Information systems (IS) and smallholder farming in developing countries: A systematic literature review

Peter Mkhize
Professor, School of Computing, University of South Africa (UNISA) Science Campus, Johannesburg
https://orcid.org/0000-0003-0554-4245

Abstract
In the context of the fourth industrial revolution, the potential of information systems (IS) to revolutionise smallholder farming practices and enhance sustainability is a topic of growing interest, particularly in developing countries. This systematic literature review examines the intersection of agriculture and IS to explore how technology adoption can help to transform small-scale, subsistence farming enterprises into profit-generating, sustainable small businesses, while at the same time addressing the unique challenges present in developing-world contexts. The review critically examines the potential barriers and challenges faced by smallholder farmers in adopting and effectively using IS solutions in their operations. Among other things, the review investigates the assumption of basic literacy in many IS theories, and the extent to which this assumption aligns with the reality of developing-world smallholder farming communities, where literacy levels and digital proficiency may be limited.

Keywords
information systems (IS), smallholder farming, developing world, technology adoption, sustainable agriculture, literacy, food security

DOI: https://doi.org/10.23962/ajic.i33.17050

Recommended citation
Mkhize, P. (2024). Information systems (IS) and smallholder farming in developing countries: A systematic literature review. *The African Journal of Information and Communication (AJIC), 33,* 1-21. https://doi.org/10.23962/ajic.i33.17050

1. Introduction

The fourth industrial revolution has sparked significant interest and eager anticipation in the academic and agricultural communities, particularly in developing countries across Africa, the Asia-Pacific, and Latin America (Schwab, 2017). This curiosity is rooted in the urgent need to discover innovative solutions to address the impending challenges faced by the agricultural sector, with global food security being one of the most critical issues. As the world faces these challenges, there is a growing recognition of the potential of information systems (IS) to transform smallholder, subsistence farming practices into profitable and sustainable enterprises, especially in the context of developing nations (Okediran & Ganiyu, 2019).

However, a fundamental quandary exists in IS theories and IS-infused business models focused on smallholder farming communities in developing countries. Many of these IS theories and models assume that individuals possess a foundational level of literacy and digital proficiency. Yet, the landscape of smallholder farming in the developing world presents a distinctive dynamic. Farmers and farmworkers in these settings may lack the basic literacy and digital literacy skills required to effectively engage with IS (Debrah & Asare, 2012). This incongruence calls for a critical examination of the integration of IS into smallholder farming businesses in developing-world contexts, with the aim of identifying barriers that could hinder successful IS adoption.

This study seeks to provide the necessary critical examination through a systematic literature review focused on the intersection of agriculture and IS in the context of smallholder farming communities in developing countries. The review explores the application of technology in farming practices in these contexts and identifies the challenges faced by smallholder farmers as they navigate the adoption and use of IS solutions. Additionally, it aims to explore how these technologies can contribute to transforming small-scale, subsistence farming into profit-generating and sustainable small businesses while addressing the unique challenges present in developing-world contexts.

To conduct this systematic literature review, a comprehensive search strategy was employed across a range of academic databases, including Scopus, Science Direct, Web of Science, and IEEE Xplore. These databases were selected for their extensive coverage of both IS and agricultural research. The literature search focused on peer-reviewed journals and conference proceedings that were widely recognised as credible in the fields of IS and agriculture. Key journals included the *Journal of Agricultural & Food Information*, *Computers and Electronics in Agriculture*, and *Information Systems Research*. The search was conducted using a combination of keywords including "information systems", "smallholder farming", "technology adoption", "sustainable agriculture", and "food security", to ensure a thorough exploration of the intersection between these fields. While the reviewed literature was primarily drawn from the fields of agriculture and IS, the review also included relevant literature from adjacent disciplines to provide a broader perspective.

The review seeks to identify an inclusive and sustainable path for smallholder farmers in developing countries. If these farmers can harness the power of appropriate IS solutions sustainably, they can potentially not only enhance their productivity and profitability but also make substantial contributions to addressing the global challenge of food security.

The findings of this study can potentially be valuable to a diverse range of stakeholders, including researchers, agricultural practitioners, policymakers, and technology developers, as they seek to identify ways in which IS can be leveraged to support smallholder farmers in overcoming the unique challenges that they face.

2. Background and research problem

In developing countries, the narrative of industrial revolutions unfolds within a historical pattern of transitioning away from agriculture as the dominant economic force. However, throughout these revolutions, agriculture has continued to retain enduring significance, extending into subsequent industrial eras. Within this trajectory, a pressing concern is ensuring global food security, a mandate prominently featured in the UN Sustainable Development Goals (SDGs), and recognised as essential to averting future food insecurity crises (Okediran & Ganiyu, 2019; Schroeder et al., 2021) environmentally sustainable, and equitable, one that can help deliver the Sustainable Development Goals. Implicitly interconnected with food security, agriculture holds a central position, encompassing both livestock and crop production (Sekaran et al., 2021)

The rapid rise of IS has created new industry giants. Technology has been a cornerstone of growth across diverse industries, seamlessly integrating into their operational frameworks (Chandra & Malaya, 2012; Rahaman et al., 2021). Conversely, smallholder, subsistence agriculture in the developing world, addressing the fundamental sustenance needs of households and communities, provides a livelihood for those lacking the modern technical skills required in other sectors. Given this context, there is a quest to determine the potential of IS to drive the evolution and progress of smallholder agriculture, akin to the influence of IS across numerous other domains.

Envisaging a synergy between agriculture and technological advancements, including automation and increased access to vital farm intelligence, aligns with the impressive advancements witnessed in IS and computer science. These advancements have led to innovations, applications, and tools spanning different sectors. Even in the traditionally self-sustaining realm of smallholder farming, a shift towards commercialisation has occurred in many settings. In developing nations, government entities have implemented support frameworks that seek to transform smallholder farms into income- and employment-generating businesses (Chandra & Malaya, 2012). The infusion of technology into smallholder farming is regarded as a logical progression.

The fourth industrial revolution has sparked discussions about the potentially symbiotic role between IS and smallholder farming (Rahaman et al., 2021). These discussions align with the overarching objective of revitalising agricultural growth and addressing the imminent global food security challenge. However, it is essential to acknowledge the unique context of smallholder farmers, often self-employed land inheritors who may lack literacy skills (Range, 2017). This reality challenges prevailing IS theories and IS-driven business models that assume a certain level of collective literacy and digital literacy within the social fabric of a business.

