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Digital Technologies for Integrated Food Loss and Waste Reduction in Agrifood Chains in Sub-Saharan Africa: A Scoping Review

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Abstract: Sub-Saharan Africa (SSA) is grappling with a food insecurity crisis exacerbated by the decline in agriculture production and food loss and waste (FLW) that requires immediate attention. The challenge of declining agricultural production and FLW in agrifood chains has devastating consequences ranging from farmers and retailers losing income to the region's population's well-being. Given the critical challenge of food insecurity in SSA, this review paper explores prospective opportunities for digital technologies application in agrifood chains to facilitate an integrated approach to FLW reduction management. The scoping review 5-stage framework is employed to select relevant articles from Google scholar database over a 10-year timeframe period (2013-2022). The findings suggest that digital technologies such as Internet of Things, big data analytics, and Artificial Intelligence can help to reduce FLW by increasing efficiency, improving coordination, and connectivity in the agrifood chain phases, and thus creating value added transformation in agrifood chains. However, contextual factors such as inadequate digital skills, digital divide and connectivity issues that hinder effective use of technologies in SSA must be addressed if the region is to realise their transformative potential. This paper aims to add to the body of knowledge by highlighting potential opportunities to use digital technology to facilitate FLW reduction in SSA, to address crisis of food insecurity in SSA and, by extension, Africa.

Keywords: Digital technology, Agrifood chains, Food loss and waste management, Africa, Agriculture digitalization

1. Introduction

Food loss and waste (FLW), as well as food security, are high on the global agenda because of the impact they have on a country's social, economic, and environmental standing [1,2]. FLW is regarded as one of the threats to food security and as a result, there is a global call for sustainable FLW reduction management solutions. The Food and Agriculture Organization of the United Nations (FAO) defines FLW as a decrease in the quantity or quality of food along the agrifood chains [2]. Based on this definition, food that exists the agrifood chain is referred to as quantitative FLW whereas qualitative FLW refers to a decrease in food attributes that reduces its value in terms of intended use. On a global scale, an estimated 40% of annual farm produce is wasted or lost along the agrifood chains [3]. However, the quantity, quality, and composition of FLW vary greatly along the agrifood chain phases (production, processing, distribution, retailing and consumption) as well as by region [2,4]. This is attributed to several factors ranging from socio-economic to infrastructure and resource capacity availability [5, 6].

FLW has a devastating impact no matter how or where it occurs, ranging from farmers losing income to retailers suffering significant losses on unsold items [5,6]. Food considered ‘waste’ often ends up in landfills which causes environmental issues such as pollution of the air, soil, and water [6,7]. As the global population grows and food demand rises, the challenge of FLW in agrifood chains highlight the importance of prioritizing FLW reduction management strategies. With roughly a third of global food going to waste, it is surprising that c.2.7 billion people lack access to adequate and nutritious food according to FAO’s recent report on the global state of food security and nutrition [8].

Given the severity of the problem of food insecurity around the globe, the United Nations (UN) set up the goal of halving global food waste and significantly reducing food loss by 2030 as part of its Sustainable Development Goals (SDGs) agenda. According to [9], reducing FLW along the agrifood chains particularly at the early stages could increase supplies and decrease food prices. Further, FLW reduction management could address socioeconomic and environmental problems it causes.

1.1 Contextualising the Problem: FLW in Africa’s Agrifood Chains

In Africa, particularly in SSA, where food insecurity is more severe, there is limited information and significant gaps in data on quantitative and qualitative FLW along the agrifood chains [10]. However, literature does suggest that there is significant food loss at post-harvest and storage processing stages of the agrifood chains [2, 9, 11]. The FAO estimates that 16% of food produced in Africa is lost, and mostly exists in agrifood chains as quantitative FLW [2]. Post-harvest food loss in Africa is attributed to farmers lack of access to lucrative markets, inadequate storage infrastructure, and resource capacity [11, 12]. Authors like [12,13] suggests that food loss in Africa is heavily influenced by agricultural production choices and patterns, a lack of timely market information, and a lack of awareness of market demands and production practices required to meet these demands.

