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Towards a framework to implement a digital agriculture value chain in South Africa for small-scale farmers

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Background: Digital technology adopted in agriculture value chains (AVCs) improves efficiency. There is a need to understand why some actors benefit more than others in AVCs and why this pattern at a global level is replicated locally.

Objectives: To understand how existing frameworks can enhance the understanding of Digital for Development (D4D) associated with digital AVCs to achieve the following: Distribute power and economic value amongst actors in the AVC more equally; retain the identity of small-scale farmers and their sustainable practices; establish effective communication to confront asymmetric information and the lack of access to knowledge effectively; to enhance research, development and innovation.

Method: The method used is a Systematic Literature Review (SLR). Numerous frameworks to implement digital AVCs were assessed and presented. These were then compared and aligned to policies and strategies that may be associated with D4D in South Africa. Ultimately, a framework that lists the institutional information, digital services and Information and Communication Technology (ICT) design architecture was proposed.

Results: This article proposes a framework for the implementation of Provincial Agriculture Digital Innovation Hubs (PADIHs) and Extended District Agro-food Sustainable Knowledge Hubs (DASKHs). These institutions will support small-scale farmers to adopt digital technology in their AVCs.

Conclusion: When answering the research question, an alternate conceptualisation of a framework for digital AVCs adoption is made. This helps D4D practitioners and scholars who implement or research digital AVCs to better organise, conceptualise and conduct their research going forward. This research adds to the literature of D4D. It presents a better understanding of how small-scale farmers are empowered when adopting a digital AVC.

Keywords: digital development; framework; small-scale; farmers; agriculture value chains; institutions; innovation hubs.

Introduction

The United Nations (UN) 2030 Agenda sets out 17 Sustainable Development Goals (SDGs) (Sustainable Development Solutions Network [SDSN] 2015). Developing small-scale farmers can contribute to achieving at least three SDGs, which include, eradicating poverty (SDG1), decreasing hunger (SDG2) and assisting the sustainable production of food (SDG12) (Food and Agriculture Organisation of the United Nations [FAO] 2015). Agenda 2063 was adopted by the African Union to modernise agriculture for increased productivity by expanding irrigation, increasing mechanisation and developing weak agriculture value chains (AVCs). Coupled with expanded land use and infrastructure development will assist small-scale farmers to become commercial farmers (African Union Commission & African Union Development Agency 2020).

South Africa expects agriculture to create new jobs by 2030 using the National Development Plan (NDP). The plan advocates more usage of irrigated agriculture, cultivating land that is not fully utilised and making small-scale farmers' land-reform projects commercially viable (National Animal Health Forum [NAHF] 2017). Thus, the development of small-scale agriculture plays a major role in achieving the above objectives.

Efficiency within AVCs can be improved when digital technology is integrated with agriculture development (Heeks 2018). On the other hand, gains can be limited by the digital divide that is characterised by a lack of institutional capacity and not enough human development (Mago & Mago 2015). There is a need to understand why some actors benefit more than others in AVCs and why this pattern at a global level is replicated locally (Bukht & Heeks 2018). South Africa's National e-Strategy provides strategic direction to create an inclusive digital knowledge economy (Department of Telecommunication and Postal Services [DTPS] 2017), but digital policies have constraints to create inclusive innovation for vulnerable and marginalised small-scale farmers (FAO 2015).

Aim and problem statement

Policies to drive inclusive innovation and address inequality and social exclusion (Foster & Heeks 2015) need a participative approach to address unequal power relations and consider local contexts (Martin & Duncombe 2017). Implications and identification of positive and negative scenarios need to be explored (Stugeon 2017). This need for digital platforms to facilitate economic, political and social transformation is known as Digital for Development (D4D) (Heeks 2016).

The understanding of the complexity of D4D caused by different constituencies with different viewpoints can be addressed using a multidisciplinary approach (Jokonya 2016). There must be appropriate motivations to create value and governance structures that make stakeholders to balance openness and dominance amongst themselves (Constantinides, Henfridsson & Parker 2018). Collaboration must create digital policy for inclusion and sustainability, to prevent digital harm (Heeks 2018). Digital dividends must improve skills and hold the public sector accountable to deploy technology that empowers the poor (Deichmann & Mishra 2019).

The aim of this article, therefore, seeks to understand how existing frameworks can enhance the implementation of a digital AVC. Ultimately, it proposes a framework that can unmask strategies and policies to alter the underdevelopment in South Africa for small-scale farmers.

Research gap

Most literature on digital AVC frameworks focuses on benefits that are not self-evident and may be elusive to achieve. A broad framework is needed that firstly assists the participation of small-scale farmers in existing agri-tech spaces through responsible innovation. Secondly, it was investigated whether such a framework can create more socially responsible innovation processes (Rose & Chilvers 2018).

Despite several studies on digital AVCs, there remains a knowledge gap between nations and social groups (Heeks 2018). Evidence of huge transformative changes is mostly available in high-income countries with little focus on poorer countries. There must also be better protection and governance for the digital technologies that are fuelling this new economy to avoid favouring the rich over the poor (Graham 2019). The importance of understanding these constraints to growth in digital AVCs of South Africa and how to overcome them have not been explored. Critics argue that social implications have been ignored and question the suitability of existing frameworks for this complex phenomenon.

Considering the above, this study answers the question 'What are the components of a framework that can unmask strategies and policies to implement digital AVCs for small-scale farmers in South Africa?' The answer to this question presents a foundation for future research around the importance to facilitate innovation and training together with collaboration and participation.

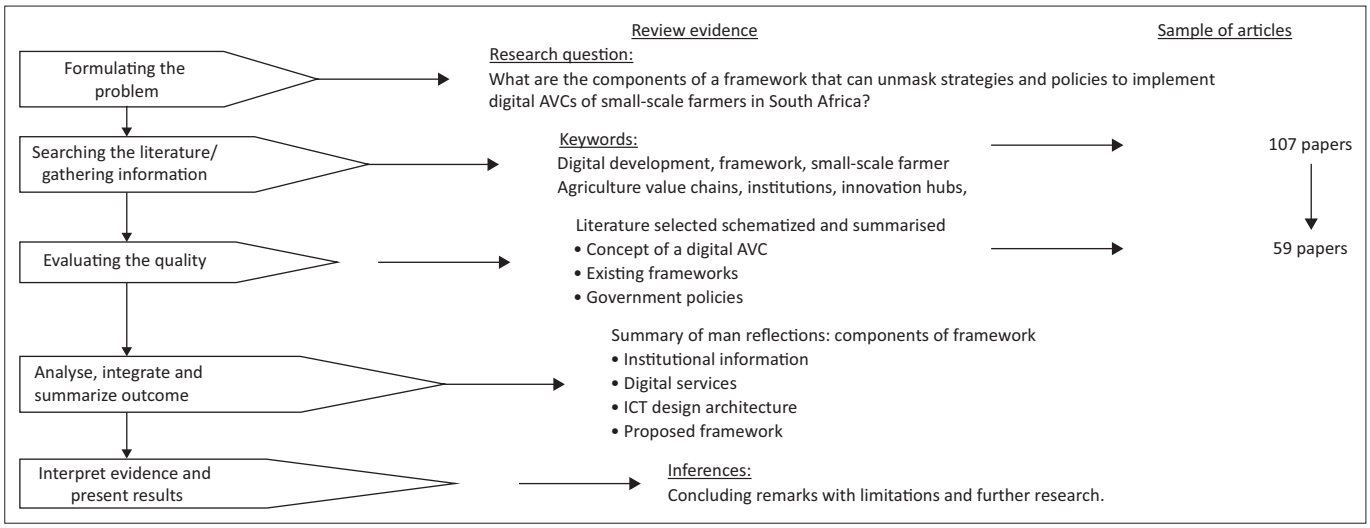
When answering the research question, an alternate conceptualisation of a framework for digital AVCs adoption is made. This helps D4D practitioners and scholars who implement or research digital AVCs to better organise, conceptualise and conduct their research going forward. This article adds to D4D research in helping to understand how farmers can be empowered to adopt digital technology.

The structure of this article starts with 'Research methodology' section describing Cooper's (2010) Systematic Literature Review (SLR) approach that is used as the research methodology for this study. 'Analysing, summarising, and integrating the outcomes' section analyses, integrates and summarises the outcomes around thematic areas. 'Towards a framework for the adoption of a digital agriculture value chain' section identifies the different components of the framework and presents a successful network of Provincial Agriculture Digital Innovation Hubs (PADIHs) and District Agro-food Sustainable Knowledge Hubs (DASKHs). 'Discussion' section argues the need for and importance of research, innovation, training and collaboration. 'Concluding remarks' section interprets the evidence and concludes by highlighting shortcomings and areas for further study.

Research methodology

A SLR is a necessity for any academic research project to first collect and analyse relevant literature. This forms a sound platform for producing new knowledge. Previously, published significant studies are identified, selected and appraised to also identify knowledge gaps for further research (Webster & Watson 2002).

