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Food System Digital Transformation in Africa: Constraints and Interventions

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Abstract:

The Fourth Industrial Revolution (4IR) and its associated technologies are revolutionising socio-economic sectors, including agriculture. This article explores the impact of digitalisation on African food systems. The article uses secondary and primary sources in academic and grey formats to examine how digital tools can shape agriculture and create new opportunities for developing Africa's food system. It identifies digital tools usable across the food system chain and explores their potential impact on food production, processing, storage, marketing, transportation, and consumption. The article also examines the challenges to transforming the digital food system in Africa. The article shows that while digital technology has the potential to increase food production, reduce food waste, and improve food marketing and distribution, several economic, political, and social challenges exist that frustrate digital uptake. It argues that African governments should enhance the capacity of actors in the food systems chain to adopt digital tools. This can be achieved through adopting relevant policies and rolling out digital infrastructure to enable actors to access it in their areas of operation.

1- Introduction

Africa's agriculture sector has experienced sustained attempts at innovation since the past decade when it became widely accepted that innovation wielded much potential to facilitate the achievement of food security through hunger and poverty reduction, as well as the improvement of rural livelihoods and incomes. Empirical evidence also demonstrated how innovations such as improved seed varieties enabled smallholder farmers to increase yields and incomes to improve their living standards significantly (Shilomboleni et al., 2019). Widespread

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interest and attempts at agricultural innovation saw the gradual transformation of food systems (Wang et al., 2023).

In Africa, where 80% of the food consumed locally is produced by smallholder farmers, who also make up 70% of all the farmers on the continent (Moyo, 2016), the transformation of the food systems needs urgent attention and intervention. About 333.2 million people were classified as severely food insecure on the continent (Food Agricultural Organisation (FAO), 2017)). The number of undernourished people has also been growing in the last three decades. In East Africa, a total of 124.2 million people were recorded as undernourished between 2014-2016, up from 103.9 in 1992; 58.9 million people were recorded in Central Africa, up from 24.2 million in 1992, while in Southern Africa, the number had risen to 217.8 million in 2016 from 175.7 million in 1992. In West Africa, 31.5 million people were undernourished in 2016, slightly down from 44.6 million in 1992 (FAO, 2017). The transformation of Africa's food systems is necessitated by its vulnerability to various factors: rapid urbanisation, conflicts, global economic shocks, natural resource and environmental degradation, rapid population growth, and climate change-related challenges (Low & Thiele, 2019; Nalwimba, 2024). COVID-19 and the Russia-Ukraine conflict have also further exposed the fragility and vulnerability of Africa's food systems through global supply chains and trade disruptions, higher food prices, and income and job losses that have worsened food insecurity and poverty (Ndhlovu, 2024). Africa's food systems, therefore, require massive, sustained, and sustainable transformation to meet its mandate of ensuring the food requirements of the people on the continent. However, although opportunities exist, several challenges to Africa's food systems transformation exist.

Several development economists and other scholars working in the agricultural space have, for a long time, implicated the continent's history of colonialism, climate change, misplaced development policies, and conflicts in the continent's underdeveloped food systems (Abdulai, 2022; Baumüller & Kah, 2022; Mhlanga & Ndhlovu, 2023a; Thomas et al., 2022). The proposed solutions to these challenges included decolonisation (Nkrumah, 1964), the need for delinking from the global capitalist system (Amin, 1973), the pursuit of indigenous policies (inward-looking projects) (Mafeje, 1978), regional economic and political cooperation (Nyerere, 1969), and the implementation of broad-based land reforms programmes (Moyo, 1995). However, seven decades have passed since the first African countries attained political independence, yet Africa's agriculture sector remains underdeveloped globally. Therefore, additional theorisations and conceptualisations are needed to highlight practical interventions to resolve Africa's food system's woes. This article contributes to ongoing theorisations and conceptualisations on developing Africa's food systems by exploring the diagnostic potential of digitising the agriculture sector's associated components.

