (2014), documented a rise in proportions of people going hungry as an outcome of food insecurity. More recently, for instance, as a result of the COVID-19 pandemic, vulnerable population groups' food security is projected to be adversely affected (WHO, 2020). In terms of the challenges of implementing IoT in the agricultural sector, globally, according to some authors, (e.g., Foster, 2004; Hornbeck & Keskin, 2015), agricultural technologies that boost productivity raise demand for capital as well as labor since farms seek more people to support growing production. This culminates in higher compensation. In that same global context, multiple agricultural producers claimed brand hurdles, technology acceptance fears, perceived higher costs, along with perceived threats as 'reasons against' the implementation of IoT-related technologies (Pillai & Sivathanu, 2020). From a developing world context which can also be translated into a South African perspective, for example, Owade (2018), hypothesized that the IoT remains beset by several obstacles that render the implementation of technological advances in the agricultural sector tricky. Several farms exist in faraway regions where connectivity to the internet could prove poor for facilitating fast data transfer frequencies. In addition, the use of tracking and monitoring technologies, aspects such as crops, woodlands, and a variety of natural obstacles could hinder connectedness (Owade, 2018). Likewise, Owade (2018) stressed that, although these reservations affect the cost of data transmission, which accounts for the sporadic implementation of smart technology within agriculture, the expansion of Big Data could trigger escalating expenditures.

Regarding opportunities or benefits of adopting IoT in the agricultural sector across varying contexts, authors like Sundmaeker, Guillemin, Friess and Woelffle (2010), as well as Martin and Leurent (2017), postulated that IoT would lead to improved farming through data. Whereas the former argues in favor of data as a vital instrument for farmers to reach proof-based predictions and informed choices, the latter argues in favor of IoT technologies' networks and sensors to yield rapid and straightforward results in farming (Sundmaeker et al., 2010 Martin & Leurent, 2017). While this is the case, other researchers such as Kahan (2013) believe IoT to be beneficial for demand-driven farming where farmers would easily obtain client feedback regarding their produce and estimate quantities of supply through monitoring technologies.

Other scholars such as Vermes and Friess (2016) perceive IoT as an opportunity to enable green farming, through the technological advances that enable management to use it for ecologically friendly practices amongst various stakeholders in farming. On the one hand, this is further substantiated by AppsforAgri (2018) which is a proponent of the automation of independent farm operations, without human interference, thus increasing yield more since machines, unlike humans, do not experience exhaustion. On the other hand, sensing device technologies are perceived as an important IoT component to convert food factories into more agile places of agricultural production through artificial intelligence (AI). An example would be when food production is remotely controlled and speeded up through decentralized technological approaches (Shimizu, Sugihara, Wakizaka, Oe & Katsuta, 2015; Kaur, Shukla & Singh, 2022).

In terms of IoT technologies that can be adapted or are readily proven to be useful in agriculture, it is evident from a variety of literature that the developed world context (especially the United States) has had prospects. For instance, Charania and Li (2020) highlighted IoT instruments such as Farm Logs' drones which have the capabilities to handle farming activities and increase production by producing proper imagery of fields. In addition, Chanaria and Li (2020) noted the usefulness of software by Farmer's Edge which provides capabilities for collecting data using weather stations or satellites to assess farming fields and crop conditions. Amongst the many other IoT technologies, tools and technologies to be adapted for agriculture and optimize farming, the authors mentioned many important aspects. For instance, agricultural sensors help farmers adapt to ensure their farm crops, soil and irrigation systems are tracked or monitored to adapt farms to changing climates (Schriber, 2020; Larios, Michaelson, Virtanen, Talola, Maciel & Beltran, 2019); networking technologies aggregating and analyzing farming data through wireless connections (Weng, Zhu, Zhang, Yuan, Zheng, Zhao, Huang & Han, 2019; McGowan & Vasilakis, 2019); and lastly, cloud computing which involves an array of technological software infrastructure. This is regarded as the cheaper way of storing, applying and analyzing farming data for smooth farming operations (Boursianis, Papadopoulou, Diamantoulakis, Liopa-Tsakalidi, Barouchas, Salahas, Karagiannidis, Wan & Goudos, 2020; Namani & Gonen, 2020).

The gaps identified in this regard across all the highlighted literature is that there is limited information regarding the South African agricultural sector's challenges or benefits of applying IoT, as well as available technologies that can be adapted. The next section outlines the scholarly and research methodological traditions and principles followed to gain extensive insights to fill in the gaps and address the limitations that were highlighted.

3. Methods

A research approach is an essential and unique strategy that should be adhered to when undertaking research. It is further explained as a procedure that is considered a plan of action on which the search, gathering, or acquiring of information sources, and insights derived from sources rests (Kabir, 2016). Research approaches can be either qualitative, quantitative or a combination of both which is mixed research (Creswell & Creswell, 2017).

