Interdisciplinary Journal of Information, Knowledge, and Management

An Official Publication of the Informing Science Institute
InformingScience.org

IJIKM.org

Volume 19, 2024

A Smart Agricultural Knowledge Management Framework to Support Emergent Farmers in Developmental Settings

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Abstract

Aim/Purpose	This research aims to develop a smart agricultural knowledge management framework to empower emergent farmers and extension officers (advisors to farmers) in developing countries as part of a smart farming lab (SFL). The framework utilizes knowledge objects (KOs) to capture information and knowledge of different forms, including indigenous knowledge. It builds upon a foundation of established agricultural knowledge management (AKM) models and serves as the cornerstone for an envisioned SFL. This framework facilitates optimal decision support by fostering linkages between these KOs and relevant organizations, knowledge holders, and knowledge seekers within the SFL environment.
Background	Emergent farmers and extension officers encounter numerous obstacles in their knowledge operations and decision-making. This includes limited access to agricultural information and difficulties in applying it effectively. Many lack reliable sources of support, and even when information is available, understanding and applying it to specific situations can be challenging. Additionally, extension offices struggle with operational decisions and knowledge management due to agricultural organizations operating isolated in silos, hindering their access to necessary knowledge. This research introduces an SFL with a proposed AKM process model aimed at transforming emergent farmers into smart, innovative entities by addressing these challenges.

Accepting Editor Geoffrey Z. Liu │Received: January 24, 2024│ Revised: April 15, May 1, June 7, 2024 │ Accepted: June 7, 2024.

Cite as: Buitendag, A., & Hattingh, F. (2024). A smart agricultural knowledge management framework to support emergent farmers in developmental settings. *Interdisciplinary Journal of Information, Knowledge, and Management, 19,* Article 16. https://doi.org/10.28945/5315

Methodology This study is presented as a theory-concept paper and utilizes a literature review to evaluate and synthesize three distinct AKM models using several approaches. The results of the analysis are used to design a new AKM process model.

Contribution This research culminates in a new AKM process framework that incorporates the strengths of various existing AKM models and supports emergent farmers and extension officers to become smart, innovative entities. One main difference between the three models analyzed, and the one proposed in this research, is the deployment and use of knowledge assets in the form of KOs. The proposed framework also incorporates metadata and annotations to enhance knowledge discoverability and enable AI-powered applications to leverage captured knowledge effectively. In practical terms, it contributes by further motivating the use of KOs to enable the transfer and the capturing of organizational knowledge.

Findings A model for an SFL that incorporates the proposed agricultural knowledge management framework is presented. This model is part of a larger knowledge factory (KF). It includes feedback loops, KOs, and mechanisms to facilitate intelligent decision-making. The significance of fostering interconnected communities is emphasized through the creation of linkages. These communities consist of knowledge seekers and bearers, with information disseminated through social media and other communication integration platforms.

Limitations The proposed AKM process model is a conceptual design based on the context of an agricultural setting, and the model is not empirically evaluated in this research.

Recommendations for Practitioners Practitioners and other scholars should consider implementing the proposed AKM process model as part of a larger SFL to support emergent farmers and extension officers in making operational decisions and applying knowledge management strategies.

Recommendations for Researchers The AKM process model is only presented in conceptual form. Therefore, researchers can practically test and assess the new framework in an agricultural setting. They can also further explore the potential of social media integration platforms to connect knowledge seekers with knowledge holders.

Impact on Society The proposed AKM process model has the potential to support emergent farmers and extension officers in becoming smart, innovative entities, leading to improved agricultural practices and potentially contributing to food security.

Future Research This paper discusses the AKM process model in an agrarian setting, but it can also be applied in other domains, such as education and the healthcare sector. Future research can evaluate the model's effectiveness and explore and further investigate the semantic web and social media integration.

Keywords smart farming lab, emergent farmers, extension officers, agricultural knowledge management, AKM process model, knowledge objects, social media integration

INTRODUCTION

The complexity surrounding the deployment of sound knowledge management practices and related knowledge management and support systems within the agricultural sector is highlighted in the works of several scholars (Gardeazabal et al., 2023; Manesh et al., 2020).

The emergent farming sector in South Africa and other African countries faces many challenges in terms of extension and knowledge support due to knowledge gaps within the system (Gwiriri et al., 2019; Mujeyi & Mutodi, 2021; Pousga et al., 2022). Other notable challenges include becoming sustainable and competitive, advancing into larger-scale commercial or corporate farmer status, or becoming viable entities (Gwiriri et al., 2019, 2021; Hadebe, 2022). These challenges include a lack of knowledge and skills from both emergent farmers and extension officers and limited collaboration between farmers, extension officers, and researchers (Sihlangu & Odeku, 2021).

Farming and extension are still largely organized in ineffective silos, with one-dimensional approaches to farming, extension, and governance still dominant (Kadzere et al., 2016; Laichena et al., 2022). Several studies (Folake et al., 2020; Llewellyn & Brown, 2020; Mapiye et al., 2021) note that there are weak linkages between researchers, extension workers, smallholder farmers, and input providers.

The farming extension officer (as an advisor) in South Africa has a formal role. Most South African extensionists view extension as a professional or technical practice aimed at improving farming practices. The highest objective is productive modernization for increased productivity and profitability, followed by increasing farmers' knowledge through training (Greenberg, 2013). An extension officer will, for the most part, have a special focus on rural development and may report to different governmental or non-governmental agricultural departments or organizations (Oladele & Mabe, 2010). In its essence, the primary roles of an extension officer involve facilitating knowledge transfer, acting as a broker, and enabling linkages between agricultural research and development institutions and farmers, especially emerging farmers (Khwidzhili & Worth, 2019; Mujeyi & Mutodi, 2021; Zwane & Davis, 2017).

One suggested way to address the knowledge gaps and problems related to extension is through the creation of linkages (Raidimi & Kabiti, 2019; Rivera & Schram, 2022). Therefore, mechanisms to support the creation of linkages and to connect knowledge seekers with knowledge holders are essential. Effective extension models and knowledge-driven systems are critical to addressing knowledge-based challenges. Sufficient training, knowledge adoption, technology facilitation, and peer mentoring are all crucial for successful knowledge transfer within larger knowledge management (KM) systems.

To enhance their competitive advantage and influence within the agricultural landscape, farming organizations should strategically transition from 'market takers' to 'market shapers.' Cultivating a dynamic innovation ecosystem can facilitate this transformation. Key components of this ecosystem include a living lab (LL) to foster the co-creation of knowledge and solutions and robust knowledge management practices that prioritize knowledge generation, exchange, and brokering. This knowledge ecosystem forms the foundation for a smart AKM framework (or process model). Our paper investigates the design of a smart AKM framework within emergent, rural, and developmental settings. This study builds upon the doctoral research by Buitendag (2021) that investigated how LLs can assist the knowledge operations of the agricultural sector in South Africa through the deployment of smart farming tools and practices. The main research question that we, therefore, attempt to answer, expanding on the research by Buitendag (2021), is:

> *How can we strategically design a smart AKM framework that effectively integrates and harnesses the best practices and strengths from existing AKM models and frameworks while investigating the role and potential deployment of knowledge assets to support intelligent decision-making and knowledge support-related operations?*

This paper's main novel contribution is our proposed design and composition of the smart AKM framework depicted in Figure 10, realized within an SFL. The framework promotes the deployment and use of knowledge assets in the form of knowledge objects (KOs). This is to support and enable effective knowledge exchanges, the creation of linkages, and smart decision-making utilizing feedback loops.

The paper is presented and organized as follows. First, the need for knowledge management within an SFL is outlined. This is followed by a literature review and analysis of three selected agricultural-specific knowledge management frameworks. The analysis methods deployed are twofold: first, a SWOT analysis is conducted, and second, each of the frameworks is analyzed through the lens of activity theory (AT). The analysis results are used to present the main requirements for an AKM framework as part of a smart farming lab (SFL). The section that follows contextualizes and presents our notion of an SFL and its constituents as factories that, in essence, provide the blueprint for establishing an LL to support emergent farmers. We pay particular attention to the components of an SFL and how these components facilitate and support the KM operations of the intended community, including emergent farmers and extension officers. Then, we outline how decision-making and the creation of linkages can be achieved in the SFL using knowledge assets in the form of KOs.

Subsequently, we present our novel smart AKM framework that incorporates the use of KOs and feedback loops. The KOs are used as a mechanism to capture and transfer knowledge within the SFL. Thereafter, the proposed strengths of the smart AKM framework are discussed, suggestions for future research are highlighted, and the conclusion is presented.

NEED FOR KNOWLEDGE MANAGEMENT IN A SMART FARMING ENVIRONMENT

This research conceptualizes the idea and role of an SFL to support emergent farmers in becoming smart, innovative entities and addresses the challenges identified in the problem statement. Emergent farmers and extension officers need to know what to do and when to do it (main proposition). Advancing a learning environment and culture is crucial for the generation of evidence to guide and inform the decision-making processes in complex market systems and changes (Wach, 2015). Emergent farmers and extension officers are constantly challenged to make the right decisions and apply effective operational knowledge management strategies (Vangala et al., 2017). On this point, research shows that farmers play a crucial role in driving innovation in agriculture. They bring their practical understanding of local conditions and their ingenuity to the table (Padel et al., 2017).

The main role of KM is to enhance innovation (Ode & Ayavoo, 2020). In addition, KM is about creating, storing, using, and sharing knowledge effectively, leading to better-informed decisions and streamlined operations within the organization (Davenport, 2005). The necessity and importance of applying sound KM practices in an LL (of which the SFL is an example) is prominently described in the literature (see Breytenbach & Kariem, 2020; Lehmann et al., 2015; Terziev & Arabska, 2015). Hence, KM is a fundamental aspect of any cognitive activity (Gherardi, 2017). How we support learning, innovation, and applying already-known best practices is fundamental to successfully and effectively using an LL as a knowledge and innovation space (Lehmann et al., 2015; Pancholi et al., 2015). Effective KM can improve the capacity for knowledge exchange (Chen & Huang, 2009) and the use of knowledge brokering and boundary organization networks (including social networks). Doing so can help and support the transformation and diffusion of different types of knowledge and information about the ecosystem (or network) of concern (Cvitanovic et al., 2015; Luo et al., 2015). Emergent farmers and extension officers should explore ways to capture and exchange this knowledge and direct their energy to promote a healthy, competitive agricultural environment (Ahmad et al., 2015).

KM systems are required for effective KM, and such systems are important for managing tangible items (for example, reports, drawings, and models) and intangible items, such as employees' knowledge within enterprise environments, for example, in an LL (Latino et al., 2016).

EXISTING FRAMEWORKS FOR AGRICULTURAL KNOWLEDGE MANAGEMENT

The consensus in the literature is that AKM is unique and multidimensional, with distinct characteristics such as the need to preserve indigenous knowledge that necessitates ongoing research (Borthakur & Singh, 2021; Gardeazabal et al., 2023; Short et al., 2023). Gardeazabal et al. (2023) highlight the need for innovative knowledge management tools in the agri-food sector to promote inclusive knowledge exchange among all stakeholders. Short et al. (2023) further highlight that spatial relationships and local contexts play a significant role in agricultural knowledge, requiring potentially unique solutions compared to other knowledge management fields. Hence, the development of AKM frameworks.