This article examines how digital tools that emerged with the advent of the Fourth Industrial Revolution (4IR) can shape agriculture and create new opportunities and challenges for the food system. This is achieved through (i) identifying the different types of digital tools usable across the food system chain and (ii) exploring their potential impact on food production, processing, storage, marketing, transportation, and consumption. This conceptual article is based on various secondary and primary sources available in academic and grey formats that were reviewed to guide and inform the overall arguments. The author also draws from personal experiences as a land reform activist and as a scholar of African agriculture and food systems, having previously published in these areas (Ndhlovu, 2022a; Ndhlovu, 2024; Ndhlovu & Mhlanga, 2024; Ndhlovu et al., 2024). This article flags how African governments must be roped in digital technologies as part of agricultural development to develop and sustain their food systems. It also shows policymakers where digital technologies are most effective in the food systems chain. The article can also conscientise African farmers on the benefits of adopting and integrating digital tools in their operations.

This article is divided into seven sections. After the current introduction, the following section presents the research methods. Theoretical and empirical reviews of the literature on food security and food systems in Africa follow this. After that, digital technologies in agriculture and the constraints and opportunities for digital transformation in Africa's food systems are outlined and discussed. Lastly, conclusions are drawn from the discussion.

2. Methods and Materials

This conceptual article is based on a review of debates on food systems and prospects for food sovereignty and security in Africa. It also benefits from related conferences and discussions the author has participated in over the years. In addition, the article utilises secondary and academic literature to explore how the African food system can benefit from digital transformation. The author used key terms such as 'social protection', 'digital', 'Agriculture', 'Food system', and' Africa' to access relevant literature. Articles were read through to decipher their standpoint on the issues under investigation. Articles that were closely related to the study were then integrated into the discussion. The aim was not to quantify articles on particular themes but rather to back up the arguments using previous and ongoing studies on the continent's food systems. The articles used in this article are referenced within the findings and discussion section. Complete references are provided in the list of references.

The author is aware that the methodology adopted in the study offers no scientific guidelines to allow for replication. It is hoped that the study will inspire further debates and theorisation that are more steeped in the empirical data.

3. Literature Review: Hunger and Food Insecurity in Africa

The literature review is presented from two angles, namely, the theoretical and the empirical perspectives.

3.1. Theoretical Literature Review

Much of the existing literature agrees that food insecurity is fast increasing in Africa compared to other regions (Beyene, 2023; FAO, 2017; Giller, 2020; World Health Organisation (WHO), 2018). FAO, IFAD, and WFP define food insecurity. (2013, p. 50) "A situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life." This definition has four key dimensions: the physical availability, access, utilisation, and stability of the other three dimensions over time (Delgado et al., 2023).

The literature shows that several interventions can be adopted to ensure adequate food supply and security at the national level. Such interventions include promoting domestic food production, trade openness, and food assistance. In Africa and Asia, for instance, food shortages have been mainly an outcome of poor crop yields due to climate change-related natural hazards: drought, storms, floods, and heatwaves, among others (Pereira, 2017; Zougmoré et al., 2021). As a result, development policies that promote the provision of agricultural support in these two regions have received widespread endorsement among agricultural economists and agrarian scholars who posit that concerted support for farmers to boost domestic agriculture could boost both food availability and access (Moyo, 2016; Msuya et al., 2017; Ndhlovu, 2022b). Adequate food access can also help to increase productivity through its effect on human capital (particularly health and education) and, thus, promote domestic production (Gafa & Chachu, 2023).

Trade openness is also endorsed as having much potential to improve food security, particularly in developing countries (Gnedeka & Wonyra, 2023; Sun & Zhang, 2021). Theory submits that trade enables nations to specialise in producing and processing goods with a comparative advantage and import products with relatively higher production costs (Upton et al., 2016). If countries boost their exports, they can acquire enough foreign currency to purchase the commodities they do not have a comparative advantage for local production, thus increasing food availability and access through reduced prices. Theory suggests that trade liberalisation improves attractiveness and new technology inflows and encourages farmers' innovation (Gnedeka & Wonyra, 2023). Subsequently, trade openness increases local farmers' food productivity. In food shortages, imports can also help facilitate food availability, reducing hunger and malnutrition (Mary, 2019). However, some scholars and land activists draw attention to the negative consequences of open trade on smallholder farmers and peasant communities (Clapp, 2014). It is argued that trade liberalisation negatively impacts the demand for locally-produced products, thus weakening local production and threatening farmers' livelihoods and income in developing countries (Bezuneh & Yiheyis,

2014; Dithmer & Abdulai, 2017; Ndhlovu, 2022a). Food import dependency is also problematic as it can increase the vulnerability of countries in cases of price and supply shocks on the global food market, as has been the case when a war between Russia and Ukraine, thereby generating food challenges for countries that depended on the two countries for commodities, including grains (Mhlanga & Ndhlovu, 2023a).