This literature review interprets the relative research that answers the question after it has been identified and evaluated. Figure 1 presents the steps for this research according to Cooper (2010) that include: the problem to be formulated; databases being searched and information gathered from selected literature; evaluating the study's quality; the outcomes of the study are analysed and



Source: Cooper, H., 2010, *Research synthesis and meta-analysis: A step-by-step approach,* 5th edn., Sage
AVC, Agriculture value chain; ICT, Information and Communication Technology.

FIGURE 1: Adoption of the systematic literature review.

integrated; finally presenting the results after the evidence are interpreted.

Formulating the problem

This article aims to develop a conceptual developmental framework to facilitate digital technology adoption by small-scale farmers in AVCs. To answer the proposed research question 'What are the components of a framework that can unmask strategies and policies to implement digital AVCs for small-scale farmers in South Africa?' in this study, the SLR approach was adopted.

All the features and elements of the digital AVCs implementation concept are embraced by this research. It tries to understand the challenges of developing such a framework that can assist researchers and practitioners to address these challenges.

Searching the literature

The keywords that defined the topic were not all precise. Thus, using traditional and electronic library systems, the titles, abstracts and documents of academic and industrial journals were reviewed and sorted. Related publications are still scattered as digital AVCs are a phenomenon that has emerged recently. The most dominant procedure to identify the most appropriate literature today is to review databases online rather than going through collections in libraries. Online databases accessed were Science Direct (Elsevier), JSTOR, Google Scholar, Nexus (NRF), Scopus and Wiley Online Library.

The keywords developed gradually during the extensive reading were not predetermined before the search. To obtain systematic and exhaustive results, attempts were made using other more specific search strategies. The following search strategies used for searching databases included 'Boolean Logic', 'Parenthesis', 'Phrase Searching', 'Truncation' and 'Field searching'. The following criteria were applied in the search and selection of papers:

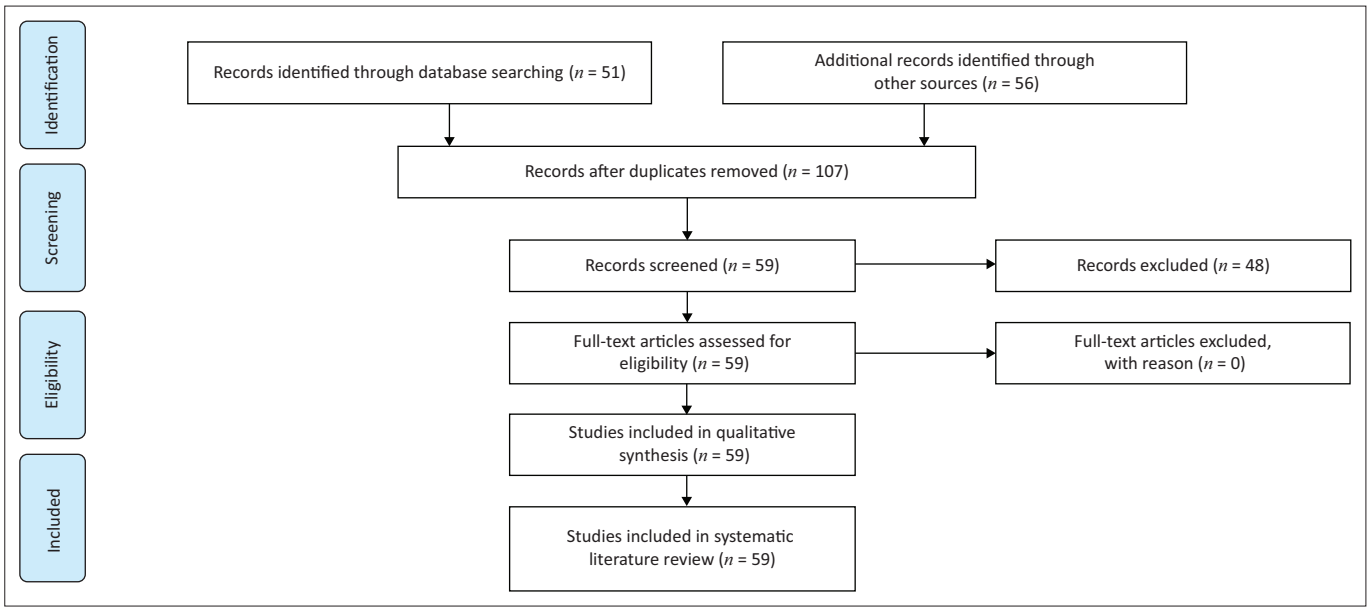
- 'Digital development' AND 'Small-scale farmer' OR 'Agriculture value chains'.
- 'Framework' AND 'Digital development' OR 'Agriculture value chains'.
- 'Institutions' AND 'innovation hubs' OR 'digital development'.
- 'Institutions' AND 'Digital development' OR 'framework'.
- 'Agriculture value chains' AND 'institutions' OR 'Small-scale farmer'.
- 'Digital development' AND 'framework' OR 'institutions'.
- 'Small-scale farmer' AND 'Digital development' OR 'framework'.

By searching online databases, 51 papers were identified and 56 through other sources, which gave a number 107 papers identified. Additional papers were identified. Only 59 papers out of 107 identified by the SLR were relevant for analysis.

The Prisma flow diagram in Figure 2 shows the decisions that were made after scrutinising the published abstracts and titles. The papers identified different viewpoints and addressed several elements related to the study. A research question that addressed the challenges was specified before beginning the review work. The review question was used as a direct input when formulating the study selection criteria. Grey literature was included, as there were a limited number of relevant peer-reviewed articles.

Summarising and evaluating the quality of studies

Literature was next evaluated, and the main reflections were summarised under the following thematic areas: the concept of a digital AVC, existing frameworks and government policies. The literature review further provides a summary of the components of such a framework such as the institutional information, digital services required and the



Source: Moher, D., Liberati, A., Tetzlaff, J. & Altman, D.G., 2009, 'Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement', *PLoS Medicine* 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

FIGURE 2: Prisma flow diagram illustrating the decisions made.

Information and Communication Technology (ICT) design architecture. Thus, this review identified what is trending in the literature about frameworks used for implementing digital AVCs.

When summarising the main reflections, many challenges are experienced to adequately ensure that articles are investigated subjectively, objectively and methodically. An exception was made for industry publications because of the small number researched. This SLR ensures objectivity as it follows an organised approach with structured procedures. The formal steps recommended for an SLR by Cooper (2010) ensured validity, whilst reliability is addressed by following all the formal processes.

Analysing, summarising and integrating the outcomes

This section analyses, integrates and summarises the outcomes of studies in the key thematic areas. This includes the concept of a digital AVC, determining its importance to the development of small-scale farmers and an overview of existing policies to be considered.

The concept of a digital agriculture value chain

To explore new opportunities for digital transformation in a business, Sealey (2018) suggests Porter's value chain as a framework to separate business activities across primary and supporting activities. Primary activities are those that relate to the production, marketing and sales of a product, whilst support activities are there to support the primary activities (Sealey 2018). An AVC takes raw materials and resources through a sequence of steps that convert them into marketable products. Thus, it brings produce from production to final consumption by several actors using certain activities that add value to the product at each stage (African Development Bank Group 2013).

To adopt a digital AVC, the power and use of information systems are used as a strategic value-adding decision-making tool. This is more than the simple technological support activity initially defined by Michael Porter's value chain (Sealey 2018). It is important to understand the role of data, information, knowledge and wisdom in value chains. Digital transformation is an internal process that allows organisations to transform data into wisdom (Ribeiro 2021).

The digital economy provides digital-driven solutions to numerous agricultural challenges and unlocks opportunities to meet agricultural goals (Stugeon 2017; Ungerer et al. 2018). Digital innovation can improve agricultural production, transport and storage where digital-enabled marketing increases intra-company efficiency and competitiveness (Corallo, Latino & Menegoli 2018; Krone & Dannenberg 2018). Agriculture value chains need to include information systems strategies as a core activity to transform real-time data to wisdom, so as to rapidly optimise their market value (Ribeiro 2021).

Digital technology can lead to vertical integration which is the combination of two or more stages of production and/or distribution that are usually separate. The numerous considerations or benefits lead to enhanced innovation (Amadeo & Rasur 2022). Figure 3 represents a digital AVC vertical integration and the available digital technology.

A vertically integrated business model creates a legacy of long-term sustainable value for all stakeholders to participate in more segments of the value chain giving customers, communities and shareholders more benefits. Through vertical integration, stakeholders establish own suppliers,

Farmer's suppliers (input supply industry)	Farmers/producers	Processing post-harvest and storage	Distribution and retail	Consumer
		Technology service providers		
		AI and IoT big data collection and analysis	E-business	
	GNSS precision agriculture		Blockchain traceability	
	Smart farming and Smart irrigation			
		ICT digitalised communication (broadband)		
		Robotics automation		
		Blockchain smart contracts		

Source: Pesce, M., Kirova, M., Soma, K., Bogaardt, M.-J., Poppe, K., Thurston, C. et al., 2019, *Research for AGRI Committee – Impacts of the digital economy on the food-chain and the CAP,* European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

GNSS, Global Navigation Satellite Systems; ICT, Information and Communication Technology.

