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The Potential of Digital Agriculture in Enhancing Productivity, Production and Livelihoods of Smallholder Farmers in Sub Saharan Africa: A Review

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ABSTRACT

Agriculture is a cornerstone of the economy in many sub-Saharan African (SSA) countries, providing livelihoods for the majority of the population and contributing significantly to GDP. Despite its importance, agricultural productivity in the region remains relatively low, with various indicators highlighting persistent challenges such as limited access to modern inputs, inadequate infrastructure, and traditional farming methods. To enhance production efficiency and become competitive in the global market, agricultural producers in SSA must adopt the latest technological innovations. Digital technologies offer a promising pathway to unlock the vast, untapped potential of agriculture across the region by improving access to information, market linkages, and resource management. However, successful digital transformation in agriculture requires more than technology adoption; it demands supportive policies, regulatory frameworks, and investment in digital infrastructure and skills. Governments at all levels play a critical role in fostering an enabling environment that encourages innovation while ensuring equitable access, especially for smallholder farmers. This paper presents an overview of the current state of agricultural digitisation in selected SSA countries, examining key components such as digital infrastructure, public services, and private sector innovations. Although public digital services remain underdeveloped, emerging private sector initiatives reflect gradual but promising progress in the region's digital agricultural landscape.

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1.0 Introduction

According to Bahn et al. (2021), digital agriculture—sometimes referred to as "smart farming"—involves the design, development, and use of digital technologies in agriculture and the broader agri-food sector. It encompasses a range of technologies, including robots, sensors, blockchain systems, digital communication tools, computational decision-making and analytical tools, and cloud-based technologies. Digital agriculture integrates these new and advanced technologies into a single system, enabling farmers and other stakeholders along the agricultural value chain to enhance their products and processes.

Sub-Saharan Africa (SSA) is home to a significant number of smallholder farmers who face multiple challenges, including declining soil fertility, climate change, poor infrastructure, limited access to credit facilities, high input costs (e.g., fertilisers and seeds), and a lack of organised markets for agricultural produce.

More recently, the COVID-19 pandemic has further exacerbated these challenges, making it difficult for smallholder farmers to carry out their activities. Many no longer have regular access to agricultural extension services, as quarterly meetings have been reduced or cancelled altogether. Field days, which were once vital for exchanging technical knowledge, have also become rare. In this context, digital agriculture presents a promising solution for addressing some of the challenges brought about by the pandemic.

The agricultural sector is progressively adopting digital technologies across the value chain. To remain competitive and meet market demands, farmers must adopt innovative practices that enhance productivity.

Promoting digital technologies can also contribute to achieving several Sustainable Development Goals (SDGs), including Goal 1 (No Poverty), Goal 2 (Zero Hunger), Goal 3 (Good Health and Well-being), and Goal 13 (Climate Action). These goals are aligned with the aspirations and policy priorities of the African Union's Agenda 2063, which aims for key transformational outcomes across the continent.

The aim of this review paper is to highlight for policymakers and other key stakeholders the potential of digital agriculture to improve agricultural productivity, enhance production, and strengthen the livelihoods of vulnerable smallholder farmers. This is particularly relevant in the developing world, where agricultural challenges are more pronounced, especially regarding timely access to information for smallholder farmers.

2.0 Digital Agriculture Contribution to Increased Agriculture Productivity and Production

Sub-Saharan Africa needs to double, or even triple, current levels of agricultural productivity to meet the continent's demand for food and nutrition security (FAO, 2017). Climate variability is adversely affecting the agricultural sector, intensifying the occurrence of invasive species, floods, droughts, pests, and diseases—all of which contribute to low productivity and production. In response, many governments are investing in agricultural transformation by supporting digital agricultural solutions. These technologies can capture high-precision data and tailor it for farmers' use to optimise production, improve access to information and services, and strengthen market linkages.

