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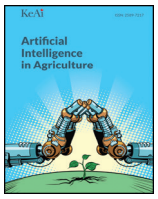

# Will digital solution transform Sub-Sahara African agriculture?

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ABSTRACT

Given its superior importance of digital agricultural solutions to overcome challenges in agricultural activities, many of the solutions are in face of challenges to scale in Sub-Saharan Africa (SSA). On the other hand, the impact of digitalization on economic development in developing countries is documented in several literatures but digital technologies have lately touched the agricultural sector in SSA. The objective of this study was to briefly review the impact of digital solution on smallholder farmers agriculture transformation, and the key and challenges influencing of agricultural digitalization in SSA. We used all-inclusive approach comprising original research articles, peer-reviewed articles, working papers, conference papers, book chapters, database, guide book, and indexes from 60 recent empirical academic studies conducted on impacts on digital solution in the region to produce a broad review. Results show that digital solution, when effectively used in SSA, has enabled smallholder farmers to gain a wide range of benefits involving access to real timely price, market, and farming information and safe financial transactions, alternative value chain linkages, multifaceted knowledge, better earning and yield, reduce costs, social well-being and risk minimization, women empowerment benefits. In contrast, fail to use adaptable tools, unaffordability, digital illiterateness, low participation of women and old smallholder farmers due to their low income and education status, are main barriers to digitalization in agriculture. Accordingly, it essential to the SSA countries to invest on technologies that is adaptable their target population, ensure balancing regulatory and delivery approaches that permit equal involvement of women, old age category, and remote areas, realize affordable access to digital services through reducing data costs and tax cuts on digital agricultural tools, and offering digital skill training for farmers by segmenting them into their gender, age, and education to fully harness the opportunities of digitalization in agriculture.



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## 1. Introduction

Agriculture is the mainstay for several Low and Middle-Income Countries (LMICs), where 54% of labor force in Sub-Saharan Africa are actively engaged in it and rely on the sector for their livelihoods (GSMA, 2020a). On the other hand, Africa need to increase more than double the current status of agricultural production over the next 30 years so as to meet the growing demand of food and nutrition security (Tsan et al., 2019). Specially, Sub-Saharan Africa (SSA) has been facing the highest food security problem than any other region. The greatest growth in food demand will call for considerably outperform rate of agricultural productivity and yield increases than the usual in the region (Tsan et al., 2019). Furthermore, high input costs, poor access to information and credit, and deteriorating productivity are worsening African farmers' potentials to boom agricultural yield and sustainability of farming business (Abell et al., 2019). Consequently, it calls for agricultural transformation a state in which agriculture become vibrant, and modern that generates value for farmers, entrepreneurs, youth and women, and produces affordable, nutritious and healthy food for all on continuous basis (Tsan et al., 2019).

Despite the improvement and decision making in agriculture is not an easy task (Tamene et al., 2021), digital breakthroughs have the power to transform the sectors (Goedde et al., 2021). Utilization of digital technologies is helpful in providing the right solutions to few of the most burning issues of our time, comprising climate variability, food insecurity and malnutrition, and environmental degradation (Abell et al., 2019). Digital technologies enhance user benefits via facilitating instantaneous information exchange, and access to new information among people (Deichmann et al., 2016).

Historically, agriculture has experienced a number of dramatical change that involves digital agricultural breakthroughs. The digital agricultural revolution becomes the latest change which could help realizes agriculture meets the food demand of the world in the future (Trendov et al., 2019). The introduction of digital solutions like machine learning, drone technology, robotics and related technologies in agriculture are paving the way towards agricultural sector advancement (Tamene et al., 2021). Digitalization will highly optimize agricultural resources management and allocation to the best of their own optimal recommendations through facilitating access of information in real time in a super-connected means (Trendov et al., 2019). Moreover, digital agriculture will generate means that are extremely productive, and adaptable to changes such as those associated to climate change. Consequently, it can ensure higher food security, profitability and sustainability (Trendov et al., 2019).

Digitalization for agriculture (D4Ag), the application of digital breakthroughs in the whole ranges agricultural value chains, overcomes challenges in agricultural activities and helps better earning for smallholder farmers, food and nutrition security, climate change adaptation and extends the involvement of youth and women (Tsan et al., 2019). D4Ag contributes to a structural transformation of the agri-food sector via accelerating the information to smallholder farmers or to other agricultural value chains actors, involving extension agents, agri-inputs dealers, agribusinesses, financial service providers and policymakers by using digital tools, and channels (Tsan et al., 2019; Muyiramye and Addom, 2020). These solutions comprise mobile-accessible apps and tools that rise access to timely market price data, financial services, weather predictions, pest outbreaks, and more (Thompson and Gyatso, 2020). The variety of digital tools in agriculture is wide-ranging from low-tech solutions disseminating voice and text-based advisory on feature phones, to advanced holistic tools including satellites, sensors and big data analytics (GSMA, 2020a).

Digital solutions have risen steeply in figure. About 60% (227 out of 390 active solutions) have begun to provide services over last three years in Africa (Tsan et al., 2019). Digital agriculture solutions in use provide five primary services involving, advisory and information services, market linkage, financial services, supply chain management, and business intelligence in the continent (Tsan et al., 2019; Goedde et al., 2021).

In the last decade, among many of different digital solutions trials, some have got satisfactory measure to attract viable investment. A few of such successful digital services have changed the lives of several smallholder farmers and have led them to larger productivity and incomes (Tsan et al., 2019). Digital agriculture is growing rapidly and 13% of Africa's smallholder farmers have accessed the digital solutions and yield up to ~€144 million revenue per year, with growing evidence of the sector's positive effect on smallholder farmers. The recent revolution of digital agriculture, therefore, will be the good news to SSA that help address their key challenges currently facing the region (GSMA, 2020a).