FIGURE 3: Digital agriculture value chain vertical integration and available technology.

manufacturers or distributors rather than outsource them (Odeyale 2007).

Commercial AVCs are critical for assisting to alleviate poverty in developing countries (International Telecommunications Union [ITU] 2016). Digital technologies make agriculture knowledge-intensive and provide new ways of extension services tailored to local conditions (Deichmann, Goyal & Mishra 2016; NAHF 2017). Agriculture value chains must also comply with food traceability rules. Digital systems store data related to the processing of food to contain safety challenges and enhance marketing (Corallo et al. 2018; FAO & ITU 2016).

The importance of a digital agriculture value chain for small-scale farmers in South Africa

Information about digital AVCs is not reaching smallholder farms in South Africa and this leads them to having a lack of knowledge about the subject (Department of Agriculture, Forestry and Fisheries [DAFF] 2016; Heeks 2018; SDSN 2015). Digital AVCs create opportunities that can assist to address the lack of economies of scale, access to land, credit and technology (Malan 2018). Digital technologies fill the information gap in AVCs as an enabler of trade, standards, traceability and integrity (Organisation for Economic Co-operation and Development 2019).

Government often fails to understand the reforms needed to overcome development constraints (Graham 2019; Juma 2019). Digital AVCs to improve agricultural production and promote food security should be promoted by the government (Mago & Mago 2015) by providing comprehensive support to small-scale farmers (NAHF 2017). Agricultural advisory services should be re-orientated and re-equipped with better knowledge and technologies. Thus, the following section looks at existing digital AVC frameworks.

Existing frameworks for adopting a digital agriculture value chain

Existing frameworks assist to adopt digital AVC platforms that can be used to build powerful innovation ecosystems with governance rules so that platform members create usefulness for each other (Constantinides et al. 2018). Related to this are frameworks for intentional digital AVCs adoption to enhance the livelihoods of small-scale farmers (GSMA 2018). Thus, some of the frameworks from existing literature that can assist in constructing such a framework will be briefly discussed in this section.

E-agriculture framework in Kenya

The e-agriculture framework proposed by Awuor et al. (2016) covers a single point of access for digital adoption. It discourages middlemen and argues that all stakeholders formulate the model. The modules comprise a data centre, machine learning and information retrieval. Data collected are hosted, structured, stored and processed by a data centre.

Machine algorithms extract information that is relevant to a farmer from various sources to enrich the data centre and an information retrieval module retrieves data from the data centre. The framework governance structure includes a management layer, data layer that develops and maintains a data centre, whilst the information access layer meets information needs (Awuor et al. 2016).

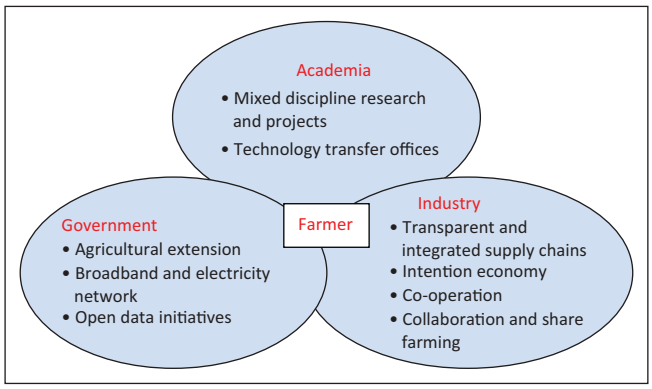
Digital innovation hubs

Digital Innovation Hubs (DIHs) use digital platforms to catalyse the innovation process by bringing research and practice closer together. Through a network of DIHs and competence centres (European Innovation Partnership-Agricultural Productivity and Sustainability [EIP-AGRI] 2017). This aligns with the diffusion of innovations (DOI) paradigm that has a set of concepts to explain how individuals and organisations adopt new digital technology policies and practices. Diffusion of innovation principles can be used to accelerate the rate of adoption and broaden the reach of digital innovations (Dearing & Cox 2018).

Digital Innovation Hubs serve companies and start-up entrepreneurs to develop their businesses using digital technologies. Competence centres are the core element of the operations and provide technical expertise, facilities and infrastructure. Different forms of support are available at conception, development and production. Digital Innovation Hubs show a clear, practical and 'hands-on' approach (EIP-AGRI 2017). Figure 4 shows that DIHs are not technology-centred but farmer-centred with a sound business model.

The Agro-Food Sustainability Knowledge Hub model

The Agro-Food Sustainability Knowledge Hub (Agro-Food) model is based on the concepts of sustainable supply chain



Source: European Innovation Partnership 'Agricultural Productivity and Sustainability (EIP-AGRI), 2017, *Seminar digital innovation hubs for agriculture*, Final report October 2017, European Commission

FIGURE 4: Digital innovation hubs.

management (SSCM) and corporate social responsibility (CSR) (Manikas, Malindretos & Moschuris 2019). This is aligned with Carroll's CSR pyramid driven by globalisation, institutionalisation, reconciliation with profitability and academic proliferation (Carroll 2016). It enables small and medium enterprises (SMEs) to develop sustainably within established AVCs. These strategic, operational and institutional approaches create opportunities amongst agricultural SMEs to distribute and create value using alternative sustainable channels (Manikas et al. 2019). The four types of responsibilities of Carroll's CSR pyramid include: being profitable; obeying laws and regulations; being ethically responsible; plus being a good corporate citizen that supports philanthropic causes (Carroll 2016).

A community approach links small farms, agri-food SMEs with the globalised urban market. Value addition, distribution and consumption are integrated. This strengthens existence or develops new relationships that enhance a specific region in terms of the environment, economy and society (Manikas et al. 2019). The vertical integration business model encompasses the entire value chain of the agricultural commodity business. Through scale, integration and the logistical advantages of the business model, margins are extracted at every step of the value chain (Amadeo & Rasur 2022).

The Agro-Food hub considers a hierarchy of horizontally integrated communities with a local, regional, national or global reach. A regional community is built on farms within a region, or several local communities or a combination of both. Similarly, a national community is built on regional communities, local communities, individual farms or any combination. Cooperatives are an example of a local or regional community. Farmers' associations or sectoral industries are examples of country-wide communities. Fair trade is an example of a global-level organisation (Manikas et al. 2019).

Digital adoption expands this model into the e-community concept that integrates rural business entities with urban-based small businesses (Manikas et al. 2019). Thus, the model integrates Carroll's pyramid of CSR that focuses on sustainable development within the framework of social responsibility and vertical integration to support economies of scale in logistics and marketing functions.

The above frameworks can assist in the development of a framework to adopt a digital AVC; however, it is important to understand government policy in South Africa that can influence the design. This is to avoid duplication of the structure while promoting trust amongst farmers and society. Thus, policies that can influence the adoption of this framework are investigated in the following section.

National policies that influence the adoption of a digital agriculture value chain in South Africa for small-scale farmers

The New Growth Path (NGP) identified AVCs as drivers for economic growth, and based on this analysis, the Agricultural Policy Action Plan (APAP) outlines appropriate responses. Agricultural Policy Action Plan aligns NGP, the NDP and the National Industrial Policy Framework to translate high-level responses into tangible and concrete steps (DAFF 2016). The NDP argues that agriculture and agri-processing can transform the South African economy and propose a multifaceted approach for agricultural development. The NDP suggests increasing exports and focusing on regional economic integration (NAHF 2017). To achieve this, the government must provide comprehensive support to farmers.

The 2018 Policy on Comprehensive Producer Development Support (PCPDS) guides and regulates the provision of support services to producers. The policy clarifies the roles and responsibilities of institutions that provide efficient and effective extension and advisory services, through participatory approaches (DAFF 2018).

As digital technology innovations are integrated with farming, it is important to know the development need of small-scale farmers and understand how to engage locally (Agri-Symposium 2019). The NDP proposes a network of innovation hubs located in a district municipality to increase investment in new agricultural technologies and research (Department of Rural Development and Land Reform 2015). Agricultural technologies must be cost-effective and assist in the minimisation of post-harvest losses (DAFF 2018).

The Department of Telecommunications' iKamva National E-Skills Institute (iNeSI) Bill (Government Gazette, Vol. 629, November 8, 2017, No. 41233) partners with stakeholders to develop future digital skills. The bill establishes iNeSI and collaborative laboratories for knowledge production, training and coordination (Ungerer et al. 2018). Government should cooperate with tertiary institutions and support strategic initiatives that develop digital skills and capabilities to accelerate growth in agriculture-economic outputs. To achieve this, the country needs to reflect, implement and measure what has worked. Information sharing poses

opportunities to better respond to critical issues affecting the sector. In the following section, a framework for digital adoption in AVCs is defined and proposed.