Agriculture remains the primary source of livelihood in Africa, and much of the food production is carried out by smallholder farmers [14]. As a result, smallholder farming makes a significant contribution to the continent’s socioeconomic growth. Consequently, when food is lost, the impact ripples throughout society. In recent years, Africa, like many other parts of the world, has seen a significant decline in agriculture productivity due to several factors. Among the factors are severe weather events associated with climate change, rapid urbanization, regional conflicts, and environmental degradation [15,16]. The consequences of these factors can be seen in crop failures and poor harvests, as well as a decline in animal husbandry. Consequently, the agrifood chains in the continent have also been greatly affected, resulting in an imbalance in the supply and demand of food products [17]. The imbalance of supply vs demand has resulted in high food prices, leaving most of the population without access to sufficient affordable nutritious food. A decline in agriculture productivity has derailed Africa’s efforts toward achieving UN’s SDGs particularly the first three goals.

The decline in agricultural productivity necessitates the implementation of immediate measures to not only address FLW at various stages of the agrifood chain, but also to develop measures to improve agriculture productivity. To achieve this requires a multistakeholder partnership and collaboration to find sustainable solutions especially as the continent’s population continues to grow. One approach can be through digitalization of the agrifood chains [18, 19]. Integrating digital information technology into agrifood processes could result in a value-creating transformation in the agriculture sector [18,20]. Digital technologies, for example, could play a critical role in coordinating, connecting, managing, and sharing information among the various actors in agrifood chains [18, 19, 20].

2. Objectives

With SSA's critical food insecurity problem, this paper seeks to explore the opportunities for digital technology application in agrifood chains to facilitate FLW reduction management. To achieve this the objective is to identify potential benefits and opportunities for adopting digital technologies enhance a FLW reduction management in SSA's agrifood chains. These opportunities are discussed under the contextual realities facing most of the continent's agrifood chain multi-actors. The guiding research question is: *how can digital technologies be used to facilitate reduction management of FLW in Africa's agrifood chains?*

3. Literature Review

Agrifood chains, according to FAO, encompass the entire agriculture production chain, from production to consumption [2]. From this description, the agrifood chain is a multi-actor-based system, with farmers, shipping companies, wholesalers and retailers, distributors, and consumers as participants. It goes without saying that digital technologies have great potential for facilitating a seamless integrated approach to FLW reduction management throughout the agrifood chain. Digital technology in agrifood chains can be viewed as an enabler of flexible food production, a facilitator of logistical processes, and a facilitator of information management and sharing [20]. It is therefore not surprising that FAO refers to the role of digital technologies in the agriculture sector as "Digital agricultural revolution" [21].

In Africa, the agriculture sector has already seen widespread use of digital technologies in several ways ranging from precision farming to e-commerce platforms [18, 19, 20, 22]. The proliferation of digital technology application is largely attributed to improved mobile telecommunication infrastructure that has bolstered connectivity in many regions [23]. This together with the rise in mobile phone ownership, has created an enabling environment for the implementation of digital technology initiatives across different sectors [23]. The application of technology can create value added solutions that addresses the needs of several stakeholders in the agriculture sectors as well as the population at large [24].

Digital technology in Africa's agriculture sector is being used in several countries for a variety of purposes. These include irrigation farming management [22], precision farming [19], drought prediction [25], microclimate monitoring [26], and crop disease risk assessment [27]. Digital technologies have also been used to provide rapid, reliable information on sales, demand, and supply, thereby preventing food overproduction [20]. With advancement in technology and in the wake of industry 4.1, technologies such as Artificial intelligence (AI), the internet of things (IoTs), sensor-based, and data-driven technologies have been widely advocated for in the agriculture sector [18, 19, 20]. These technologies have great potential for increasing connectivity and coordination in the entire agrifood chain, thereby creating efficiency in all activities within those phases.

In the context of FLW reduction management, digital technologies can be used in a variety of ways including smart packaging, forecasting, FLW analysis, radio-frequency identification tagging, and food traceability [18, 20]. In addition, digital tools can be used in forecasting sales, demand, supply, as well as resell surplus food at reduced prices and repurpose what is considered waste [18, 20, 28]. The potential benefits of digital technology application in the reduction management of FLW is evident, however, for the benefits to be fully realised, individual actors in the agrifood chains must adopt and effectively use the technologies. In addition, operationalization of policies and strategies concerning digital technology use and the agriculture sector must be done adequately.