For this study, three distinct scholarly works were selected to be examined, each presenting a unique AKM framework or model. The works of Lwoga (2011), Reed et al. (2013), and Vangala et al. (2014), were selected based on the following criteria:

1. In terms of content, it was decided that each study should:
   - focus on the integration of different knowledge sources;
   - emphasize the role and importance of indigenous knowledge, including knowledge from external entities;
   - highlight the importance of knowledge co-creation and the role that extension plays; and
   - be presented within a development or rural context.
2. In terms of the publication itself, studies were selected from reputable existing databases and collections, such as Emerald, Wiley, and the ACM, which were cited more than ten times.

When analyzing these works to answer the main research question, we also sought to obtain answers to the following sub-research questions:

1. What are the potential strengths, weaknesses, opportunities, and threats evident in the presentation of each framework?
2. How is the concept and process of knowledge exchange proposed and envisaged in each framework?
3. What mechanisms are suggested to capture and store knowledge indigenous knowledge?
4. Who or what are the subject and object in terms of AT, and what tools are suggested to attain the desired outcome in each framework?
5. What role does the community play, and how does the division of labor impact the knowledge management process?
6. Are any contradictions and deviations evident in each framework?

To address the research questions outlined above, we employed a multifaceted methodological approach that incorporated a SWOT analysis (to answer sub-research question 1), a thematic analysis in terms of the elements of AT (to answer sub-research questions 2 to 5), and an analysis of the frameworks in terms of the third generation of AT (to answer sub-research question 6). This approach ensured a comprehensive examination of the research topic and frameworks at hand and allowed for the triangulation of findings from various viewpoints and examination perspectives.

What follows is a short overview of each of the three AKM frameworks or models. Then, the results of a SWOT analysis and an analysis based on using AT as a lens are presented. The analysis results form the basis of our proposed model, as depicted in Figure 10.

LWOGA'S KNOWLEDGE MANAGEMENT MODEL FOR RURAL COMMUNITIES

Lwoga (2011) identified the need for research regarding the application of sound KM principles within an agricultural setting where there is a focus on the integration of indigenous agricultural knowledge (IAK) as part of the KM process. Highlighted is a need to include indigenous knowledge

(IK) and exogenous knowledge (EK) in the process of knowledge dissemination, where dialogue as a means of knowledge transfer within a social setting as a component plays a pivotal role in the overall KM activities. The author underlined that most of the existing KM models for agriculture are based on corporate knowledge environments and fail to address the informal needs of rural agricultural communities (Lwoga, 2011). The proposed model strongly focuses on the provision of mechanisms to provide and enable linkages between KM processes and the underlying principles. In the model, as shown in Figure 1, the various KM processes (identification, acquisition, sharing and distribution, preservation, application, and validation) are presented as a cyclic process with the possibility of transitions between the various processes (in a forward and backward manner).

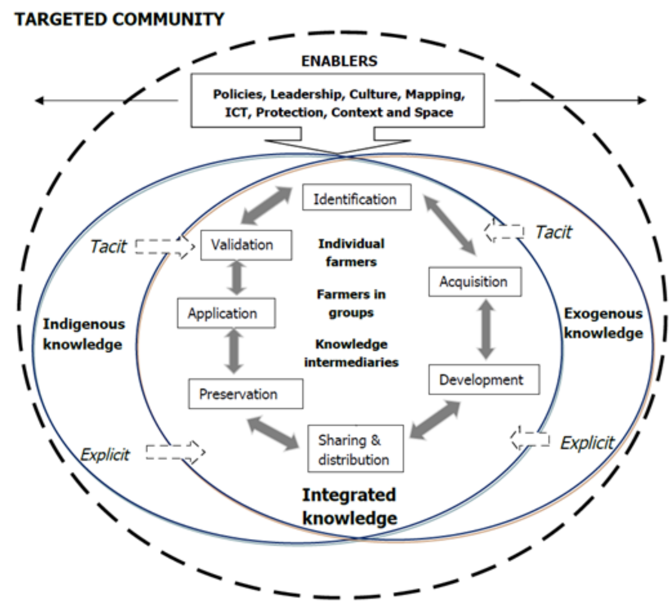


Figure 1. KM model of Lwoga (2011) for rural agricultural communities

Lwoga (2011) further argues that the starting point of the process and the subsequent success thereof reside in the proper identification and involvement of all the enablers, which include various aspects such as policies, leadership, ICT usage, and the context and space of the operations. The model also depicts the combination of IK and EK to form an integrated knowledge space originally suggested by Hess (2006). This convergence between the IK and EK domains, as evidenced by a larger overlap area, is hypothesized to facilitate smoother communication between farmers and experts. This, in turn, is theorized to foster a more comprehensive understanding and integration of knowledge about agricultural practices. The scope of collective knowledge can be broadened by fostering increased collaboration between farmers and external specialists. This can be achieved through the open and polite exchange of ideas without the need to categorize each other's information as either true or untrue (Hess, 2006).

This notion is supported by Lwoga (2011), who concludes that the application of the proposed KM model could improve agricultural productivity due to how knowledge is managed. This could lead to and stimulate innovation and a sense of community learning. The creation of new knowledge would be achievable for the community by harnessing and using knowledge from within and outside their environment with greater integration of IK and EK systems. The proposed KM model includes ideas from the work of Nonaka and Takeuchi (1995), where tacit knowledge is converted into explicit knowledge, with the latter process intrinsically applied through the sharing and distribution phase of the framework. The identification, acquisition, and validation processes require applying tacit knowledge from both the indigenous and exogenous knowledge spheres.

Reed et al.'s Conceptual Framework for KM

Reed et al. (2013) developed a conceptual knowledge management framework for monitoring land degradation, requiring data interpretation from various sources and systems. The researchers emphasize the need to revisit knowledge management within recent contexts and requirements and emphasize that there is a definite need to move towards the following knowledge aspects (Reed et al., 2013):

1. Two-way knowledge exchanges through partnerships between knowledge producers and knowledge users. (The two-way knowledge exchange process recognizes and supports an iterative approach to knowledge exchange as opposed to a linear one).
2. Collaborative knowledge generation where the knowledge user can also become a knowledge producer.

Figure 2 presents the conceptual KM framework that Reed et al. (2013) suggested. The model advances the idea that knowledge creation is a two-way process of knowledge exchange comprising of the four phases depicted.

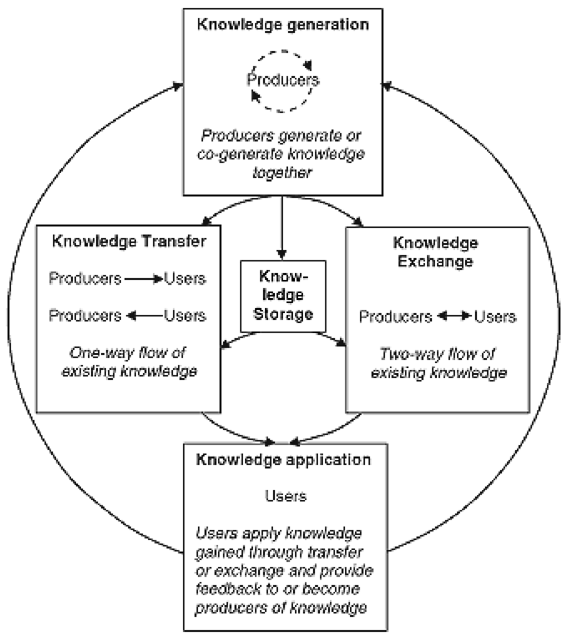


Figure 2. The conceptual framework for KM of Reed et al. (2013)

As depicted in Figure 2, two of the four phases in the framework are knowledge generation and knowledge application. The latter phase could be the source or initiator of new knowledge. The knowledge transfer and exchange phases emphasize the idea that the users of knowledge can also take on the role of knowledge producers. Both these phases allow for the storage of knowledge. Reed et al. (2013) differentiate between the knowledge transfer and knowledge exchange phases. This is done by expounding that the knowledge exchange phase is based on a two-way flow of information and knowledge. The knowledge generation phase consists of co-creating knowledge and the storage thereof within a knowledge base. The knowledge application phase sprouts from the knowledge transfer and knowledge exchange phases (or processes).

It is underlined that the framework presented aims to overcome some of the traditional challenges found in KM practices, where linear modes of knowledge production, dissemination, and implementation are transformed into processes. These processes encourage and stimulate mutual learning and dialogue and provide motivation for real-time sustained actions (Reed et al., 2013).

VANGALA ET AL.'S FRAMEWORK FOR AGRICULTURAL KM

A study relating to the KM practices of agricultural organizations and farming communities in India was conducted by Vangala et al. (2015). This resulted in the framework depicted in Figure 3, which was redrawn for this study.

Vangala et al. (2015) identified a significant issue in their research, which they sought to tackle in their model. They found that the tacit knowledge, both acquired within and outside the organization and farming communities, was weak and not properly documented. As a result, valuable tacit knowledge was being lost. The process of externalizing tacit information into explicit knowledge generation was absent. This same notion is evident in the work of Lwoga (2011), who emphasizes how the oral dissemination of knowledge frequently characterizes indigenous knowledge-sharing practices.

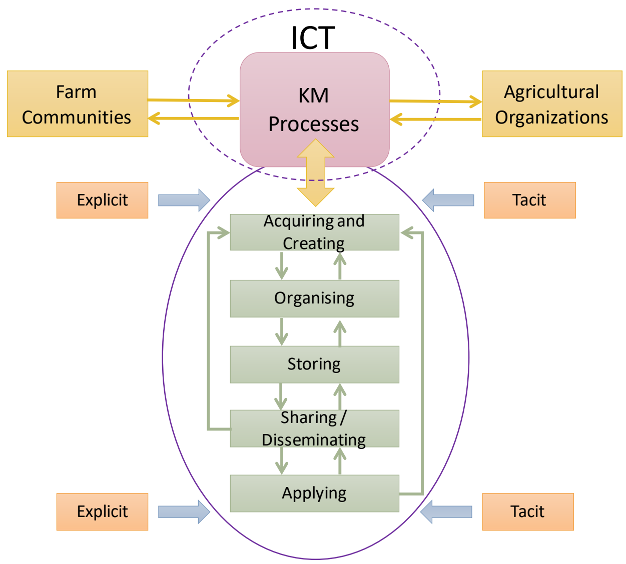


Figure 3. Conceptual framework of Vangala et al. (2015) for knowledge management process

Vangala et al. (2015) accentuate that their agricultural knowledge management framework requires provisions within the system that enable effective dissemination of both tacit and explicit knowledge while catering to its efficient management. They further explain that their model is based on the principles of the knowledge creation spiral of Nonaka and Takeuchi (1995), where knowledge creation is achieved in each process as part of their model (Vangala et al., 2015). Each phase or process allows for an opportunity for knowledge creation by socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit), and internalization (explicit to tacit), as described by (Nonaka & Takeuchi, 1995).

As shown in Figure 3, the model of Vangala et al. (2015) presents the various KM processes (namely acquiring and creating, organizing, storing, sharing and disseminating, and applying knowledge) as cyclic, where there is also the possibility of two-way information flows between each of the processes. They further explain that the two-way flows should include tacit and explicit knowledge. It is emphasized that farmers and other agricultural entities should be involved to some extent in each process. To have an effective AKM, Vangala et al. (2015) suggest codifying and sharing tacit knowledge, creating new knowledge, and involving everyone in the organization, including stakeholders, such as farmers, farming communities, scientists, policymakers, extension officers, private sectors, and non-profit organizations.

It is emphasized that one of the most important aspects in successfully implementing this framework is that farmers predominantly rely on face-to-face communication and that this requirement should be provided for in the application of the framework in each of the processes (Vangala et al., 2015). In other words, each process should include one or another form or mechanism to facilitate the exchange of face-to-face knowledge (and information). The process of facilitating communication by intermediaries (such as extension officers) should also be documented and captured as part of the knowledge repository (Vangala et al., 2015).