Across Africa, smallholder farmers often face limited access to information, markets, capital, secure land tenure, and essential agricultural inputs such as fertilisers and seeds. Digitalisation offers a potential pathway to overcome these barriers by increasing access to information, resources, and tailored solutions. However, environmental challenges—such as soil erosion and climate-related issues, including drought and El Niño events—make traditional farming practices increasingly difficult. These constraints can limit smallholders' ability to fully benefit from the digital revolution.

According to FAO (2019), progress is being made in integrating smallholders into digital agriculture. Approximately 13% of all smallholders and pastoralists in sub-Saharan Africa are already registered for digital services such as weather updates and market access tools. In Ethiopia alone, over 4 million users access digital extension

services. Studies indicate that digital technologies can enhance the efficiency, inclusiveness, and environmental sustainability of the agri-food sector, thus benefiting farmers, consumers, and society at large (World Bank Group, 2019). As demand grows for high-quality and sustainable agricultural products, digital agriculture can improve environmental monitoring and food system traceability—enhancing the value of farm produce while reducing resource waste and negative environmental externalities. Moreover, digital tools can support increased on-farm productivity, more efficient resource use, and climate resilience (Trendov et al., 2019). Therefore, it is essential to train value chain actors in the use of digital tools to boost agricultural productivity and production.

Digital technologies provide the agricultural sector with tools and critical information that enable informed decision-making to improve productivity and production. The sector is influenced by a rapidly evolving market environment, and information technology serves as a key vehicle through which farmers can improve both productivity and market competitiveness. Notably, the agri-food sector has the potential to contribute to improved trade balances in developing countries by reducing dependence on imports and increasing agricultural exports. Expansion of agri-food exports has been shown to enhance foreign currency inflows—an important benefit for countries facing foreign exchange shortages (FAO, 2020). Thus, increasing agricultural productivity could help reduce reliance on food imports, which remains high in many developing economies.

Bahn et al. (2021) argue that digital technologies—such as precision agriculture, e-extension services, and digital market platforms connecting inputs, producers, and consumers—hold immense potential to boost on-farm productivity and efficiency along the value chain, support climate change adaptation, and promote sustainable development. Empirical evidence shows that digital precision agriculture technologies help reduce the costs of replication, transportation, tracking, verification, and input use, ultimately increasing yields. For example, a study in Argentina demonstrated that a precision agriculture approach based on crop physiological principles could increase farm output by 54% (Monzon et al., 2018). Furthermore, the growing volume and quality of agricultural data and digital solutions are significantly lowering the costs of service provision, input distribution, and information delivery for farmers and other actors in the value chain (CTA, 2018–2019).

3.0 Digital Agriculture Contribution to Improved Smallholder Farmers' Livelihoods

The agricultural sector remains a major source of livelihoods in rural areas across Africa (Ekekwe, 2017). Most farmers still rely on conventional farming methods, heavily dependent on historical norms and rudimentary tools such as hand hoes that have remained largely unchanged for centuries. Agricultural technology plays a vital role in building viable and sustainable food systems. In recent years, African entrepreneurs have broken barriers to accessing modern farming technologies by introducing innovations such as cloud computing, integrated computing systems, connectivity solutions, open-source software, and other digital communication tools that are becoming increasingly affordable and accessible to smallholder farmers. Digital technology opens up vast, untapped potential for farmers, investors, and entrepreneurs to improve the efficiency of food production and consumption across the continent.

However, many farmers who attempt to leverage these technologies are deterred by the high cost of innovation. The use of digital tools to access customised, real-time agricultural information could revolutionise how rural communities secure and improve their livelihoods. Digitally enabled agricultural transformation has the potential to create employment opportunities and enhance the engagement of women and youth along agricultural value chains. When applied effectively across the entire value chain, digital technologies can increase productivity, yield, and income.

The drive to increase agricultural yields requires a shift from conventional practices—such as manual planting, weeding, and harvesting—towards precision agriculture techniques that leverage data and automation. These include the use of robots,

satellites, and computerised systems that reduce physical labour and improve efficiency, such as milking robots on dairy farms or automated climate control systems in greenhouses. Such innovations enable smallholder farmers to operate more efficiently, leading to improved yields and higher incomes.