Policies and regulations play an important role in not only creating an enabling environment for digital technology use, but also in a fair-trade or market environment. For example, in Africa, the Africa Union's (AU) Digital Transformation Strategy for Africa (2020-2030) is a significant policy that can create an enabling environment for digital technology use in agrifood chains [29]. The strategy was formulated in recognition of the continent's progress toward technology application in various sectors, with the goal of promoting inclusive growth and development through digital transformation (DT) [29]. One of the critical sectors highlighted in the strategy to drive DT is agriculture. Another important policy is the recently signed African Continental Free Trade Area (AfCFTA) agreement that promises among other objectives, to create a single market for goods and services particularly in a digital economy [30]. The establishment of a single market could provide a solution to the problem of farmers, particularly smallholder farmers, not having access to lucrative regional markets.

The expectation is that by creating a single market, African farmers can be able to sell their produce, reducing food loss at the post-harvest level of the agrifood chains. Another important role that the AfCFTA agreement could play is in promoting regional value chain and agricultural development. This could boost Africa's agriculture productivity, which has been declining while also addressing food loss in the agrifood chains. These two policies, if properly operationalised, have the potential to pave the way for the development of an integrated approach to critical sectors that drives Africa's economy including agriculture. In the context of this paper, these two policy documents have the potential to drive FLW reduction in Africa's agrifood chains using digital technologies in key areas.

4. Methodology

Arksey and O'Malley's 5-stage scoping review framework was used for this paper [31]. A scoping review focuses on an iterative process in which researchers begin with a broad search and then refine it as they become familiar with the breadth of literature. The focus of this review was on the application of digital technology in Africa's agrifood chain to facilitate reduction management of FLW. The 5-stage framework was employed to identify and map the available evidence in literature on the application of technology in Africa's agrifood chains. The application of the 5-stage framework is described below.

Stage 1: Identification of research question or objectives. The guiding question posed in this paper is *how can digital technologies be used to facilitate reduction management of FLW in Africa's agrifood chains?*

Stage 2: Identification of relevant studies in literature. As a guideline to identify relevant articles for this paper, the author employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [32] (see figure 1). A search criterion was established based keywords and a 10-year timeframe.

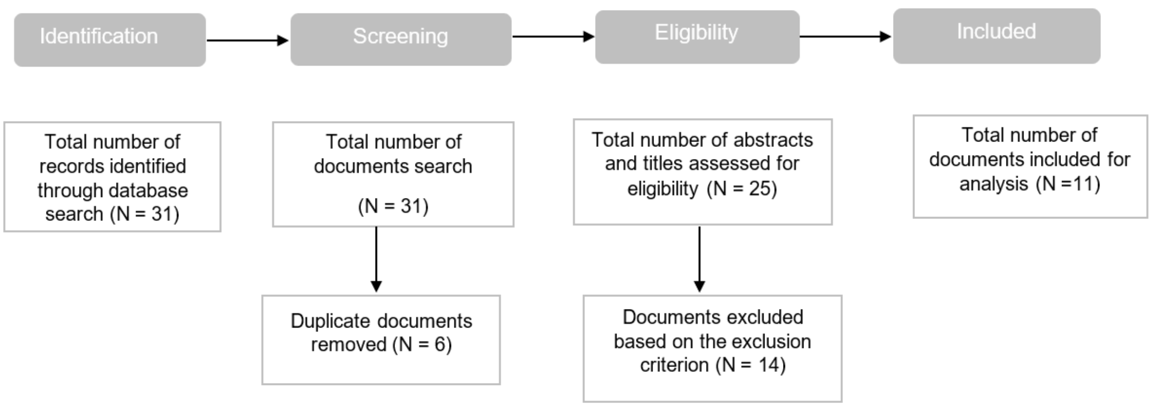

Figure 1: PRISMA Steps Followed in Identifying Documents

Search criteria and identification of sources: To find relevant peer-reviewed articles on the research question, Google Scholar database was used. Multiple iterations of searches were conducted within a 10-year timeframe to identify relevant articles (2013-2022). A set of keywords was combined into a single query used to search the databases. The strings included (i) "Food supply chain" "Information and communication technology (ICT) use" "food waste" "Africa" OR "sub-Saharan Africa" (ii) "Food supply chain" "ICT adoption" "food waste" "Africa" OR "sub-Saharan Africa". (iii) "Food supply chain" "digital technology adoption" "food waste" "Africa" OR "sub-Saharan Africa" (iv) "Food supply chain" "digital technology use" "food waste" "Africa" OR "sub-Saharan Africa".

