



Review

Financing Sustainable Agriculture in Sub-Saharan Africa: A Review of the Role of Financial Technologies

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Abstract: African agriculture needs to adapt to climate change and shift from unsustainable production practices to sustainable ones. This requires innovative, substantial, and long-term agricultural investments that can allow all agricultural actors to adopt sustainable agricultural practices. Better and more inclusive options to leapfrog Africa's sustainable agricultural development lie in financial technologies (FinTech). FinTech uses digital technology innovations to ease the provision of financial services to users and thus enhance financial inclusion. The aim of this study is to clarify the important role that FinTech can play in financing sustainability in agriculture in sub-Saharan Africa (SSA). To examine this role, the study shortlisted 17 SSA countries. The literature on FinTech-enhanced agricultural initiatives in these countries was reviewed. The results confirm that FinTech has the opportunity to become the much needed 'support system' for sustainable agriculture in SSA. Most of the financial products accessed by smallholder farmers in the selected countries helped the farmers in addressing production and marketing challenges in agriculture. The technologies can also help to improve efficiency in financing smallholder agriculture, enabling wider adoption of sustainable agricultural practices. To promote the financing of sustainable agriculture at scale, there is a need to train the farmers about the functionality of digital platforms, and policymakers need to address challenges such as gaps in infrastructure between the urban and rural areas.

Keywords: FinTech; sustainable agriculture; digital financial services; financial inclusion; smallholder farmers



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1. Introduction

African agriculture is vulnerable to climate change. Climate-change-induced hazards, such as floods, droughts, pests, diseases, and invasive species, have devastating effects on the livelihoods of smallholder farmers across the continent [1]. These hazards are increasingly impacting yields and destroying the resource base on which farmers depend for their livelihoods. In addition to being vulnerable to climate change, the agricultural sector is a significant contributor to greenhouse gas (GHG) emissions. Despite this, the agricultural sector remains central to the achievement of many Sustainable Development Goals (SDGs) [2]. To meet the increasing demand for food and the challenges of decarbonizing the agricultural sector, there is a need for a transition, where all agricultural producers shift from the current unsustainable production practices to sustainable ones [3]. The transition is an integral part of the global effort to achieve the SDGs, with a focus on SDG 13, and it would ensure that nations pursue climate-resilient development pathways. Shifting to sustainable pathways requires innovative, substantial, and long-term agricultural investments that can allow all agricultural actors to adopt sustainable agricultural practices (SAPs).

The financial sector plays a key role in allowing the agricultural sector to adapt to climate change and contribute to poverty reduction and economic growth [4]. This can happen as a result of improved financial intermediation processes, especially in the

rural sectors of the economy. According to Nsiah et al. [5], financial inclusion is a means to achieve a number of SDGs. Some of these SDGs include no poverty (SDG 1), zero hunger (SDG 2), and good health and well-being (SDG 3). However, the financial sector in Sub-Saharan Africa (SSA) has been widely reported to be less efficient than that in developed countries [6,7]. Traditional financial institutions in the region are associated with several challenges, such as poor governance and insufficient capital growth, and they offer expensive financial services to their customers. Financial inclusion is still narrow in SSA [6] with the poor, especially smallholder farmers in the rural economy, being excluded from formal financial services. This limits poverty reduction, sustained growth, employment, and development in rural areas.

According to Jellason et al. [7] agriculture in SSA is dominated by smallholder farmers who produce up to 80% of the food. However, since smallholder farmers lack access to affordable financial services/products that are tailored to their funding needs, the adoption of sustainable agricultural practices in SSA is quite low. Historically, smallholder farmers in SSA have been financially excluded from formal financial markets. They have generally been considered to be un-bankable by traditional financial institutions like banks. Access to formal financial services for smallholder farmers has been limited by factors such as poorly defined property rights, information asymmetry, and the transaction costs of reaching out to them [8,9].