Scholars have also emphasised the importance of good governance and leadership in ensuring food security in countries (Phungwayo et al., 2021; Yunusa et al., 2018). Governance and accountable institutions are emphasised as key to achieving national food security. Ills such as corruption, weak laws, and incompetence by government officials often result in the inefficient and ineffective implementation of agricultural policies, thus creating avenues for food shortages (Bezuneh & Yiheyis, 2014; Gnedeka & Wonyra, 2023). Technology transfers, land ownership and utilisation, inputs and credit access are closely tied to national policies and laws. The stronger and more transparent the laws are, the smoother the agriculture sector will likely perform better and create opportunities for food security (Ndhlovu, 2024). Factors such as food marketing, distribution, and prices are also influenced by the quality of available institutions. Thus, if institutions are weak and presided over by corrupt officials, abusive food and market controls may emerge, leading to food scarcity or inequalities in food access. Governance is vital for providing the necessary infrastructure and conditions for agricultural production, food processing, storage, and transportation. The capacity of governments to provide social services also affects human capital ability and productivity, which, in turn, influences domestic food supply and consumption (Gnedeka & Wonyra, 2023). Production challenges such as war, climate change, conflicts, diseases, and financial crises often require the intervention of national governments. Interventions may include training farmers on new crop varieties in response to climate change, diplomatic interventions to cool down conflicts, interventions during disease outbreaks, and informed or scientific responses to financial crises. Therefore, the state remains vital in realising food security in any country.

3.2. Empirical Literature Review

In Africa, each food security dimension (food availability, access, utilisation, and stability) has been undermined by four key factors, namely, climate change, conflict, diseases, and the rising cost of living (Bjornlund et al., 2022; Msuya et al., 2017). Most households on the continent have yet to be able to produce or purchase adequate nutritious food. Food access across the region was only notably stable in the 1960s and 70s, partly due to US grain imports (Bjornlund et al., 2022) but mainly due to widespread focus on the agriculture sector as African countries emerged from colonial dominance (Ndhlovu & Mhlanga, 2023a). However, the debt crisis and Adjustment Policies imposed by the International

Monetary Fund (IMF) in the 1980s and 90s cut spending on imports, much to the decline of food availability. In 2021, about 20.2% of the African population faced severe hunger, compared to 9.1% in Asia, 8.6% in Latin America and the Caribbean, 5.8% in Oceania and below 2.5% in North America and Europe (FAO et al., 2022). The number of people facing moderate and severe food insecurity remained relatively high in Sub-Saharan Africa (Figure 1). Undernourishment is projected to soar to 25.7% in 2030 from 19.1% in 2019 (FAO, 2020).

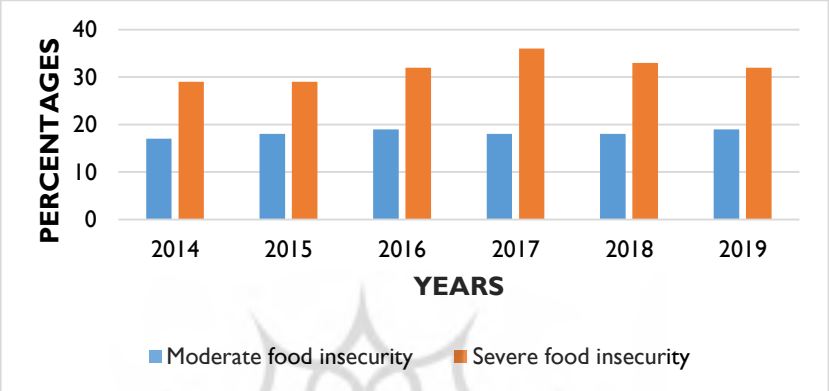

Figure 1: Food insecurity condition in Africa

Source: Atukunda et al. (2021)

There are, however, mixed views of the causes of food insecurity on the continent. For instance, a study on food supply and demand mechanisms in Morocco by Aker and Lemtouni (1999) showed that food security (availability) was determined by production (measured by cereal production) and influenced by rainfall amounts, prices of food and inputs, literacy of farmers, and the general health of human capital. The findings also indicated that income had a substantial positive effect on food access and utilisation. There was no significant relationship between food production and availability.