Exclusion and Inclusion criterion: To keep the relevant articles from the search, an inclusion/exclusion criterion was established. The retrieved articles were deemed relevant if they met the pre-established inclusion criteria after screening and reading through the titles and abstracts: (1) All articles addressed digital technology or ICT use in the food supply chains, (2) articles addressed food waste or loss reduction in Africa; (3) All articles were written in English; and (4) studies with sound scientific and empirical design. For the exclusion criteria, non-open access articles, thesis and dissertations, studies conducted outside of Africa, and articles written in foreign languages were all excluded.

Stage 3: Selection of relevant articles. The following results were obtained by querying the two databases with the combined string of keywords. (i) "Food supply chain" "ICT use" "food waste" "Africa" OR "sub-Saharan Africa" yielded 9 results (ii) "Food supply chain" "ICT adoption" "food waste" "Africa" OR "sub-Saharan Africa" yielded 14 results, (iii) "Food supply chain" "digital technology use" "food waste" "Africa" OR "sub-Saharan Africa" yielded 2 results (iv) "Food supply chain" "digital technology adoption" "Africa" OR "sub-Saharan Africa" yielded 6 results. Before proceeding to full-text screening, all titles and abstracts were screened against the inclusion/exclusion criteria. The articles whose abstracts passed the screening were exported to the Mendeley reference manager for further synthesis and analysis.

A total of 31articles were retrieved from Google Scholar database. Of the 31 articles, 6 were removed as duplicates leaving 25 articles. Of the 25 articles, 14 did not meet the inclusion criteria based on the title and abstracts. A total of 11 articles were included for further analysis. From the analysis of the included articles, there is paucity of literature on digital technology use to facilitate FLW reduction management in Africa's agrifood chain.

Stage 4: Charting the retrieved data: At this point, the included articles, which served as primary data for this review, were reviewed again using an analytical criterion that involved data synthesis and interpretation. This was accomplished by sifting through and sorting extracted material (data) based on the study's research question. A total of 5 articles were analysed, the studies indicate that the use of digital agriculture technology is mainly at the production and storage processing phases of the SSA's agrifood chains. For example, [11] in their study looked at FLW reduction at post-harvest stage using ICTs particularly for marketing purposes. [12] in their study investigated the potential of ICT use in disseminating agriculture information to smallholder farmers. [9] reviewed literature on FLW in SSA at post-harvest level and mitigation measure. Although not relevant to digital technologies these two articles were also analysed for their mention of storage technologies. Table 1 presents a sample of the articles reviewed in this paper.

Table 1: Sample of Reviewed Articles on Digital Technologies Application in FLW Reduction Management in SSA's Agrifood Chain

No	Authors, year	Title of study	Study design	Focus region/country	Opportunities for application digital technology use in FLW reduction management
1	Sheahan & Barrett (2017)	Food loss and waste in Sub-Saharan Africa	Review	SSA	Post-harvest loss management
2	Acquah et al. (2021)	Minimizing post-harvest losses through digitally enabled supply chain visibility: a design science approach	Qualitative	SSA	Digitally enabled supply chain. Managing farm produce at post-harvest stage
3	Mapiye et al., 2021	Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-Saharan Africa	Review	SSA	Agriculture information management and sharing for improved efficiency in agriculture production
4	Conteh et al. (2015)	The determinants of grain storage technology adoption in Sierra Leone.	Qualitative	Sierra Leone	Post-harvest and storage farm produce management
5	Tesfaye et al. (2018)	The impacts of postharvest storage innovations on food security and welfare in Ethiopia.	Quantitative	Ethiopia	Post-harvest and storage farm produce management

Stage 5: Summarising and reporting results. This stage of the framework included three steps: data analysis, reporting results, and considering the study results in a broader context. To provide a meaningful understanding of the paper's topic, the extracted synthesised data were first analysed and summarized based on the research question posed. The three steps of this stage are presented in the following sections of the paper.