Common IS theories, which assume a foundational literacy and digital literacy baseline among employees, encounter a discrepancy in developing nations. In such settings, farmers and farm labourers often lack basic literacy and digital literacy skills. In this study, the systematic literature review was grounded in the following research questions:

- Which specific barriers and challenges do smallholder farmers encounter when attempting to adopt and effectively use IS solutions in their farming operations, particularly in developing countries?
- To what extent does the foundational assumption of basic literacy in IS solutions align with the literacy levels and digital proficiency of smallholder farming communities in developing countries, and how does this impact the adoption of IS solutions?
- To what extent can the adoption of technology contribute to narrowing the literacy and digital literacy gap in smallholder farming communities in developing countries, and what tailored IS application strategies can be developed to address the unique characteristics and requirements of these farmers?
- What insights can be extracted regarding the successful integration of IS into smallholder farming enterprises in the developing world, and how can these insights guide the development of strategies to maximise the advantages of IS adoption by such enterprises?

3. Methodology for systematic literature review

Systematic literature review, the method deployed in this research, is a distinct and rigorous methodology (Okoli, 2015), which encompasses the following steps:

- formulate research questions;
- prepare a comprehensive research protocol;
- conduct an exhaustive literature search;
- develop a coding framework;

- code the articles, ensuring reliability; and
- analyse and discuss the results.

Research questions

After defining the research problem, I thoroughly analysed it in order to identify key aspects, which aided in formulating the above-listed four research questions. These questions were instrumental in guiding me towards comprehensive conclusions regarding the issues at hand (Rowley & Slack, 2004). The research questions were designed to explore theories that elucidated the role and application of IS in smallholder agriculture, with a specific focus on ensuring food security in developing-world settings.

Research protocol

The research questions played a vital role in shaping the research protocol. Using the questions, I crafted a protocol to guide the review, ensuring that the review was conducted within defined parameters and addressed core concerns (Kitchenham & Brereton, 2013). The protocol development began with gaining familiarity with the literature through extensive reading and initial coding to identify potential themes. Subsequently, I identified specific themes and keywords, which were then used in the comprehensive literature search.

Literature search

The relevant literature was identified based on the parameters specified in the research protocol. The literature search adhered to the defined keywords, timeline, and the type of literature to be reviewed. The keywords included information systems (IS), smallholder farming, technology adoption, sustainable agriculture, literacy gaps, and food security. These keywords were applied across various databases. The article search was confined to articles published between 2005 and 2021.

Initially, the use of the logical operator “AND” to combine all keywords yielded zero results across all databases. To broaden the search, I introduced the logical operator “OR” between IS-related keywords and agriculture-related keywords. However, I retained the “AND” logical operator between agriculture and IS keywords in order to find articles at the intersection of both disciplines. This approach led to the identification of 124 articles after experimenting with different keyword combinations.

The selected articles encompassed topics from the agriculture and IS disciplines. However, it is essential to note that their inclusion did not guarantee relevance or the ability to address the research questions. To ensure the selection of pertinent articles, I established specific inclusion and exclusion criteria based on relevance. Significantly, the contextual setting emerged as a significant exclusion criterion, resulting in the specific exclusion of articles focused solely on developed-country contexts, yielding a total of 57 articles.

Coding framework

For an in-depth analysis, I imported the selected articles into the ATLAS.ti qualitative data analysis software. Each article's abstract, introduction, and conclusion were scrutinised to gauge its relevance and potential contribution to addressing the research questions. During the initial review, a codebook containing essential phrases was formulated and served as the coding framework in ATLAS.ti.

Coding

Using the ATLAS.ti software, codes were assigned to information and quotations extracted from each article. Following this process, related codes were aggregated to form five themes. ATLAS.ti facilitated the organisation of quotations associated with code groups under each theme. These collections of quotations were then employed to construct a coherent narrative, guided by the research questions. The narrative aligned with the code network for each theme, as presented in the next section via a set of thematic relationship networks. Each thematic relationship network visually represents relationships between codes within a theme. The findings presented in the next section are narratives that reflect my interpretation of the compiled codes and quotations.

4. Findings: Intersections between IS and smallholder farming in the developing world

As stated above, five key themes emerged from the coding of the literature:

- improving knowledge-sharing;
- strengthening the supply chain;
- increasing food security;
- leveraging existing agricultural technology; and
- enhancing technology use.

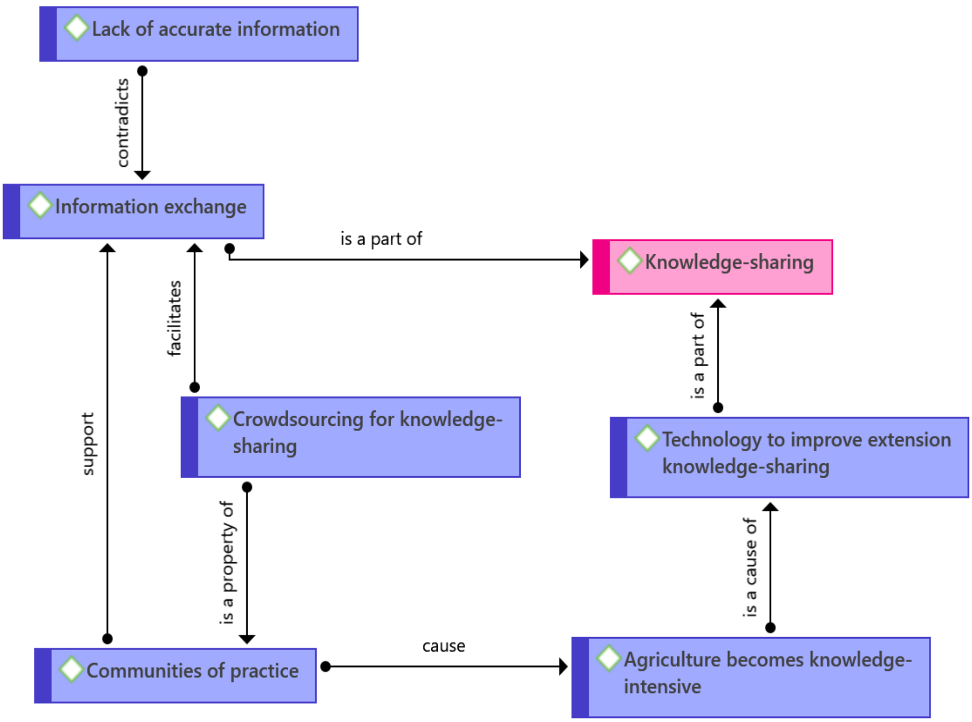
The themes, and the relationship networks generated by the coding of the themes, are set out in the five sub-sections that follow.