In Azerbaijan, an investigation on the multidimensional determinants of national food security by Huseynov (2019) showed that food imports increased food availability and the chances for food security, albeit only in the short term. Using 151 countries globally and covering the period between 1980 and 2007, Dithmer and Abdulai (2017) investigated how trade liberalisation affected food security, focusing on dietary energy consumption. The findings showed that trade liberalisation had a positive effect on food security.

Bonuedi et al. (2020) collected between 2006 and 2015 in 45 African countries to examine the implications of trade openness for food security. They measured

trade facilitation by indicators, such as paperwork procedures, time, and costs associated with exports and imports. They found poor trade facilitation triggered food insecurity. The study also revealed that food availability was significantly negatively affected by increased documentation (much of which was being processed manually), which caused longer export and import timeframes. This implies that faster paperwork and border processing could help improve food transportation and, thus, improve food security.

Sacks and Levi (2010) used data from 17 countries to examine how physical infrastructure, governance, and law affected African food security. The study showed that physical infrastructure, governance, and law were vital in ensuring food security on the African continent. Sassi (2015) also examined food insecurity determinants of undernourishment prevalence in 40 countries to differentiate between the effects of global and local determining factors. The study found that food import, production, and income reduced food insecurity.

Regarding the impact of governance on food security, Bayyurt and Yilmaz (2012) used data from 64 developed and developing countries collected between 2002 and 2008 on the impact on agricultural efficiency. For developed countries, the findings showed no significant effect of on agricultural productivity. However, the findings suggested that regulatory quality significantly affected agricultural production in developing countries. Ogunniyi et al. (2020) also examined the effects of governance on food security in SSA using 15 countries. The results indicated that government effectiveness, political stability, and rule of law had favourable impacts on food production and nutrition security.

The diagnostic potential of 4IR and associated digital tools to revolutionise and strengthen the African food system has yet to be explored adequately. 4IR tools include software such as Cyber Physical Systems (CPS), the IoT, and cloud computing (Mhlanga et al., 2021). When software and hardware technologies such as computers, laptops, mobile phones, sensors, and robots, among others, are used together, they can control and influence physical processes, generate a virtual imitation of the physical dominion, and even make decentralised decisions and resolutions. Using the internet, CPS can interconnect and transfer information in real-time as people who operate them would require (Ponnambalam et al., 2020).

Cloud computing is another form of 4IR-based technology and is Internet-based. This technology facilitates the transmission and sharing of information between software and hardware tools such as computers (Mhlanga et al., 2021). Cloud computing can be used to control other devices remotely using the internet. It can be used for machines (large and small), equipment, and direct human workers using the Internet to maximise production and improve product distribution (Prosekov & Ivanova, 2018). In the agriculture sector, the adoption of 4IR-based tools led to the advent of terminologies such as ‘Smart agriculture,’ ‘Digital

farming,' and "Agriculture 4.0", which all refer to the general integration of digital technology with agriculture (Benke & Tomkins, 2017). This technology communicates electronically with all stakeholders while data handling, transfer, and analysis are programmed (Mhlanga et al., 2021). Internet-based tools can speed up the management of large amounts of data and the interconnection of actors in the food system value chain. In proposing interventions to the challenges faced within African agriculture, the existing literature needs to expand on the diagnostic potential of adopting digital tools to improve food security and strengthen food systems. This may be the case because the digitalisation of economic sectors only gained much traction following the advent of COVID-19. As a result, most of the studies are still in their embryonic stages. However, building on these existing works, this article identifies digital tools that can be used in the transformation agenda of Africa's food systems and the opportunities for and challenges of adopting and implementing digital tools.

4. Discussion: Digital Tools for Food System Transformation

The reviewed literature shows that the African food system is primarily susceptible to climate change and its associated hazards: drought, storms, floods, and wildfires, among others (Delgado et al., 2023), which makes crop production and fisheries an enormous challenge. The food system faces challenges from violent conflicts within and outside the continent, disrupting supply chains, pandemics such as COVID-19, restricting food production and access, and financial crises (local or global), limiting buying power. Local and international factors include corruption, weak laws and rules, official incompetence, delays in paperwork processing and border posts, airports, and ship harbours. On various levels, all these factors affect the different activities across the food system. However, several digital tools and digital-based approaches can be integrated to help reduce or eliminate some of the challenges in the system.