Analysis of Three Agricultural KM Frameworks

In this section, the analysis of the three frameworks described above is presented in three forms in our effort to find answers to sub-research questions 1 to 6, as outlined earlier. First, the SWOT analysis results of the three agricultural KM frameworks are presented. Second, the frameworks are analyzed using the elements of AT as a lens, and third, each framework is analyzed as an activity system itself.

SWOT Analysis of AKM Frameworks

This section presents the answer to sub-research question 1, which is to identify the potential strengths, weaknesses, opportunities, and threats evident in each framework's presentation.

Performing a SWOT analysis aids the understanding of the strengths (S), weaknesses (W), opportunities (O), and threats (T) that are potentially part of and involved in a project or activity (Fernández-Getino et al., 2018). Such an analysis is commonly applied in the improvement of the day-to-day activities of an organization to evaluate and advance performance and compete effectively in the marketplace (Rao et al., 2018). This can be achieved if the various factors that influence the operations of the organization are defined and identified (Noordin et al., 2017). The application of the principles and practices proposed in the three frameworks described above, in essence, attempts to present guidelines to conduct the knowledge management operations in the environments where they are to be applied.

Table 1 presents the results of our basic SWOT analysis of the three agricultural KM frameworks (and models) introduced above. The frameworks have a common objective, namely, to enhance and promote the collective knowledge management practices of agricultural CoPs and the inherent network of knowledge (NoK). For each of the frameworks (models) evaluated, the internal *Strengths* proposed within the contextualization and practical application to achieve the common objective described by the authors are summarized. The *Weaknesses* relate to possible internal limitations evident in the processes suggested and or identified by the authors. The *Opportunities* are presented as descriptions by the authors as future research possibilities, enhancements, and suggestions for future research considerations. *Threats* entail identifying potential external factors that could hinder KM activity. The latter were identified by evaluating the authors' views on likely threats that could become a reality or factors that require meticulous attention if the objective is to be attained.

Table 1. SWOT analysis of three KM frameworks

	SWOT analysis	
	Lwoga's (2011) KM model for rural agricultural communities	
	Helpful to objectives	**Harmful to objectives**
Internal	**Strengths** ▪ Focus on the application of indigenous and exogenous knowledge. ▪ Based on a social context. ▪ Focus on rural community knowledge needs. ▪ Linkages between KM processes and principles are emphasized.	**Weaknesses** ▪ Limited focus on the roles and positions of people with leadership roles. ▪ Rural-only focus. ▪ Limited description of how tacit knowledge should be managed and processed externally.

<table>
<tr><th colspan="3">SWOT analysis</th></tr>
<tr><td>External</td><td>Opportunities
Focus is on a learning community for development.
Linkages between ICT policies and other KM enablers should be investigated</td><td>Threats
Not linked and tied to existing policies and procedures.</td></tr>
<tr><th colspan="3">Reed et al.’s (2013) conceptual framework for KM</th></tr>
<tr><td></td><td>Helpful to objectives</td><td>Harmful to objectives</td></tr>
<tr><td>Internal</td><td>Strengths
Emphasizes two-way knowledge exchanges and flows both horizontally and vertically.
Knowledge exchange should be regarded as iterative rather than linear.
Knowledge generation highlighted where users of knowledge also become producers.
Linkages of boundary organizations and knowledge brokers.</td><td>Weaknesses
Social constructions are difficult to classify.
Knowledge differentiation becomes difficult.</td></tr>
<tr><td>External</td><td>Opportunities
Coupling of agent-based models with other management systems.
Mechanisms that promote change and understanding through mutual learning and dialogue are required.</td><td>Threats
Long-term land reforms and institutional reforms
Changes in generational and environmental knowledge
De-contextualization of local knowledge</td></tr>
<tr><th colspan="3">Vangala et al.’s (2015) framework for KM in agricultural organizations</th></tr>
<tr><td></td><td>Helpful to objectives</td><td>Harmful to objectives</td></tr>
<tr><td>Internal</td><td>Strengths
Emphasis is placed on agricultural domains.
Focusses on contextualized community-based knowledge
Recognizes the cyclic nature of knowledge.
All levels of stakeholders are involved.</td><td>Weaknesses
Limited description of the process of and methods for storing knowledge
Codification processes and techniques are not stipulated (How and by which means?)
Limited description of the role of ICTs in realizing and facilitating the operations</td></tr>
<tr><td>External</td><td>Opportunities
Scope for the development of metrics for the evaluation of the effectiveness of the framework
Scope for developing mechanisms to facilitate the integration of tacit and explicit knowledge.</td><td>Threats
Suggested framework and implementation have not been tested in practice</td></tr>
</table>

By combining the strengths of the existing frameworks with the opportunities for further development, it is possible to create a new KM framework that harnesses the strengths and opportunities of each framework (or model) and limits the identified weaknesses and threats. Addressing these concerns can lead to a more robust and effective framework to leverage all the benefits and avoid potential problems and pitfalls. These considerations, as highlighted in Table 1 (which presents an answer to sub-research question 1), are incorporated in the design of our smart AKM, as depicted in Figure 10, especially regarding the strengths and opportunities identified. The common objective of each analyzed framework is to present and suggest mechanisms to assist with capturing and managing the corporate memories and the indigenous knowledge of the community involved. Our proposed model aims to achieve this objective by deploying knowledge assets in the form of KOs.

Evaluating AKM Frameworks From an Activity Perspective

Historically, activity theory (AT) looks at artifacts (tools) and people as embedded in dynamic activity systems (Engeström, 2006). The initial description of AT was presented as a framework for studying different forms of human practices as development processes (Kuutti, 1996). Vygotsky (1978) presented AT as a model consisting of four basic elements: the tool, subject, object, and outcome. These elements remain foundational in work on AT and systems, where the activity relates to a particular action or form of doing directed to an object.

An important aspect of AT is that a fundamental transformation process takes place. In terms of the model, (1) a subject is an individual or group of individuals involved in a common activity; (2) the subject undertakes an activity directed to a particular object to achieve an outcome; and (3) activities comprise working with tools or mediating artifacts. Examining the different agricultural frameworks through the perspective of AT offers fresh perspectives on the structure of the AKM process, which is the primary activity suggested by each framework. Doing so also opens the opportunity to answer sub-research questions 2 to 4 that, in essence, relate to the core activity of knowledge management.

Analyzing the components of an activity system and the interconnected parts of the different AKM models or frameworks outlined by different researchers allows us to observe and note both similarities and discrepancies. To identify the elements and practitioners involved in the division of labor (DoL) aspect, the focus and analysis are placed not only on the people involved but also on the interrelated tasks and operations to accomplish the main AKM process (as an activity).

Lwoga's KM model for rural agricultural communities through the lens of AT

Figure 4 offers an AT-based analysis of Lwoga's (2011) knowledge management model for rural agricultural communities.

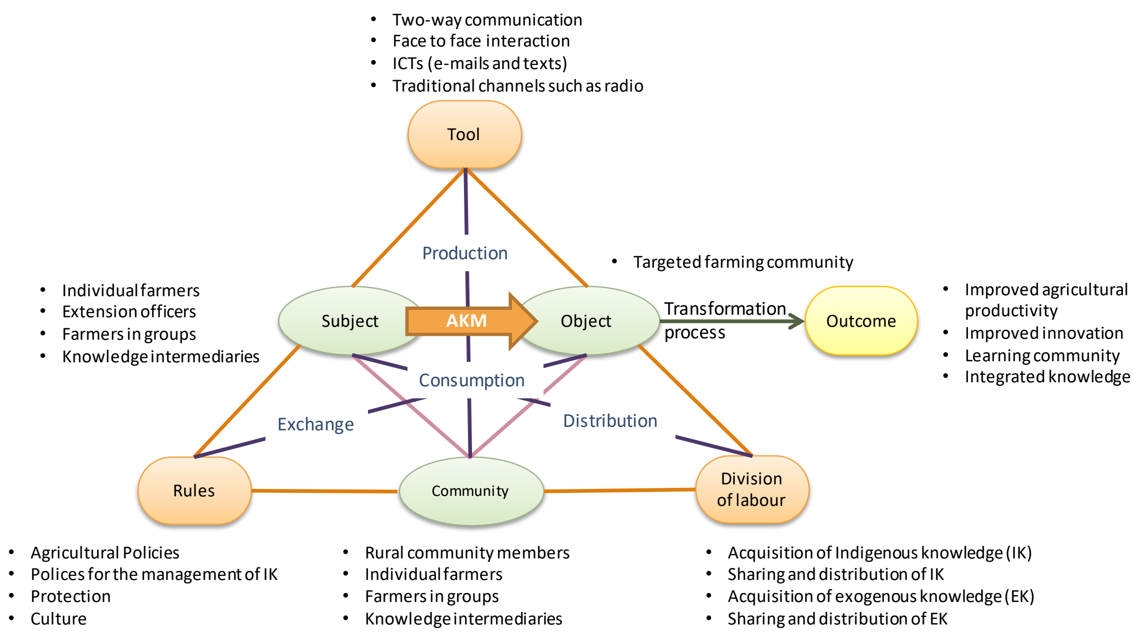


Figure 4. Lwoga's (2011) KM model for rural agricultural communities through the lens of AT

As depicted in Figure 4, the model aims to achieve the integrated management of agricultural knowledge in rural areas, fostering indigenous and exogenous knowledge for improved productivity, innovation, and creating a learning community. The main subjects described by Lwoga (2011) are the individual farmers, extension officers, farmer groups, and knowledge intermediaries that apply agricultural KM practices in a targeted community as an instantiation. The means by which this is to be achieved is through two-way communication and dialogue, basic ICT implementation, and traditional channels such as radio programs. Various agricultural policies, including an acquisition of IK policy and the culture of the farming community, govern the operations. The community consists of all stakeholders, individuals, rural community members, and knowledge intermediaries. The division of labor (DoL) is grounded in the functions of the acquisition, sharing, and distribution of IK and EK. Other tasks assigned to the AKM process include the identification, acquisition, development, dissemination, preservation, application, and validation of integrated knowledge comprising of both indigenous and exogenous knowledge.

Reed et al.'s conceptual framework for KM for rural agricultural communities through the lens of AT

Expanding on Figure 2, Figure 5 presents an AT-based analysis of Reed et al.'s (2013) conceptual framework for KM in rural agricultural communities. The framework is grounded on providing best practice-based KM services for monitoring and assessing land degradation. This is evident in the main outcome of the AKM process, depicted in Figure 5.