Whereas traditional financial mechanisms have failed many generations of smallholder farmers in Africa [4], the emergence of financial technologies (FinTech) has been viewed as an engine for growth and innovation that fosters financial inclusion and growth in SSA. Through FinTech, entrepreneurs in the financial sector can leverage innovative and cheaper business models to provide financial services to the large uncovered markets of smallholder farmers in the rural economy. In SSA, the provision of financial services, such as credit, savings, insurance, and remittances, is still under-developed despite the broad demand for the services. FinTech has the potential to meet the demands of different groups in an economy, and thus, enhance financial inclusion, which goes beyond just owning a formal bank account to being able to: (a) Access credit/loan to start a business; (b) Save for the future; (c) Conveniently make payments and send/receive money; and (d) Insure assets/belongings.

FinTech uses digital technology innovations in providing financial services to clients through mobile phones/computers using the internet or bank cards [10]. Examples of FinTech technologies include the internet, cloud, smartphones, machine learning, digital identity, and application programming interfaces. FinTech has disrupted many business models and processes in every sector, and this has been accelerated by the COVID-19 pandemic.

FinTech and Potential Contribution to Sustainable Agriculture in SSA

Improved financial services can help farmers increase agricultural production, adapt to climate change, increase income security, and make riskier and more profitable investments, thus improving their revenues [11]. According to FAO (2015) [11] farmers' lack of access to credit and insurance services prevents them from making investment decisions that could help increase crop yields and strengthen their food security. The diffusion of FinTech or digital financial services into the rural areas of SSA can make it easier for farmers to access credit, insurance, and other financial services.

To date, there is growth in the types of credit services that are accessible to farmers in SSA. Examples include digital credit from financial institutions, crowdfunding (an entrepreneurial finance mechanism that permits the raising of funds from a crowd of investors through online platforms), and peer-to-peer lending. By penetrating the under-served markets of economies in SSA, FinTech has managed to expand access to digital credit at lower transaction costs, greater transparency, and more security for many rural households [4]. Access to appropriate credit can help farmers produce more, thus reducing hunger and promoting food security and sustainability in the SSA agricultural sector.

Through technological innovations, FinTech is also disrupting the insurance markets in SSA. Insurance is an important climate risk mitigation tool for smallholder agriculture in Africa as it is typically rain-fed [8]. Access to insurance by smallholder farmers in Africa is still a challenge. This is because historically, conventional/traditional insurance models offered premiums that were generally high and costly to low-income individuals and smallholder farmers, due to the high transaction/administration costs of reaching out to them. Studies conducted across Africa have increased awareness of index-based insurance services as a promising innovation that seeks to provide protection for small-scale farmers and help increase their productivity and food security. Uptake of the product has increased in recent years but it is still insufficient to make the product commercially viable [12].

In SSA, provision of savings products is led by Mobile Network Operators (MNO) (e.g., M-SHWARI in Kenya and Eco-cash in Zimbabwe) [13], whereas others are bank-led and linked to particular mobile money services (e.g., M-CASH in Uganda <https://www.mcash.ug/projects>, accessed on 10 August 2022). Such savings products allow smallholder farmers to deposit their money toward an established goal (e.g., the next planting season). They also provide smallholder farmers with access to formal savings at a lower cost to the financial service providers. Other common types of savings products accessed by farmers in SSA include remittance products and commitment savings accounts. Remittance products are linked digitally and directly to farmers' savings accounts, and they allow funds to be saved for later uses, rather than to be cashed out immediately. Commitment savings accounts freeze farmers' funds until there is a particular need that has to be financed on a particular date (e.g., seasonal purchasing of seeds). They keep funds safe, secure, and away from family/community pressures.

Smallholder farmers in SSA can potentially benefit from electronic transactions. Digital payment platforms present smallholder farmers with a great opportunity to connect to agricultural value chains in their countries and regions [14]. They can also improve the dissemination of agricultural information/extension services to farmers. Through their mobile devices, farmers can access information on sustainable agronomic practices, pests and disease control, weather forecasts, input and output prices, etc.

As the ecosystem of FinTech continues to grow, it is expected to play a crucial role in the transition to a green and digital economy in SSA. In addition to improving financial inclusion in the region, FinTech has the potential to catalyse the emergence and adoption of innovations in the agricultural sector, promoting growth and development within the sector. This study is important as it contributes to the emerging literature on FinTech and how it relates to growth and sustainability in the agricultural sector. The aim is to clarify the important role that FinTech can play in financing sustainability in smallholder agriculture in SSA. The financial services considered in this study include credit, savings, digital payment platforms, and micro-insurance. The review seeks to answer the following research questions:

1. Which digital financial technologies are accessed and utilized by smallholder farmers in SSA?
2. How does FinTech help finance sustainable agriculture in SSA, and what are the current challenges?
3. How does FinTech help promote financial inclusion in SSA?