Empirical evidence supports these advancements: six studies have shown that the transmission of agricultural information through mobile technologies increased yields by 4% in sub-Saharan Africa and India and raised the likelihood of adopting recommended agrochemical inputs by 22% (Xie et al., 2021). One critical but often overlooked factor in food security is post-harvest loss. Digital technologies offer significant opportunities to improve primary production, enhance supply chain and logistics efficiency, and reduce food loss and waste. Tools such as digital piloting and knowledge exchange platforms are particularly well suited to the needs of smallholder farmers.

Technology remains essential to boosting agricultural yields and promoting sectoral growth. However, future technological interventions must also aim to minimise environmental externalities and promote productivity gains across a broader diversity of crops. While digitalisation has the potential to transform the agricultural sector in developing countries, it requires continuous innovation, strong partnerships along the value chain, and a robust regulatory framework to ensure equitable access and affordability (Kremer, 2020).

No single digital agriculture solution can resolve all market inefficiencies. Instead, integrated systems of digital technologies are needed to address the sector's complex challenges. Reports indicate that specialised software can support tasks such as tracking seeding, watering, and nutrient application while also analysing the relationships between specific farming activities and crop outcomes (Murphy, 2021). In other applications, sensors are used to detect plot-level variables such as soil moisture, fertiliser inputs, weeds, and diseases (Xie et al., 2021). Additionally, satellite imaging can deliver real-time data on crop yield, water content, and nutrient status with geospatial precision. Table 1 provides a summary of progress made by select African countries in advancing digital agriculture innovations.

Table 1
Digitalization in the Agricultural Systems for the EAC and SADC Regions

Country	Number of Digital Innovations
Uganda	53
Kenya	64
Tanzania	57
Rwanda	42
Burundi	35
DRC	6
Zambia	22
Angola	1
Namibia	2
Botswana	3
RSA	9
Lesotho	1
Eswatini	5
Zimbabwe	0
Madagascar	6
Mozambique	0
Mauritius	1
Malawi	10
Comoros	1
Seychelles	1

Source: CCARDESA (2021) and World Bank (2019); EAC implies East African Community and SADC Southern African Development Community

Digital technologies are also recognized for their potential to create a more equitable agriculture-food value chain by reducing transaction costs and minimizing information asymmetries. These improvements can enhance smallholder farmers' access to credit, markets, insurance, and banking services in various ways. For instance, e-commerce and other market linkage platforms can directly connect smallholder farmers to consumers, bypassing intermediaries who often impose high fees. This direct access increases farmers' profits by allowing them to capture a larger share of the market value. A study conducted in the central highlands of Peru found that farmers who received market price information via mobile phone SMS were able to increase their sales prices by 13–14% compared to those without access to such information (Nakasone, 2013).

4.0 Key Aspects of Digital Agriculture

There is no doubt that digital transformation has revolutionized agriculture by enhancing efficiency, increasing yields, and boosting profitability along the agribusiness value chain. The introduction of mobile technologies, remote sensing services, and distributed computing has improved smallholders' access to information, inputs, and markets—resulting in increased production and productivity, streamlined supply chains, and reduced operational costs (FAO, 2021).

However, several key challenges must be addressed to fully realize the benefits of digital agriculture. These include the limited adoption of digital technologies among rural populations and farmers, inadequate digital skills, insufficient policies and programs that enable digital agriculture, limited accessibility to digital tools, gender disparities, restricted data access, and weak data governance frameworks.