Improving knowledge-sharing

The discourse about industrial revolutions often begins by acknowledging the significance of the agricultural revolution, recognised as the first recorded revolution. Subsequently, three successive industrial revolutions gradually streamlined production processes and business methodologies, culminating in the fourth industrial revolution. Even amidst these transformations, agriculture's importance remains undiminished, captivating scholars across both developed and developing nations, particularly in the context of the fourth industrial revolution (Nehra et al., 2018; Schroeder et al., 2021). This enduring significance of agriculture is underscored by the inclusion of food security as a pivotal objective in the UN SDGs document (UN, 2015), emphasising the vital role of the agricultural and food sector (Lee et al., 2021). Consequently, the agricultural domain must thrive in order to address global food insecurity in the fourth industrial revolution era (Schroeder et al., 2021). However, industrial revolution trajectories are marked by the fusion of technological advancement and human behaviour to achieve the revolution's objectives. The rapid technological progress of the fourth industrial revolution necessitates concurrent skills acquisition to keep pace with emerging technologies. There is no reason for the agricultural sector to lag behind; rather, its technological progress should be paralleled by the swift accumulation of knowledge in the farming community (Okediran & Ganiyu, 2019).

Historically, farming relied on manual labour by workers with limited education (Camargo et al., 2012). This labour-intensive approach undermined the appeal of agriculture as a livelihood, leading to underused or repurposed land (Birt et al., 2012). However, a shift towards knowledge-based farming is revitalising the sector, and foregrounding its importance in addressing the global challenges of food security and environmental sustainability (Ortmann, 2000). This transition underscores agriculture's evolving role in the modern industrial landscape, as shown in the thematic relationship network illustrated in Figure 1.

Figure 1: Thematic relationship network: Improving knowledge-sharing



The knowledge era, characterised by rapid knowledge acquisition to meet the demand for skills fuelled by technological development, requires swift decision-making by farmers to enhance seasonal yields (Schroeder et al., 2021). Farming communities traditionally rely on each other for relevant information on soil management, fertilisation, cost reduction strategies, and other tips to boost farm productivity (Schroeder et al., 2021). This practice has endured among smallholder farmers, who have shared knowledge through traditional methods.

Evidence highlights the global impact of digital transformation across various economic sectors, influencing business operations and the urgency of decision-making (Okediran & Ganiyu, 2019). Emerging technologies, integral to this transformation, find extensive use for information dissemination on platforms such as social network sites. The widespread penetration of mobile technology in developing countries indicates that smallholder farmers are likely to participate in this digital transformation, especially if knowledge acquisition experiences are designed for mobile technology.

Even during the agricultural revolution, farmers engaged in some form of crowdsourcing and crowdfunding when coming together for the common goal of agricultural prosperity (Schroeder et al., 2021). In the era of digital transformation, information technology has facilitated even easier crowdsourcing for specific communities of practice. Social network sites could enable the aggregation of produce and production by smallholder farmers, potentially fostering business growth if user experiences are thoughtfully designed.

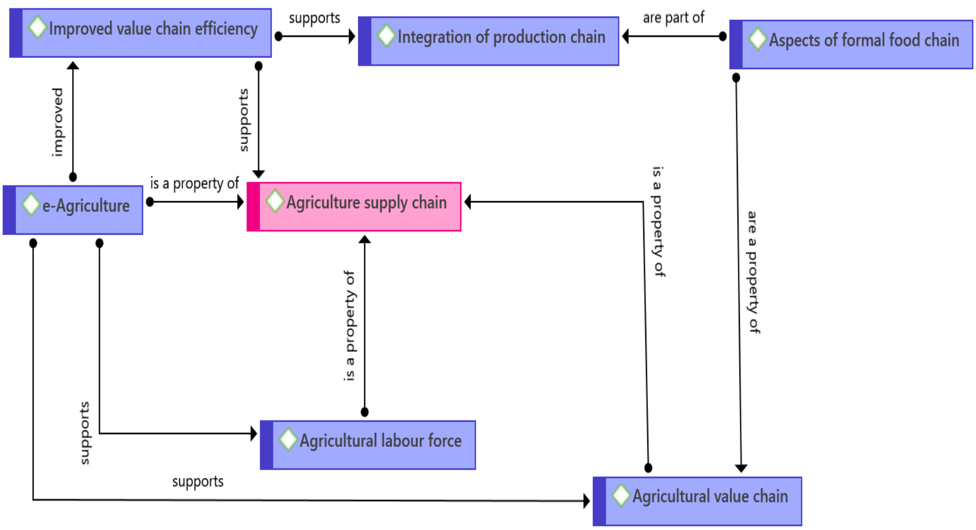
As Okediran and Ganiyu (2019) assert, the agricultural sector is increasingly becoming knowledge intensive. Access to accurate information in the right format, at the right time, and through the appropriate platform and device is critical for rapid decision-making. Informed decisions are vital due to the unpredictable nature of factors such as sudden weather changes that could decimate crops, like hail for butternut or frost for other crops (Walisadeera et al., 2015). Communities of interest are valuable for alerting farmers about impending disasters and exchanging information about available preventative measures.

Social platforms' inherent nature—requiring no specialised training and aligning with social inclinations—renders them universally accessible (Helmi et al., 2019; Pi et al., 2013). Engaging with these networks becomes second nature, transcending social strata and literacy levels. This accessibility fosters a supportive environment where community members readily seek technical insights about shared interests, like market reports. Despite their primary focus on social interaction, these platforms have proven useful for business purposes. This unexpected yet valuable application indirectly addresses literacy challenges in the farming community, empowering individuals to glean sector-specific insights, make informed decisions, and seize opportunities (Liao & Chou, 2012). Initiating this transformation could begin with extension officers forming groups to disseminate information about market trends, prevalent crops, and locally successful agricultural practices.

Strengthening the supply chain

It is crucial to acknowledge that farming enterprises do not exist in isolation; they are integral components of broader ecosystems that involve various businesses contributing value to the farm's processes and outputs. The importance of an efficient supply chain cannot be overstated, and warrants attention from farmers and their supporting organisations. As noted by Schroeder et al. (2021), the remarkable agricultural growth experienced in recent decades in developing countries is not solely attributable to the expansion of land, water, and agricultural inputs, but is equally attributed to the optimised use of agricultural resources through advanced technology and innovative production techniques. As illustrated in the thematic relationship network provided in Figure 2, the rapid integration of enhanced technological solutions into agriculture has the potential to function as a catalyst for improved agricultural production practices and efficient supply-chain management in smallholder farming communities (Okediran & Ganiyu, 2019).