The remaining sections of this paper describe the conceptual framework that guided the review, the methodology adopted in identifying relevant materials for review, key findings and discussion points from the literature surveyed, and the conclusion.

2. Conceptual Framework

Sustainable agriculture is important for the development of African societies. To critically analyse the role of FinTech in financing sustainable agriculture among smallholder farmers in SSA, this study relied on the conceptual framework shown in Figure 1. This conceptual framework is a modification of the Food and Agriculture Organization's (FAO) climate-smart agriculture concept [15] and the Department for International Development's

(DFID) sustainable livelihoods framework [16]. According to the FAO, agriculture is a potential investment opportunity to address both mitigation and adaptation, through climate-smart agriculture. However, some climate-smart/sustainable agricultural practices (e.g., irrigation, high-yielding seed varieties) require large amounts of upfront capital. Given the vulnerability context within which smallholder farmers operate (e.g., they are credit-constrained), it is a challenge for them to move to sustainable practices [17].

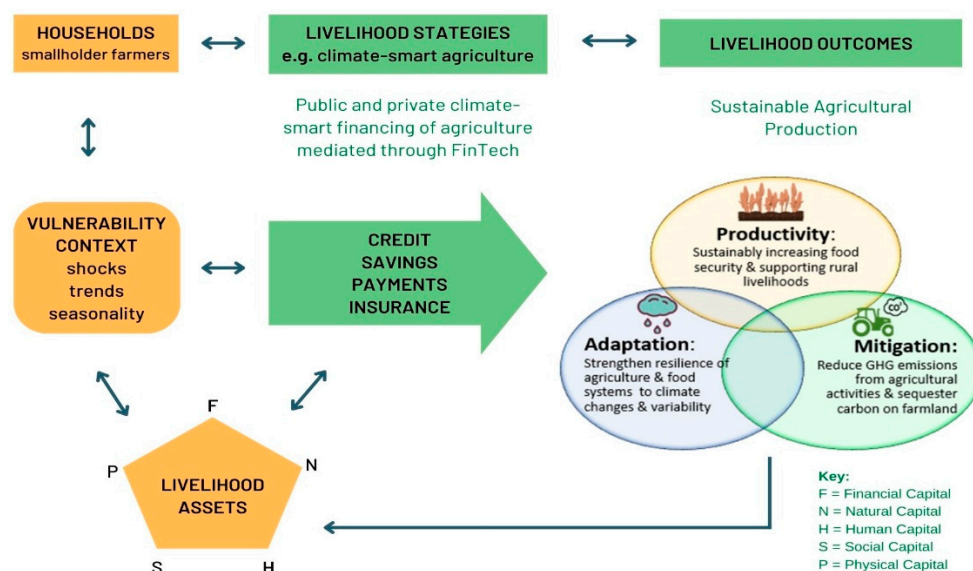


Figure 1. The conceptual framework for financing sustainable agriculture (adapted from FAO [15] and DfID [16]).

The conceptual framework illustrates that financing sustainability in agriculture is realized through FinTech. The emergence of FinTech provides smallholder farmers with new methods of accessing financial services, thus alleviating their credit and other financial constraints. FinTech also offers financial service providers opportunities to tap into the under-served markets of the economy. Along similar lines, Zhao et al. [18] argue that new methods of accessing financial services, such as crowdfunding, index-based insurance, and digital marketplaces, impact smallholder farmers' adoption of sustainable agricultural practices. Coupled with favourable public policy frameworks, this provides important incentives for changing the behaviour of smallholder farmers. This is critical for making the transition towards sustainable agriculture in the smallholder farming sector, and it can lead to more diversified rural livelihood outcomes and assets.