It is important to understand that quantitative research's main purpose is to quantify data using different variables like measurements, numbers, ratings, statistical measures, and frequencies (Leavy, 2017). Qualitative research is the approach that utilizes descriptive data devoid of conventional statistical techniques but constructed in a naturalistic context to help learn more about phenomena (Creswell & Creswell, 2017). Researchers usually associate with the descriptive technique of qualitative research. This method includes more subjective judgment (Akhtar, 2016. Interpretive perspectives, according to this study technique, are frequently employed to comprehend events in the context of the meaning that individuals assign to such occurrences (Christensen, Johnson, & Turner, 2015). For the same reason, the qualitative research approach was deemed suitable for this investigation

4. Data Collection and Data Analysis

Qualitative data-gathering approaches are exploratory, focusing on acquiring information and insight into underlying causes and intentions. Qualitative data comprise language or visual data (Tracy, 2019). Qualitative data collection methods were established as it became evident that traditional quantitative data-gathering methods were unable to represent meanings and practices (Tracy, 2019). These qualitative techniques are attributed to recognizing abstraction as well as a generalization (Monette, Gullivan, & De Jong, 2010). Qualitative data collection methods include concepts, pictures, patterns, and structures in numerous channels, as well as recorded, printed, and written words or phrases (Polonsky & Waller, 2011).

The systematic literature review (SLR) is a research tool/instrument that collects, organizes, and evaluates data by extrapolating meaning from texts and documents (Billups, 2021). According to Richards (2014), qualitative SLRs collect data from a variety of sources and focus on the conclusions reached from those sources about the issue investigated. This helps the reader to identify key findings that cannot be quantified. To investigate the specified research topic and answer its research questions concerning the implementation of IoT in agriculture, the study made use of all available material, including academic and literary works**.**

This research employed thematic analysis, a popular method for identifying, assessing, and describing patterns in a text that evolve into a range of themes. The goal of thematic analysis is to uncover themes, or meaningful or fascinating patterns in data, and then use those themes to address the issue or say something about a specific situation (Maguire, 2017). Explicit themes are those that have clear or obvious interpretations of the material, as well as the fact that the researcher is not looking for more meaning than what is stated (Braun & Clarke, 2006). In the data analysis of this research, themes were developed with inferences to produce meaning according to what has been expressed in words or published concerning IoT applications in agriculture.

Suter (2014) defines sampling as the technique of picking pertinent subjects or sources amongst a large target group for the inquiry. Purposive sampling was used dependent on a predetermined set of inclusion criteria (Emmel, 2013), to achieve the sample purpose. The sample size was 20 publications, and proof of their relevance and usefulness in terms of IoT application in agriculture was interpreted to achieve the study's objectives of filling identified gaps in the existing literature to tackle the research problem.

5. Results and Discussion

The researchers extracted information from 20 scientific publications on IoT applications in agriculture using themes. The themes covered are 1) Opportunities of implementing IoT within the agricultural sector in South Africa; 2) Challenges of implementing IoT within the agricultural sector of South Africa; and 3) Technology applications that can be adapted within the South African agricultural sector. Before analyzing and discussing the findings, it is necessary to present a list of the applicable sources to indicate their relevance in this section.

Table 1. Synthesis of Systematic Literature Review

Competencies	Literature References
Automation	Zhang et al. (2021) “Factors influencing environmental performance”
Precision	Khanna and Kaur (2019), Tsouros, Bibi and Sarigiannidis (2019)
Risk reduction	Nakano and Magezi (2020) “The impact of microcredit on agricultural technology adoption and productivity”
Quality	Odame et al. (2020) “The role of technology in inclusive innovation of urban agriculture”, Jew et al. (2020)
Efficiency	Klerkx and Rose (2020), Odame (2020), Danbaki et al. (2020), Jew et al. (2020)
Expansion	Danbaki et al. (2020), Geetha (2018)
Resource demand	Markovic et al. (2015), Geetha (2018), Kulkarni and Surwade (2019)
Processes	Sushanti et al. (2020), Gao et al. (2020)

According to Higgins and Green (2011), the data gathered in a systematic review comprised results (or conclusions) drawn from individual research publications that apply to the SLR research questions. In the context of Table 1, the results of the review are part of a synthesis of papers that all emphasize the application of IoT in agriculture.

Theme 1: Opportunities for implementing IoT in the agricultural sector in South Africa

In terms of this theme, the primary outcome is that by employing innovation to generate or add value to the agricultural sector, IoT technologies not only provide prospects for expansion but also solutions for the whole industry. This is demonstrated by how IoT allows previously unobtainable productivity through resource cost savings, automated machinery, and data-driven processes.