4.1. Digital Tools in Agriculture

Droughts trigger water shortages and, thus, negatively impact food production. With the advent of digital tools under 4IR, non-traditional food production methods such as factory farming or automated indoor farming have become possible to respond to water scarcity challenges. Instead of soil, plants are grown under LED lights in a water-based solution through a hydroponic indoor system that allows crops and plants to be grown for the whole year (Firbank et al., 2018). In Africa, the CAN-Agri in Pretoria, South Africa, is an example of this type of farming where vertical farming is used for vegetable production. The Valcent Products Company in the United Kingdom also uses climate-controlled glass enclosures to grow tomatoes. Using digital-based farming methods, the Mirai Company in Japan produces lettuce using 99% less water than traditional farming, 40% less energy, and 80% less food waste (Benke & Tomkins, 2017). In Africa, where droughts abound, particularly in West Africa and Southern Africa

(Chivangulula et al., 2023; Danevad, 2022), non-traditional farming methods can help boost production and promote efficiency within the food system.

The advent of the Internet and Artificial Intelligence (AI) have also facilitated the automation of outdoor farming. AI systems and machines are now used in agriculture to perform tasks such as replanting, weeding (robots), chemical spraying, and harvesting (Mhlanga & Ndhlovu, 2023b). Digital tools are also being harnessed and integrated into agriculture for the practice of precision farming, where technologies such as GPS, sensors, robots, satellite imagery, control systems, etc.) Are being deployed to help improve yields, reduce harvest times, cut labour costs and decrease environmental impact. In Western Cape, South Africa, FruitLook is one of the technologies being used by farmers to help them use water in deciduous fruit and grape farming in more efficient and climate-smart ways (Ntoyanto-Tyatyantsi & Amadi-Echendu, 2021). Ncube et al. (2018) also report that small-scale farmers use Chameleon and Wetting Front Detector Sensors in countries such as Mozambique, Tanzania, and Zimbabwe to reduce irrigation frequency by 50% while doubling productivity.

Driverless machinery is also now standard in contemporary agriculture. Cloud-based platforms are being used to control the speed of these types of machinery as they spray chemicals and apply fertiliser, plough, and during harvesting fields (Ntoyanto-Tyatyantsi & Amadi-Echendu, 2021). Agro-robots are also being deployed to detect and kill weeds and pests in targeted areas using cameras and sensors, thus increasing chances for high yields.

The Food Circles Network can organise food systems by linking the different role-players within food systems networks. The Food Circles Network promotes safe food production and consumption methods (Ponnambalam et al., 2020). These networks can help communities meet their food needs.

Blockchain technologies may also be used within the entire food system network to consolidate the system for easier and shorter delivery time to markets (Ntoyanto-Tyatyantsi & Amadi-Echendu, 2021). Using these technologies, regulators can trace and identify the sources of products, legitimacy, and safety. This can help curb corruption at different levels of the value chain, improve official efficiency and competence at ports of entry, and thus, smoothen food transportation processes.

Blockchain technologies can also connect global networks to facilitate peer-to-peer dealings in self-organising communities, thus replacing complex contracting models that often require mediating financial institutions. Blockchain also enables the realisation of transparency since information cannot be altered once entered into the system and is accessible across the value chain. Blockchain technology can also record data such as the quantity of inputs used, thus ensuring efficiency by monitoring and avoiding wastage (Sharma et al., 2019).

Drones are being used to locate stray livestock and spray pesticides on crops. Farmers can cover larger surface areas than traditional knapsack sprayers (Veroustraete, 2015). Technologically advanced drones with hyper-spectral, multispectral, or thermal sensors are used in irrigations to detect dry field parts that need additional moisturisation. Ntoyanto-Tyatyantsi and Amadi-Echendu (2021) also argue that some drones are used to compute the vegetation index and ascertain the density and health of crops. When used successfully, these drones can also contribute to increasing farm yields.