Despite their clear benefits, numerous digital solutions struggle to expand and some of them fail to advance the lives of farmers and other end users. In SSA, for instance, most applications possess beneath 30% active users (Goedde et al., 2021). On the other hand, the under developed status of enabling environment, including policies, institutions, infrastructure, and other conditions required to use the digital solutions are also key barriers to the expansion of digital agriculture in the continent. Furthermore, poor technological infrastructure, high costs of technology, low levels of e-literacy and digital skills, poor governing framework and limit the access to facilities are challenges hindering the use agricultural digital solution in developing counties (Trendov et al., 2019). Rural areas also have less established digital ecosystems (resources, skills, networks) when compared with urban areas. When such limitations combined with global movements of urbanization and middle and rich classes subsiding in cities, digitalization is capable to aggravate existing rural-urban disparities (UN DESA, 2018; Trendov et al., 2019) which can lead to fall behind in the progression of a digital revolution in agriculture (Trendov et al., 2019).

The impact of digitalization on economic development in developing countries is documented in several literatures but digital technologies have lately touched the agricultural sector in SSA (Thompson and Gyatso, 2020). Consequently, literatures are scare on the role that digital solution can play on agriculture transformation in the region.

Drawing on the lessons from the forementioned discussions and high research gap currently observed on the role of digitalization on agriculture in Sub Sahara African, this article provides a brief review of the impact of digital solutions on smallholder farmers agriculture transformation in Sub Sahara African. Moreover, this review paper aims to investigate the following research questions: Will digital solution transform smallholder farmers agriculture? Does digital technology in agriculture inclusive? what are the main challenges faced by firms within the agri-food value chains in the adoption of digital breakthroughs?

## 2. Methodology

### 2.1. Literature search

we used all-inclusive approach comprising original research articles, peer-reviewed articles, working papers, conference papers, book chapters, database, guide book, and indexes from different sources to produce a broad review. The literature was collected via, Web of science, and Google scholar and so forth, largely focusing on recent studies. The key words used were: impact of digitalization on smallholder farmers agricultural transformation, influence of digitalization on facilitating market information and agricultural value chain linkages, impact of digitalization on farm yield and income improvement, the effect of digitalization on social well-being and risk minimization, digital inclusive and divide in agriculture, effects of digitalization on access to financial services, and challenges influencing of agricultural digitalization in SSA.

We reviewed 29 peer reviewed journals, 2 books, 2 book chapters, 1, manual guide, 2 workshop papers, 17 reports, 4 working papers, 1

**Table 1**
Effect of digital solution interventions on agriculture outcomes.

| Main Finding | Location | Product or services | Technology | Study |
|---|---|---|---|---|
| Facilitating market information and VCA | | | | |
| Increase multifaceted, options to navigate the variety of chain alternatives, and emerging digital markets among smallholder farmers | Mt Kenya | Horticulture | Smartphone adoption | (Hartmann et al., 2020) |
| Reduce farmers' search cost | Niger | Agricultural product | Mobile phone | (Aker and Mbiti, 2010) |
| Productivity and profit | | | | |
| Increase farm productivity | Kaduna State, Nigeria | Agricultural product | SMS text reminders | (Sennuga et al., 2020) |
| Has positive association with maize productivity and increase profit | Iringa, Tanzania | Maize | Mobile phone | Quandt et al. (2020) |
| Facilitates the adoption of legume based sustainable agricultural intensification practices and increases knowledge on new practices | Tanzania | Legume | Radio and SMS | Silvestri et al. (2020) |
| Facilitates the groundnut farmers services and reduced the workload of extension workers | South-East Tanzania | Groundnut | Interactive voice Message | Ortiz-Crespo et al. (2020) |
| Increases farmers' use of seeds and fertilizers as well as land and labor productivity | Kenya | Seeds and fertilizers | ICT | Ochieng et al. (2013) |
| Increased yield and profit | Nigeria | Rice | Mobile application | Arouna et al. (2020) |
| Financial services | | | | |
| Increase access to loan | Malawi | Loan | Mobile phone | Montfaucon (2020) |
| Increase money transmissions, the nonfarm employment, and the portion of households food security | Northern Uganda | Money transactions | Mobile money | Wieser et al. (2019) |
| Women empowering and inclusive | | | | |
| Enhance women empowerment, household income, food security, and dietary quality | Central Uganda | Mobile service | Mobile phone | (Sekabira and Qaim, 2017) |

conference papers, and 2 facts and figures. Among the 29 peer reviewed journals, 23 are empirical studies, and 6 are literature reviews papers. There has been plenty of evidence on the ways in which digital solutions help improve the lives of smallholder farmers. A summary of the review results given in Table 1 below. The subsequent sections briefly review this evidence as well as challenges influencing agricultural digitalization.

## 3. Findings

Based on the relations of the topics the review results were categorized into digitalization on (1) facilitating market information and agricultural value chain linkages, (2) farm productivity and income, (3) access to financial services, (4) social well-being and risk minimization, (5) women empowering and inclusive, and (6) risks and challenges of agricultural digitalization in SSA.

### *3.1. Facilitating market information and value chain linkages*

The proportions of the agribusiness sector development is low when compared to that of farming size in most of SSA (World Bank, 2013). Many of these countries (such as Ethiopia, Malawi, Burundi) remain to depend on the export of agricultural commodities. The agricultural commodities export of them accounts for about 75% of their exports with very slight or no processing included (UNIDO, 2011). Furthermore, the majority of African farmers still face challenges to access real-time marketing and price information that help them to make sound decisions on time and market and at what price to sell their produces.

Digital solutions are potential to enhance farmers' negotiating power and reduce the risk of selling produce at low prices via facilitating price and marketing information access to farmers (Malabo Montpellier Panel, 2019). For example, in the rural areas of Niger, the use mobile phones reduced farmers' search cost on agricultural price information by 50% when related with personal travel (Aker and Mbiti, 2010).