5. Analysis and Discussions

The results of querying Google Scholar using the combined string of keywords revealed that the digital technology use in the agriculture sector in Africa has receive a lot attention over the last decade [12, 13, 24,33,34]. For example, digital technologies are currently being used in many production activities from precision farming, irrigation management, access to weather patterns, and crop and animal disease assessment [19, 22, 25, 26]. In these examples what comes out clear is that although there is evidence of digital technology use in the agrifood chains in Africa, a lot of focus has been on improving agriculture production, processing, distribution, and marketing. However, there is paucity of literature on the use of digital technologies in the agrifood chains that facilitates FLW reduction management.

The sub-sections that follow discuss the opportunities for digital technology application in Africa's agrifood chains to facilitate a seamless integrated approach to FLW reduction management. These opportunities are discussed considering the contextual realities that most actors in the agrifood chain in Africa, from farmers to consumers, face.

5.1 Digital Technology in Agrifood Chains Phase

Based on the reviewed articles, the focus has been on digital technology use to improve agriculture production. FLW and food insecurity, has recently gained attention and with it the use of digital technologies to facilitate reduction management particularly at post-harvest and storage stages. The use of digital technology in FLW reduction management can increase efficiency, transparency, and traceability, ensuring high food quality and reducing FLW [35, 36]. However, if digital technologies are to produce the desired outcome of FLW reduction in Africa's agrifood chains, their application must be considered within Africa's contextual realities of technology adoption and use. For example, while most African countries have made significant advances in technological and digital infrastructure development, particularly in mobile telecommunication infrastructure, the reality is that connectivity, digital divide, socioeconomic, and other factors continue to be barriers to technology use for most of the population.

5.1.1 Digital Technology in Agriculture Production and Processing

The agriculture production and processing phases of the agrifood chain is where most of the FLW occurs in Africa [2, 9, 11]. Capitalizing on existing agriculture digital technologies in production and processing phases can fast track FLW reduction management at post-harvest and storage processing levels. In their study [11] highlight the critical role of ICTs in marketing of farm produce in the effort reducing post-harvest loss in SSA. In their study, the [11] aim to design an ICT enabled artifact that facilitates high supply chain visibility in SSA. Lack of market access for farm produce is one of the challenges that face most smallholder farmers that contributes to food loss at post-harvest level, supply chain visibility could be a solution. Digital technologies are currently used to improve supply of food commodities, market connections, and regulatory monitoring in countries such as Kenya [37].

Emerging digital technologies such as AI, IoTs, and big data analytics also provide great opportunities for addressing lack of market access. IoTs, for example, could enable visualization, monitoring, and control of agrifood chain processes, thereby optimizing them, by providing self-adaptive and autonomous ICT systems [38]. Another area where digital technologies are currently in use in certain parts of Africa, is precision farming [19]. Precision farming employs a variety of technologies, including sensors, Global Positioning Systems (GPS), and Geographic Information Systems (GIS), among others, to improve efficiency in agriculture productivity. Including resource optimization for water, pesticides, and fertilizers. Other ways in which digital technologies are being used to improve agriculture production and processing is in irrigation management [22], access to weather patterns [25], and crop and animal disease assessment [27]. Authors such as [20], for example, suggest that analysing historical data and big data with digital forecasting tools can foster conditions for achieving reliable and accurate information on sales, demand, and supply, thereby preventing food overproduction.

Digital technologies play an important role in these two phases of the agrifood chain by providing means to reducing overproduction, increasing efficiency in resource use in agriculture production, and facilitating easy access to information to all multi-actors in the agrifood chain. All these can prevent or minimize FLW in Africa's agrifood chains.

5.1.2 Digital Technology in Food Distribution, Retailing and Consumption

Digital technologies offer numerous opportunities in the distribution, retail, and consumption phases of the agrifood chain. Digital technologies can be used to create peer food networks that provide solutions to food surplus at retail and consumption phases to reduce food waste. For example, digital/mobile applications can be used to resell surplus food at a reduced price or donating to other businesses, organizations, or customers [20]. Smart mobile phones applications can be used at retail and consumer phases of the agrifood chain to promote food products approaching their expiration date. Using such innovative solutions can reduce the volume of food wasted at the consumer and retail phases. Other areas where digital technologies can be used in the latter phases of the agrifood chain include in smart packaging and labelling, which makes use of sensors and data carrier that ensure food quality; forecasting on food demand to enable adequate supply without wastage, FLW analysis, and radio-frequency identification tagging technologies [18, 20].