Towards a framework for the adoption of a digital agriculture value chain

Technology adoption in agriculture is a new phenomenon, thus, it is important to define the right institutions that exist or need to be created. Important actors, institutions and technology infrastructure that can enhance collaboration and participation must be identified to prevent duplication of effort. Firstly, the following subsection identifies the institutions that exist or needs to be created. Secondly, it looks at digital services that can be offered to small-scale farmers. Lastly, it describes the ICT design architecture needed to deliver these services.

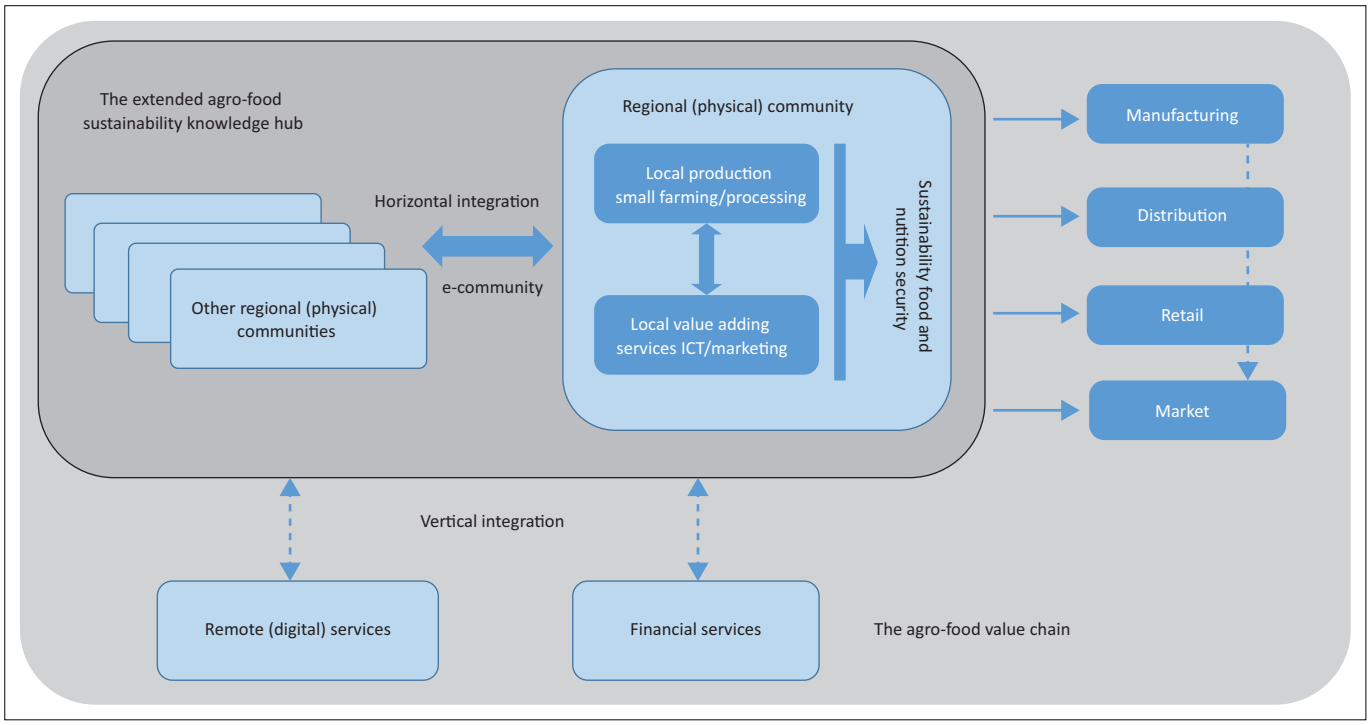
Institutional information

Institutional theory enables an alternative analysis of the forms and design of organisations in all sectors. It describes organisations as local instantiations of wider institutions that comply with institutionalised prescriptions to gain legitimacy. This decreases uncertainty and increases the intelligibility of an organisation's actions and activities (Berthod 2016). Institutional theory is about the stability and change of institutions to attain a stable and durable state (Sæbø 2017).

Institutionalisation is evolutionary, and in the beginning, it is determined by existing organisational structure and modalities of operation (Anandajayasekeram 2011). Peters (2000) argues against institutional explanations that are generally static and the difficulties of measuring institutional variables as simplistic nominal categories. He proposes that it should be a continuous variable to better understand the dynamics and develop better institutional explanations for social and political phenomena.

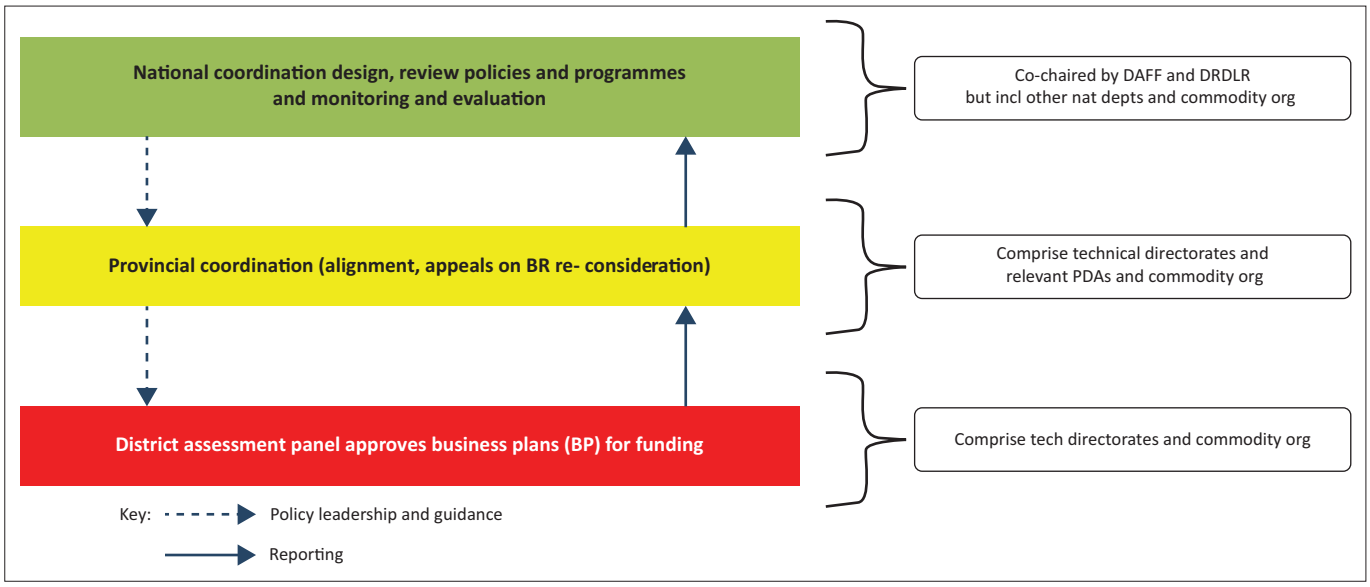
Institutionalisation for this framework is aligned to the District-Centred Development (DCD) model adopted by the South African government. The model secures maximum coordination and cooperation amongst the national, provincial and district spheres of government. It acts in partnership with civil society at the district level to fast-track service delivery (Department of Monitoring and Evaluation [DPME] 2019). The institutional mechanism for implementing the Comprehensive Producer Development Support (PCPDS), shown in Figure 6, is aligned with the DCD Model. The PCPDS strengthens institutional mechanisms, standardises producer categories and mainstreams the participation of vulnerable groups. It consists of a national coordination unit, provincial coordination units and district assessment panels.

For institutionalisation, the systems' approach together with participatory processes is emphasised. This is undertaken in two phases, a preparatory phase and an institutionalisation phase (Anandajayasekeram 2011). Development strategies, community participation and collaboration can be used to gain the trust of small-scale farmers. Farmers must be part of the design and development of technology solutions (Bayer 2018). The DCD model strengthens participation and places communities at the heart of service delivery to ensure



Source: Manikas, I.G., Malindretos, G. & Moschuris, S., 2019, 'A community-based agro-food hub model for sustainable farming', *Sustainability* 11(4), 1017. https://doi.org/10.3390/su11041017

FIGURE 5: A community-based Agro-Food Knowledge Hub.



Source: Department of Agriculture, Forestry and Fisheries (DAFF), 2018, *Policy on Comprehensive Producer Development Support (PCPDS): Draft 5 ver. 3*, 30 May 2018, Department of Agriculture, Forestry and Fisheries, Pretoria

DAFF, Department of Agriculture, Forestry and Fisheries; DRDLR, Department of Rural Development and Land Reform.

FIGURE 6: Institutional mechanism for implementing the Policy on Comprehensive Producer Development Support.

that development meets the needs of local stakeholders (DPME 2019).

In South Africa, iNeSI forms partnerships that maximise impact, avoid duplication and maximise the use of infrastructure and resources. iNeSI identifies digital gaps across industry, populations and geography through research. Figure 7 shows a schematic representation of iNeSI Provincial CoLabs that leads thematic areas and aligns digital skills interventions with national and developmental priorities (iNeSI 2018).