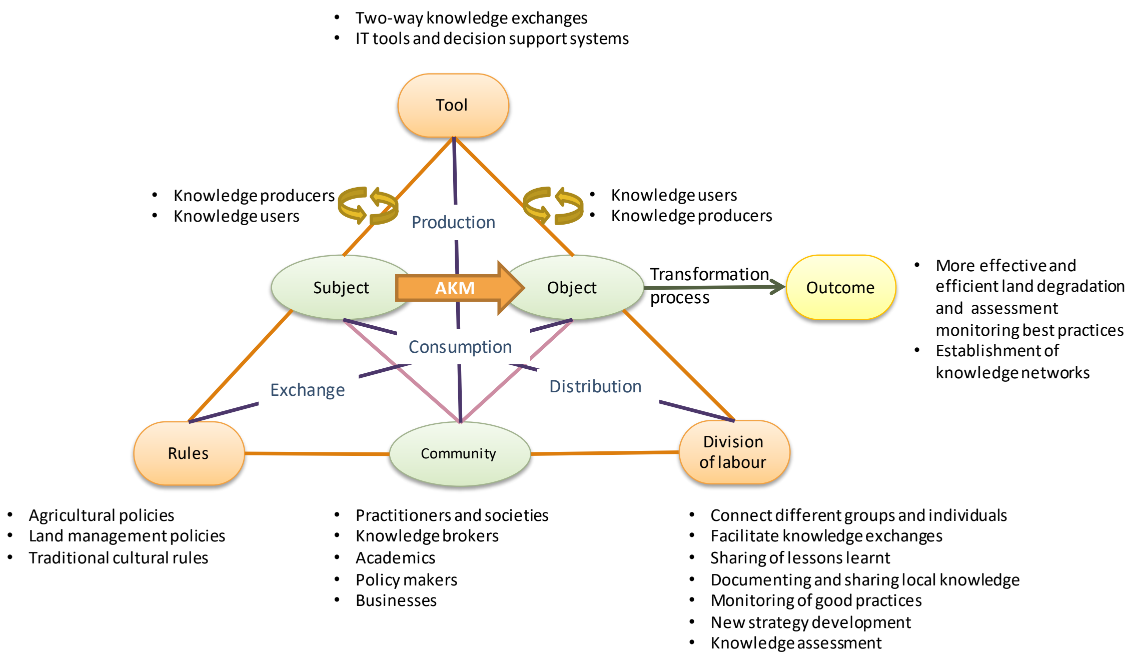


Figure 5. Reed et al.'s (2013) conceptual framework for KM for rural agricultural communities through the lens of AT

As portrayed in Figure 5, the focus of this framework is placed on the interchangeable roles of the knowledge producers and the knowledge users who, from an AT perspective, can either be the subject or the object, depending on the case. Reed et al. (2013) emphasize that "knowledge producers can become users of knowledge, and users can become producers of knowledge, providing the potential for different actors to co-generate knowledge together." The tools to facilitate the KM process are indicated as enabling two-way knowledge exchanges, shifting away from singular, linear knowledge processes towards both intra- and inter-organizational levels. The rules of operation are encapsulated and stipulated within the various agricultural policies, land management policies, and the traditional cultural rules of the stakeholders. The community is comprised of various practitioners and stakeholders, knowledge brokers, policymakers, academics, and business entities. The division of labor (DoL) entails the connection of different groups and individuals, the facilitation, documenting, assessment, and sharing of knowledge and exchanges, the sharing of lessons learned, and new strategy development.

Vangala et al.'s framework for KM in agricultural organizations through the lens of AT

Vangala et al.'s (2015) framework, presented in Figure 3 for knowledge management in agricultural organizations analyzed through the lens of AT, is presented in Figure 6 in more detail.

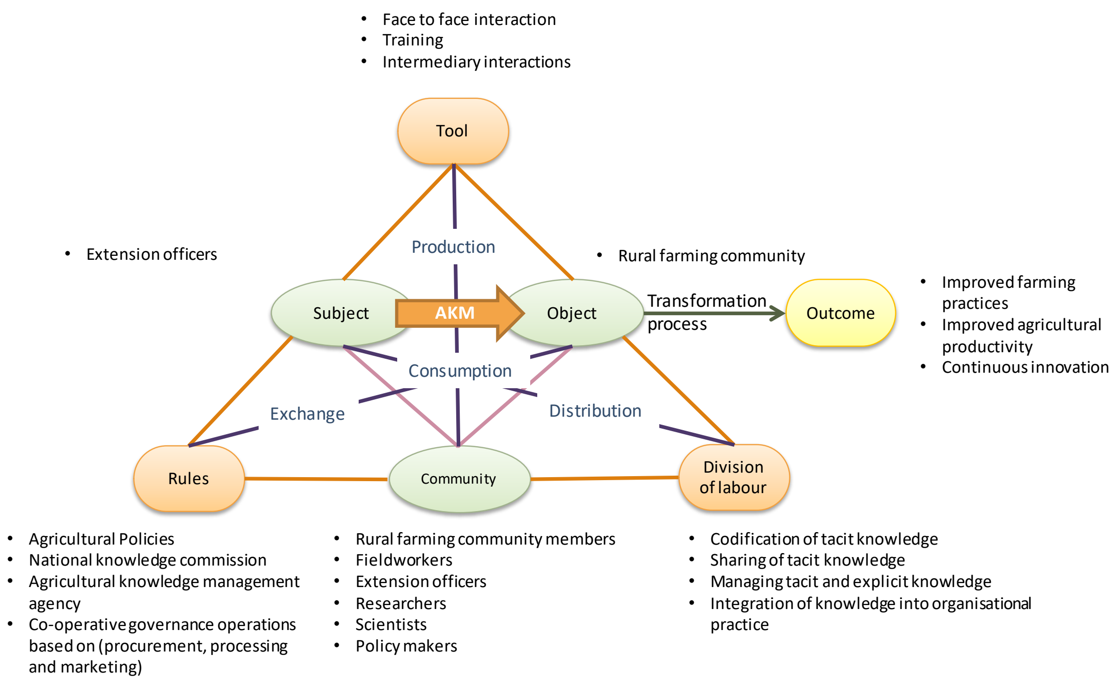


Figure 6. Vangala et al.'s (2015) framework for KM in agricultural organizations through the lens of AT

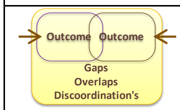
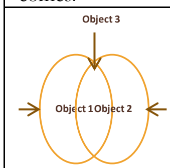
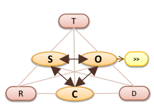
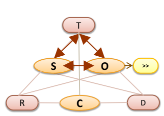
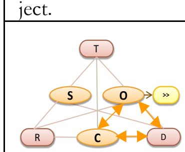
As summarized in Figure 6, the primary focus of the framework is to provide techniques and procedures that facilitate the timely dissemination of relevant knowledge to the appropriate individuals, enabling effective information sharing and implementation. By applying AKM, the perceived outcomes are improved innovations and farming practices that lead to better agricultural productivity. The subject and object in the framework are the extension officers and the rural farming community, respectively. The consumers of the transformation process are the community members, which comprise the farmers themselves, various field workers, extension officers, and other stakeholders such as researchers, policymakers, and scientists. The practice is guided by various agricultural policies, including cooperative governance procedures, operations, and government institutions.

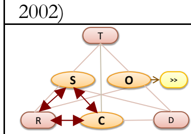
Analysis of AKM Framework (Model) Elements as Separate Activity Systems

The principle behind the third generation of AT is highlighted by Engeström (2001) as consisting of two interacting activity systems where the object moves from an initial state to a collectively meaningful object or a shared jointly constructed object. It also includes the contradictions between the various objects and their intended outcomes. Looking at and examining the contradictions could reveal gap overlaps and discrepancies between the intended outcomes and the outcomes itself.

Table 2 presents an AT analysis of contradictions, discoordination, and tensions between the three different AKM models/frameworks in terms of the third generation of the AT model (which answers research question 6). Systematic contradictions are deviations from standard scripts, and the analysis of the contradictions within a model could lead to the development of a new solution and a new pattern of activity (Engeström, 2000). Contradictions are also sources of change (Engeström, 2001).

Table 2. AT analysis of contradictions, discoordination, and tensions of the different AKM models

AT component viewpoint	AKM framework/model			Contradictions, gaps, accentuations, and overlaps
	Lwoga's (2011) KM model	Reed et al.'s (2013) conceptual framework for KM	Vangala et al.'s (2015) framework for KM	
 Investigating the gaps, overlaps, and discrepancies between the various intended outcomes.	Improved agricultural productivity. Improved innovation. Learning. Community. Integrated knowledge.	More effective and efficient land degradation and assessment monitoring of best practices. Establishment of knowledge networks.	Improved farming practices. Improved agricultural productivity. Continuous innovation.	Improved productivity is a central outcome for all three models. Two models include innovation as an outcome, while one stresses establishing appropriate knowledge networks.
 Looking at how the integration or merging of the two objects in separate activity systems could lead to the identification of a new object.	Targeted farming community requiring assistance.	Knowledge users and knowledge producers in interchangeable roles.	Rural farming community.	The interchangeable roles of the knowledge seeker and knowledge producer are cardinal. In revisiting the notion of the 3rd object, which relates to the idea that both the knowledge seeker and the knowledge producer leave with (as Engeström (2000) states) "a collaboratively constructed understanding" of the AKM process and the required and or intended outcomes.
 Examining the connections between the subject, object, and the community, which are vital to the health of an activity (Dodds et al., 2017).	The model emphasizes the various stakeholders in interchangeable positions and roles, where the community members are sometimes the subject triggering the AKM process to manage and assist the transfer of knowledge.	The strong connection between the subject and the object is evident in their model. The applicable community entails the various entities and stakeholders that are part of the bigger value chain.	The same theme as with the other two is also evident in this model, including fieldworkers, extension officers, and the farming community. Extension officers are regarded as the main subject facilitating AKM and knowledge transfer to the applicable rural farming community.	The central role and importance of involving all stakeholders within the mutually promotive community is evident to act as a catalyst in the transformation process. Establishing a strong community base could lead to it evolving into a self-organizing community with common goals and objectives.
 Reviewing the relationship between the suggested tools recommended to facilitate AKM and the subject and object.	The interaction and facilitating process between the subject and the object is placed with the subject using various tools, emphasizing two-way communication and interaction.	Two-way knowledge exchanges using ICT tools are emphasized, with tools available as needed by either knowledge users or knowledge producers.	In addition to two-way interactions and face-to-face communication, training and intermediary interactions, such as those from market agents, are also suggested.	This process facilitates the production and management of knowledge. All three frameworks emphasize two-way interactions and communication. The interchangeable roles of knowledge seekers and producers are also important. Training and the use of applicable ICT tools and traditional communication mediums are also encouraged.
	The targeted farming community as the object interacts with the other community members and stakeholders. Each participant plays a	The distribution of activities is indicated as the sharing of lessons learned, the documentation and the sharing of local	Here, the rural farming community, as part of the community and as an object, is central, and various tasks such as	The distribution of tasks, which also entails cognitive labor, between the community and the object in action is key to the transformation process. The community constantly interacts with the

AT component viewpoint	**AKM framework/model**			**Contradictions, gaps, accentuations, and overlaps**
	Lwoga's (2011) KM model	**Reed et al.'s (2013) conceptual framework for KM**	**Vangala et al.'s (2015) framework for KM**	
The relationship between the object, community, and the division of labor elements, i.e., distribution subsystem, which "ties the object of activity to the community by defining a division of labor. That is, it divides up activities according to social laws or expectations." (Jonassen, 2002)	role in acquiring and distributing indigenous and exogenous knowledge. The participants include knowledge intermediaries, community members, and the farmers themself.	knowledge, the development of strategies, and the assessment of the knowledge generated and shared. These are enabled through the collaboration of knowledge brokers and other societal entities such as businesses and policymakers.	codification, integration, management, and sharing of knowledge are the responsibility of all members, including fieldworkers and extension officers, researchers, scientists, and policymakers.	object, and the division of tasks includes the coding, management, sharing, integration, and assessment of the available knowledge. Monitoring and feedback regarding the implementation and outcomes are also key. Creating different knowledge networks presents opportunities for expanding the community's knowledge base.
 The exchange subsystem concerns the individual, social, and cultural norms in the working community. It determines and establishes the operational climate of the activity system (Liaw et al., 2007).	The applicable rules by which the various subjects are constrained include various agricultural policies and policies for the management of indigenous knowledge, often based on the cultural norms of the applicable community and the protection of the knowledge of the various groups and intermediaries.	Both knowledge seekers and users are bound by agricultural policies and traditional cultural rules. These rules also apply to various members of academia and other business entities. The various practitioners and knowledge brokers are also bound by traditional rules and other cultural policies and guidelines.	As with the other models, various agricultural policies guide the broader community. The rules are presented by various government institutions and cooperative governance procedures.	The three-exchange subsystem reveals that the various policymakers and the rules governing the subject's operations are interdependent. The community members should participate in the rule-making process and negotiate how the subject is regulated to perform the applicable action. In this research case, the subject is guided in providing agricultural knowledge management through various rules, partly decided and negotiated by the community itself.