In responds to quick changes in the agri-food sector over the previous two decades, smallholders' involvement in global value chains (GVCs) arose as a new approach towards poverty mitigation (Ruben, 2017). However, the involvement of small farmers agricultural value chains is low in SSA (Deutsche Bank Research, 2014). Some of the vital value chain challenges in the sub-region involves, output markets (like price risk, lack of regional integration, quality issues, policies distorting markets, food safety, social and environmental issues), access to inputs and technology, infrastructure, finance, inadequate skills and issues with engaging smallholders (World Bank, 2013).

On the other hand, it is commonly accepted that digital connectivity is becoming a crucial aspect in facilitating more discrete, standardized agri-food value chains in SSA value chain in recent years. Digitization of value chains supports these trends, since legible information lets improved management and monitoring of GVCs. The use of digitally-enabled solutions is potential to reduce the problems of smallholder farmers in agri-food value chain through linking them to high-quality farm inputs (such as seeds, fertilizers, herbicides/pesticides), production and post-harvest machinery and mechanization services, off-take markets, or even to the end -consumer (Tsan et al., 2019). For instance, Twiga Foods, a company began in 2014 to link small fruit and vegetable farmers in rural Kenya with small and medium-sized sellers in cities (Malabo Montpellier Panel, 2019; Thompson and Gyatso, 2020) has been able to provide higher prices and a guaranteed market to more than 17,000 farmers in the country in 2019. The high price obtained by farmers is due to avoiding the inclusion of intermediaries in wholesale markets (Thompson and Gyatso, 2020).

With regard to opportunities of digital connectivity, the Information Communication Technology (ICT) innovations rise efficiency gains due to the minimized need for physical journeys between value chain actors. Furthermore, ICT enabled information permit firms the capability to improve monitor and manage vital resources and employees (Esselaar et al., 2007; Donner and Escobari, 2010). Higher information flows help build stronger networks between firms. As a result, ICTs enable new creative and innovative activities between groups of firms (Foster and Heeks, 2013). Moreover, digital technologies and marketplaces might potentially alter the interaction of small firms with markets, and enable new types of business model and innovation at scale online (World Bank, 2016). The research finding by Hartmann et al. (2020) in Kenya indicates that the adoption of smartphone increased multifaceted knowledge (vertical knowledge flows, and horizontal knowledge networks), options to navigate the variety of chain alternatives (domestic production, informal export production), and emerging digital markets among horticultural smallholder farmers.

### *3.2. Farm productivity and income*

SSA remains the most important sector for economic growth, poverty reduction and food security (Asfaw et al., 2012; Deutsche Bank

Research, 2014). The region has huge amounts of uncultivated land (nearly the half of world availability), unused water resources and greater possibility for improvements in inputs to rise agricultural productivity. Consequently, advancing African agriculture is considered as a way to achieve the growing global food demand. However, agricultural productivity in SSA remains low compared with other areas (Bjornlund et al., 2020), due to numerous reasons involving underinvestment, poor infrastructure, insecure land tenure, unfavorable price policies and weak institutions (Deutsche Bank Research, 2014). Many other factors, including climate, soil quality, slavery and disease (Bjornlund et al., 2020).

In addition, food production in the region has not kept pace with population growth (Tittonell and Giller, 2013; Deutsche Bank Research, 2014), due to lowest land and labor productivity rates of the region in the world (Tittonell and Giller, 2013). However, there is no single solution for agricultural productivity improvement in SSA. Consequently, it necessitates improved access to numerous inputs, enabling policies, and a good-operational supply and value chains (Thompson and Gyatso, 2020). Furthermore, attaining agricultural production growth will be unthinkable unless developing and disseminating yield-enhancing technologies since it is no longer possible to meet the growing food demand along with the increasing population through the enlargement of cultivable area (Asfaw et al., 2012).

Previous studies witnessed that information asymmetry has conventionally inhibited smallholder farmers' access to markets, which in turns limited the adoption of modern technologies that could have boosted their farm productivities (Ochieng et al., 2013). Often extension agents have traditionally been the primary means of reducing the information asymmetries related to technology adoption and provider advisory services to farmers in SSA (Davis, 2008). Despite the role of extension workers is mainly crucial when it comes to promoting modern agricultural technologies, their capacity to provide updated and actionable information might be limited by the low ratio extension agent to farmer, under developed infrastructure, together with low incentive and responsibility (Aker, 2011). The comprehensive advice on recommendable fertilizer application rates has failed to realize attainable yield improvements for crop production in several SSA (Arouna et al., 2020).

Farmers need lifelong learning and continuous access to diverse sustainable yield improvement technology-related information, to care ongoing, flexible adaptation to varying burdens and opportunities (Pretty and Bharucha, 2014; Brown et al., 2017). As a result, farmers tend to be more interested to information that is easier to access than conventional extension services, and more personalized to their specific situation. Which suggests the need to access efficiently information delivery means in the context of the adoption technology to the target farmers' specific situations (Davis and Sulaiman, 2014). The use of ICT platforms have a potential to shift the traditional extension scenario (Ochieng et al., 2013) by accelerating and offering more information for farmers (Thompson and Gyatso, 2020).

Unlike traditional extension approaches, e-extension advisory allow to reach more farmers, often with updated information and cost-effective way (Davis, 2008). Moreover, the digital technology nowadays, makes it easy access to offer individualized extension services to farmers at a much lesser expense (Arouna et al., 2020). The study conducted in rural Tanzania, by Silvestri et al. (2020) shows that information provided through radio and SMS to farmers boosted their adoption in legume based sustainable agricultural intensification practices and knowledge on something new practices such as planting, seeds, fertilizers and soil fertility, pests and diseases control, weeding, harvesting, and storage. The same finding displays that both awareness and adoption are boosted if SMS supports radio campaigns. The study further demonstrated that radio alone was the most cost-effective approach; each dollar spent on the radio campaign results in 2.1 farmers that have adopted at least one new practice, compared with 0.5 farmers for SMS and 0.4 farmers for radio and SMS jointed (Silvestri et al., 2020).