To promote the effective use of digital agriculture in developing countries, it is essential to invest in the following areas:

4.1 Information and Technology (IT) Infrastructure and Network

Affordability and access to IT infrastructure are critical for the adoption of digital technologies by smallholder farmers. According to Trendov et al. (2019), the high costs associated with IT infrastructure are a significant barrier in rural areas. The capacity to apply digital approaches varies widely across countries—particularly in developing and least-developed countries (LDCs), where a large portion of the population lives below the poverty line. Although some countries have made progress in addressing infrastructural challenges, issues of accessibility and affordability persist, especially regarding digital devices and accounts. The high cost of network connectivity often excludes smallholders, poor farmers, and those living in remote areas.

Digital infrastructure requires substantial development to drive meaningful agricultural transformation in Africa. Moreover, realizing the full potential of digitalizing the agricultural sector and food value chains may demand broader transformations in communities, farming systems, natural resource management, and rural economies. Therefore, a well-developed digital infrastructure—particularly in rural areas—is a fundamental prerequisite for the successful adoption of digital agriculture and food systems.

This aligns with the findings of Casaburi et al. (2014), whose randomized control trial revealed that sugarcane growers who received agricultural advice via SMS increased their yields by 11.5% compared to a control group.

4.2 Develop Human Capital across all Levels (Digital Skills)

The rate of literacy—both educational and digital—is a critical factor in the effective use of digital technologies and is often lower in rural areas compared to urban areas. Even in some urban areas where digital tools are available, limited internet access can still hinder the adoption of digital technologies in agriculture. Therefore, digital literacy is a prerequisite for promoting the use of these technologies. Appropriate education and training will be essential to build the necessary skills. Farmers and agricultural stakeholders may require support in areas such as basic digital literacy, business and farm operations management, and the use of customer-facing technologies like digital marketplaces.

4.3 Policies, Strategies and Programmes for Enabling Digital Agriculture

The introduction of digital technologies in agriculture requires governments to create an enabling environment by developing supportive policies and frameworks that drive digitalization. This includes the deployment of e-services—such as e-extension and e-commerce—in the agricultural sector. Weak regulatory frameworks and limited access to services pose a risk of leaving certain regions and communities behind in the digitalization process. To support the adoption and effective application of digital technologies within the agriculture-food sector, governments must implement appropriate policies that can transform the sector into a driver of economic growth, social inclusion, and environmental sustainability.

Studies have raised concerns about equity of access, transparency in the use of digital tools, data protection, and potential adverse impacts on labour. Therefore, it is essential that policies not only promote the adoption of digital technologies but also address these critical issues. Well-crafted policies can establish a foundation for good governance and ensure data integrity, fostering greater trust in digital systems and their role in evidence-based policymaking.

It is recommended that countries develop a clear vision and strategy for the role of digital technologies in their agricultural sectors and broader agri-food systems. These strategies should highlight the potential contributions of digital agriculture to outcomes such as food security, while also recognizing that technology-driven, production-focused solutions are only part of the answer. They must be complemented by interventions that address parallel issues such as food access and distribution. Importantly, these strategies should incorporate gender-sensitive approaches to ensure that smallholder farmers and small businesses can benefit equitably from digital innovation, just as larger commercial enterprises do (Bahn et al., 2021).

4.4 Accessibility of Digital Technologies

An inclusive, digitally enabled agricultural transformation could bring meaningful livelihood improvements to Africa's smallholder farmers and pastoralists (Tsan et al., 2019). While the benefits of digital technologies in agriculture are substantial, there is no guarantee that these technologies will not exacerbate existing inequalities. Without intentional inclusivity, digital agriculture could exclude a wide range of farmers from accessing and adopting its innovations. As agricultural productivity increases through digitalization, a "digital divide" may emerge between small and large farms (Xie et al., 2021). When digital agricultural technologies require significant upfront investment, only large-scale farms with adequate assets and access to credit are likely to adopt them. Additionally, variations in digital literacy and the lack of specific technical skills among smallholder farmers can limit their ability to use and benefit from information and communication technologies (ICTs). This could result in uneven adoption and, consequently, uneven benefits from digital agriculture across different farming groups.