Figure 2: Thematic relationship network: Strengthening the supply chain



Debrah and Asare (2012) emphasise the potential of technology to enhance the agricultural value chain by reducing transaction costs, expanding market access, increasing productivity, and facilitating effective communication with stakeholders in the farming business. Technology plays a pivotal role in providing access to crucial market information and facilitating the flow of information throughout the agricultural supply chain. This seamless information flow benefits both farmworkers and management, ensuring that each participant in the supply chain understands their role and expectations. Typically, when the objectives of all chain members are aligned, this leads to improved efficiency, ultimately enhancing the distribution of farm products (Okediran & Ganiyu, 2019). An efficient supply chain in smallholder farming businesses is argued to enhance overall success, encompassing aspects of office automation and field operations.

Even though smallholder farmers often receive training and financial support from governmental and agricultural organisations, they require real-time information that covers all aspects of supply-chain activities. This information is essential for making informed business decisions related to market dynamics and production processes (Chandra & Malaya, 2012; Rahaman et al., 2021). Such information assists in decisions about the management of crop diseases, the identification of high-value crops, the prediction of weather patterns, and the logistics and transportation arrangements for aggregation purposes (Rahaman et al., 2021). Equipped with pertinent and timely information, a farmer can make informed choices about participation in produce aggregation or pursuing independent operations for the season. The effective integration of farming resources and produce is advantageous for both individual farmers and aggregators, although individual farmers may choose to opt out of aggregation based on yield projections and market prices. Access to accurate and timely information, made achievable through relevant IS systems, is indispensable for making such decisions (Chandra & Malaya, 2012), especially in the context of smallholder farming in developing countries.

Okediran and Ganiyu (2019) assert that the integration of IS into agriculture has the potential to elevate the socioeconomic status of farmers, particularly in developing countries. This transformation is achieved by exchanging valuable information, a shift that brings tangible benefits to economically disadvantaged farming communities. This process of information exchange significantly enhances knowledge acquisition in the labour force in smallholder farming communities, fostering improved decision-making and workflow efficiency. The end result is increased productivity, as noted by Phiri et al. (2020).

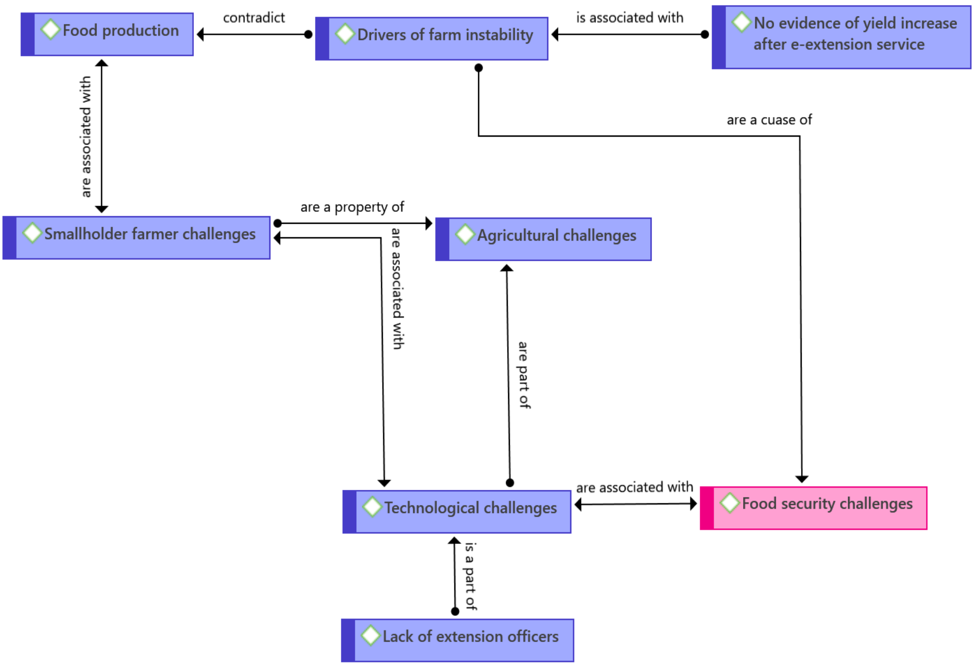
Highly productive smallholder farms not only serve to improve their own economic well-being but also extend their advantages to communities that may otherwise struggle to generate income. This ripple effect reaches beyond the farm, benefiting other businesses as well (Chandra & Malaya, 2012). Retailers, for example, gain a steady source of agricultural products for sale, while transport businesses play a crucial role in transporting the farmers' produce to wider markets (Phiri et al. 2020). The integration of IS thus becomes a key driver in improving the socioeconomic status of farmers and their surrounding communities, effectively contributing to economic growth and stability, particularly in developing regions.

Increasing food security

Food insecurity is a global concern that arises when nations struggle to afford or produce an adequate amount of food to sustain their populations, thus posing a critical threat to the achievement of the UN SDGs (Sekaran et al., 2021). While food insecurity is especially prevalent in developing countries, it remains a threat that transcends national borders. Even developed nations, constrained by limited arable land, grapple with their own food production challenges (Matlou, 2018).

The primary responsibility for food production falls on the agricultural sector, which faces an array of challenges. Factors like the urbanisation of agricultural land, insufficient farming knowledge, inadequate investment in information technology and innovation, and inconsistent governmental sectoral support contribute to the sector's difficulties (Sekaran et al., 2021). The reallocation of arable land for urban development, driven by the profitability challenges faced by smallholder farms, exacerbates this problem (Lee et al., 2021). In this context, selling arable land can appear to be a more viable option than contending with a multitude of threats, including natural and climatic factors, as well as technological advancements (Hatab et al., 2019). Urgent action is required to address the food security threat if the goal of achieving food security by 2030, under the UN SDGs, is to be met, acknowledging that agricultural investment initiatives typically entail a considerable lag time to realise returns (Stats SA, 2019). Figure 3 illustrates the thematic relationship network, as generated by the systematic literature review, for the imperative of increasing food security.