In case it might be challenging to fit the broadcasts with farmers on regular procedures due to the high labor load of farming and related activities, user-centered interactive voice response can also be alternative means of digital agricultural advice. For example, the research findings of Ortiz-Crespo et al. (2020) display that groundnut farmers dynamically engaged with user-centered interactive voice message response to agricultural advice in Tanzania. Furthermore, the study illustrates that user-centered interactive voice message minimized the workload of extension workers compared to traditional communication channels via sharing automated push-calls responses to a group of farmers at once for questions seeking similar answering raised from different farmers.

In the same analogous, the study results by Ochieng et al. (2013) in Kenya shows that participation in ICT relied market information services (MIS) project increased farmers' use of seeds and fertilizers significantly and enhanced land and labor productivity. Similarly, the study results by Arouna et al. (2020) in Nigeria show that use of mobile application personalized advice on rice nutrient management enhanced farmers' rice yield and profit by 7% and 10% respectively with the same average amount of fertilizer application. Likewise, Sennuga et al. (2020) show that in Kaduna State, Nigeria, information provided via mobile phones (SMS text reminders) to farmers increased their farm productivity. Similarly, Quandt et al. (2020) in Iringa rural district, Tanzania indicates that the use of mobile phone for agricultural operations by smallholder farmer has positive association with maize productivity and increased the profit of the smallholder farmers obtained from maize production.

### 3.3. Financial services

The 2017 After Access survey shows that only 29% have access to formal financial services among 10 surveyed countries in SSA (Gillwald and Mothobi, 2019). Moreover, among surveyed countries, mobile money services are merely fruitful in Kenya (85%), Ghana (55%) and Tanzania (45%), whereas very low in Nigeria (4%) and South Africa (8%). The low performance of mobile money in countries such as Nigeria is largely due to lack a good partnership among mobile phone service providers and banks. Despite their uneven adoption and use, mobile money services have had a positive effect on financial inclusion in Africa (Gillwald and Mothobi, 2019; Research ICT Africa, 2019).

The financial service has a crucial role in permitting agriculture to contribute to economic advancement and poverty alleviation (Mcintosh and Mansini, 2018). In particular, agriculture plays the significant role in economic growth, poverty reduction and food security in SSA since the sector generates about 25% of GDP on average in the sub-region (Deutsche Bank Research, 2014). Despite agriculture offer employments for more than of half the population in SSA, the large mass of farmers still not have access to formal financial institutions and relinquish access to basic banking services, loans and pensions (Malabo Montpellier Panel, 2019; The World Bank Group, 2020).

This in turns, affects farmers' working decisions, such as devoting in seeds and other inputs, choice of crop, timing of harvest and sales as well as it limits their longer-period decisions on the management and implementation of production approaches (Deutsche Bank Research, 2014; Malabo Montpellier Panel, 2019).

On the other hand, digital financial service (DFS) offers a hopeful opportunity to address some of these persistent desires (Martin and Harihareswara, 2016), and facilitates easier access to banking, saving and transaction roles (Malabo Montpellier Panel, 2019). Digital financial service is a wide-ranging sort that incorporates Mobile Financial Services (MFS) and all branchless banking facilities that are empowered through automated channels (Martin and Harihareswara, 2016).

In addition to its a role to increasing agricultural productivity, digitization can guarantee timely and safe payments, and enhance savings (The World Bank Group, 2020). Wieser et al. (2019) in rural Northern Uganda shows that mobile money transactions enhanced money

transmissions. Another study investigated the access to financial services through mobile technology on agricultural income in Malawi (Montfaucon, 2020). According to the author, a higher number of mobile phones in a household significantly and positively affects the probability of the household's access to financial capitals. Another similar study, Suri and Jack (2016) reveals that M-PESA (mobile money in Swahili), helped households to develop the habit of financial management and increased their savings particularly for female-headed households (Suri and Jack, 2016).

### 3.4. Social well-being and risk sharing

Digital payments are also potential to improve customer well-being both directly or indirectly (Karlan et al., 2016). For instance, M-PESA (mobile money in Swahili) improved per capita consumption levels and lifted 194,000 households out of poverty in Kenya (Suri and Jack, 2016). In addition, it provided alternative jobs, mostly for women, who engaged into business from agriculture (Suri and Jack, 2016).

In addition to its benefit to lowering transaction costs, increasing availability of credit and savings DFS is capable to reduce risk for farmers (Martin and Harihareswara, 2016). Likewise, the study finding in Kenya shows that M-PESA improved households' respond to shocks by borrowing or receiving gifts from friends and relatives through strengthening their informal risk-sharing networks (Jack and Suri, 2014). Consequently, the M-PESA users are more likely to take a larger number and higher value of remittances from long distances and greater networks, upon they face unforeseen negative shocks. The study result further indicates that while M-PESA user households' consumption was indifferent to negative income shocks, such as illness or drought, non-user households' consumption was reduced by 7% (Jack and Suri, 2014).

Furthermore, Wieser et al. (2019) in rural Northern Uganda shows that mobile money transactions enhanced money transmissions, the nonfarm self-employment rate by two-fold (from 3.4 to 6.4%), and reduced the portion of households with very low food security from 62.9 to 47.2%, in distant areas from a bank service.