4.5 Gender Inclusion

Given gender-based disparities in access to ICTs (World Bank, 2017) and the existing gender gap in agribusiness value chains (Alexa and Ilona, 2016), studies have shown that men are more likely than women to adopt digital agriculture technologies (World Bank, 2019). As a result, digital technologies risk perpetuating or even widening gender inequalities within the agricultural sector (Mendonca et al., 2015). To address this, the Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA) has taken deliberate steps to empower women by supporting digital platforms that promote inclusion for women entrepreneurs in agricultural value chains (Tsan et al., 2019). Such initiatives aim to increase the participation of women and youth in agriculture and create employment opportunities throughout the value chain.

4.6 Data Access and Governance

Increased reliance on big data may hinder smallholder farmers' access to and control over such data, potentially diminishing their bargaining power compared to larger value chain actors like supermarkets and data collectors. It is therefore imperative to standardize data access and technological advancements for smallholder farmers in ways that are both useful and usable. This underscores the need to embrace the opportunities that open data provides to transform agriculture and food systems, creating new avenues for data-driven agriculture that is smallholder-friendly (Maru et al., 2018). Dongoski (2018) supports this view, noting that farmers often distrust others with their data and want to understand how they will benefit, which limits data sharing from sensors and farms to those who could generate significant impact from it.

By improving digital infrastructure, selecting digital agriculture technologies appropriate for smallholder farmers, and investing in human capital and digital skills development, policymakers can support equitable access to technology, finance,

data governance, and markets (see Figure 1). To address risks associated with digital technologies, governments should enact public policies that lower barriers to entry for service providers, ensure robust data governance, foster inclusion through targeted support for smallholder farmers, youth, women, and other vulnerable groups, and promote skills development (World Bank, 2019).

Figure 1

An Illustration of Crop Knowledge Bank Dissemination Pathway with Use of Digital Agriculture, Adapted from FAO and ITU (2017) with Modifications