Figure 3: Thematic relationship network: Increasing food security



In the face of these formidable challenges, smallholder farming businesses in developing countries confront significant difficulties in making a profit and sustaining their operations. These businesses serve as both sources of employment and primary income for local communities, which are simultaneously their customers (Topal, 2007). As the value and supply chains falter, a vicious cycle ensues, perpetuating poverty and malnutrition in communities. In contrast, larger farming enterprises are reaping the benefits of agricultural technology, such as precision agriculture and e-Agriculture, due to their capacity to invest in advanced technologies. However, it is worth noting that some farmers in developing countries possess mobile phones and use them to a limited extent for certain farming functions, although the potential impact of this technological solution remains restricted for smallholder farmers (Lee et al., 2021).

In regions where extension services are available, smallholder farmers often rely on extension officers for product advice, including guidance on technology adoption in farming (Mohamad & Gombe, 2017). Nevertheless, the inability of extension officers to provide appropriate counsel on technology infusion might deprive farmers of the benefits that effective technological application could offer.

In smallholder farming communities, the most used and preferred technological tool is the mobile phone, albeit with limited business application capabilities unless equipped with suitable applications (Okediran & Ganiyu, 2019). Despite the extensive market penetration of mobile phones in developing countries, it is important to differentiate between mobile phone availability and the prevalence of effective technology use. While many mobile devices owned by farmers in these regions are technically capable of running useful software, the challenge lies in developing cost-effective software that genuinely contributes to the agricultural endeavours of smallholder farmers (FAO, 2014).

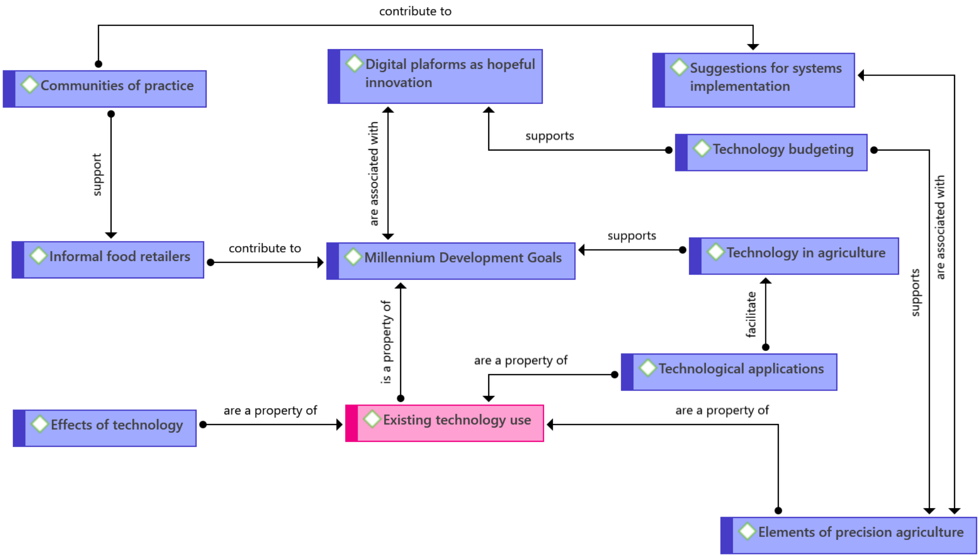
Although information technology alone may not provide a comprehensive solution to food security challenges, it has the potential to empower smallholder farmers with enhanced business capabilities. This, in turn, could lead to more efficient farm operations, allowing these farmers to compete on an equal footing with larger producers in specific sectors. By strengthening the resilience of smallholder farmers, the burden of addressing food insecurity would be lightened for larger agricultural players. Ultimately, this could assist governments in their mission to ensure adequate sustenance for their populations, particularly in the context of developing countries.

Leveraging existing agricultural technology

The role of technology in agriculture is witnessing an upward trajectory, accompanied by innovative production methods and emerging technologies that have become integral to the daily lives of individuals across various educational backgrounds and geographic regions. These transformative technologies are evident in their influence on various aspects of life, including electronic social media interactions (Rahaman et al., 2021), and in the fortunes amassed by numerous tech entrepreneurs, some of whom are among the world's wealthiest individuals. Given this global context, there is a logical expectation that the integration of IS should extend to industries central to a nation's well-being, such as agriculture, particularly in developing countries (Sekaran et al., 2021).

The integration of technology into smallholder farming communities is as crucial as it is for any other business sector that has experienced enhanced efficiency and efficacy in achieving its goals. However, the ability of individual smallholder farmers to invest in advanced technologies, including precision agriculture, is often constrained unless government support is provided (Lee et al., 2021). Nevertheless, envisioning a future where all smallholder farmers in developing countries can access and benefit from farming information technology investments is feasible and promises to contribute to eradicating food insecurity. Figure 4 illustrates the thematic relationship network, as generated by the systematic literature review, for the imperative of leveraging agricultural technology.

Figure 4: Thematic relationship network: Leveraging existing agricultural technology



It is important to note that certain well-researched and developed farming technologies, such as precision agriculture, are already available (Camargo et al., 2012). These technologies have been proven to enhance production efficiency and effectiveness, particularly on large commercial farms (Schroeder et al., 2021). However, these larger farms, while significant, cannot single-handedly supply the quantities of crops or meat required to meet a nation's food demands, let alone address food shortages in other developing countries (Okediran & Ganiyu, 2019). The review reveals instances where certain developing countries, with government support, have invested in technology infusion primarily in enhancing information-sharing among farmers, although not necessarily in precision agricultural technology.

Despite the efforts of governmental bodies to introduce information technology into farming operations, many countries seem to prioritise other government matters over technology infusion, even in the face of persistent hunger crises (FAO, 2014). Eradicating hunger, a prominent objective in the UN SDGs, should be a top priority, not only for the governments of developing countries, but also for developed nations. It is imperative to recognise that food is a fundamental requirement for individuals and communities worldwide (Schroeder et al., 2021). As a result, it is perplexing why those responsible for fostering and nurturing the agricultural sector in their regions often place less emphasis on technology infusion when technology has clearly demonstrated its significance as a critical component of the business value chain (Rahaman et al., 2021).

Most large commercial farming businesses have successfully integrated information technology into their operations, reaping the benefits of improved economies of scale. In contrast, smallholder farmers often struggle to sustain their businesses, with some unable to break even (Sekaran et al., 2021). Technology infusion has the potential to enhance business efficiency and effectiveness, provided that the technology is customised to address the specific operational needs of each farm (Camargo et al., 2012; Chandra & Malaya, 2012).

The emergence of technologies in the context of the fourth industrial revolution offers numerous opportunities for farming communities to thrive and achieve prosperity in the agricultural sector (Camargo et al., 2012). E-Agriculture capabilities in both plant and animal farming have demonstrated their ability to revolutionise business operations for those who are able to invest in such technology. Particularly, advancements in animal production have significantly benefited from current technological applications, with a focus on monitoring vital health information for livestock and animal tracking solutions. This data feeds into management systems for scheduling and overseeing vaccination and other animal health activities (Okediran & Ganiyu, 2019).