Based on the analysis presented above, it is evident that each of the KM frameworks and models investigated had the common objective of enhancing and promoting the knowledge management practices of agricultural organizations and rural agricultural communities. In terms of outcomes, all three frameworks provide descriptions of improved knowledge productivity, but two also emphasize innovation. The importance of prioritizing the creation of sustainable knowledge networks is also highlighted. Concerning the knowledge flows in each of the frameworks, both knowledge seekers and producers can interchange their roles, where the two-way interaction is not only encouraged but crucial to the operations of the knowledge network. All frameworks prioritize collaborative learning, shared responsibilities, and community participation for effective agricultural knowledge management, where success is contingent upon ongoing feedback, adaptation, and interaction.

The use of various tools, including traditional tools and ICTs, is encouraged. In relation to the processes of knowledge production and management, the following facets and processes are emphasized in all three frameworks:

- Collaborative learning: The community interacts with the "object" (agricultural knowledge) through coding, managing, and sharing tasks.
- Distribution of cognitive labor: Tasks are shared between the community and the object.
- Monitoring and feedback: Regular assessment and adaptation are essential.
- Expanding knowledge base: New knowledge networks create wider learning opportunities.

Main Requirements for an AKM Framework Utilized in an SFL

The main requirement of a smart agricultural knowledge management framework based on our analysis as outlined above is to establish strategies and create mechanisms to get the right knowledge to the right people at the right time (that is, to create linkages) and help people share and put information into action. The goal is to improve innovations and farming practices, leading to better agricultural productivity.

This requirement relates to the provisioning of mechanisms for:

- Knowledge coordination.
- Managing and coordinating the body of knowledge within the LL including corporate memories.
- Managing the network of knowledge and the creation of linkages.
- Managing available knowledge resources, including knowledge objects (KOs) and knowledge object wrappers (KOWs), which are semantically annotated metadata files.
- Establishing and maintaining knowledge linkages.

An additional requirement is to present mechanisms to support intelligent decision-making based on feedback loops and the application of previous experiences and knowledge. Doing so would assist the SFL in operating on smart principles and deploying technologies and tools. The SFL should, in addition, provide smart mechanisms and tools that allow, support, and manage the creation of linkages between various entities. In practical terms, this renders the SFL a social and knowledge brokerage. Social interactions are based on activities. Therefore, the foundation of any LL design should be underpinned by the components of an activity system.

An SFL should function and operate within existing and set frameworks that include:

1. A refined enterprise resource planning (ERP) framework that can help to describe what problems the SFL should solve and then refine the model to describe how the SFL system solves the agricultural problem;
2. A virtual organization framework where farmers and other role players can function as small businesses within the farming community; for example, one farmer can specialize in plowing for other farmers; and
3. A design and impact framework based on AT.

As part of the SFL, each activity is reliant to some extent on proper decision-making. Effective decision-making means considering all issues and role players that affect a particular decision to deliver environmental, social, economic, technological, and other outcomes for the markets.

Smart Farming Lab

In essence, an SFL is an LL saturated by deploying smart tools and collaborative technologies grouped in relevant factories. For this research, an LL is regarded as an open co-creation and innovation network for exchanging knowledge, where user involvement in the micro levels helps generate information and foster innovation (Schuurman et al., 2016; van der Walt et al., 2009). The relationship between the concepts of an LL and that of an ecosystem is frequently presented in the literature (Schuurman et al., 2019; Westerlund et al., 2018). As an open ecosystem, an LL creates, allows, and offers specific opportunities for all the members to develop new business models and test various value propositions (McPhee et al., 2021; Merino-Barbancho et al., 2023). We also regard the LL as having the potential to transform farming into smart farming by adopting smart technologies enabled through, amongst others, sound knowledge management practices (Jakobsen et al., 2023; O'Grady & O'Hare, 2017).

The concept of the co-creation of solutions, business models, and the evaluation of value propositions within an LL involving various stakeholders is also an important deliverable (Hooli et al., 2019; Schuurman et al., 2019). Scholars relate the LL concept with that of a methodology for "addressing real-life issues through the attribution of knowledge from science and society, the latter being a form of trans-disciplinary social learning" (Hagy et al., 2017, p. 169).

Leveraging and utilizing current web-based technologies, such as the Internet of Things (IoT), social media platforms, semantic web, APIs, and other tools, should lead to the realization of smart agricultural and farming practices (Ilham et al., 2022; Wang et al., 2021).

Our SFL framework is presented as an LL environment, focusing on the knowledge drivers, role players, and perceived outcomes regarding the knowledge processes to support emergent farmers and extension officers. Figure 7 depicts a visual bird's-eye view of our interpretation of the design and conceptual composition of an SFL framework.

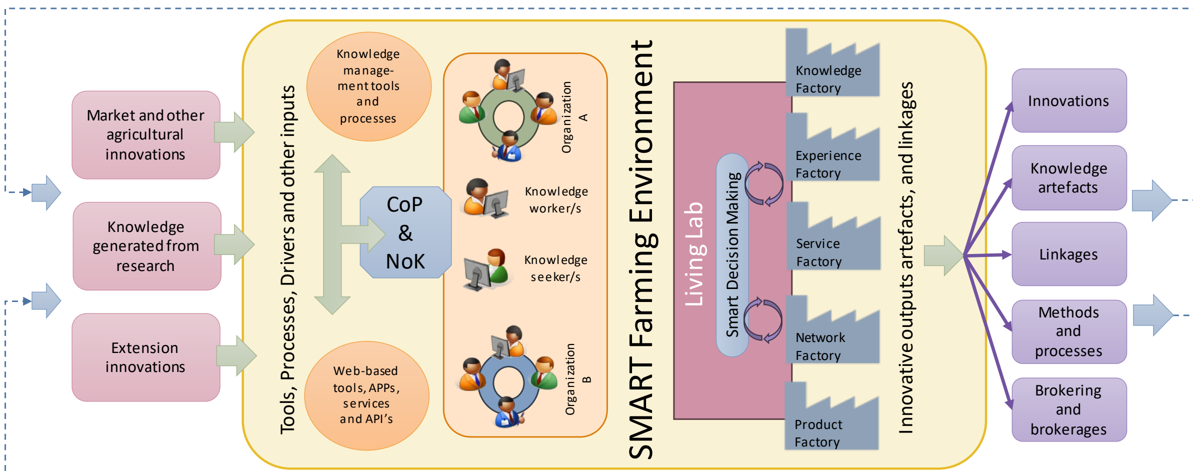


Figure 7. Smart farming lab elements and environment

In the next sections, we describe each of the constituents of our SFL framework, as depicted in Figure 7.

Tools Processes, Drivers, and Other Inputs

As shown in Figure 7, the tools processes, drivers, and other inputs to the SFL are as follows:

Market and other agricultural innovations fuel the demand for new knowledge and knowledge creation through knowledge management practices.

Knowledge gaps are generated by emerging market trends and technologies such as vertical farming, automation, precision farming, and the utilization of drones (Klerkx et al., 2019; Qazi et al., 2022). These gaps inherently motivate communities to proactively seek, create, exchange, and modify pre-existing knowledge to suit their needs, of which the interchange is done within the existing NoK. This, in turn, can lead to profitable innovations that become the focus of knowledge exchange, pushing communities to prioritize knowledge that directly addresses their market challenges and opportunities (Feo et al., 2022; Tiwari, 2022).

Knowledge generated from research includes research findings that offer new lenses for interpreting existing knowledge, sparking critical reflection and innovation within the community. It also entails the validation and refinement of existing knowledge and practices (Houessou et al., 2023) and has the potential to identify areas for improvement, guiding the community's knowledge management towards evidence-based practices (Ladouceur et al., 2022).

Extension innovations that facilitate bridging the gap between research and practice (Ingram et al., 2018). Extension innovations like farmer field schools facilitate knowledge transference (Osumba et al., 2021), directly integrating research findings into the community's knowledge base (Mabon et al., 2023), and empowering knowledge creation. This is achieved by intrinsically fostering co-learning and participatory research. Extension innovations equip communities to generate their own knowledge tailored to their specific context. This supports our proposition that emergent farmers and extension officers need applicable and timely information to make the right decisions, inform their farm management practices, and navigate the complexities of the agricultural landscape.

Knowledge Management, the Network of Knowledge and Tools

The concepts of and the interrelationship between the process of KM and the NoK presented in Figure 7 include the larger community of practice (CoP) and web-based and other tools. Each of these entails the following:

> **Knowledge management, tools, and processes** that relate to providing a means and systematic method for capturing, storing, sharing, and utilizing the large volumes of data produced (Zaim et al., 2019). This facilitates ongoing innovation and improvement within the larger NoK (Abbas & Sağsan, 2019).
>
> **Network of knowledge and community of practice** that facilitates the exchange of expertise and best practices among the SFL stakeholders, including organizations and individuals, towards fostering collaboration and accelerating the adoption of sustainable farming practices (Robles, 2023; Santini et al., 2023). These include farmers and extension officers regarded as multi-agents within an agricultural setting with a focus on interactive learning, research, and development, which can be facilitated through knowledge brokering (Coggins et al., 2022; Nguyen & Evers, 2011).
>
> **Web-based tools, APIs, and apps** are created, implemented, and utilized by the community. This enables the community to provide accessible and user-friendly platforms and tools for managing data, connecting with experts, disseminating knowledge, empowering farmers and other stakeholders to make informed decisions, and optimizing their agricultural practices (Borrero & Mariscal, 2022; Kumar et al., 2023).

Smart Operations and Smart Decision-Making in a Smart Farming Lab

For the SFL to operate smartly and facilitate smart operations, collaborative mechanisms must be provided to assist the users in their decision-making processes (Andronie et al., 2021; Tran Thi Hoang et al., 2019). Therefore, in this section, we explore the concept of smart operations and decision-making towards presenting its role as part of our AKM framework within an SFL environment.

The concepts of 'living laboratory,' 'smart city,' and 'smart operations' are intrinsically tied to knowledge of the effective environment for practical decision-making (Evans & Karvonen, 2014). Living labs foster the concept of co-creation, and making decisions is a key part of the methodological operations of an LL (Nesterova & Quak, 2016). Decision-making is pivotal in any organization and is vital for clear indications of action, which can result in either success or failure (Persson & Sjöö, 2017).

Adequate knowledge management and support systems facilitate decision-making (Deng et al., 2023). Using available data sources and involving various stakeholders creates the opportunity to gain new ideas and innovations and to advantageously inform operational decision-making to address various challenges in smart operations, such as sustainability (Bates & Friday, 2017). Regarding new directions and possibilities, Le Pira et al. (2017) present a three-layered description of an LL environment that comprises activities that include "strategic, practical and ex-post results observation, enabling a 'feedback loop' to decide for new directions and possibilities of the living lab."