The iNeSI distributive model has a physical presence in each of the nine provinces to engage in digital skills (iNeSI 2018). Collaboration with DIHs can assist small-scale farmers to see the real added value of technologies, help decide which ones to invest in, when to invest and to what extent (EIP-AGRI 2017). A tailored approach based on an assessment of farmers' resources and capabilities is to identify the support needed to convince small-scale to adopt technologies (Campion 2018).

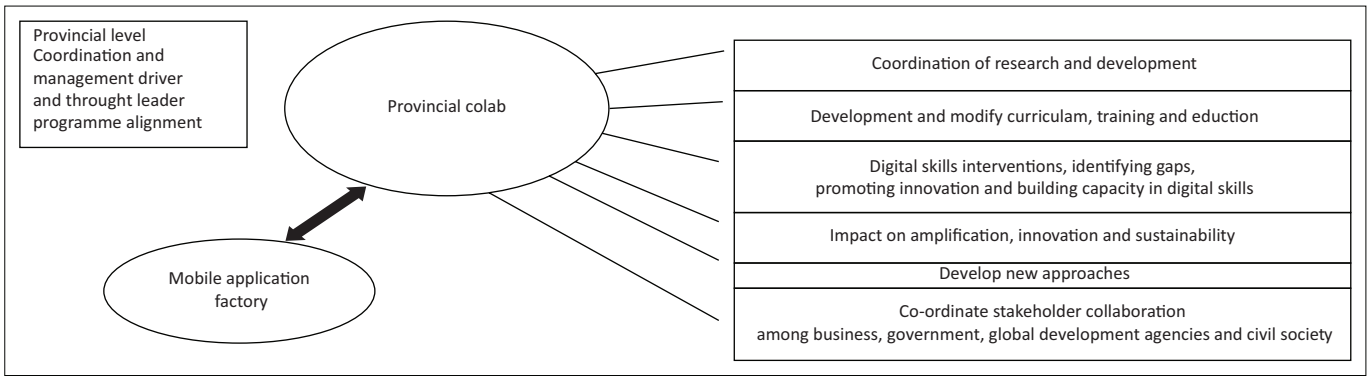
Thus, this article proposes the creation of PADIHs that will collaborate with iNeSI Colabs on a provincial level. Using the DOI principles, competence centres of PADIHs provide access to infrastructure and technology platforms. This supports innovation through experimentation, fabrication of new products and demonstrates best practices by technologies (EIP-AGRI 2017).

Rural poverty, agricultural production and environmental protection are all intertwined concerns for international development. To manage the inter-relationships and interdependencies that contribute to this complexity, sustainable natural resource use and poverty reduction need to be promoted (Campion 2018). We can achieve this by using Carroll's pyramid of CSR together with the DCD model to maximise impact by crowding in public, private and not-for-profit investments to a district. It further ensures that urban and rural development complements each other, with an emphasis on local economic development and sustainability (DPME 2019).

Using vertical integration to create alternative sustainable channels of distribution, the Agro-Food Hub (see Figure 7) creates opportunities for potential synergies amongst agricultural SMEs with functions such as logistics, marketing, training, trading and innovation. Farmers can mitigate warehousing, transport and infrastructure logistics costs consolidating them through economies of scale (Manikas et al. 2019).

The DDM prioritises local procurement of services and goods to develop, support and promote local entrepreneurs and create an enabling environment for economic development (DPME 2019). As shown in Figure 8, the Agro-Food Hub acts as a knowledge broker, building long-term relationships amongst AVC actors. This leads to competitiveness, sustainability and responsibility amongst stakeholders (Manikas et al. 2019).

District Agro-food Sustainable Knowledge Hubs promote grassroots innovation amongst SMEs when adopting digital technology. Power is shared between stakeholders using 'distributive justice' (distribution of value along the AVC) and 'procedural justice' (management of processes and relationships). To achieve supply chain 'justice', DASKHs unlock the full potential of SMEs by facilitating for them to participate in making decisions (Manikas et al. 2019). District Agro-food Sustainable Knowledge Hub thus aligns with Carroll's CSR pyramid four types of responsibilities of being profitable economically, obeying laws and regulations, being ethically responsible and doing what is just and fair to avoid harm.



Source: iNeSI (Ikamva National eSkills Institute), 2018, *Ikamva National eSkills Institute Bill (As introduced in the National Assembly (proposed section 75)*, Government Gazette No. 41581 of 20 April 2018, Department of Telecommunication and Postal Services, viewed from https://www.inesi.org.za/pages/collaborative-network.php

FIGURE 7: Provincial knowledge production and coordination Colab.

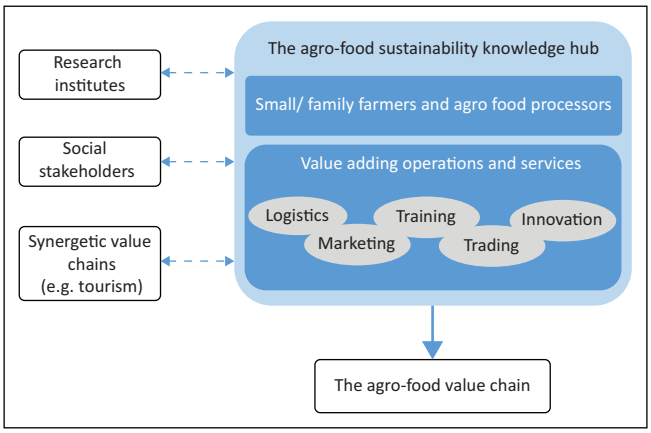
Provincial Agriculture Digital Innovation Hubs network with DASKHs at a district level in the AVC to develop an innovation ecosystem and support SME agri-businesses in their digital transformation. Thus, the institutional framework is aligned with the principles of DOI, vertical integration and Carroll's CSR pyramid. It supports the DCD model and PCPDS in collaboration with the iNeSI.

Bencherki (2017) describes the concept of Actor-Network Theory as a multitude of people and things and suggests that for an actor to act, many others must act. We need to understand the electronic and digital constructs that are social as the awareness of connectivity raises a deep sense of ambiguity (Lezaun 2017). Actor-Network analysis can be used across the agriculture discipline to examine how political actors or institutions are interrelated by analysing the connections across individuals, groups and institutions (Elder-Vass 2019).

Figure 9 represents the institutional arrangements of such a framework. The management layer is formed by PADIHs and DASKHs. The foundation layers are representatives of national and provincial stakeholders such as farmers, industry associations, NGOs, investors, banks, development agencies, women, youth, SMEs, start-ups, incubators, research institutes plus SOEs and extension services (Manikas et al. 2019).

District Agro-food Sustainable Knowledge Hubs provide a strategic collaborative network that involves producers, transport carriers, wholesalers, retailers and even consumers. These also network between AVC partners and other sectors such as tourism and research institutions. District Agro-food Sustainable Knowledge Hubs transform challenges into new opportunities by developing farmers' sustainability through innovative thinking value creation networks (Manikas et al. 2019).

After proposing an institutional framework and identifying the roles of different stakeholders, the digital services needed to be developed for small-scale farmers are suggested in the following subsection.



Source: Manikas, I.G., Malindretos, G. & Moschuris, S., 2019, 'A community-based agro-food hub model for sustainable farming', *Sustainability* 11(4), 1017. https://doi.org/10.3390/su11041017