In contrast, smallholder farmers often rely on extension services for business support and farming information, making decisions based on a combination of technology and knowledge-sharing. Smallholder farmers find hope in the community of practice that they form, where they informally exchange information pertinent to their shared objectives (Maumbe, 2012). Mobile phone-based applications serve as a common platform for farmers to exchange accurate and timely market-related information (Lee et al., 2021).

These mobile phone-based applications play a pivotal role in the spectrum of technology infusion for business growth. Their efficacy ranges from menu-driven interactions to graphic and video interfaces, depending on whether they operate on smartphones or conventional phones (Walisadeera et al., 2015). The substantial increase in mobile phone penetration in developing markets over the past decade, coupled with the dual functionality of most app development for both mobile and computer platforms, eases access to technology for smallholder farmers (ARC, 2020; Walisadeera et al., 2015). This dynamic landscape enables software developers to create mobile apps tailored to smallholder farm business rules without requiring significant investment in sophisticated computing equipment.

Until smallholder farmers can afford state-of-the-art computing equipment, software developers can serve as allies by crafting mobile apps aligned with smallholder farm needs (Uduji et al., 2020). These apps can be tailored to mobile platforms, facilitating integration with precision agriculture equipment. This approach offers a solution for maximising the potential of advanced equipment that may otherwise remain underused on farms.

Furthermore, the infusion of IS into smallholder farm businesses can be achieved by leveraging affordable and accessible technology already prevalent in these communities, mainly mobile phones. Such devices can be harnessed for knowledge acquisition and collaboration between farmers and extension officers (Sekaran et al., 2021). By sharing information on specific crops and market dynamics, farmers can collaborate in production processes, thereby contributing to market price determination and efficient crop scheduling.

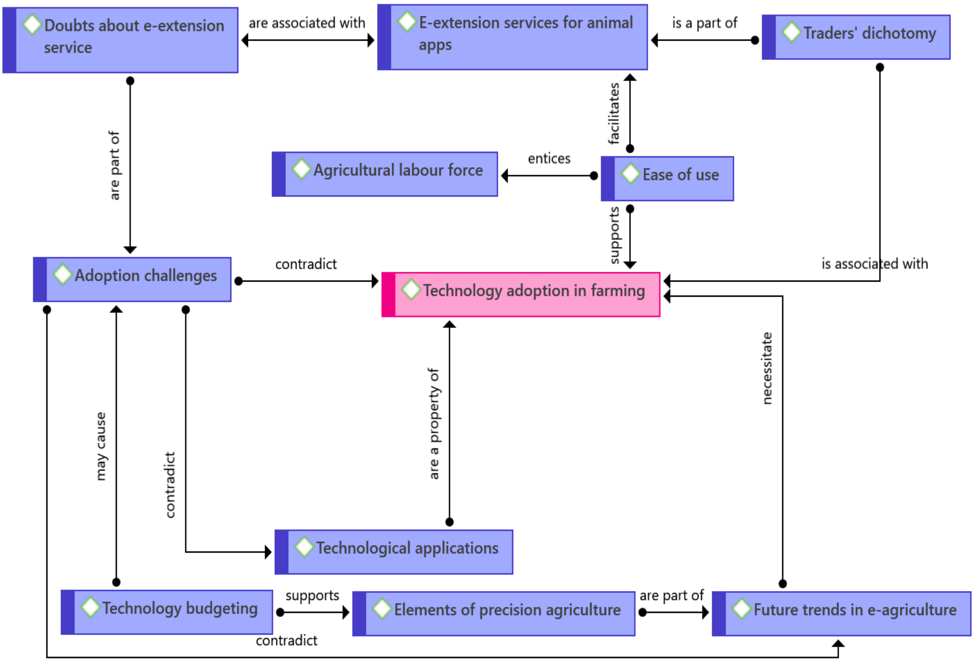
In essence, the information revolution has ushered in modern technologies that can enhance farm management, field production, and information dissemination in farm operations (Adeyeye & Idowu-Adebayo, 2019). However, the successful adoption of innovative technologies depends on their alignment with local contexts and the customisation of content to address the unique needs of the farmers who will use the technology (FAO, 2014). This approach ensures that technology plays a transformative role in the socioeconomic upliftment of smallholder farming communities in developing countries.

Enhancing technology use

While fostering technology adoption is crucial, the use of these technologies by smallholder farmers remains a significant challenge. Similar to other businesses, farming employs information technology to enhance decision-making, efficient transactions, and effective communication (Lee et al., 2021; Nutter et al., 2011; Schroeder et al., 2021). However, the adoption and use of IS will not yield the intended results unless embraced by those who stand to benefit from it. The reported use of IS by smallholder farmers is primarily for office automation and record-keeping, even though numerous IS technologies could enhance production and environmental management for these farmers (Nam et al., 2017).

Superficially, one might assume that smallholder farmers, due to their nature, lack the means or inclination to adopt advanced technologies. Nonetheless, it is crucial to examine the factors influencing technology adoption by smallholder farmers in developing countries to enhance the return on technology investments. Ortmann (2000) contends that complex information systems are predominantly used by expert advisors in the agricultural sector, rather than directly benefiting each smallholder farmer's production. Moreover, smallholder farmers' decisions to invest in technology primarily depend on perceived ease of use, usefulness compared to the associated costs, and the capital required to implement such technology. Given that smallholder farming typically involves limited capital investment and restricted access to funding, these factors play a substantial role. Figure 5 shows the thematic relationship network, as generated by the systematic literature review, for enhancing technology use.

Figure 5: Thematic relationship network: Enhancing technology use



While a few commercial farmers report innovative technology use and state-of-the-art technologies, the growth in agricultural technology development has not yet reached smallholder farmers, especially in developing countries (Nehra et al., 2018). Agricultural technologies can extend beyond office automation to improve decision-making and the coordination of farming activities. A slightly increased investment could enable farmers to sponsor systems development that enhances various aspects of their farming business, from transportation and market information updates to farm management and field production management (Debrah & Asare, 2012).