Blockchain technologies can be used to improve traceability in the agrifood chains by connecting farmers, suppliers, buyers, and other relevant actors in agrifood chain [35]. Traceability in the food industry can help reduce food recalls that contribute to FLW. Furthermore, digital tools and platforms can be used to develop upcycling and FLW repurposing awareness strategies to avoid unnecessary loss and waste along the agrifood chain. Agriculture-based technology applications for e-commerce are already in use in several countreis. Kenya’s Twiga and iProcure supply chain platforms, Ghana’s AgroCenta, Nigeria’s HelloTractor and Agro-Allied Services social AgriTech enterprise, and South Africa’s Yellow Beast precision irrigation product and H2O Catchers fog farming project are just a few examples [36].

There is a promising future in terms of digital technology use in agrifood chains to facilitate reduction management of FLW in Africa. Used effectively, these technologies can improve efficiency in the agrifood chain and thus reduce FLW. However, the challenge that faces the key actors in these two phases is that most of these technologies are not easily accessible nor affordable. In Africa, most farmers practice smallholder farming and are self-funded therefore lack of finances is often a barrier to digital technology adoption and use [21]. Secondly, smallholder farmers main farm in rural or semi-urban areas where connectivity and digital divide are still a challenge [21]. Connectivity and digital divide play a critical role in enabling collaboration between the multi-actors and coordination of the production and processing activities. Where technology infrastructure and connectivity are available and adequate, other factors such as unstable power supply and prohibitive high costs are a barrier to the adoption and effective use of digital technologies. For digital technologies to effectively facilitate an integrated approach to reduction management of FLW in Africa’s agrifood chains, contextual barriers to digital technology use must be first addressed.

6. Conclusions and Recommendations

Food security in Africa is dependent not only on increased agricultural productivity, but also on reducing FLW that occurs along the agrifood chains. Africa loses and wastes a substantial amount of food, particularly during the post-harvest and storage phases of the agrifood chain. This paradox of FLW and food insecurity requires governments, civil society, and the private sector to develop long-term solutions to the continent’s food insecurity. In this review paper, the application of digital technology along the agrifood chain is proposed as a potential solution to facilitate FLW reduction management. The use of digital technologies can not only help with FLW reduction management, but also boost agricultural productivity. For example, digital technologies can provide farmers, with access to a larger market to sell their produce, reducing the possibility of post-harvest loss.

Furthermore, using big data analytics techniques to analyse historical data, in conjunction with digital forecasting tools, can create conditions for accessing reliable and accurate information on sales, demand, and supply, thereby preventing food overproduction.

Effective application of digital technologies along the agrifood chain necessitates comprehensive policies as well as regulatory and legislative frameworks to assist the agriculture sector in realizing their transformative potential. Furthermore, the formulation of policies, as well as regulatory and legislative frameworks, should take into consideration the contextual barriers to digital technology adoption and use that many countries in the SSA region face to foster an environment conducive to adaptability, responsiveness, and transformation. Factors such as disparities in digital infrastructure, lack of digital skills and literacy, as well as lack of stable power supply have negative influence on achieving digital technology transformative potential. Addressing these factors could potentially create an environment conducive for improved agriculture productivity as well as FLW reduction management. Africa has the AfCFTA agreement and the Digital Transformation Strategy for Africa, which could play a critical role in promoting regional value chain and agricultural development by creating an enabling environment for digital technology use and market trade.

The contributions made in this paper can benefit those interested in long-term food security in Africa. Achieving long-term food security necessitates good governance involving collaboration from governments, the private sector, and civil society. A multistakeholder governance can inform an appropriate decision-making process that facilitates the realization of values that are important to society. The study's findings offer an opportunity for researchers, particularly those on the African continent, to expand the study by gathering primary data on FLW and its impact on food security. Further research should also focus on the readiness factors of digital technology application in the agrifood chains, as well as the ethical implications and strategies that would allow governments to address the contextual factors that impede the application of digital technologies in Africa's agrifood chains to facilitate FLW reduction management.

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References

[1] K. M. Kibler, D. Reinhart, C. Hawkins, A. M. Motlagh, and J. Wright, "Food waste and the food-energy-water nexus: a review of food waste management alternatives," *Waste Manag.*, vol. 74, pp. 52–62, 2018.