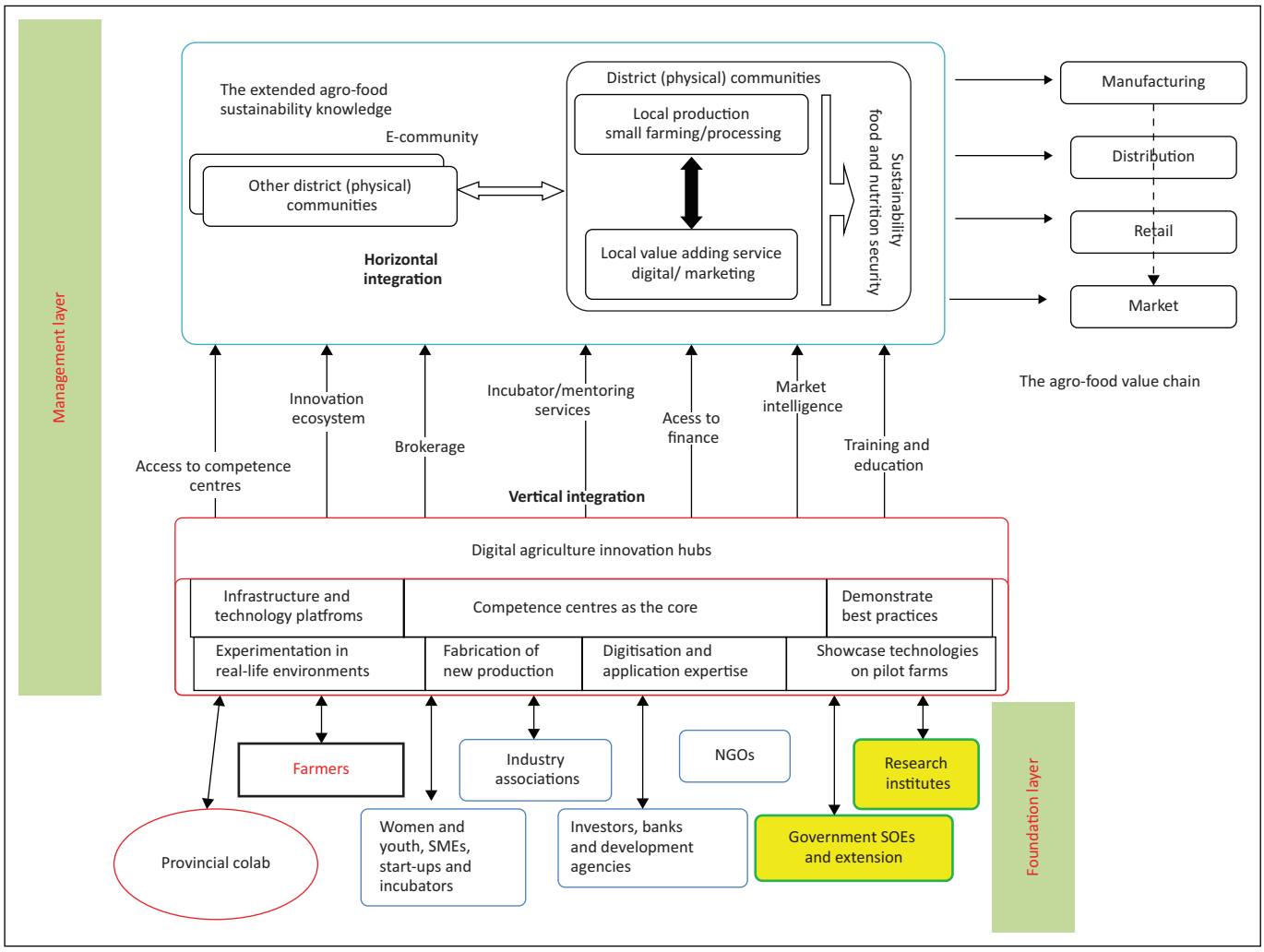
FIGURE 8: A holistic integrated Agro-Food Sustainability Knowledge Hub.

Digital services suggested developing small-scale farmers

A new agriculture revolution is being unleashed by digital tools that improve communications across AVCs (Campion 2018). A digital platform enables value to be created through various interactions between actors in an AVC (Constantinides et al. 2018). We use farming data to plan, monitor and assess events so that we can better manage, intervene, optimise and forecast. Tracking and tracing data are also used to negotiate better market access (Maru et al. 2018).

Figure 10 gives a representation of the different digital facilitated and digital-driven services within the agriculture sector. Technologies are used to create digital marketplaces for market information and scalable payment systems (FAO & ITU 2016).

Digital platforms automate a variety of management functions to reduce transaction costs and facilitate the flow of knowledge, resources and finance to agribusinesses across the AVC (Campion 2018). Traceability and tracking of agro-chemical movement through AVCs and electronic pest surveillance systems are linked to Good Agriculture Practices (GAP) (FAO & ITU 2016). The services identified above need to be supported by an ICT design architecture that is described in the following subsection.



Source: Adapted from Manikas, I.G., Malindretos, G. & Moschuris, S., 2019, 'A community-based agro-food hub model for sustainable farming', *Sustainability* 11(4), 1017. https://doi.org/10.3390/su11041017, iNeSI (Ikamva National eSkills Institute), 2018, Ikamva National eSkills Institute Bill (As introduced in the National Assembly (proposed section 75), Government Gazette No. 41581 of 20 April 2018, Department of Telecommunication and Postal Services, viewed from https://www.inesi.org.za/pages/collaborative-network.php. and European Innovation Partnership 'Agricultural Productivity and Sustainability (EIP-AGRI), 2017, Seminar digital innovation hubs for agriculture, Final report October 2017, European Commission

FIGURE 9: Institutional arrangement for a digital agriculture value chain.

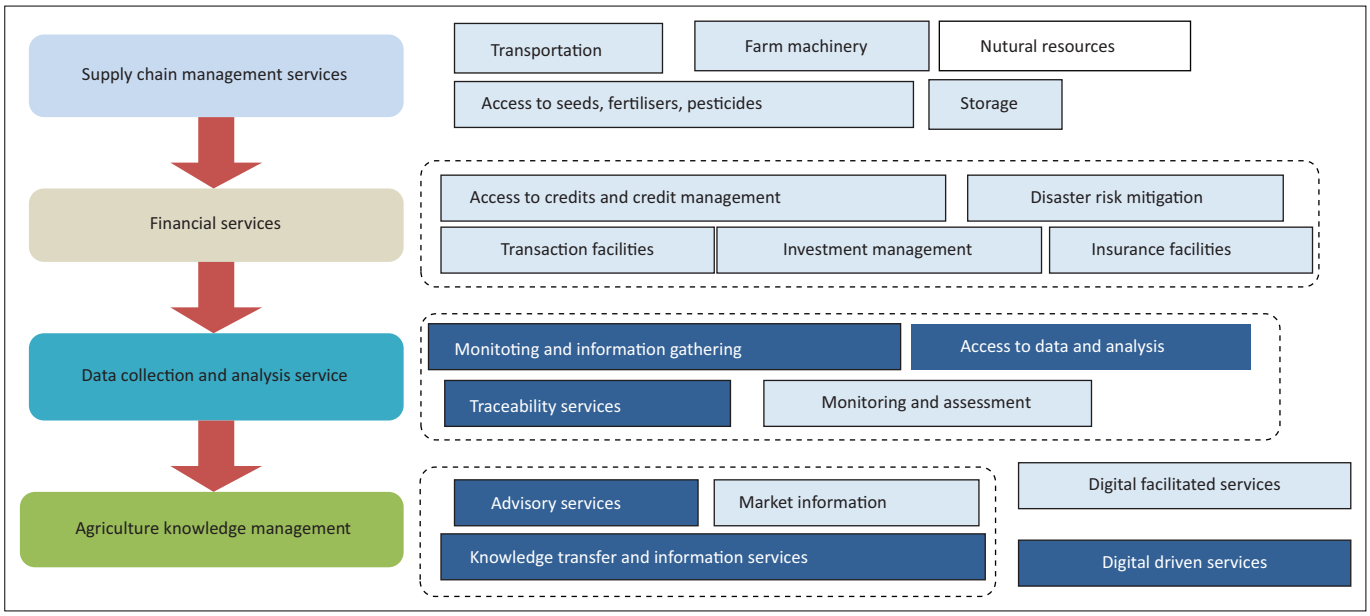
ICT design architecture

According to Baker (2011), the Technological Organisation Environment (TOE) framework has broad applicability and can explain technological innovations across several, industrial, national and cultural contexts. The TOE has shown that technology adoption is affected by technological, organisational and environmental factors. Thus, the debate on whether technology shapes society or society shapes technology fails to give a comprehensive view of technological change and the major forces driving it (Salazar & Holbrook 2008). If new technologies are developed, the TOE framework is used for empirical research to understand the adoption of innovation in organisations and also for inter-organisational adoption (Baker 2011).

The challenge is that institutional theory has traditionally been concerned with stability, whilst technologies are often associated with rapid and sometimes disruptive societal and organisational changes. We need to understand these phenomena that are not so well explained by economic-rationalist models (Sæbø 2017). Thus, ADMIT (Architecture Design [or Development] Methodology for Information Technology) can be used as a decision-making tool for systematically developing a robust architecture using design forces and strategies, as well as aspects of the lifecycle processes. This methodology defines an architecture development lifecycle, its phases and processes of managing the architecture development. This is used in conjunction with other frameworks such as TOE, Institutional Theory and Actor-network theory.