### 3.5. Women empowering and inclusive

In numerous developing countries, agricultural extension services are largely delivered in favor of men, with information focused mostly to male members of a farming household and in arrangements that are hardly adapted for women (Lecoutere et al., 2019). Moreover, in developing countries, women have been inconclusive to the access and use of digital information and communication technologies so far (Hilbert, 2011).

On the other hand, it is well documented in literature that the use of digital solutions has improved smallholder farmers' market access and income. Beyond these, digital technologies can possibly influence other extents of social welfare, such as gender equality and women empowerment. A study in 12 Latin American and 13 African countries by controlling women's unfavorable conditions (such as employment, education and income) revealed that women become more active users of digital tools as compared to men (Hilbert, 2011). Similarly, the experimental study conducted by viewing videos on improved maize management practices to both men and women maize-farming households in eastern Uganda showed that the video-enabled extension increases women involvement in productive decision-making processes (Lecoutere et al., 2019). The same source, further assured that video-mediated agricultural extension enhances women's knowledge about improved maize management practices, role in agricultural decision-making, up taking of the recommended practices and inputs use, increases the quantity of maize supply to the market and production-related outcomes on women-managed maize plots (Lecoutere et al., 2019).

The study conducted in Masaka and Luwero districts, central Uganda show that the use of mobile phone has positive association with household income, women empowerment, food security, and dietary quality (Sekabira and Qaim, 2017). The same study revealed that that female possessing mobile phones, increased household incomes and social welfare in excess of male mobile phone users (Sekabira and Qaim, 2017). Thus, provided that women were capacitated to use mobile phones, they would be more benefited than men (Aker and Ksoll, 2016; Sekabira and Qaim, 2017).

In addition to its advantage of technology uptake, the new digital facilities can also deliver specific advice to women engaged in agribusinesses and advance their links to markets (Malabo Montpellier Panel, 2019). For example, enhancing women's access to international markets and links to buyers via mobile breakthroughs in the shea nut butter sector decreased the interferences of middlemen and tend to increase their profits by 82% in Ghana (Braun von, 2019) as cited in (Malabo Montpellier Panel, 2019).

### 3.6. Risks and challenges influencing of agricultural digitalization in SSA

Despite digital breakthrough can play a crucial role in supporting agricultural transformation in Africa, the introduction of new technologies also involves challenges, limitations and risks, especially for smallholder farming and women (Malabo Montpellier Panel, 2019).

The critics to digital connectivity in the region, suggest that connectivity may not benefit all, rather it leads to power and control among different types of firms. Moreover, connectivity might empower stronger firms at the expense of weaker ones (Foster and Graham, 2017; Murphy et al., 2014). For instance, Foster et al. (2018) show that in Kenya and Rwanda, digital connectivity shifted modes of value chain governance, led to control of lead firms and data standards are leading to new challenges for firms looking to digitally integrate in tea and tourism GVC sub sectors. Their finding further indicates that Digital connectivity has mostly led to shrill integration, through which small firms be able to make little communication and productivity enhancements without more considerable advancement with exception to some small firms who are able to supply to emerging niche customers, and local or regional markets. However, their findings show nothing about the effect of digital connectivity on tea producers (Hartmann et al., 2020).

Despite affordable internet is a requirement for smallholder farmers to fully harness the opportunities of digitalization in agriculture, the prices for internet use in the region is still the world leading prices with wide-ranging prices across the region (Malabo Montpellier Panel, 2019). In addition, in numerous African countries, mobile-data baskets (voice, mobile data and fixed broadband) are still beyond reach for a big portion of the population, costing higher than 10% of GNI (Gross National Income) per capita, in conditions where incomes are already inadequate (ITU, 2021). Besides, given the superior importance of smartphone for accessing the internet and use of digital technologies and services, affordability and prices of handsets are a major limitation for smartphone ownership, especially in rural SSA (Malabo Montpellier Panel, 2019). In several African countries, regressive taxes on digital devices and services are one the factors that escalate the cost of communication and undermine the use digital technologies. Moreover, excessive increases can lead to counterproductive and generate disincentives for investment, but the reduction of direct and indirect taxes from fees will separate one of the foremost cost amplifiers. Reducing the cost of communication become successful in countries like Namibia tend to increase use of digital technologies, economies of scale, and increase taxes derived from profits. Accordingly, it needs the region to review taxation system on the sector (Research ICT Africa, 2019). Moreover, the proportion of people using the Internet remains low as compared to the other region in the world. Whilst the percentage of individuals using the Internet in 2019 totaled 28.6% in Africa, it accounts for 51.4% globally (ITU, 2021).

Despite its paramount prerequisite for enabling digital technologies, lack of infrastructure is not the vital cause for the relatively small

numbers of people using the Internet in SSA (GSMA, 2020b; ITU, 2021). For instance, at the end of 2019, about 49% of people across Sub-Saharan Africa were connected to the mobile Internet, but not using the Internet. Unaffordability (high cost of smartphones, relative to average income levels), and low digital skills are the key barriers to mobile internet adoption in the region (GSMA, 2020b; ITU, 2021). Moreover, After Access Survey, carried out in 10 SSA countries – Ghana, Kenya, Lesotho, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Tanzania and Uganda indicates that the key barriers to Internet use for those who do not use the Internet are the lack of Internet-enabled devices (23%) and lack of digital literacy (16%) (Gillwald and Mothobi, 2019). The same study result further indicates that the main barriers to Internet use for those who use the Internet is the cost of data (36%) (Gillwald and Mothobi, 2019).

Likewise, many of digital agriculture solutions are in face of challenges to scale. In sub-Saharan Africa alone, in excess of 400 digital agriculture solutions are in use, but numerous of them struggle to scale and fail to advance the lives of farmers and other end users. Most platforms have below 30% active users and merely 5% of them have more than 80% of user farmers and achieved scale of more than one million farmers. (Goedde et al., 2021).