This theme's sub-themes extensively revealed pertinent answers to the research question: How will the Internet of Things (IoT) help farms meet the demand for food production in South Africa? A select set of literature from the synthesis discusses such sub-themes, including data collection; reduction of risks; automation; higher quality; excelled efficiency; expansion; reduced resources; cleaner process; agility; better control; and cost management and reduction.

Across all such sub-themes, various scholars' viewpoints highlight the benefits and opportunities of IoT adoption in agriculture. For instance, Geetha (2018) points out that all agricultural information can be accessed using IoT technology with the help of implanted sensors. Nakano and Magezi (2020) assert that IoT keeps farmers informed and lowers risks, for example through weather forecasting and monitoring. Furthermore, a crucial sub-theme of automation has evolved where Zhang et al. (2021) demonstrate how the automation of agricultural procedures may assist in monitoring elements impacting performance, such as the use of sensors to track temperature, humidity, soil moisture, and light intensity. This is in conjunction with the use of sensors to identify plant nutrient deficits and drip irrigation systems driven by IoT capabilities, which was promoted by (Odame et al., 2019). Thus, enhancing crop quality as a result.

In addition, Klerkx and Rose's (2020) research demonstrates exceptional efficiency from which farmers would gain quicker access to real-time data and insights as well as the capacity to foresee and decide on activities related to their farms. Even though the authors don't specifically mention any IoT instruments or tools, their analysis can be supported by the use of robot harvesting. This was suggested by Odame et al. (2020), giving farmers the ability to reach and surpass efficiency levels that are unmatched in the agricultural sector.

Danbaki et al. (2020), referring to hydroponic systems and IoT-based greenhouses, contend that IoT provides the agricultural industry with possibilities that enable quick food supply chains, further solidifying the theme's outcomes. The authors also show how advantageous smart closed-cycle technologies are by making it possible to produce food almost everywhere, even on the walls and rooftops of buildings, in shipping containers, as well as in supermarkets (Danbaki et al., 2020).

As a summary of the themes' findings, it can be said that this theme found that precision farming goals can be attained by minimizing the resources farmers would normally waste on crop monitoring by using technological tools like sensors for data collection (Markovic et al., 2015). This is coupled with IoT-based systems for precision farming. Farmers and producers may reduce the use of pesticides and fertilizers while also conserving energy and water and making farming more ecologically friendly (Sushanti et al., 2020). It is crucial to watch out that the use of pesticides and other farming practices is not excessive to prevent harming the environment (Gao et al., 2020).

Higher process agility serves as one of the positive impacts of IoT in agriculture, yet this flexibility and agility in farming operations can only be as effective as the infrastructure and machinery supporting operations (Jew et al., 2020). In addition, farmers may employ IoT to detect irregularities and discrepancies in crop production, reduce costs, and boost output (Kulkarni & Surwade, 2019). This is without a doubt the most effective measure that IoT can provide for the agricultural industry. The analysis by Zhang et al. (2021 showing IoT could enable farmers to have full oversight over the volume of production and harvesting complements this.

Theme 2: Challenges of implementing IoT in the agricultural sector of South Africa

The results of this theme highlight a variety of concerns, such as poor internet access on farms; high hardware prices; disrupted cloud connectivity; lack of security; lack of technical expertise; and potential for incorrect weather analysis. How will IoT help farms meet the demand for food production in South Africa? is further addressed by such sub-themes.

To begin, it is imperative to explain that inadequate information, high expansion costs, possible vulnerabilities, and other factors are the main challenges for IoT applications in the agricultural industry.

In this context, in addition to the greater expenses of Big Data, physical and environmental barriers like shrubs, crops, and forests may hinder communication (Markovic et al., 2015). Geetha (2018) supports this by stating that IoT acceptance and utilization will be hindered by a lack of infrastructure. Gao et al. (2020) and Odame et al. (2020) both referred to farmers' high hardware costs. According to Nakano and Magezi (2020), the presence of farms might make it difficult for IoT to work in situations when a connection is present. If so, additional scholarly works including Zhang et al. (2021) indicate that IoT agricultural systems are challenging to safeguard. They cite security problems with things like drones or sensors employed. Zhang et al. (2021) underline that, notwithstanding unexpected occurrences of various natural climatic phenomena across various areas, IoT devices may fail to provide reliable reporting of weather conditions.

Theme 3: Technology applications that can be adapted in the South African agricultural sector
Precision farming, monitoring climate conditions, crop management, smart greenhouses, data analytics, agricultural drones, cattle monitoring and management, predictive analytics for smart farming, end-to-end farm management systems, and data security are some of the emerging sub-themes within this theme. The content of such sub-themes helps answer the following research question: What technology applications are available to farmers in South Africa?

The fact that precision farming is essential to enable farmers to have greater control over farming practices and offer excellent goods while keeping the highest standard is one of the important theme results to be aware of (Kanchana S., 2018). It has been found that precision farming, in an IoT capacity, can also assure soil moisture and that farmers may assist professionals and consultants in increasing productivity by using cloud-based apps (Kanchana et al., 2018).