3. Materials and Methods

3.1. Study Area

The research was focused on SSA. The region lies south of the Sahara and, according to the African Development Bank classification, it consists of 48 African countries (<https://www.afdb.org/en/countries>, accessed 5 February 2023). Out of the 48 countries, a total of 17 countries were shortlisted for the study, representing about 35% of the region. In the shortlisting process, firstly, SSA countries where M-PESA, ACRE, and MyAgro are operating were selected. These three are the main FinTech associations reviewed in this study. Countries with M-PESA include Kenya, Tanzania, Mozambique, Lesotho, the Democratic Republic of Congo, Ghana, and South Africa. Countries with ACRE include Kenya, Tanzania, Rwanda, Senegal, Ghana, Uganda, Zambia, Malawi, and Mozambique. MyAgro operates in Mali, Senegal, and Tanzania. Secondly, in order to improve the geographic representation for each of the four regions in Africa, more countries in which FinTech products targeted the agricultural sector/smallholder farmers were identified. These include Uganda, Nigeria, Papua New Guinea, Zimbabwe, and Botswana, as illustrated in

Appendix A, Table A1. Table 1 presents a summary of the number of countries shortlisted in the review from Southern, East, West, and Central Africa.

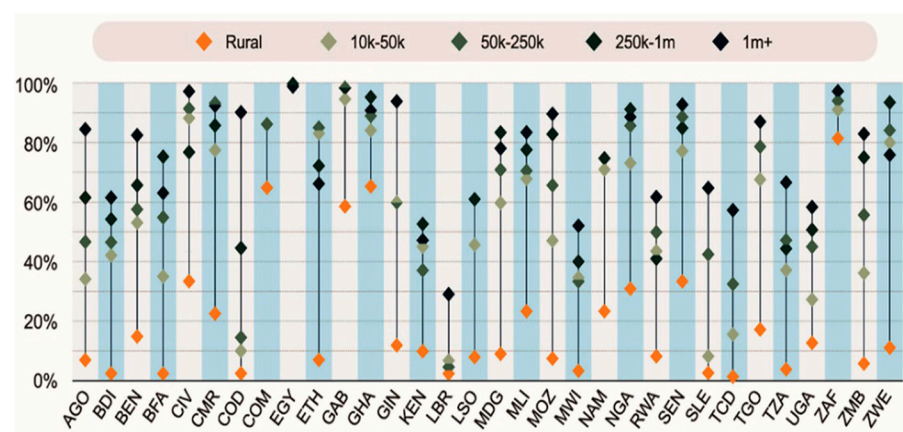
Table 1. Number of countries reviewed from each geographical region.

SSA Region	Total No. of Countries	No. of Countries Shortlisted
Southern Africa	13	7
East Africa	13	4
West Africa	15	5
Central Africa	7	1
Total	48	17

Source: scoping survey, 2022.

SSA is the least climate-resilient region globally, has a limited adaptive capacity [19], and has a low socio-economic base. Approximately 60% of SSA's population lives in rural areas, where they depend on rain-fed agriculture as the main source of household income and livelihood [7]. Climate impacts are continually being felt in the agricultural sector across the region, and they are accompanied by an explosion in population, as well as shifts in consumption patterns [20]. This poses a significant threat to food security in the region. Therefore, the need for a transition towards sustainability in the region cannot be over-emphasized. The transition to sustainability in the agricultural sector can be promoted and strengthened by allowing innovative services such as FinTech to transform the business models in the sector. If well supported by reliable and adequate physical infrastructure (e.g., electricity and mobile network), innovative financial services can be key drivers of financial inclusion, especially in the rural areas of SSA.

On average, approximately 25 percent of the rural population in SSA have access to electricity [21], and only 6 percent have access to internet services [22]. As illustrated in Figure 2, there is a considerable gap in access to electricity between rural and urban households in SSA. In many SSA countries, less than 20 percent of rural households have access to electricity.



Note: Data for various years between 2010 and 2019 and Egypt 2008.

Figure 2. Share of households with access to electricity by country and city size (Source: OECD 2022 [23]).

Figure 3 shows that rural households in Africa have less access to the internet than urban households. The gap in infrastructure between the urban and rural areas in SSA has over the past years deprived rural residents of the opportunities available to urban residents. It is a considerable obstacle to reaching smallholder farmers through digital financial services.