Digital literateness also remains low in SSA (Kim et al., 2020). A review research conducted by Annosi et al. (2020) on digitalization and agri-food sector found that the use of information and communication technologies is reliant on the literateness of the people. Thus, skills for handling, browsing, and evaluating data as well as digital know how are supreme (Baumüller and Addom, 2020). Having alone digital devise and traditional literacy (able to read or write), is not enough to use digital breakthroughs. Information and data literateness are crucial for digital technology users like smallholder farmers, researchers, traders, extension agents, and policymakers (Baumüller and Addom, 2020). In contrast, the size of uneducated people who possess digital devises comprise considerable share in several African countries (Gillwald and Mothobi, 2019). For example, Gillwald and Mothobi (2019) in their survey found that merely around 30% of smartphone handlers replying to the survey in Ghana and Nigeria had ever deployed an application on their phone. This figure largely cut with an increasing reliance on agriculture as a means of livelihood (Baumüller and Addom, 2020).

Despite digital literacy and skills are desirable for the scaling up and the use digital solutions in agriculture, digital literacy still a major blockade in the continent (Trendov et al., 2019; Baumüller and Addom, 2020). For example, the study by Foster et al. (2018) show that digital skill incapacities, and lack of finance is the main exclusionary digital barriers for small firms in tea and tourism GVC sub sectors. Moreover, farmers throughout Africa are mainly low-income earner and older that often less technologically skillful than the younger and urban population (Malabo Montpellier Panel, 2019). Consequently, the low digital skill and knowledge status of rural community, continue to hinder the adoption of digital solutions for agriculture (Gillwald and Mothobi, 2019; Kim et al., 2020).

The digital divide, unevenly distribution of digital technologies between rural and urban areas, gender, and youth population still a common problem in transforming agriculture in SSA (World Bank, 2016; Trendov et al., 2019; Tsan et al., 2019). It is mainly affected by restricted or no access to electricity, weak networks, meagre basic connectivity and low digital knowledge, which cause considerable differences in telephone and internet penetration (Malabo Montpellier Panel, 2019). The percentage of individuals using the Internet and digital adoption rate greatly varies across the SSA region. For example, the adoption index and share of individuals using internet is large between SSA for which consistent data are existing (Figs. 1 and 2). In 2016, the Digital adoption index is as high as 0.64 in South Africa, and as low as 0.27 in Ethiopia. The percentage of individuals using internet is 56.17% and 15.37%, respectively, in the same two countries. The disparities are much greater than those between women and men, between the old and the youth or among rural and urban areas. This severely in turns,

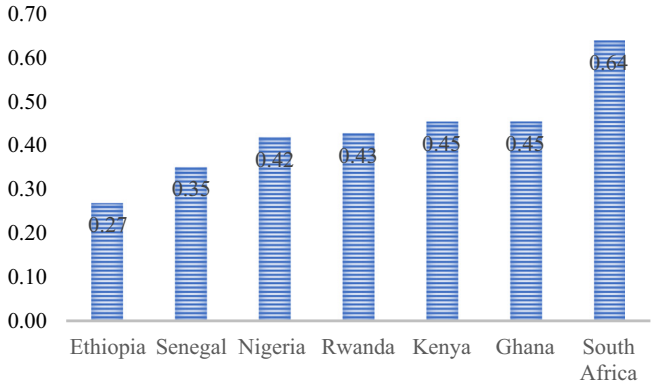


**Fig. 1.** Digital Adoption Index in 2016.
Source: World Bank (2016).

limits access to information on farm-related activities, nutrition and health, financial support, market access, bargaining power, decision-making power as well as thickening their dependency of women in the sub-region (Malabo Montpellier Panel, 2019).

In contrast to the developed economies, the digital gender gap trend in Africa has been increasing over time. While the Internet user gender gap has increased from 20.7 to 33% in between 2013 and 2019 in Africa, it has declined from 9.4 to 5.3% for the same period in Europe (ITU, 2019). On the other hand, the gender inequality is also high in mobile phone use with wide range among the countries (Gillwald and Mothobi, 2019). Whilst disparity in mobile phone use between men and women is as low as −5% in South Africa, it is as high as 42% in Rwanda (Fig. 3). Moreover, on average 14% women less probable to possess a mobile phone than men, and 25% less likely to have internet access than men in SSA (Gillwald and Mothobi, 2019).

Like other digital technologies, women smallholder farmers are underrepresented among digital agricultural solution users in SSA. While share of women smallholder farmers in SSA is estimated to 40–50%, only 25% of registered users of digital agricultural solutions are women (Tsan et al., 2019; Thompson and Gyatso, 2020). The D4Ag solution gender divide is also large between 5 SSA for which reliable data are available (Fig. 4). Whilst gender disparity in using D4Ag solution is highest with 90% in Senegal, relatively the lowest gap has been recorded, 70% in Ghana (Tsan et al., 2019).

Numerous empirical evidences suggest that digital gender disparities associate with years of education and income (Gillwald and Mothobi, 2019). Similarly, Deen-Swarray et al. (2013) found that a positive and significant correlation between use of the Internet and level of education and income (more significantly, use of the Internet and years of education and income in Africa. By the same token, Deen-Swarray