IoT technologies that can be used, are valuable for monitoring climate conditions, may alter traditional farming methods, and can provide effective innovation for any agricultural organization (Klerkx & Rose, 2020). These technologies also offer favorable circumstances so that a farmer may measure important indicators to gain insight into the health of crops and then apply for the necessary medications (Chandhini, 2019. Authors like Valencia-Garcia et al. (2019) believed that another technology that can be used is the smart greenhouse, which can automate irrigation and lighting, alongside heating, ventilation, and air conditioning (HVAC) operations in addition to collecting data on crops and farm surroundings around the clock.

This theme also demonstrates how agricultural enterprises may easily scale up technological upgrades in response to demand or the findings of a data-driven examination as an effect of data analytics (Navarro, Costa & Pereira, 2020). Drone use, which Singh, Javaid, Haleem and Suman (2020) consider valuable to gather data on plant health when crops begin to grow and can also have less of an adverse environmental impact, is another IoT technology that can be adopted in the agricultural industry. By implementing IoT technology for cattle monitoring, farmers can manage their businesses. Overall, performance, or managing livestock, is diverse and stress-free (Singh et al., 2020). To give each animal the ideal temperature, health, exercise, and nutrition, Singh et al. (2020) provided examples including Cowlar. According to Nakano and Magezi (2020), adopting predictive analytics is crucial in farming, particularly in "smart agriculture," where IoT smart sensors can gather relevant real-time farm data and forecast catastrophic weather conditions, minimizing risk, protecting crops, and boosting worker productivity.

Another adaptive technology is end-to-end farm management systems, with which a farmer may operate a farm remotely using software including Farm Logs or Cropio without ever having to be on site (Sushanti et al., 2020). In addition, cutting-edge features like tracking of vehicles, robotics, data storage, and logistic support are offered by modern farm management techniques (Sushanti et al., 2020). Data security is another technology that can be used, so farmers may also employ internal security measures, look for suspicious activities, and store data in blockchain networks to ensure the integrity of the data (Geetha, 2018; Singh et al., 2020).

Summary of themes
All these themes' overall outcomes revealed that there are many advantages to implementing IoT in the agricultural industry, but there are also challenges. The biggest challenges for IoT in agriculture are, among others, a lack of data, high adoption costs, and possible security concerns. The majority of farmers are unaware of IoT's application in agriculture. The fundamental issue is that some farmers are unwilling to accept new concepts, even though several benefits can arise through IoT.

6. Conclusion and Recommendations

To respond to the question "How will IoT help farms meet the demand for food production in South Africa?" the SLR was employed. Only the key point of automation, however, received complete consideration, omitting other aspects like decreased agricultural business risk and crop quality. Several research findings on automation exhibit a stronger correlation between automation in the agricultural sector and productivity growth. Nevertheless, there is inadequate evidence of how South African farmers have enhanced their skills to match their skills with IoT use, given its advantages.

The results showed that the first research question is consistent with the current literature used in the analysis of the data. This is because South Africa's grain output has drastically decreased, and both public and private funds have already been depleted. The initial and most noteworthy example of IoT application in a South African farming environment to increase food production and guarantee food security is monitoring systems, which are classified as IoT embedded. Nonetheless, there is evidence that most farming in South Africa occurs in isolated areas that may lack the necessary technological infrastructure, encompassing network connectivity, to expedite processes of monitoring farm activities.

The gap in the body of knowledge is that money and other aspects of resource availability have not been emphasized. This covers the methods for educating, preparing, and upgrading farmers to utilize IoT-related products, instruments, devices, or procedures through incubator programs. In a South African environment of small-scale farming populated by impoverished and disadvantaged farm communities, the literature does not explain how farmers may acquire such technology without financial assistance and support.

To employ IoT technology to carry out routine farming tasks, farmers need to complete courses and receive training from professionals. While large-scale farmers must integrate IoT into their operations to ensure the supply of food and boost productivity and profitability, small-scale farmers must allocate a portion of their income toward sustaining IoT applications on their farms. It is also crucial for farmers to grasp data-handling techniques for farming. To maintain farming practices and ensure the continuous production of food, the government must provide a favorable environment. This entails assisting farmers with IoT technologies to improve their agricultural practices, such as setting up programs and funding for beginner- and small-scale farmers from historically underserved communities; introducing training/course programs for farm owners and employees; and working with innovators across multiple industries to help them come up with unique smart farming methods and equipment.

Prioritizing IoT investments for farmers above other types of support, including grants for smart farming technology; financial support for the growth of the agricultural industrial base for innovative, IoT-enabled farming practices is an appropriate approach for investors. This could have a positive impact on future growth and boost for agriculture.

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