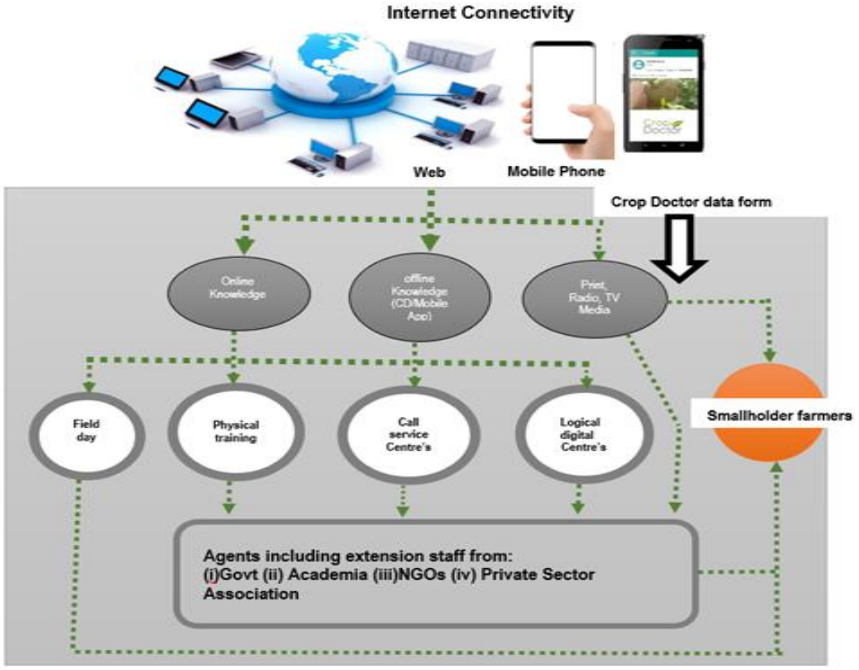

Table 2

Digital Agriculture Adoption in Sub-Sahara Africa

Item	Description	References
Information and technology (IT) infrastructure and network	In the era of digitalization, Information and Communication Technologies (ICT) such as mobile phones and computers have revolutionized how people access knowledge and information, do business and use services.	*(Trendov et al., 2019), Casaburi et al., 2014)*
Develop human capital across all levels (digital skills)	The use of digital technologies requires basic literacy and numeracy as well as special technical knowledge and skills. People without such competencies can end up marginalized in increasingly digitally driven societies.	(Advisors, 2019) *(World Bank, 2019; Mendonca, et al., 2015).*
Policies, strategies and programmes for enabling digital agriculture	In many countries, government policies and frameworks are one of the driving forces behind digitalization. These create an enabling environment for competitive digital markets and e-services. There is also a trend towards governments themselves deploying e-services 'e-government' especially in health, education, environment, and employment.	*(Bahn et al., 2021;World Bank, 2019;. Mendonca, et al., 2015).* (Advisors, 2019; Kosareva *et al.*, 2019)
Accessibility of digital technologies	Digital technologies have been touted as a potentially revolutionary solution to improve agricultural production systems' performance and sustainability. It can make the agri-food sector more efficient, inclusive, and environmentally sustainable, thereby increasing benefits for farmers, consumers, and society. Lack of access to information and knowledge transfer can hamper agricultural production in rural farming communities in sub-Saharan Africa (SSA).	*(Tsan, et al., 2019;* Bahn *et al.*, 2021;*, Xie. et al., 2021;* Krell *et al.*, 2021).
Gender inclusion	At the household level, men's and women's roles on farms are different,	*(World Bank, 201;*

Item	Description	References
	and therefore levels of agricultural decision-making may vary depending on gender roles when men are head of household.	*Alexa and Ilona, 2016;* Krell *et al.*, 2021; *Tsan, et al., 2019)*
Data access and governance	Increased reliance on big data may hinder smallholder farmers' access to this type of data and/or control of their data hence may lose bargaining power as opposed to large value chain actors (like supermarkets) and data collectors. It is imperative to standardise access to data and technological advances for the smallholder farmers, in forms that are both useful and usable.	*(Maru et al., 2018; Dongoski, 2018;* Advisors, 2019)

5.0 Future Prospects for Digital Agriculture

Given the widespread use of ICTs in everyday life globally, including among farmers, there is hope for increased adoption of digital tools in agriculture to enhance productivity and production. Crucial to this will be the continued implementation of capacity-building programs and awareness-raising initiatives that educate farmers about the importance of using digital tools in agricultural production. Such efforts can be supported by policies that encourage the adoption of digital tools and provide financial empowerment, particularly for high-risk farmers. Integrating digital solutions into agriculture can improve efficiency by reducing financial and labor costs, providing information to support management decisions, increasing both product quantity and quality, and ensuring the effective and sustainable use of resources at the farm level.

With appropriate policy support, the adoption and application of digital agriculture technologies in sub-Saharan Africa could foster economic growth, social inclusion, and environmental sustainability. Conversely, without adequate policy frameworks, digitalization may disrupt the sector negatively—reducing employment opportunities, widening inequalities, and further depleting already scarce resources. Policymakers must take prompt, comprehensive, and thoughtful action to ensure that the digital transformation of agriculture benefits all stakeholders and societies collectively. Public interventions should address urgent needs and leverage the most promising opportunities for the digital transformation of agriculture in the region.

6.0 Conclusion

Agriculture remains a priority on the policy agendas of African governments as they seek to address pressing challenges such as food and nutrition insecurity, climate change, youth unemployment, and overall economic growth. With the right policies, innovation, and investment, agriculture across the continent has the potential to become a powerhouse—not only feeding a rapidly growing population but also creating decent employment opportunities for millions of young people. Central to achieving significant livelihood improvements and sustainable agricultural growth in Africa is the adoption of digital technologies to drive agricultural transformation. Consequently, it is essential for smallholder farmers to embrace digital agriculture technologies, which offer promising solutions to enhance the economic, social, and environmental sustainability of agri-food systems across sub-Saharan Africa.

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The authors declare no conflict of interest.

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