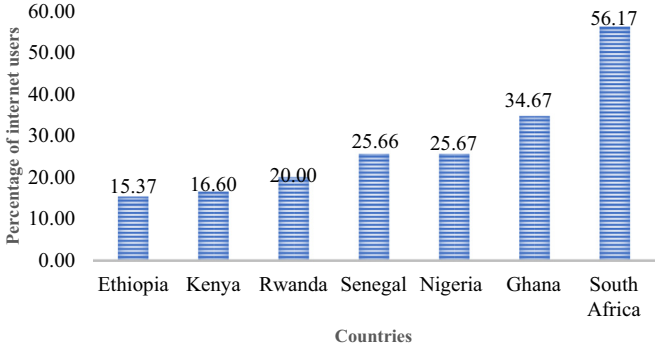


**Fig. 2.** Percentage of individuals using internet in 2016.
Source: World Bank (2016).

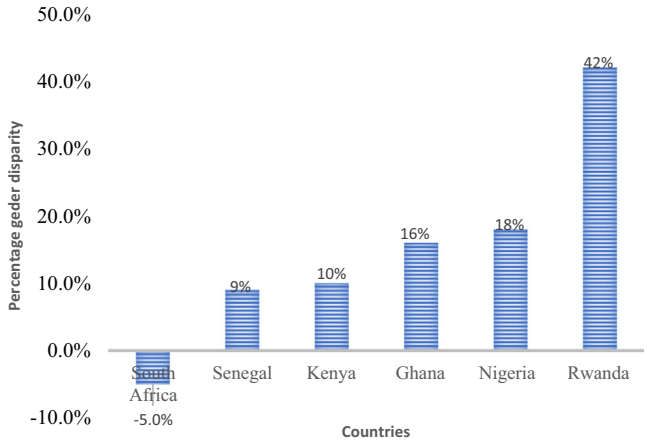


**Fig. 3.** Gender disparity in mobile phone use.
Source: RIA After Access Survey data, 2017.

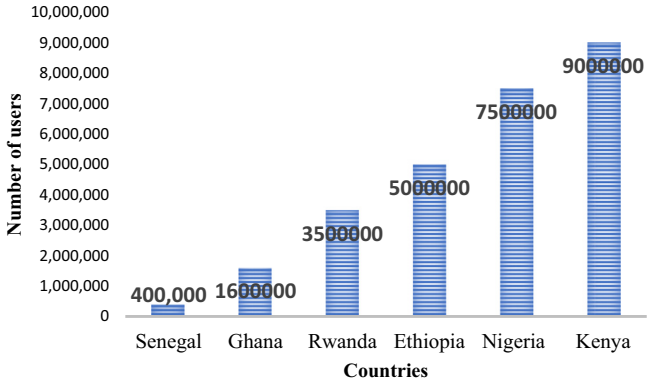


**Fig. 5.** D4Ag solutions by number users in 2018.
Source: Tsan et al. (2019).

et al. (2012) found that education and income were the foremost determinants of gender inequalities in ICT access and use, rather than gender per se. Likewise, the low level of women's mobile phone ownership in the region might be determined by low level of women in terms of income and education when compared to men (Gillwald, 2017; Gillwald and Mothobi, 2019).

Similarly, the urban–rural gap in mobile use in Africa increased from 34% in 2007 to 61% in 2017 (Gillwald and Mothobi, 2019). The substantial urban–rural divide is mainly due to lack of coverage in the rural areas, since mobile operators consider rural areas unprofitable (Gillwald and Mothobi, 2019). There is also evidence that the digital divide continuously tracks historical social inequalities, in such a way that it further broadening the difference among the poor and the rich. Digital exclusion is mainly a matter of poverty, with those at the bottom of the pyramid (women and the poor) being the most disregarded (Research ICT Africa, 2019). Consequently, the effect digital divide is triple that of its gender inequality for poor women farm households residing in rural areas and severely affects their digital uptake in agriculture.

On the other hand, the D4Ag solutions largely succeed in attracting youth but the average age of farmers in Africa exceeds 50 (Tsan et al., 2019). For example, in 2018, the share of youth (under 35 age) users was 65% (Tsan et al., 2019). The big portion of youth show that difficult of the solutions for old-aged group and a vital age divide that must be overwhelmed so as to involve the important share of farmers from older groups.

In addition, the expansion of D4Ag solutions with digital adoption index and services don't coincide in most countries of SSA. While Kenya has lower percentage of individuals internet user when compared countries like South Africa, the country has succeeded in D4Ag among the rest Sub-Sahara African countries for which real data existing (Figs. 2 and 3). Moreover, the country has extra D4Ag enterprises and users than any other SSA (Tsan et al., 2019). The success behind in Kenya might be linked with better collaboration between D4Ag stakeholders and encouraging policy support currently observed in the country.

Even Ethiopia, which has the lowest value for digital adoption index (0.27) and percentage of individuals using internet (15.37%) has excess number of D4Ag solution users when compared to country like, Senegal, which has higher share of internet users (26.6%) with digital adoption index value of 0.35 (Figs. 1, 2 and 5). The number of the solution users in Ethiopia exceeds that of Senegal by more than 12 folds (Fig. 5). Therefore, such big disparity among the two countries is not due to the difference in digital facilities, rather due to the policy strategy and government policy stand on D4Ag expansion.

In Ethiopia, a state-led development model for D4Ag has shown rapid scaling, despite digital literacy among farmers is nominal and facilities for digital services (such as access to the internet) is lower in the country (Tsan et al., 2019). To address these challenges the country has developed effective ways to work around the limitations via heavily investing on 8028 Farmer Hotline deployment and agents who can address smallholder farmers' queries. The platform provides free advisory services via interactive voice response (IVR)/short message service (SMS) for about 5 million farmers (Fig. 5). The service offers a much wider reach than internet-based solutions and odd from countries like Senegal, where the government policy fails to fully support D4Ag (Tsan et al., 2019).

Finally, there exists numerous encounters to accelerating digitization of agribusiness payments to farmers. These involves, restricted connectivity, poor digital literacy, and a weak regulatory ecosystem for digital payments, limited availability of cash-in, and cash-out points and opportunities to use e-money (The World Bank Group, 2020).