African countries have been rocked by energy power crises in recent years, with electricity load-shedding getting to as high as 18 hours a day in Zimbabwe and 12 hours in Zambia due to low water levels in the Kariba Dam, for instance (Mhaka et al., 2020; Mhlanga & Ndhlovu, 2021). In South Africa, load-shedding lasted up to 6 hours since 2020. With the advent of 4IR, renewable energy sources such as solar photovoltaic energy can now be harnessed to power farming and other equipment. Using digital technologies to harvest sun, wind, and geothermal energy can help sustain African food systems by not relying on depleting non-renewable energy sources.

Big data analytics are also a significant technological breakthrough. They can enable farmers and other food systems actors to interpret vast amounts of data and get deeper insights into farming production, processing, storage, transportation, and consumption processes. Using this technology, food system actors, such as farmers and suitable transporters, can predict rainfall amounts and flood possibilities in a given season and respond appropriately.

Overall, the review shows that digital technologies wield much potential to revolutionise the African food system and enable its various actors to operate more sustainably. Consequently, this helps increase farm yields by monitoring input usage on farms (production) and making informed and safe decisions during processing and transportation. Digital technologies also enable farms to be environmentally responsive, with renewable energy elevating the pressure placed on the environment due to the use of non-renewable energy sources. This enables the agriculture sector to contribute towards climate change mitigation efforts. Furthermore, digital tools also help reduce corruption by government officials who do not observe rules and regulations at ports of entry, improve efficiency through fast-tracking paperwork processing, and reduce the political economy of affection during food distribution in crises such as COVID-19. However, although these technologies can wield enormous positive results, various constraints exist for adoption and integration in Africa.

4.2. Constraints of the African Food System

As discussed in the following sub-sections, socio-economic, political, and environmental factors have also hampered the transformation of food systems.

4.2.1. Digital Infrastructure and Connectivity

SSA is an agrarian community, and much of the population is in the countryside, where farming is the primary activity (Moyo, 2016). Most rural areas are geographically located far away from towns and cities and, thus, far from the already limited services and infrastructure (Mhlanga & Ndhlovu, 2023b; Quayson et al., 2020). Limited infrastructure and connectivity in the African countryside present significant obstacles to adoption and integration within food systems, even by large-scale capital-intensive agribusinesses. For instance, the limited availability of basic infrastructure such as electricity and the Internet affects how farmers and other food systems value chain actors can adopt and utilise digital technologies (Madichie et al., 2021). Such infrastructural development requires the active intervention of the government to roll out infrastructure as part of rural development commitment.

When digital infrastructure is available and accessible to food system actors, they can use digital tools to collect data and use it to inform their activities, such as farming, storage, transportation, and marketing methods (Ntoyanto-Tyatyantsi & Amadi-Echendu, 2021). These tools will enable improved food production, substantial reduction of food wastage, and product value addition within the food system. However, with limited infrastructure, this remains a challenge. In South-eastern Zimbabwe, Ndhlovu and Dube (2024), limited digital infrastructure was a critical obstacle smallholder farmers experienced. In West Africa, Madichie et al. (2021) found that one of the significant impediments to digital adoption in rural and urban areas was the lack of technological infrastructure and low internet penetration. FAO (2022) also found that infrastructural access was the major obstacle in the SSA agri-tech sector. Therefore, for Africa's food system to benefit from digital transformation, countries must commit to digital infrastructural development to improve access and utilisation by actors.

4.2.2. Limited Technology Access

In Africa, about 80% of the food consumed on the continent is produced by smallholder peasant producers, who make up about 70% of all farmers (Ndhlovu, 2024). These farmers grow mainly for household consumption, although surplus is sold to other households or local vendors. These farmers mainly rely on traditional tools for subsistence production and have limited access to modern technologies (Kudama et al., 2021). This limited access to and utilisation of modern technologies negatively impacts production and results in local farmers needing more essential skills and knowledge to adopt technologies that could transform their operations. Farmers with the crucial skill of digital tools are more likely to accept and utilise them (Ndhlovu & Mhlanga, 2023b). They are also expected to dismiss technology as intrusive and unnecessarily costly. Therefore, limited access to technology requires more skills and knowledge on how these tools can boost food reserves locally and nationally.