Extension services play a pivotal role in smallholder farming's survival and growth by providing advisory services, training, and management guidance. Consequently, extension officers have the potential to promote technology infusion among farmers due to their influence on decision-making processes (Schroeder et al., 2021). In countries such as Niger, Kenya, and India, e-extension services have improved skills acquisition and yield by 4%, underscoring the potential of information technology to uplift the lives of smallholder farmers and eradicate food insecurity in developing countries (Schroeder et al., 2021). The impact of extension officers on technology adoption can be linked to their familiarity with and inclination towards technology. According to Phiri et al. (2020), the farming sector is likely to absorb economically active youth in Sub-Saharan Africa, given the persisting issues of unemployment and youth population growth. Youth participation in smallholder farming presents another avenue for promoting technology integration in farming activities (Phiri et al., 2020). As Matlou (2018) asserts, youth involvement in farming is already prevalent in smallholder agriculture, often due to inherited family businesses. Generally, youth are inclined towards technology use, whether for leisure or other purposes.

Several factors must be considered when influencing technology adoption in the smallholder farming community, including ease of use, perceived usefulness, the farmer's age, and extension officers' inclination towards technology (Ortmann, 2000). This calls for a comprehensive and empirical investigation into how these factors impact the application of IS in smallholder farming businesses.

In conclusion, the significance of IS in driving agricultural development in developing nations is undeniable. The key to this success lies in providing smallholder farmers with timely, relevant information to empower them to effectively manage their agricultural endeavours, including information on optimal crops, market dynamics, weather trends, and optimal farming techniques.

5. Analysis

Enhancing food security

The review findings underscore the pivotal role of IS in smallholder farming practices, particularly in the context of developing countries. By addressing the barriers and challenges faced by smallholder farmers in adopting IS solutions, these nations can significantly enhance their food security. IS can provide farmers with essential information for improved crop management, market access, and decision-making, contributing to a more stable and sustainable food supply.

Bridging the literacy gap

In many developing countries, literacy levels, including digital proficiency, are limited. Understanding how the assumption about basic literacy aligns with smallholder farming communities is crucial. IS application strategies that are tailored to the unique characteristics and needs of these farmers can help to bridge the literacy gap. By simplifying technology interfaces and providing training, governments and organisations can facilitate technology adoption and knowledge-sharing by farmers.

Empowering rural economies

Smallholder farming is a primary source of livelihood in developing countries. The adoption of IS in agriculture can uplift the socioeconomic status of rural communities. It not only benefits farmers but also extends advantages to economically disadvantaged regions. As smallholder farmers enhance productivity and gain access to wider markets through technology, this has a ripple effect on local economies, creating opportunities for related businesses and entrepreneurs. By understanding the challenges, tailoring strategies, and actively engaging with relevant stakeholders, these nations can unlock the potential of IS to transform their agricultural sector and enhance the overall well-being of their people.

6. Conclusion

In conclusion, the significance of IS in driving agricultural development in developing nations is undeniable. The key to this success lies in providing smallholder farmers with timely, relevant information to empower them in effectively managing their agricultural endeavours, including crop decisions, market dynamics, weather trends, and optimal farming techniques.

Furthermore, the democratisation of technology among smallholder farmers holds great promise for advancing agriculture. By using mobile phones, farmers can access a wealth of resources, including agricultural applications, online market platforms, and real-time weather updates. These technological tools facilitate efficient farm management, connect farmers with potential buyers, and provide essential insights crucial for success. By integrating IS throughout the agricultural value chain, not only does productivity increase, but the efficiency of distribution also rises, significantly contributing to the reduction of food insecurity.

In summary, IS empowers smallholder farmers by providing them with vital information and resources to enhance agricultural practices, establish market connections, and make significant strides in alleviating food insecurity in developing countries. It is the responsibility of governments, non-governmental organisations, and relevant stakeholders to continue their investment in, and advocacy for, the adoption of IS, ensuring sustained agricultural progress and universal food security.

Funding

No funding was received for this study.

Data availability

The data supporting the results of this study is available upon written request from the author at mkhizpl@unisa.ac.za

AI declaration

AI was used to manage language issues in the writing of this article.

Competing interests

The author has no competing interests to declare.

References

Adeyeye, S. A. O., & Idowu-Adebayo, F. (2019). Genetically modified and biofortified crops and food security in developing countries: A review. *Nutrition and Food Science*, *49*(5), 978–986. https://doi.org/10.1108/NFS-12-2018-0335

Agricultural Research Council (ARC). (2020). *ICT4Agriculture: Exploring information and communication technologies for agricultural development*. https://www.dst.gov.za/images/2017/2017_pdfs/16-946-ICT4Agriculture-Extension-project.pdf

Birt, A. G., Calixto, A., Tchakerian, M., Dean, A., Coulson, R. N., & Harris, M. K. (2012). Harnessing information technology (IT) for use in production agriculture. *Journal of Integrated Pest Management*, *3*(1), D1–D8. https://doi.org/10.1603/ipm11008

Camargo, A., Molina, J. P., Cadena-Torres, J., Jimenez, N., & Kim, J. T. (2012). Intelligent systems for the assessment of crop disorders. *Computers and Electronics in Agriculture*, *85*, 1–7. https://doi.org/10.1016/j.compag.2012.02.017

Chandra, D. G., & Malaya, D. B. (2012). Role of e-agriculture in rural development in Indian context. In *2011 International Conference on Emerging Trends in Networks and Computer Communications (ETNCC)* (pp. 320–323). https://doi.org/10.1109/etncc.2011.6255913

Debrah, S. K., & Asare, I. K. (2012). Using ICT to overcome constraints in the agriculture value chain: Emerging trends in Ghana. In B. Maumbe & C. Z. Patrikakis (Eds.), *E-agriculture and rural development: Global innovations and future prospects* (pp. 31–41). https://doi.org/10.4018/978-1-4666-2655-3.ch003

Food and Agriculture Organisation of the United Nations (FAO). (2014). *10-year WSIS action line facilitator's reports on the implementation of WSIS outcomes: WSIS action line – C7: E-agriculture*.