Regarding decision-making, Simon (1960) presented a classic multi-criteria decision-making process consisting of three phases entailing an intelligence activity (where the environment is searched for conditions requiring a decision), a design activity (involving inventing, developing, and analyzing possible courses), and a choice activity (selecting a particular course of action from those available for (of) action) have been the foundation for many other decision-making models (Adam & Humphreys, 2008). Simon (1977) subsequently added a fourth phase to the process, which he named the review phase, which entails the assessment of past choices. This phase also entails evaluating the previous activities and the choices made (Persson & Sjöö, 2017). The process is typically cyclical and evolutionary, allowing stakeholders to capture their perspectives, explore, analyze, stimulate, and review iteratively (Pretorius, 2017).

In the context of this research, it is imperative to note that an extension officer will inevitably face situations that demand a prompt decision due to certain realities or problems. The facilitation of the decision-making process would entail assisting users with the information-gathering process, allowing them to gather information about the problem and the environment.

Figure 8 presents our interpretation of the decision-making process as described by Pretorius (2017), Delir Haghighi et al. (2010), Turban et al. (2005), and Simon (1977).

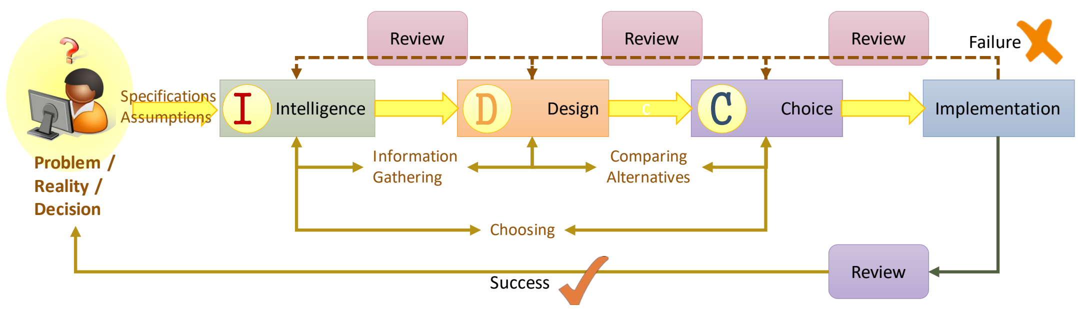


Figure 8. Decision-making process

As presented in Figure 8, during the **intelligence phase**, the researcher reviews existing knowledge and gathers information, focusing on recognizing and defining problems or opportunities. Moving to the **design phase**, the researcher must be supported in creating, analyzing, and comparing the various alternatives. As part of the design phase, a review of the choices made concerning selecting the various alternatives could also be required. Proceeding to the **choice phase**, the best possible course of action is chosen and reviewed against the original problem and the environment. Once the choice has been made, the decision is applied in the **implementation phase**. In cases where the implementation is deemed a failure, a review of the actions can occur. A new alternative can then be chosen from the original set of alternatives, or it may be decided to revert to the intelligence or design phases depending on the review's outcome. Where the implementation of the decision is seen as a success, the reality of the researcher is influenced (either positively or negatively). This process not only propels the agricultural knowledge management operations of the SFL but also necessitates the provision of support and enabling mechanisms. A prime instance of such a mechanism is our smart AKM framework, which is explicated in Figure 10.

Smart Farming Lab as a Living Lab

As indicated above, our SFL is essentially an LL, which is the main concept encompassing and enabling the operations of the emergent farming community. In our design, we present a simplistic view of an LL based on the implementation of five conceptual factories (portrayed in Figure 7) that serve as catalysts for innovation and the creation of connections and brokerages (also see van der Walt et al., 2009). In essence, the five factories are:

Product Factory (PF) catalyzes innovation, creating beneficial solutions in several formats, such as tangible things, intangible services, or even intellectual creations. The fundamental objective here is to create artifacts to meet the needs and requirements of the CoP and the NoK. It serves as the collaborative space where practitioners and other experts work together to transform ideas based on problems into reality, with KOs serving as crucial outcomes.

Experience Factory (EF), where the knowledge, skills, and experience of CoP members influence the success of the LL activities. The EF provides a mechanism for capturing, reviewing, and managing past experiences facilitated by KOs and annotated by knowledge object wrappers (KOWs). Past experiences concerning the risks of prior projects and undertakings should also be analyzed and considered.

Network Factory (NF) functions as a pivotal force, facilitating the connection of individuals with the appropriate expertise and timing. The main objective of this factory is to create a dynamic platform that facilitates the participation, cooperation, and formation of virtual teams and brokerages among various stakeholders. The participants include researchers, practitioners, and policymakers. We also regard the NF as a vibrant marketplace where knowledge and experience are openly exchanged and encouraged.

Knowledge Factory (KF) operates as a hub of intellectual innovation, consistently generating fresh insights and enhancing established expertise. The main deliverable of the KF takes the form of KOs, in essence, encapsulating both tacit and explicit knowledge through semantic and other annotations (Buitendag & Hattingh, 2020). The KF is the main promotor and enabler of sound knowledge management practices, which are essential to realizing smart AKM. This process framework, presented further on, forms the main research contribution of this paper.

Services Factory (SF) serves as the imperceptible foundation, creating and delivering the vital services that sustain the operational efficiency of the SFL. The main delivery of the SF is tailor-made services in various forms to assist with the functioning and operations of the SFL.

In essence, the five factories collaborate to form a robust smart farming ecosystem that fosters invention, ignites relationships and brokerages, facilitates knowledge expansion, and enables the SFL to thrive as an entity.

Innovative Outputs Artifacts and Linkages

The deliverables and outputs of the SFL, shown in Figure 7, entail:

- innovations such as new farming methods and tools by the SFL for its community;
- knowledge artifacts such as KOs and other forms of networked knowledge necessitating the application of sound knowledge management practices;
- links to other entities and other organizations;
- methods and processes that include best practices and tailor-made solutions; and
- brokering and brokerages that enable the linkage of organizations and other entities to share and disseminate information, knowledge, and other resources in different forms, such as tools and solutions.

All of these also feed back into the SFL as new resources, benefiting the SFL CoP members.

Knowledge Objects as Enablers of "Knowledge Capturing"

The knowledge object (KO) concept is not new, as is evident in the work of Kulpaiboon (1993), Walczak (1998), and Merrill (2000). A knowledge object is described as a unit of knowledge that can be created, evaluated, accumulated, disseminated, synthesized, and prioritized (Alter, 2020). Flynn et al. (2018) see "KOs as information artifacts." In the context of the SFL, our notion that knowledge artifacts are one of the deliverables of the SFL is in line with the above-condensed description of Flynn et al. (2018).

This research focuses on digital knowledge objects (DKOs) semantically described by knowledge object wrappers. A DKO is described as an instrument for the contextualization and re-contextualization of knowledge to facilitate the provision of advice and aid in the learning processes of a computer or an individual (Flynn et al., 2016). Muukkonen et al. (2022) add that digital knowledge objects are "developing entities open for negotiation, revisions, and co-creation." Throughout the rest of this text, a DKO and a KO are considered equivalent, and the concepts are used interchangeably.

The next sections focus on the anatomy and composition of a DKO and the notion of capturing knowledge.

Anatomy of a DKO

Figure 9 shows our diagrammatic conceptualization of the basic form of a DKO based on the work of Flynn et al. (2016).

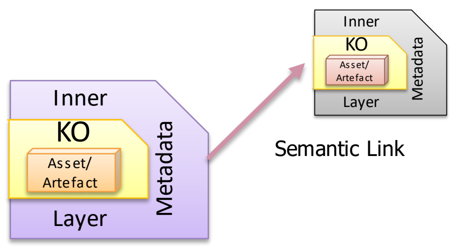


Figure 9. DKO in its most elementary form

Figure 9 depicts an elementary DKO. A DKO contains at least one asset, referred to by Flynn et al. (2016) as the knowledge core or payload, which could take on different forms (such as digital content, notes, and other LO-related artifacts) and an optional basic meta-data layer describing the object, knowledge asset, or artifact. Not included in Figure 9 is our notion that a KO may be described by several other types and more than one additional semantically enriched knowledge object wrapper (see Buitendag & Hattingh, 2020).

Enabling 'knowledge capturing'

Knowledge objects provide a structured format using metadata that assists with capturing complex information in the form of knowledge artifacts or assets that include facts, relationships, procedures, and even tacit knowledge. This structure facilitates effective knowledge storage, retrieval, and analysis, overcoming the limitations of unstructured forms like documents or narratives. Key concepts within knowledge objects can be enriched with semantic annotations using ontologies, taxonomies, and other related and applicable metadata. These annotations enhance knowledge discoverability and allow for automated reasoning and inference, enabling AI-powered applications to leverage captured knowledge effectively (Buitendag & Hattingh, 2020; Buitendag et al., 2013).

Smart Agricultural Knowledge Management Framework

This section focuses on the KM process and how it could be supported through our framework, which incorporates all the strengths of the various AKM models as evaluated, discussed, and characterized. The opportunities identified are harnessed, and the weaknesses or potential threats are limited to the greatest degree possible.

Figure 10 shows our proposed smart AKM framework, which guides the composition and operations of the SFL's knowledge factory (KF) and experience factory (EF).

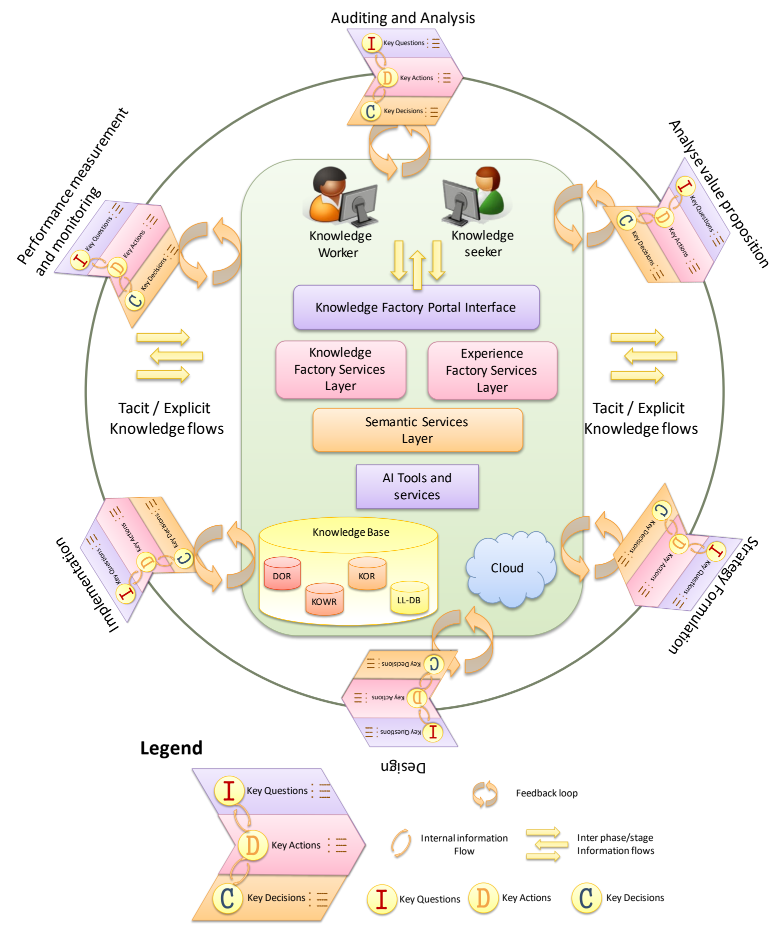


Figure 10. Smart AKM framework

The KF is responsible for rendering services and tools to facilitate the AKM practices of the SFL, whilst the EF is concerned with capturing and managing experiences and knowledge deployed in past processes. Figure 10 also depicts the notion that explicit and tacit knowledge are exchanged in each of the encapsulating generic process flow phases, which are discussed and contextualized below and in Table 3.