[2] FAO, 2019. *Moving forward on food loss and waste reduction food and agriculture*. [online] Available at: <https://www.csis.org/events/moving-forward-food-loss-and-waste-reduction> [Accessed 25 October 2022].

[3] H. Huang, X. Zhou, and J. Liu, "Food supply chain traceability scheme based on blockchain and EPC technology," in *International Conference on Smart Blockchain*, 2019, pp. 32–42.

[4] H. Fisgativa, A. Tremier, and P. Dabert, "Characterizing the variability of food waste quality: A need for efficient valorisation through anaerobic digestion," *Waste Manag.*, vol. 50, pp. 264–274, 2016.

[5] L. Bravi, F. Murmura, E. Savelli, and E. Viganò, "Motivations and actions to prevent food waste among young Italian consumers," *Sustainability*, vol. 11, no. 4, p. 1110, 2019.

[6] S. H. H. Oelofse and A. Nahman, "Estimating the magnitude of food waste generated in South Africa," *Waste Manag. Res.*, vol. 31, no. 1, pp. 80–86, 2013.

[7] C. Beretta and S. Hellweg, "Potential environmental benefits from food waste prevention in the food service sector," *Resour. Conserv. Recycl.*, vol. 147, pp. 169–178, 2019.
[8] FAO, IFAD, UNICEF, WFP and WHO, 2021. *Food security and nutrition in the world the state of transforming food systems for food security, improved nutrition and affordable healthy diets for all*. [online] Available at: <https://www.fao.org/3/ cb4474en/online/cb4474en.html> [Accessed 22 October 2022].
[9] M. Sheahan and C. B. Barrett, "Food loss and waste in Sub-Saharan Africa," *Food Policy*, vol. 70, pp. 1–12, 2017.
[10] O. O. D. Afolabi, S. A. Leonard, E. N. Osei, and K. B. Blay, "Country-level assessment of agrifood waste and enabling environment for sustainable utilisation for bioenergy in Nigeria," *J. Environ. Manage.*, vol. 294, p. 112929, 2021.
[11] I. N. Acquah, J. Akyeh, and J. Akyeh, "Minimizing post-harvest losses through digitally enabled supply chain visibility : a design science approach Minimizing post-harvest losses through digitally enabled supply chain visibility : a design science approach," in *AMCIS 2021 Proceedings. 14.*, 2021, pp. 1–6.
[12] O. Mapiye, G. Makombe, A. Molotsi, K. Dzama, and C. Mapiye, "Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-Saharan Africa," *Inf. Dev.*, p. 02666669211064847, 2021.
[13] C. Anadozie, M. Fonkam, J.-P. Cleron, and M. M. O. Kah, "The impact of mobile phone use on farmers' livelihoods in post-insurgency Northeast Nigeria," *Inf. Dev.*, vol. 37, no. 1, pp. 6–20, 2021.
[14] E. G. N. Mbanjo *et al.*, "Technological innovations for improving cassava production in sub-Saharan Africa," *Front. Genet.*, p. 1829, 2021.
[15] D. Gashu, M. W. Demment, and B. J. Stoecker, "Challenges and opportunities to the African agriculture and food systems," *African J. Food, Agric. Nutr. Dev.*, vol. 19, no. 1, pp. 14190–14217, 2019.
[16] N. Nephawe, M. Mwale, J. Zuwarimwe, and M. M. Tjale, "The impact of water-related challenges on rural communities food security initiatives," *Agrar. J. Agribus. Rural Dev. Res.*, vol. 7, no. 1, pp. 11–23, 2021.
[17] E. Fukase and W. Martin, "Economic growth, convergence, and world food demand and supply," *World Dev.*, vol. 132, p. 104954, 2020.
[18] M. K. Sott *et al.*, "Precision techniques and agriculture 4.0 technologies to promote sustainability in the coffee sector: state of the art, challenges and future trends," *IEEE Access*, vol. 8, pp. 149854–149867, 2020.
[19] C. M. Onyango, J. M. Nyaga, J. Wetterlind, M. Söderström, and K. Piikki, "Precision agriculture for resource use efficiency in smallholder farming systems in sub-saharan africa: A systematic review," *Sustainability*, vol. 13, no. 3, p. 1158, 2021.
[20] C. Strotmann, V. Baur, N. Börnert, and P. Gerwin, "Generation and prevention of food waste in the German food service sector in the COVID-19 pandemic–Digital approaches to encounter the pandemic related crisis," *Socioecon. Plann. Sci.*, vol. 82, p. 101104, 2022.
[21] M. Trendov, S. Varas, and M. Zeng, "Digital technologies in agriculture and rural areas: status report.," *Digit. Technol. Agric. Rural areas status report.*, 2019.
[22] R. O. Darko, J. Liu, S. Yuan, L. K. Sam-Amoah, and H. Yan, "Irrigated agriculture for food self-sufficiency in the sub-Saharan African region," *Int. J. Agric. Biol. Eng.*, vol. 13, no. 3, pp. 1–12, 2020.
[23] GSMA. 2021. *The Mobile Economy Sub-Saharan Africa*. Available from: https://www.gsma.com/mobileeconomy/sub-saharan-africa/ [Accessed 10 May 2022]
[24] M. Tsan, S. Totapally, M. Hailu, and B. Addon, "The Digitalisation of African Agriculture: Report 218-219," *Tech. Cent. Agric. Rural Coop. Wageningen, Netherl.*, 2019.
[25] A. Kaur and S. K. Sood, "Cloud-centric IoT-based green framework for smart drought prediction," *IEEE Internet Things J.*, vol. 7, no. 2, pp. 1111–1121, 2019.
[26] Z. Z. Oo and S. Phyu, "Microclimate prediction using cloud centric model based on IoT technology for sustainable agriculture," in *2019 IEEE 4th International Conference on Computer and Communication Systems (ICCCS)*, 2019, pp. 660–663.
[27] S. Kim, M. Lee, and C. Shin, "IoT-based strawberry disease prediction system for smart farming," *Sensors*, vol. 18, no. 11, p. 4051, 2018.
[28] D. Ddiba, "Exploring the circular economy of urban organic waste in sub-Saharan Africa: opportunities and challenges." KTH Royal Institute of Technology, 2020.
[29] Africa Union, Digital Transformation for Africa Strategy [online] Available at https://au.int/en/documents/20200518/digital-transformation-strategy-africa-2020-2030 Accessed [22 June 2022]
[30] African Union. 2018. *Agreement Establishing the African Continental Free Trade Area*. Available from: https://au.int/en/treaties/agreement-establishing-african-continental-free-trade-area [Accessed 10 May 2022].