The limited access to technology in the African countryside further worsens the challenges experienced within Africa's food system. Local farmers with first-hand information about local production specificities are unlikely to generate and share the data. This hinders the likelihood of the various actors to make decisions based on data within the food system value chain. Kudama et al. (2021) found that digitalisation in agriculture in SSA is unaffordable for most farmers and that a significant proportion of the farmers were digitally illiterate, particularly female and older farmers. Thus, revolutionising the African food system through digitalisation requires governments in the region to invest in technology, minimise the costs of digital agricultural tools, and assist with resources for the digital training of farmers.

4.2.3. Funding challenges

Digitisation within Africa's food system has also been undermined by funding challenges. Most of the countries on the continent are resource-poor and often need help to provide the basic needs of their people. The region's financial sector does not consider smallholder peasant farmers as entrepreneurs (Ndhlovu & Majova, 2023). The same challenge is faced by other small- and medium-scale enterprises, such as food outlets like restaurants (Moyo et al., 2024). Some of these businesses also lack valuable assets which they can present as collateral. As a result, they often need help accessing funding from financial institutions. This affects their capacity to adopt and integrate digital tools within their operations.

The integration of digital tools within food system activities often requires a significant upfront investment. With the African food system dominated by peasant producers at the production level and small and medium enterprises in the other nodes of the food system, rapid digitising activities have become challenging due to a lack of financial resources. Limited resources also constrain food system actors to invest in research and innovation (Ozdogan et al., 2017). With limited support from African governments, food system actors, mainly farmers, have rapidly fallen prey to external funding, often in the form of contract farming, joint ventures, and other forms of partnerships, some of which are exploitative. The African agriculture sector has seen many of these investments in recent decades, particularly since the 2007/8 global financial crisis. However, most of the partnerships do not result in significant digitisation of agricultural operations; instead, they focus on increasing production. Furthermore, these investments have disrupted the African food systems as land traditionally used for food production was converted to non-food production (Ndhlovu, 2023).

Overall, limited financial resources by African food system actors, particularly African farmers, most of whom are peasant producers, have enormous adverse impacts on the rate of digitalisation in the sector.

4.2.4. Privacy and Security Concerns

Privacy and security concerns are other constraints to digitisation within the African food system. Some food system players, particularly peasant farmers,

need more support in accepting digital tools due to concerns regarding data privacy and security (Ndhlovu & Dube, 2024). This has contributed to the adoption of digital tools on the continent. Mhlanga and Ndhlovu (2023b) also found that complex and unstable data privacy and security regulations in Southern Africa often need to be revised for farmers to meet the required legal requirements. Some farmers are also suspicious of how digital tools can make their information accessible and increase their vulnerability to scammers. These concerns reduced farmers' faith in these tools and negatively impacted adoption. This can also cause farmers to resist technology. This disadvantages the entire food system, which could have used such information and tools for rapid development and effective operation. To ensure the African food system benefits from digitisation, governments and other responsible stakeholders must prioritise data protection and boost confidence among technology users to increase acceptance and adoption.

4.2.5. Regulatory Framework

Another constraint to digitisation within Africa's food system may be adequate regulatory frameworks (Mudzengi et al., 2021). Inadequate regulatory frameworks become barriers to digitalisation within food systems in many ways. Firstly, it is difficult for farmers and other businesses across the food system to plan and invest in digital transformation initiatives when there are no national regulatory frameworks (Mhlanga & Ndhlovu, 2023b). The presence of regulatory frameworks leads to certainty. Innovation can also be hampered by rules that are too restrictive. Instance: although Internet connection is terrible in urban and rural Zimbabwe, the government has been restrictive on StarLink, a satellite internet service operated by StarLink Services. Users were tracked down and arrested until August 2024, when regulations were amended. Where this occurs, it is difficult for new digital technologies and solutions to be rapidly integrated into food system operations and activities by stakeholders.

Furthermore, with no transparent and fair regulatory framework, specific organisations and businesses within society may be better positioned to digitalise. In contrast, others are left behind, as Atanga (2020) found in Ghana. Politicians and their businesses used the service, while the rest of society was prohibited from using StarLink in Zimbabwe. This makes it difficult for food system actors across different countries to collaborate through digital technology and improve the operations within the system. Therefore, the regulatory frameworks must be developed to support rather than impede development. In a continent where undernourishment is a considerable challenge (FAO, 2017), countries' regulatory frameworks must be mobilised towards the digitalisation of agriculture to increase food production, access, and utilisation.