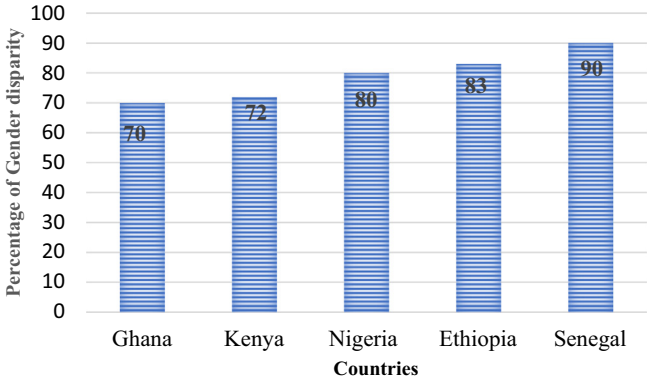


**Fig. 4.** Gender gap in D4Ag solutions use data, 2018.
Source: Based on Tsan et al. (2019).

## 4. Conclusions and policy implications

In Africa, the growing demand of food and nutrition security strive to increase more than double the current status of agricultural production over the next 30 years. The problem will be more worsen SSA, that has already been facing the highest food insecurity than any other regions. The recent revolution of digital agriculture, therefore, will be the good news to SSA that help address their key challenges currently facing the region. Numerous studies have revealed that a few of successful digital services have changed the lives of several smallholder farmers in SSA.

By harnessing disruptive agricultural technology innovations via digital solutions, smallholder farmers in SSA have recognized the advantages to be gained, with the top expected benefits including reduce their

search cost; guaranteed real timely access to safe financial transactions, increased options to navigate the variety of domestic and international chain alternatives; increased multifaceted knowledge and adoption of new sustainable practices; accessed to individualized extension services at a much lesser expense, increased productivity and incomes, enhanced self-employment rate, improved per capita consumption levels and, women empowerment, food security and dietary quality; faster access to price, market, and farming information; reduced the risk of income shocks and poverty incidence and increased adaptability to situational changes.

Despite its clear benefits of digital breakthrough in supporting agricultural transformation there is also evidence that these innovations often fail to adopt and attain broader acceptance. Primarily, the digital technology scale-up remains low, and most of digital agricultural solutions have succeeded below 30% and struggle to scale in the region. In spite of the fact that low status of digital infrastructure in SSA, is not the vital cause for the relatively small numbers of people using digital solutions. For instance, at the end of 2019, about 49% of people across Sub-Saharan Africa were connected to the mobile Internet, but not using the Internet. The failure of policy strategy to create simple workarounds and universal-access mechanisms -that can circumvent digital barriers to D4Ag scale-up are only two of many constraints farmers face. For example, Ethiopia, which has lowest access to the internet and nominal digital literacy among farmers relatively with other SSA, has addressed these challenges via heavily investing on 8028 Farmer Hotline deployment and agents who can address smallholder farmers' queries. The service offers a much wider reach than internet-based solutions, has shown rapid scaling in D4Ag, and odd from countries like Senegal, where the government policy fails to fully support D4Ag.

Others include unaffordability for digital enabling tools and data prices. For most SSA, price for mobile-data baskets and cost of smartphones are still beyond reach for a big portion of the population, in conditions where incomes are already inadequate. In several African countries, regressive taxes on digital devices and services are one the factors that escalate the cost of communication and undermine the use digital technologies. When the challenges of unaffordability sum up with higher digital illiterateness conditions of the region, the problems become more sever for poor smallholder farmers. Consequently, they jointly together lead to low digital scale up among smallholder farmers in agriculture. Accordingly, it needs the region to review taxation system on the sector.

The Digital divide also seems to intensifying existing inequalities in SSA. Unlike, developed economies, the digital gender gap in region has been persistently increasing over time. The disparities are much greater than those between women and men, between the old and the youth or among rural and urban areas, between poor and rich.

Like other digital technologies, women and old smallholder farmers are underrepresented among digital agricultural solution users in SSA. Merely a fourth of registered users of digital agricultural solutions were women among 40–50% women smallholder farmers in 2018. This is mainly due to the low level of their education and income status. Digital exclusion is mainly a matter of poverty, with those at the bottom of the pyramid (women and the poor) being the most disregarded. Moreover, Africa's urban–rural disparity is triple that of its gender inequality. On the other hand, the D4Ag solutions largely succeed in attracting youth regardless of old-aged farmers in the region. For example, in 2018, the share of youth (under 35 age) users was 65%. The big portion of youth show that difficult of the solutions for old-aged group.

Finally, there exists numerous encounters to accelerating digitization of agribusiness payments to farmers. These involves, restricted connectivity, poor digital literacy, and a weak regulatory ecosystem for digital payments, limited availability of cash-in, and cash-out points and opportunities to use e-money. Therefore, a rapid growth of digitization of agricultural payments would call for establishment of foundational drivers and the ecosystem for rural DFS.

Accordingly, one strategy to realize their potential the SSA countries need to work to digitize their own systems or replicate and adopt successful interventions that match with their target populations' digital skill and infrastructure to fully harness the opportunities of digitalization in agriculture. Moreover, to address the problem of digital divide, balancing regulatory and delivery approaches will be essential to permit different categories of services to be offered by different kinds of operators. Likewise, to ease and enhance the use of digital agricultural solution and service, it is essential to ensure affordable access to digital tools for agriculture along with fair price for mobile-data baskets particularly for the poor and women smallholder farmers. These may be realized via reducing data costs, and tax cuts or totally removing customs duty and exoneration of VAT on digital agriculture enabling tools. Similarly, countrywide allocated range not in use in remote areas must be made accessible via low-cost or license-exempt spectrum for communities, non-profit providers or micro-networks.

To tackle the problem of digital skills, capacity building training on the use digital solutions should be offered persistently to the target population by segmenting them via their gender, age, and education.

## Declaration of Competing Interest

None.

## Acknowledgements

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