[31] H. Arksey and L. O'Malley, "Scoping studies: towards a methodological framework," *Int. J. Soc. Res. Methodol.*, vol. 8, no. 1, pp. 19–32, 2005.
[32] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement," *PLoS Med*, vol. 6, 2009, doi: 10.1371/journal.pmed.1000097.
[33] Y. A. Yigezu *et al.*, "Enhancing adoption of agricultural technologies requiring high initial investment among smallholders," *Technol. Forecast. Soc. Change*, vol. 134, pp. 199–206, 2018.
[34] G. E. Mushi, G. Di Marzo Serugendo, and P.-Y. Burgi, "Digital technology and services for sustainable agriculture in Tanzania: a literature review," *Sustainability*, vol. 14, no. 4, p. 2415, 2022.
[35] H. L. Lee, H. Mendelson, S. Rammohan, and A. Srivastava, "Technology in Agribusiness: Opportunities to drive value," *White Pap.*, 2017
[36] A. U. Ordu, L. Cooley, and L. G. Monday, "Digital technology and African smallholder agriculture: Implications for public policy," *The Brookings Institution*, 2021.
[37] L. Prause, S. Hackfort, and M. Lindgren, "Digitalization and the third food regime," *Agric. Human Values*, vol. 38, no. 3, pp. 641–655, 2021.
[38] M. N. I. Sarker, M. S. Islam, H. Murmu, and E. Rozario, "Role of big data on digital farming," *Int J Sci Technol Res*, vol. 9, no. 4, pp. 1222–1225, 2020.
[39] A. M. H. Conteh, X. Yan, and J. P. Moiwo, "The determinants of grain storage technology adoption in Sierra Leone," *Cah. Agric.*, vol. 24, no. 1, pp. 47–55, 2015.
[40] W. Tesfaye and N. Tirivayi, "The impacts of postharvest storage innovations on food security and welfare in Ethiopia," *Food Policy*, vol. 75, pp. 52–67, 2018