There are, however, opportunities for technological integration to improve the effectiveness and efficiency of Africa’s food systems.

4.3. Towards African Food System Digital Transformation

African governments can deploy many strategies to address the diverse challenges that hampered rapid digital adoption within the African food system. Figure 2 summarises some of the methods that may be implemented to promote the adoption of digital tools to improve effectiveness and efficiency within Africa's food system.

Figure 2: Strategies for promoting digital adoption in Africa's food systems

Source: Author

Figure 1 shows that digitising the African food system, first, requires huge infrastructural investments by African governments. This is to ensure affordable access by food system users. Governments should promote and fund technology innovation programmes, research and training, as well as build public digital network infrastructure. When food system actors, from farmers, processors, and freighters, have access to digital tools, they can coordinate and make the system function efficiently so that quality food reaches consumers on time, with little losses across the chain. With adequate infrastructure, even actors at the bottom of the chain, such as farmers, can actively participate in the Internet, mobile devices, and other digital tools.

The actors within the food system also need knowledge and skills on how to integrate and benefit from using digital tools. A major challenge in Africa is that although technology is available, the majority of potential users lack the basic skills and knowledge to utilise the technology. Therefore, when mobilising for the digitisation of the food system to improve productivity and efficiency, it is vital that it be provided across the chain. Particular attention should be paid to those in the first stages of the chain, particularly farmers because in Africa, most

smallholder farmers use traditional knowledge, tools, and skills (Ndhlovu, 2021). Thus, these actors must be taught and trained on the benefits of digitisation and how to operate digital tools to engage in farming.

Governmental intervention is also vital, especially in developing regulations and policies supporting digitisation. Where governments need more resources to roll out digital infrastructure, they need to engage the private sector and provide them licenses to invest in such infrastructure. Government intervention may also include tax breaks for technological enterprises that invest in infrastructure to improve connectivity (Mhlanga & Ndhlovu, 2023b). African governments can also partner with local and international investors seeking to enter the digital and connectivity business. This will fast-track the rolling out of infrastructure and the subsequent adoption by actors within the food system.

Most African farmers, especially smallholder farmers and other peasant populations, simply lack the adequate resources to acquire the basic digital tools that can be used to help them improve their participation in the food system. This is due to financial exclusion in terms of access to financial services and the finance they need for their activities (Rusenga & Ndhlovu, 2023). Governments should invest in rolling out financial intervention to food system actors, particularly farmers, to enable them to buy the tools that are needed to improve production activities. In all these interventions, it is essential to first understand the needs of those being targeted for assistance so that their social and cultural needs are not intruded upon. The success of innovative food systems relies not only on technological advancements but also on understanding and integrating cultural values and practices to ensure that innovations are accepted and beneficial to local communities. While technological advancements can enhance agricultural efficiency and productivity, balancing these innovations with traditional practices that reflect local communities' cultural identity and values is essential.

4.4. Conclusion

This article explored the impact of digitalisation on African food systems. The article identified usable digital tools across the food system chain and explores their potential impact on food production, processing, storage, marketing, transportation, and consumption. It also examined the challenges to transforming the digital food system in Africa. The findings show that many digital tools, both software and hardware, can be used at different stages of the food systems, from farming on fields to food processing in processing industries, transportation by freight companies, and marketing agencies. These tools help food systems actors to manage a wealth of events. For farmers, the tools can be used to ascertain the dates of production activities (land preparation, planting, harvesting, etc.). Farmers can also predict climatic patterns, detect pests and diseases, spray

chemicals using robots and drones, and order services online. Data management and analysis through digital tools and AI can also help other actors in the food system to effectively and efficiently carry out their activities without causing food loss and contamination. It was concluded that the digitisation of the African food system wields much potential to increase productivity and improve efficiency, effectiveness, and sustainability within the system. However, challenges were also identified.

Among the many factors hampering the rapid digitisation of the African system are digital infrastructure and connectivity challenges, privacy and security concerns, and inadequate regulatory framework. The article also summarised the potential interventions to deal with the identified challenges. With most African farmers being resource-poor and unable to fund rapid technological innovation and adoption, the future should explore other potential funding models, such as foreign partnerships for digitising food systems.

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Conflict of interest

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