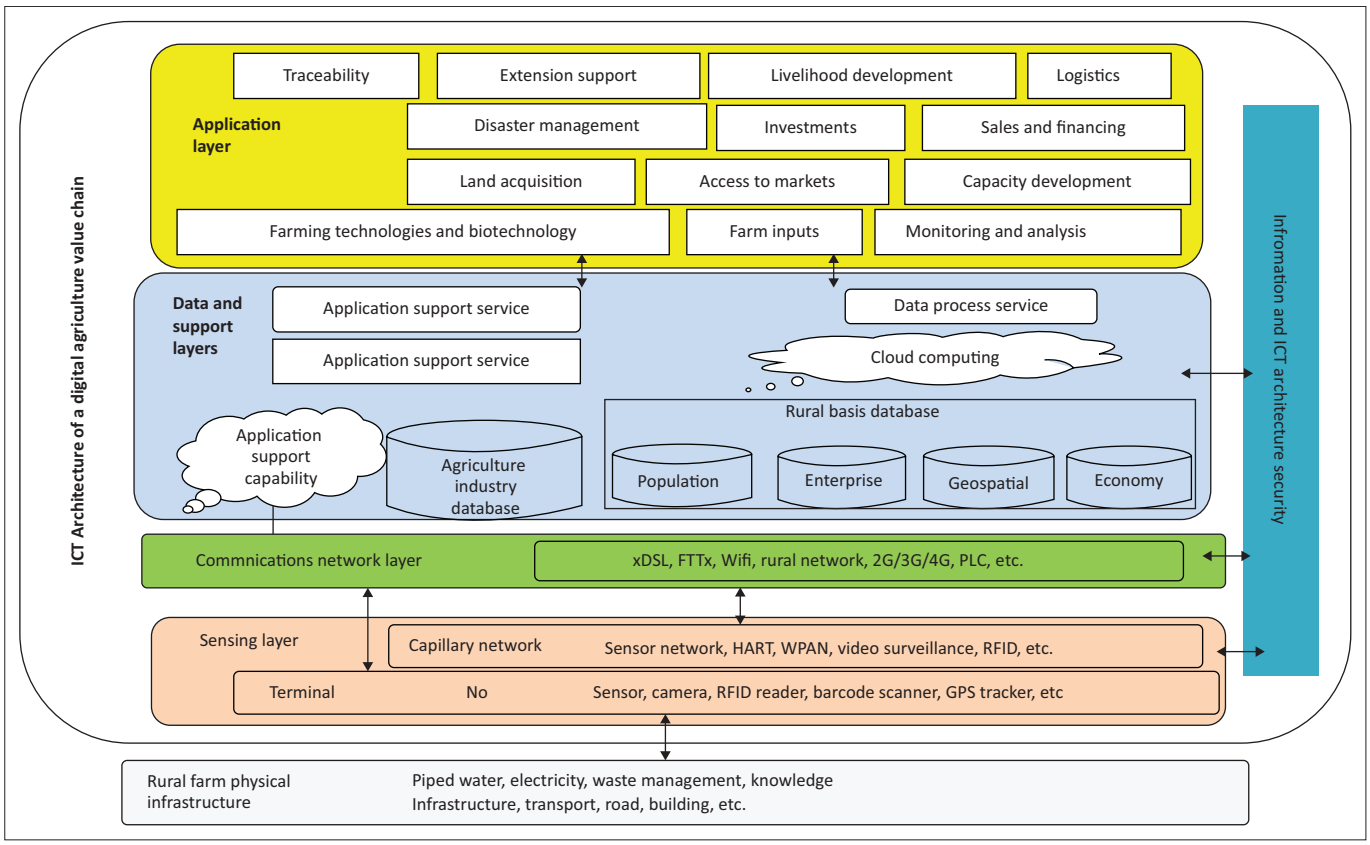
Figure 11 shows the different layers of an ICT design architecture that can support a digital AVC platform. IoT devices such as mobile smartphones and machine communication devices connect directly to the internet. The different layers are sensing; communications network; data and support; plus, the application layers.

The sensing layer collects the data input from the system environment to capture and respond to various environment stimulations. The communications network layer provides district-wide coverage for wireless broadband networks, internet access to other districts and international internet



Source: FAO & ITU, 2016, *E-agriculture strategy guide: Piloted in Asia-Pacific countries,* Published by the Food and Agriculture Organization of the United Nations and International Telecommunication Union, Bangkok

FIGURE 10: Agriculture sector cluster of digital services.



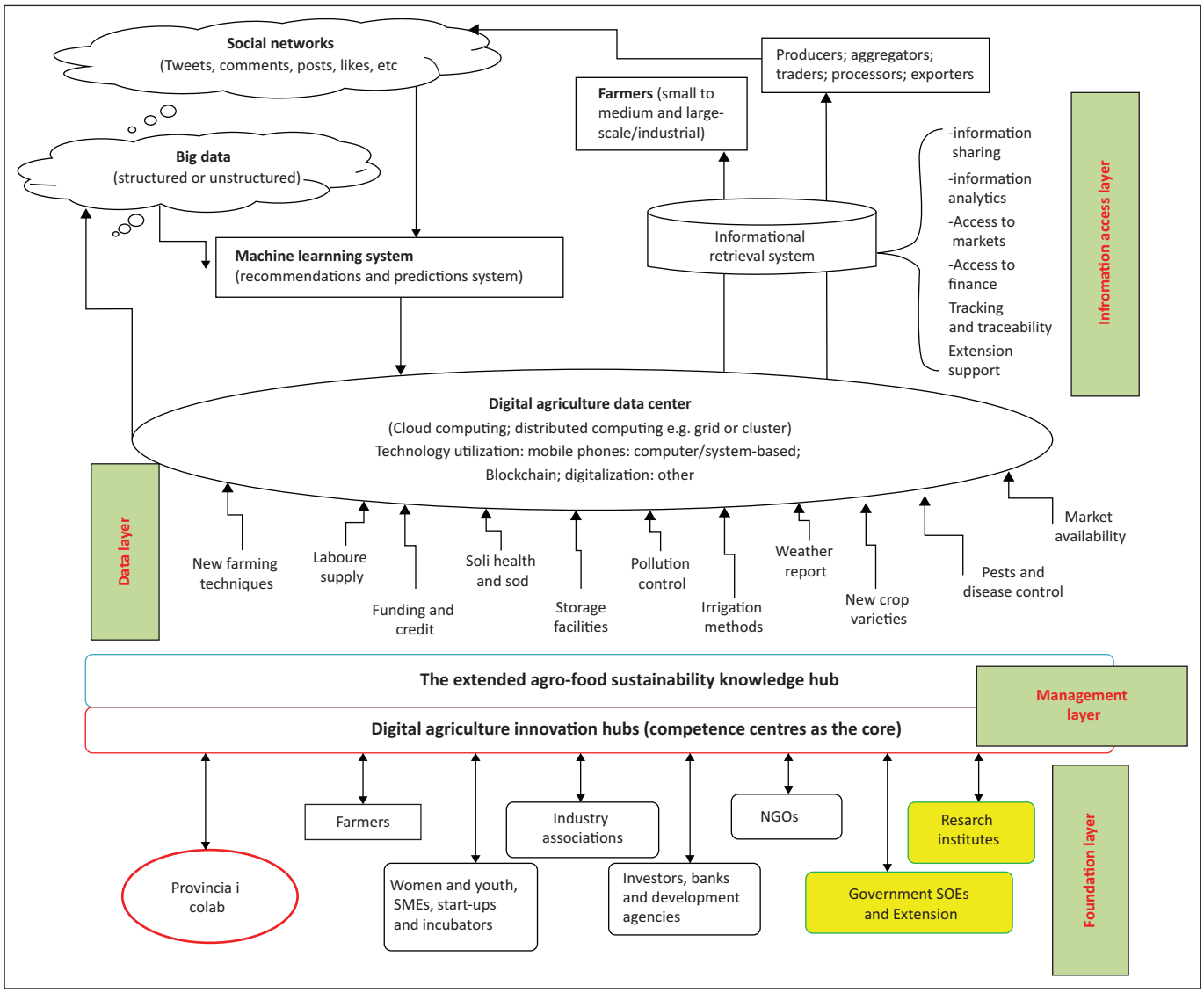
Source: ITU & FAO, 2016, *Developing e-agriculture strategy,* ITU – FAO Training, 1–2 September 2016, Nonthaburi

FIGURE 11: Digital agriculture value chain architecture.

transmission. The data layer transports data between stakeholders and centralised servers in data centres (ITU & FAO 2016).

Information facilitation and data sharing must have adequate safeguards of information and protection of intellectual property rights (Kanoktanaporn et al. 2019).

The application layer service diverse requirements and information needs enable automated decision-making and alerts to the digital AVC (ITU & FAO 2016). This study thus proposes a framework for implementing a digital AVC as shown in Figure 12 that uses the institutional arrangement in Figure 9, centred around DASKHs, supported by PADIHs and enabled by ICT architecture.



Source: Awuor, F., Raburu, G., Onditi, A. & Rambim, D., 2016, 'Building e-agriculture framework in Kenya', *Journal of Agricultural Informatics* 7(1), 75–93. https://doi.org/10.17700/jai.2016.7.1.244

FIGURE 12: Proposed framework for the adoption of a digital agriculture value chain.

A digital AVC needs to be secure, reliable and resilient against vulnerabilities. This includes hackers, political activism, unintentional damage and natural disasters. The entire system's technical foundation is built around the security infrastructure. This provides security functions such as disaster recovery, emergency monitoring, key security and identity management (ITU & FAO 2016).

There is a need of research and development (R&D) to show and ensure that new technologies are feasible and trustworthy (Campion 2018). Thus, the following section discusses the importance to facilitate research, innovation and training highlighting the need for collaboration and participation when adopting a digital AVC.