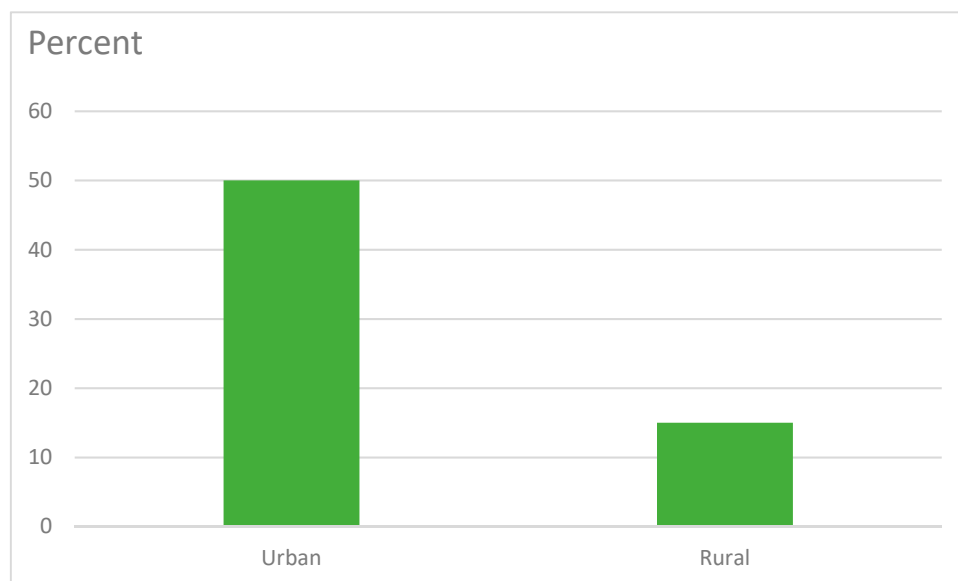


Figure 3. Internet usage differences by geographical location (Source: ITU 2021 [22]).

3.2. Data Collection

A scoping review methodology was adopted in this study. Publications that focused on the utilization of FinTech in agriculture by smallholder farmers were identified. The scoping review method was adopted because it is better than the systematic review in that it is more flexible and allows the researcher to redefine the literature and key terms of the study. Searches for this study were made through Scopus, Web of Science, Google Scholar, and Google. The following key terms were used to identify relevant articles for the study:

- “FinTech and agriculture”;
- “Financial services and agriculture”;
- “Digital agriculture”;
- “Digital credit and agriculture”;
- “Digital savings and agriculture”;
- “Digital payments and agriculture”;
- “Insurance and agriculture”.

Peer-reviewed articles were included in the study as long as they responded to the research questions and addressed issues to do with the access and utilization of digital financial services by smallholder farmers for sustainability in the agricultural sector. To identify other relevant peer-reviewed studies, a snowball strategy was applied based on a thorough review of references from each article. Duplicated papers and papers not written in English were excluded from the study. To obtain a more detailed background on FinTech in agriculture, no restriction was made on the year of publication for the literature. In addition, due to the limited number of peer-reviewed articles on the topic of “FinTech” in agriculture in the African context, grey literature (reports) and web pages were also included in the study. These were included as long as they addressed issues around the access and utilization of financial technologies by smallholder farmers in SSA. A flow diagram of the approach used in selecting the literature for this study is given in Figure 4.