Cyclic Six-Phase Decision-Making Process

Cardinal to our KM framework is the encapsulating six-phase cyclic decision-making process indicated in the chevrons, which is rooted in the decision-making process presented by Simon (1977) and outlined in Figure 8. Each phase entails the decision-making processes, including the concepts of intelligence (I), design (D), and choice (C), which are guided by key questions, actions, and decisions. The phases leverage semantically enriched KOs to facilitate knowledge capture, analysis, and utilization.

We discuss this in detail in Table 3, but in brief, the phases encompass the following:

> ***Auditing and Analysis*** - The primary objective of this phase is to initiate the systems thinking process and align community members' understanding of the applicable domain, processes, and problems. It also concerns aligning the knowledge requirements with the problem and reaching a consensus among the members.
>
> ***Analyze the Value Proposition*** - This process involves comprehensively analyzing the applicable constituent (or component) within the larger value chain.

Strategy Formulation - During this phase, the aim is to formulate an appropriate strategy or set of strategies for the constituent (or component) to achieve specific goals, and tactics are formulated to address the knowledge requirements.

Design - In the context of the knowledge and service factory, design considerations may involve typical design science processes. Here, the applicable KO is designed through exploration and optimization of the knowledge content.

Implementation - In this phase, the developed artifact, such as a KO (or applicable constituent/component), is implemented within the given scenario and evaluated within the problem or knowledge request scenario.

Performance Measurement and Monitoring - This phase focuses on evaluating the artifact's performance and assessing how well the objectives have been met. The performance of the KO is also measured and monitored to understand its impact and value.

In Table 3, the discussion is focused on a KO and the applicable KOWs created and used in evaluating it. In this research, a KO and its associated meta-data wrappers are regarded as one resource or knowledge artifact.

Table 3. The smart AKM processes facilitated by the KF and EF

<table>
<tr><th>AKM KF Phase</th><th>Description of the phase with the KF operations to support AKM</th><th>IDCs</th><th>Decision-cycle aspects related to each phase</th></tr>
<tr><td rowspan="3">Auditing and analysis</td><td rowspan="3">This phase concerns the alignment of the knowledge requirements and the problem. The applicable members must reach a consensus regarding the knowledge requirements and a common understanding of the problem.
<table>
<tr><td>Internal process</td><td>Description</td></tr>
<tr><td>Internal information flow</td><td>⇆ Feedback and information regarding the problem and knowledge requirements. Information regarding the role players and workable solutions.
⇆ Information regarding the key decisions made and the solution's value proposition in the form of what knowledge is to be gained.</td></tr>
<tr><td>Inter phase/stage Information flows</td><td>⇆ Information regarding the potential KO and its foreseen benefits.
⇆ Information relating to the key decisions taken, including who is to be involved in obtaining the knowledge.
⇆ Feedback regarding the value proposition.</td></tr>
</table></td><td>I
Key Questions</td><td>• What is the problem?
• What are the knowledge requirements?
• Who are the role players?
• Who can be part of the solution?
• What drives/ causes the problem of presenting the knowledge requirement?</td></tr>
<tr><td>D
Key Actions</td><td>• Define the knowledge requirement.
• Create a common view and understanding.
• Define the role players.
• Identify the impact that the attainment of the knowledge would have on the value chain.
• Identify likely role players.
• Identify potential collaborative actions.
• Communicate the problem and knowledge requirement.</td></tr>
<tr><td>C
Key Decisions</td><td>• Who and what must be involved?
• What resources in the form of existing KOs are required?
• Which stakeholders to involve that could have a potential solution or have had similar experiences in the past?
• Where will the knowledge fit into the larger LL?</td></tr>
<tr><td rowspan="2">Analyze the value proposition</td><td rowspan="2">This phase is concerned with analyzing the applicable KO within the larger value chain. The relationship between the KO (that is, the knowledge to be obtained) and the larger LL is also evaluated against its potential value for the LL.</td><td>I
Key Questions</td><td>• Where will the KO fit in?
• What is its purpose?
• What will it cost to develop and maintain it?
• What value will be added to the LL?
• Whom would it benefit?</td></tr>
<tr><td>D
Key Actions</td><td>• Determine the potential value of the KO.
• Determine who would benefit from the existence of the KO.</td></tr>
</table>

AKM KF Phase	Description of the phase with the KF operations to support AKM	IDCs	Decision-cycle aspects related to each phase
	Internal process — Description Internal information flow: ⇆ Communication of the KO and value proposition and which decisions are to be taken. ⇆ Information relating to the role of the artifact. ⇆ Information regarding the potential value of the KO for the SFL. Inter phase/stage Information flows: ⇆ Position and role of the KO. ⇆ Feedback regarding the strategy that is to be followed.	C Key Decisions	• Is it worthwhile to have the KO? • What resources are required to produce the KO?
Strategy formulation	In this phase, the objective is to formulate an applicable strategy or set of strategies relating to the use of the KO to attain its objectives and to address the knowledge requirements at hand. Tactics and operational use could be based on previous experiences embedded in other KOs and KOW artifacts. Internal process — Description Internal information flow: ⇆ Information flow and communication on the strategies and tactics involved in attaining or creating the KO. ⇆ Information regarding members and other stakeholders to be included. Inter phase/stage Information flows: ⇆ Strategies to be followed. ⇆ Resources and processes required. ⇆ Design approach. ⇆ Feedback regarding the design approach and process.	I Key Questions	• How will the KO be utilized? • What are the goals of the KO? • How should the KO be developed, annotated, or improved to have a competitive edge? • Which resources should be applied? • What are the best design approaches and processes to follow?
		D Key Actions	• Examine existing KOs and knowledge sources and map the knowledge domain. • Involve and inform the domain experts and other members. • Expose and test the various assumptions regarding the knowledge to be generated. • Define the best strategy and approach to the KO development.
		C Key Decisions	• To which domains should the KO be mapped or modeled (that is, which agents should be linked and against which other existing patterns)? • Strategies and tactics to apply and the use of the correct previous knowledge and knowledge sources. • How will the project (artifact/ constituent) be managed? • What are the roles of collaborators and who should be involved?
Design	At this stage, the applicable KO is designed through exploration, followed by processes to optimize the knowledge content and to communicate the designed KO. The design of the KO at hand, the process followed, and its use need to be in a form that allows it to be easily communicated to other members. Internal process — Description Internal information flow: ⇆ Proposed core knowledge encapsulation of the artifact. ⇆ Design requirements and strategies. ⇆ Expert opinions and reviews on the KO and the encapsulated knowledge.	I Key Questions	• What are the main knowledge content requirements of the KO? • How could the KO be composed, and what content should be contained (constituent)? • Who will be involved in the provisioning of the various information and knowledge components of the KO? • What other meta-artifacts are required, and which available artifacts could be employed?
		D Key Actions	• Explore existing KOs and other knowledge artifacts. • Improve and optimize the impact of the KO knowledge. • Disseminate the KO. • Obtain feedback about the KO. • Evaluate the KO against similar objects and store feedback knowledge.

<table>
<tr><th>AKM KF Phase</th><th>Description of the phase with the KF operations to support AKM</th><th>IDCs</th><th>Decision-cycle aspects related to each phase</th></tr>
<tr><td></td><td>Inter phase/stage Information flows
⇆ Selected design approach.
⇆ Resources and processes required.
⇆ Feedback regarding the design approach and process.</td><td>C
Key Decisions</td><td>• Select the best composition and design of the KO.
• Which experts and other knowledge agents and resources to involve?</td></tr>
<tr><td rowspan="3">Implementation</td><td rowspan="3">At this stage, the developed artifact KO is implemented within the problem or knowledge request scenario. The KO is actualized and evaluated. The implementation also involves demonstrating how it addresses the knowledge requirement.

Internal process | Description
Internal information flow:
⇆ KO Implementation details.
⇆ Reflection and refinement details. Details about the KO deployment and role-players involved.
Inter phase/stage Information flows:
⇆ Implementation details.
⇆ Observations regarding the implementation.
⇆ Feedback relating to the evaluation and the performance of the artifact.
⇆ Suggestions for its improvement.</td><td>I
Key Questions</td><td>• How will the KO be implemented?
• When will it be deployed?
• Where will it be deployed?
• Who will be involved?
• What are the expected outcomes?
• How does the KO fit within the larger LL knowledge domain?</td></tr>
<tr><td>D
Key Actions</td><td>• Determine the best place for the KO demonstration.
• Implement/ demonstrate knowledge of the KO in use.
• Observe and reflect on the KO in action.</td></tr>
<tr><td>C
Key Decisions</td><td>• Where should the KO be deployed?
• What are the favorable variables?
• Who to involve?
• Could the KO be improved?
• Is the KO accepted by the NoK and the broader community?</td></tr>
<tr><td rowspan="3">Performance measurement and monitoring</td><td rowspan="3">The focus of this phase is on performance thinking. The value and impact of the KO must be understood and communicated. The installed, deployed, or demonstrated KO (or constituent) needs to be measured in terms of its performance and how well the objectives in terms of the original knowledge requirements are met. Experiences and the application of the KO need to be documented and communicated, as the KO is also tied to an applicable activity within the domain. Performance measurement and monitoring should be done with a short-term and long-term focus, where the latter refers to the impact that the KO had over time.

Internal process | Description
Internal information flow:
⇆ Metrics and KPIs.
⇆ Reflection on the implementation of the KO.
⇆ Details of the results of the KO implementation.
Inter phase/stage Information flows:
⇆ Metrics and KPIs.
⇆ Observations and results regarding the performance measurement.
⇆ Feedback relating to other processes (factories) and phases.
⇆ Recommendations for the improvement of the KO and processes followed.</td><td>I
Key Questions</td><td>• What are the applicable metrics? (What should be measured?)
• What are the key performance indicators (KPIs) (against what)?
• Does the KO contribute to the value?
• What value does the KO add?
• How does the KO impact the performance?
• How effective is the KO?
• How is the artifact (constituent)/ solution received by the community?
• How does the use of the artifact impact the resources?</td></tr>
<tr><td>D
Key Actions</td><td>• Define and establish set-up applicable metrics.
• Perform a cause-and-effect analysis with and without the KO.
• Measure the KO against existing or similar artifacts.
• Monitor and reflect on the KO in action.</td></tr>
<tr><td>C
Key Decisions</td><td>• Does the KO present a suitable container for the required knowledge?
• How does the use of the KO impact the resources?
• Could the KO be improved, based on the measurement?
• Is the KO accepted by the community?
• How could the KO be marketed?</td></tr>
</table>

The applicable KOWs are mutually independent of one another but could also be used as a collective set representing a knowledge object. As depicted in our framework, the KF and EF play a central role in the knowledge-creation cycle of the SFL. As the creation and development of a knowledge object (representing a knowledge artifact or asset) are the key deliverables in the case of a knowledge request, all the other factories also have their respective roles as part of the SFL.

Knowledge Seekers and Knowledge Workers

Central to the knowledge management process is knowledge workers (such as advisors or extension officers) and knowledge seekers, who are individuals or organizations (also see Figure 7). These knowledge workers and knowledge seekers need to acquire knowledge to solve problems or make informed decisions. In assisting them, our AKM framework emphasizes collaborative learning, shared responsibilities, and community participation.