Discussion

The need for the agriculture sector to increase output with fewer resources creates the opportunity for digital technology to continue to facilitate and influence innovations in farming (Ungerer et al. 2018). Agriculture value chainss are under more scrutiny driven by concerns over food safety and sustainable production (Kanoktanaporn et al. 2019).

Small-scale farmers' importance in emerging markets is recognised globally and increased collaboration in Africa can lead to more integration across AVCs (Ungerer et al. 2018). The agriculture sector relies heavily on research to adapt to changes in the regulatory environment and market requirements. Government must support research as it remains the key source of innovation (DAFF 2018).

Research, innovation and training

The three critical elements in innovation include the knowledge generated via research, the ability to translate the knowledge into real products and services, and finally, the ability to market through commercialisation, communication and service delivery (Anandajayasekeram 2011). Research and development is the principal driver of innovation systems in the agriculture sector and the focus

should be small-scale farmers and gender-sensitive (DAFF 2018). The principles of DOI can be applied to drive technology adoption in AVCs.

Innovation is where an invention is used successfully in economic terms. The four sets of activities involved in innovation are invention, translation or realisation, commercialisation and adoption. The invention can be new concepts, products, processes derived from individuals, scientific research or a combination of existing knowledge (Anandajayasekeram 2011). The research community should communicate the availability, benefits and integration of different validated technologies as soon as these become available (Ungerer et al. 2018).

The four dimensions that affect the level of institutionalisation of any structure are, namely, autonomy, adaptability, complexity and coherence. This determines the transformation that structures must make to survive and be able to influence their environment (Peters 2000). Key activities of the institutionalisation include training of different key stakeholders and preparing academic institutes to internalise training and curriculum development (Anandajayasekeram 2011). The role of stakeholders in collaboration and participation in research, innovation and training aspects when adopting a digital AVC is discussed following subsection.

The need for collaboration and participation

South African small-scale farmers need equal access to funding and opportunities as big commercial farmers. The first requirement is to ensure that small-scale farmers are commercially productive and produce for a profitable market (Ungerer et al. 2018). Small-scale farmers need to collaborate with investors and financial institutions to attract investment (Campion 2018). Thus, they need to vertically integrate and identify which parts of their operations are best served through collaborations.

A user-centred design of agricultural technologies will ensure uptake and scale of use (Campion 2018). Collaboration provides small-scale farmers greater visibility and foresight along AVCs to influence factors previously beyond their control. This enables better participation in market structures through partnerships (Ungerer et al. 2018). The understanding of the local culture is important to know what motivates farmers and how to leverage and encourage the adoption of new technologies. Sometimes, economic and scientific benefits are insufficient to encourage such behaviours (Campion 2018).

Going forward, small-scale farmers will have to increasingly collaborate beyond the agriculture sector to adjacent sectors. To facilitate successful collaboration, a clear value must be added to the operations of all stakeholders and the participant's objectives must be culturally compatible, aligned and not contradict each other. The regulatory and legal requirements must allow for clear governance and strong leadership to facilitate ongoing open and honest communication.

Concluding remarks

South Africa needs to prevent a digital divide outcome in the agricultural sector. Government must support small-scale farmers to unlock the sector's full digital potential (Ungerer et al. 2018). The present study has proposed that agriculture stakeholders go beyond product quality and address environmental, social and ethical practices aligned with Carroll's CSR pyramid. Trade-offs between individual productivity and collective sustainability need to be made to transform towards promoting sustainable agricultural management practices using vertical integration through collaborations.

To address this challenge, this study reviewed the literature on different frameworks that can assist in the adoption of digital AVCs. After investigating policies and strategies implemented in South Africa, a framework for the adoption of a digital AVC was proposed in 'Discussion' section. The framework suggests the implementation of DASKHs aligned with DOI principles, supported by PADIHs aligned with CSR and vertical integration takes into account the above concerns to assure an impact at a district, provincial and national level. District Agro-food Sustainable Knowledge Hubs can develop and scale up the sustainability of small-scale farmers at a district level to have a global reach. Farmers control their economic strategies and retain their own independent identities. At the same time, farmers act collectively at different levels of integration and collaboration with a shared strategic agenda. Provincial Agriculture Digital Innovation Hubs provide digital services to the agriculture industry with an emphasis on SMEs. These further provide brokerage services, access to finance, market intelligence, training and education to become an incubator and mentoring services to new start-ups.

In summarising developments, this research identified several positive trends where digital adoption redefines small-scale farmers' AVCs, to become an integrated operational model within the framework of sustainability. It helps change the unequal terms of the current AVC that is controlled by a few globalised distributors. Planned cooperation and the collective use of knowledge and resources can lead to a competitive advantage.

Government and the financial sector must encourage and support agri-entrepreneurs and AgTech proposals that develop small-scale farmers. Agri-entrepreneurs could collaborate in digital AVCs through advisory services and analytic data services (Ungerer et al. 2018). New models of PPP cooperation must be explored to guarantee the long-term provision of services.

Recommendations

In general, there is a need for an agricultural digital services sector that creates opportunities that can contribute

to the commercial sustainability of small-scale farmers (Ungerer et al. 2018). Provincial Agriculture Digital Innovation Hubs are responsible for the coordination of research, development, training and education for digital skills interventions. Provincial Agriculture Digital Innovation Hubs will have a developmental focus on collaboration and networking amongst a diversity of actors. It is problem-orientated, where the farmer needs are the main driver. Digital solution services are offered by advisors and innovation brokers to small-scale farmers.

National agricultural development strategies must prioritise smart agriculture through initiatives of supporting early adopters (Kanoktanaporn et al. 2019). The government should stimulate the sharing economy through innovation challenges (Ungerer et al. 2018).

To save cost on physical and electronic infrastructure, planning and sharing from the outset are the key. Existing fixed and wireless communication networks should be exploited, whilst sensors can be added to gather data (ITU & FAO 2016). District Agro-food Sustainable Knowledge Hubs will develop digital solutions between the main economic sectors of rural areas to strengthen digital AVCs. Provincial Agriculture Digital Innovation Hubs are built on the strong actors of each province that are already established. Thus, funding and business plans of new PADIHs should be built over those centres. Certain services that already exist within public programmes should be aligned to existing funding sources rather than starting from scratch.

Cooperatives and farmers' associations have an important role in promoting the awareness and adoption of digital technologies. They are the right institutions to raise the voice of small-scale farmers during the definition and prioritisation of the PADIHs services. Rural development agencies connected to public authorities provide feedback in the design of certain PADIH services.

Limitations of the study

The study tried to understand the frameworks used for implementing digital AVCs. Past research was critically consolidated and examined to understand the contributions. It investigated the different components and presented a framework for the implementation of a successful network of PADIHs and DASKHs. On the other hand, several limitations of this study are as follow:

- Before the analysis, databases are searched separately using a SLR methodology. Using a different approach to collate these documents could have led to better results.
- The concept of digital AVCs is in its early stage of development and may need additional dimensions that should be considered with implementation.
- Academic journals or industrial reports are the main sources of these SLR findings. The findings of this review could have been enhanced if the sources had been expanded.
- Keywords were used to search these databases that deduced these findings. Because of the sensitivity, if different keywords were inputted into the search studies, we could have arrived at significantly different results.

Areas for future research

Critical to small-scale farmers is the development of their digital AVC to increase their competitiveness. Thus, the framework focuses on sustainability by reaching more markets. The proposed framework promotes an access to new resources and can be a strong motivation for policymakers.

Future research needs to investigate critical factors that lead to the effective application of such a framework. This would require policy intervention and supportive legal frameworks that seek PPPs to maximise digital AVC adoption by small-scale farmers for their sustainability.

New data about impacts on the environment are needed to develop more sustainable and competitive strategies. Small-scale farmers could use information systems as a support to become more sustainable and competitive. Research needs to be performed regarding the economic impacts and sustainability of DASKHs.

Conclusions and recommendations are drawn of how DASKHs supported by PADIHs can create alternative AVCs that contribute to the sustainability of small-scale farmers. The proposed framework shows new ways to address financing and knowledge transfer. Through entrepreneurship, small-scale farmers can develop new business models that can increase their income. To enhance farmers' innovation capacities and increase their competitiveness, the following questions are proposed:

- How do we ensure more equal distribution of power and economic value amongst all the involved actors in the AVC?
- How do we retain sustainable practices and small-scale farmers' identity when adopting digital technology?
- How do we effectively confront small-scale farmers' lack of knowledge and asymmetric information in AVCs?
- How do we enhance continuous R&D through innovation initiatives?

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Competing interests

The authors declare that no competing interest exists.

Authors' contributions

H.J.S. contributed to the conceptualisation, design and implementation of the research. He performed the visualisation, investigation, formal analysis of the results and the writing

of the original draft manuscript. O.J. contributed to the conceptualisation, design and supervision of this article.

Ethical considerations

We hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the mentioned research project HS 20/3/32.

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Data availability

Data that support the findings of this study will be provided upon reasonable request from the corresponding author, H.J.S.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

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