Hatab, A. A., Cavinato, M. E. R., & Lagerkvist, C. J. (2019). Urbanization, livestock systems and food security in developing countries: A systematic review of the literature. *Food Security*, *11*(2), 279–299. https://doi.org/10.1007/s12571-019-00906-1

Helmi, A. F., Widhiarso, W., Putri, A. K., Marvianto, R. D., Priwati, A. R., & Shaleha, R. R. A. (2019). A model of online trust among adolescents. *International Journal of Cyber Behavior, Psychology and Learning*, *9*(2), 34–50. https://doi.org/10.4018/IJCBPL.2019040103

Kitchenham, B., & Brereton, P. (2013). A systematic review of systematic review process research in software engineering. *Information and Software Technology*, *55*(12), 2049–2075. https://doi.org/10.1016/j.infsof.2013.07.010

Lee, J., Oh, Y.-G., Yoo, S.-H., & Suh, K. (2021). Vulnerability assessment of rural aging community for abandoned farmaland in South Korea. *Land Use Policy*, *11*(1), 1–10. https://doi.org/10.1108/BFJ-05-2021-0552

Liao, S., & Chou, E. (2012). Intention to adopt knowledge through virtual communities: Posters vs lurkers. *Online Information Review*, *36*(3), 442–461. https://doi.org/10.1108/14684521211241440

Massaro, M., Dumay, J., & Garlatti, A. (2015). Public sector knowledge management: A structured literature review. *Journal of Knowledge Management*, *19*(3), 530–558. https://doi.org/10.1108/JKM-11-2014-0466

Matlou, M. (2018). Facing the facts: Challenges and constraints for small-scale farmers' agricultural productivity in South Africa. *Harvest SA*.

Maumbe, B. M. (2012). Global e-agriculture and rural development: E-value creation, implementation challenges, and future directions. In In B. Maumbe & C. Z. Patrikakis (Eds.), *E-agriculture and rural development: Global innovations and future prospects* (pp. 1–15). https://doi.org/10.4018/978-1-4666-2655-3.ch001

Mohamad, M. R., & Gombe, I. (2017). e-Agriculture revisited: A systematic literature review of theories, concept, practices, methods, and future trends. In *British Academy of Management Annual Conference* (pp. 1–13). 5–7 September 2017, Warwick Business School. https://nrl.northumbria.ac.uk/43317

Nehra, K., Jangra, M. R., Jangra, S., & Kumar, R. (2018). Role of information technology in agriculture. In P. K. Yadav, S. Kumar, S. Kumar, & R. C. Yadav (Eds.), *Crop improvement for sustainability* (pp. 537-555). Daya Publishing.

Nam, W. H., Kim, T., Hong, E. M., Choi, J. Y., & Kim, J. T. (2017). A Wireless Sensor Network (WSN) application for irrigation facilities management based on Information and Communication Technologies (ICTs). *Computers and Electronics in Agriculture*, *143*(October), 185–192. https://doi.org/10.1016/j.compag.2017.10.007

Nutter, F. W., Byamukama, E. Z., Coelho-Netto, R. A., Eggenberger, S. K., Gleason, M. L., Gougherty, A., Robertson, A. E., & Van Rij, N. (2011). Integrating GPS, GIS, and remote sensing technologies with disease management principles to improve plant health. In S. A. Clay (Ed.), *GIS applications in agriculture, volume three: Invasive species* (pp. 59–90). Routledge. https://doi.org/10.1201/b10597-5

Okediran, O. O., & Ganiyu, R. A. (2019). E-agriculture reviewed: Theories, concepts and trends. *FUOYE Journal of Engineering and Technology*, *4*(1), 125–130. https://doi.org/10.46792/fuoyejet.v4i1.366

Okoli, C. (2015). A guide to conducting a standalone systematic literature review. *Communications of the Association for Information Systems*, *37*, 879–910. https://doi.org/10.17705/1CAIS.03743

Ortmann, G. F. (2000). Use of information technology in South African agriculture. *Agrekon*, *39*(1), 26–35. https://doi.org/10.1080/03031853.2000.9523564

Phiri, H., Phiri, J., & Kunda, D. (2020). A review of e-agriculture application in developing countries for the youth: Challenges, opportunities and open issues. In *Issues on Zambia's ICT sector, volume 1* (pp. 6–13). Zambia Information and Communications Technology Authority.

Pi, S. M., Chou, C. H., & Liao, H. L. (2013). A study of Facebook Groups members' knowledge sharing. *Computers in Human Behavior*, *29*(5), 1971–1979. https://doi.org/10.1016/j.chb.2013.04.019

Rahaman, A., Kumari, A., Zeng, X. A., Khalifa, I., Farooq, M. A., Singh, N., Ali, S., Alee, M., & Aadil, R. M. (2021). The increasing hunger concern and current need in the development of sustainable food security in the developing countries. *Trends in Food Science and Technology*, *113*(April), 423–429. https://doi.org/10.1016/j.tifs.2021.04.048

Range, J. (2017, November 6). Farming in the age of technology. *Farmer's Weekly*. https://www.farmersweekly.co.za/agri-technology/farming-for-tomorrow/farming-age-information-technology

Rowley, J., & Slack, F. (2004). Conducting the literature review. *Management Research News*, *27*(6), 31–39. https://doi.org/10.1108/01409170410784185

Schroeder, K., Lampietti, J., & Elabed, G. (2021). *What's cooking: Digital transformation of the agrifood system*. World Bank. https://doi.org/10.1596/978-1-4648-1657-4

Schwab, K. (2017). *The fourth industrial revolution*. Crown Publishing Group.

Sekaran, U., Lai, L., Ussiri, D. A. N., Kumar, S., & Clay, S. (2021). Role of integrated crop-livestock systems in improving agriculture production and addressing food security – A review. *Journal of Agriculture and Food Research*, *5*, 100190. https://doi.org/10.1016/j.jafr.2021.100190

Statistics South Africa (Stats SA). (2019). *Towards measuring the extent of food security in South Africa: An examination of hunger and food adequacy*. Report No. 03-00–14.

Topal, R. S. (2007). Food safety problem in the world and in Turkey. *Social Responsibility Journal*, *1*(1), 70–80. https://www.emerald.com/insight/content/doi/10.1108/SRJ-01-2017-0012/full/html

Torraco, R. J. (2005). Writing integrative literature reviews: Guidelines and examples. *Human Resource Development Review*, *4*(3), 356–367. https://doi.org/10.1177/1534484305278283

Uduji, J. I., Okolo-Obasi, E. N., & Asongu, S. A. (2020). Does growth enhancement support scheme (GESS) contribute to youth development in informal farm entrepreneurship? Evidence from rural communities in Nigeria. *Journal of Enterprising Communities*, *15*(3), 451–476. https://doi.org/10.1108/JEC-06-2020-0116

United Nations (UN). (2015). *Transforming our world: The 2030 agenda for sustainable development*. https://sdgs.un.org/2030agenda

Walisadeera, A. I., Ginige, A., & Wikramanayake, G. N. (2015). User centered ontology for Sri Lankan farmers. *Ecological Informatics*, *26*(2), 140–150. https://doi.org/10.1016/j.ecoinf.2014.07.008