Our framework recognizes that knowledge production and management are not one-way processes but involve a two-way interaction between knowledge producers (workers) and knowledge users (seekers). This means that knowledge seekers can also become knowledge producers, contributing their insights and experiences to the knowledge network. The framework facilitates knowledge management operations by promoting ongoing feedback (as indicated in each phase), adaptation, and interaction. It encourages using various tools, including traditional and ICTs and semantically enriched assets, to facilitate knowledge sharing and collaboration. By fostering a collaborative environment, the framework enables knowledge workers and seekers to form linkages, engage in meaningful interactions, exchange ideas, and co-create knowledge. Furthermore, the framework highlights the importance of knowledge transfer and knowledge exchange phases with inter-phase information flows that include tacit and explicit knowledge flows. It recognizes that knowledge users can also be knowledge producers, contributing to generating and applying new knowledge. We believe that sharing information and knowledge between phases will enhance knowledge management operations and leverage the insights of workers and seekers. By facilitating the exchange of knowledge and fostering a culture of continuous learning, the framework enhances the efficiency and effectiveness of knowledge management operations.

Knowledge Factory Portal Interface

Outlined are provisions for each of the stakeholders in the form of interfaces provisioned by the knowledge and experience factories. The KF portal interface provides a mechanism for all members to interact using direct or indirect communication through dedicated platforms such as apps or websites that are rendered as services. Internal ICT software and service provisions are also suggested for use, including semantically supported tools and other AI services. These are interfaced with several types of databases and repositories as required by the organization to, amongst others, also manage the organization's knowledge assets. It also allows access to knowledge from external sources such as the cloud and API services.

The KF services layer presents the various subsystems as a single set or embedded sets of tools to allow learning, knowledge interchange, and knowledge sharing in various formats utilizing KOs. These services are rendered, designed, hosted, and maintained as part of the service factory. The semantic layer provides the technical functionality and embedded process logic of the knowledge support service, which are enabled by applying KOs predominantly described using KOWs. The various envisaged operations of the KF are all rendered through the provision of a range of services and the utilization of a knowledge base. The knowledge base of the SFL comprises of a domain object repository, knowledge object repository, knowledge object wrapper repository, and the LL DB.

Knowledge Objects Storage and Data Management

We propose that the storage and management of data about each of these processes (and prior decisions taken) in the form of KOs, which are annotated semantically with KOWs, would lead to the inherent application of best practices as part of the EF. In particular, the KF supports AKM and knowledge engineering practices and encourages the utilization of services provided by both the KF and the EF.

The processes of socialization, externalization, combination, and internalization are all achieved by:

- feedback loops in each of the phases that necessitate dialogue and the application of various thinking processes, which include, as described, performance thinking, systems thinking, and realization thinking;
- exchanging knowledge with diverse practitioners through the review and use of different KOs and their associated assets;
- the creation of new KOs and KOWs and the semantic annotation thereof, which could entail the combination of existing KOs using KOWs (see Buitendag & Hattingh, 2020); and
- acquiring knowledge through research practices and knowledge gained from past experiences, and examining knowledge contained within KOs and described with different KOWs based on prior experiences and corporate memories.

STRENGTHS AND APPLICATION OF THE PROPOSED SMART AKM FRAMEWORK

One of the main strengths of our smart AKM framework is its emphasis on collaborative learning, shared responsibilities, and community participation, which can lead to improved knowledge productivity and innovation. Another strength of our framework is that it prioritizes the creation of sustainable knowledge networks, which is crucial for effective agricultural knowledge management.

In addition, our framework involves the mentioned six-phase cyclic decision-making process that aims to enhance and promote the common knowledge management practices of agricultural organizations and rural agricultural communities. These phases are auditing and analyzing the problem, analyzing the value proposition, formulating a strategy on how to proceed, designing the knowledge object, attempting to solve the problem by applying gained knowledge, and monitoring the outcome. Intrinsically embedded in this process is the use of feedback loops. Each of the phases proposed as part of the smart AKM is driven by questions, which are part of the analysis of operations to facilitate informed decision-making. This is highlighted in the decision-making cycle questions presented in Table 3. We believe that incorporating feedback loops in each phase is novel in our framework, which is driven by questions. The main role and purpose of using feedback loops in our proposed AKM framework is to enable continuous improvement and learning. Feedback loops allow for collecting and analyzing inputs from various stakeholders, including users, experts, and practitioners, to inform decision-making and enhance the effectiveness of KM processes.

We foresee the following benefits of the inclusion of feedback loops:

- *Continuous improvement of the KM process:* Feedback loops provide a mechanism for ongoing evaluation and refinement of knowledge management practices. By collecting feedback from users, stakeholders, and organizations included in the NoK and CoP, it will be possible to identify areas for improvement and make necessary adjustments to enhance the quality and relevance of knowledge resources.
- *Promoting a user-centric approach:* Feedback loops enable organizations to gather insights directly from users and other direct and indirect stakeholders, allowing them to understand their interrelated needs, preferences, and challenges. It also assists in tailoring knowledge management processes and resources to better meet the specific requirements of the target audience.
- *Ensuring quality:* Feedback loops help ensure knowledge resources' accuracy, reliability, and relevance. By collecting and analyzing feedback from users and experts as part of the CoP, organizations can identify and rectify any errors, gaps, or outdated information in their knowledge repositories, thereby improving the overall quality of knowledge assets.
- *Enhancing continuous innovation and adaptation:* Feedback loops facilitate the identification of emerging trends, best practices, and new knowledge. By actively seeking feedback from users

and stakeholders, organizations can stay updated with the latest developments in their field and incorporate new knowledge into their practices, fostering innovation and adaptation.

- *Promoting stakeholder engagement and collaboration:* By involving users and stakeholders in the feedback process, organizations can create a sense of ownership and foster a culture of participation and co-creation. This engagement has the potential to lead to increased buy-in, improved knowledge sharing, and stronger relationships among stakeholders.

In addition to the strengths highlighted above, our framework also emphasizes the integration of different knowledge sources, the importance of indigenous knowledge, knowledge co-creation, and the role of extension in a development or rural context. We believe that the frameworks' emphasis on using knowledge assets in the form of semantically described KOs holds the best potential of capturing not just indigenous knowledge but also corporate memories. Implementing annotated KOs provides a structured format for capturing complex information, including facts, relationships, procedures, and tacit knowledge. By enriching key concepts within KOs with semantic annotations using ontologies and other metadata, the discoverability of knowledge is enhanced. This enables automated reasoning and inference, allowing AI-powered applications to effectively leverage captured knowledge. The authors further elaborate on the application and use of KOs in previous research (see Buitendag & Hattingh, 2020).

Although we presented our AKM framework within an agricultural context, we believe it could be suitable for use in other KM contexts. Some examples of this could include the following:

- The healthcare and medical industry, where the framework can be used to integrate different sources of medical knowledge, including traditional and alternative medicine, to provide holistic and comprehensive healthcare solutions. It can also emphasize the importance of co-creating knowledge with patients and involving them in decision-making processes.
- The educational sector, where the framework can be applied to integrate diverse knowledge sources, including academic research, practical experience, and community knowledge, to enhance teaching and learning processes. In addition, the knowledge management of teacher peers and educational advisors can also be strengthened.

Overall, the AKM framework's principles of integrating knowledge sources, emphasizing indigenous knowledge, promoting co-creation, and considering the context can be adapted and applied in various other knowledge management contexts to enhance knowledge sharing, collaboration, and innovation.

FUTURE RESEARCH

There are several potential areas for further and future research based on the smart AKM framework, including the following:

- Further research could be conducted on the framework's effectiveness in promoting sustainable agricultural development, particularly in South Africa.
- The framework's applicability could be investigated if deployed in other sectors, such as education and healthcare. This research could involve case studies and evaluations of the framework in practice, as well as assessments of its impact on the implemented community, such as emergent farmers or healthcare workers in the agricultural or healthcare sectors, respectively.
- Research could be undertaken on using traditional and ICT tools in knowledge management practices in the agricultural sector. This could involve investigations into the most effective tools and methods for capturing, sharing, and utilizing knowledge, as well as assessments of the impact of these tools on agricultural productivity and sustainability.
- The role of community participation and collaboration in agricultural and or other domains of knowledge management could be researched. This could involve investigations into the

most effective methods for promoting community participation and collaboration, as well as assessments of the impact of these methods on knowledge productivity and innovation.

CONCLUSION

The dynamic nature of modern agriculture and the specific needs of emergent farmers in developing countries such as those in South Africa necessitate adaptable knowledge management systems and approaches. Therefore, this research was undertaken to develop a smart agricultural knowledge management framework to empower emergent farmers and extension officers.

The main proposition underlying this research is that both emergent farmers and extension officers need access to information and guidance on applying the provided knowledge and information in their real-world scenarios. This can be realized if they have access to knowledge regarding the correct know-how and know-what and by knowing who knows what (namely, knowledge of the community and other communities' knowledge). We believe that our framework provides guidelines to achieve this.

The main research question posed was stated as follows:

> *How can we strategically design a smart AKM framework that effectively integrates and harnesses the best practices and strengths from existing AKM models and frameworks, while also investigating the role and potential deployment of knowledge assets to support intelligent decision-making and knowledge support-related operations?*

This has been answered in the composition and description of our smart AKM framework as presented in Figure 10. We reiterate that the main goal for the proposed smart AKM framework is to establish strategies and create mechanisms to support the creation of linkages and to manage not only the tangible items but also the intangible items, such as the knowledge of the community within the SFL. The framework aims to encourage and stimulate mutual learning and dialogue and motivate real-time sustained actions, where results are monitored and evaluated based on their effectiveness.

Within SFL, KOs can facilitate the co-creation of new solutions by involving users and stakeholders. These knowledge objects can include data, information, tools, and resources that help users and stakeholders collaborate and generate innovative ideas. The KF in the SFL is the main generator and enabler of sound KM practices, which is essential to realizing smart AKM. The main deliverable of the KF takes the form of KOs, which encapsulate both tacit and explicit knowledge through semantic and other annotations. The KOs are enhanced with KOWs. The KOWs act as wrappers for knowledge assets and artifacts describing, amongst others, best practices, know-how, and know-how, enabling their seamless integration into the farming process while maintaining individual modularity. These modular KOWs can also dynamically aggregate to form larger knowledge objects, fostering co-creation and collaboration among the NoK members, further stimulating, nurturing, and enabling innovation and knowledge exchange.

By leveraging KOs, KOWs, and our smart AKM approach through the deployment of an SFL, emergent farming communities and their interrelated CoP can:

- *Effectively capture and codify best practices:* KOWs provide a structured approach to encapsulating best practices, facilitating their storage, retrieval, and reuse.
- *Foster collaborative knowledge creation:* The modularity of KOWs enables farmers to contribute individual expertise, leading to the collective construction of comprehensive knowledge objects.
- *Promote adaptation and continuous improvement:* Living labs are platforms for testing and refining best practices in real-world contexts, ensuring their ongoing relevance and efficacy.
- *Enhance competitiveness and resilience:* Effective knowledge sharing empowers farming organizations to adapt to changing market conditions and environmental challenges, fostering long-term success.

Integrating knowledge objects, living labs, and the KF/EF ecosystem offers an avenue for enhancing best practice sharing within the emergent farming sector. This framework empowers farming organizations to navigate the dynamic agricultural landscape by facilitating collaboration, adaptation, and continuous improvement.

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