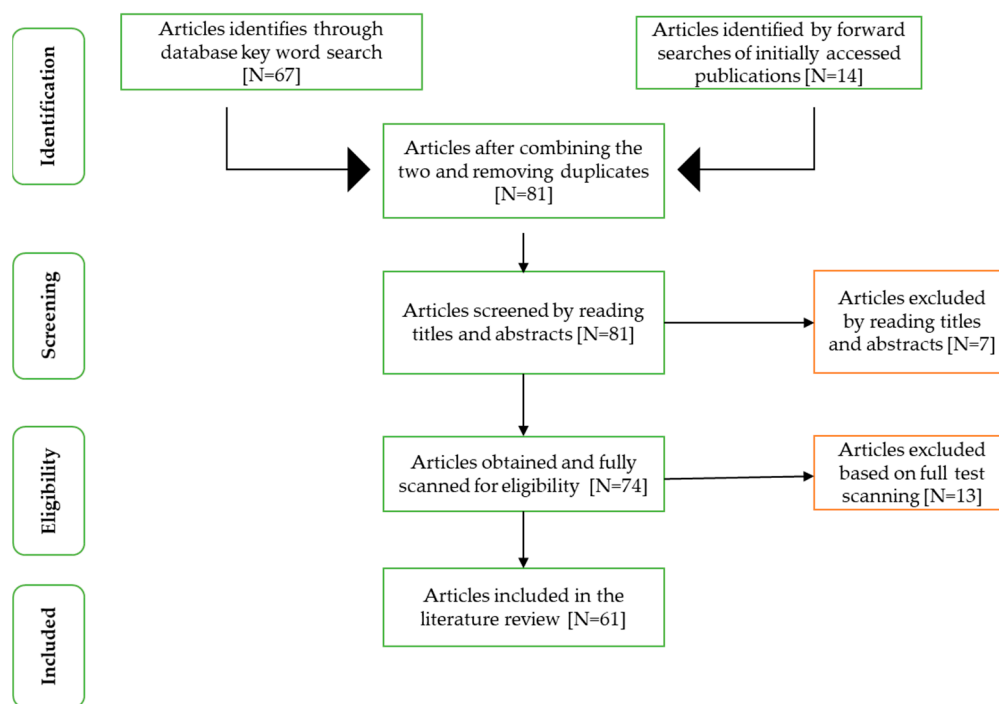


Figure 4. Flow diagram summarising the approach used in selecting literature.

After the inclusion and exclusion process, a total of 61 relevant articles were identified. They include 27 peer-reviewed articles, 29 reports, and 5 web pages, as shown in Table 2. It is important to note that of the 27 peer-reviewed articles, 8 articles were supporting literature outside the given criteria, which were also used in this study.

Table 2. Type of articles accessed.

Type of Article	Number
Peer-reviewed	19
Reports	29
Peer-reviewed *	8
Web pages	5
Total	61

* Literature outside the search criteria. Source: scoping survey 2022.

4. Results and Discussion

The key findings of this study are presented in response to the research questions outlined in the introduction. Firstly, the results on financial technologies that are accessed and utilized by smallholder farmers in SSA are given in Table 3. Secondly, the results on how FinTech is helping finance sustainability in SSA agriculture are given in Section 4.2. The review results, in this case, were categorized according to financial services/products that include digital credit, digital savings, insurance, and digital payments. Then, in Section 4.3, a discussion on how FinTech helps promote financial inclusion in SSA is given.

Table 3. Findings on financial technologies accessed and utilized by smallholder farmers.

Title	Year	Findings
Digital platforms for smallholder credit access: The mediation of trust for cooperation in maize value chain financing.	Agyekumhene et al., 2018 [24]	Interaction between farmers and traders on a digital credit platform increases farmers' access to information that helps them address farm conditions. Farmers' access to hybrid seeds that are drought-resistant and have high-yield potential also increased.
Defamiliarizing the Domestic: Exploring "M-Kopa Solar" and Sustainable Practices in Rural Kenyan Households	Wyche et al., 2018 [25]	M-Kopa Solar is a green solution to the problem of limited access to electricity faced by farmers in rural Kenya. Small livestock farmers in Kenya use M-Kopa solar-powered LED bulbs to keep their poultry warm, increasing productivity.
Use of mobile financial services among farmers in Africa: Insights from Kenya	Parlasca et al., 2022 [26]	Through platforms like M-PESA, smallholder farmers have access to fast money to finance farm-related activities, such as early planting, casual labor, purchasing of improved breeds for livestock, etc.
Does bundling crop insurance with certified seeds crowd in investments? Experimental evidence from Kenya	Bulte et al., 2020 [17]	After receiving a free hybrid crop insurance product, farmers increased investments in agriculture and expanded land under production. They also invested more in complementary inputs such as fertilizers.
Uber for tractors? Opportunities and challenges of digital tools for tractor hire in India and Nigeria	Daum et al., 2021 [27]	Smallholder farmers in Nigeria benefit indirectly as the supply-side constraints to mechanization are relaxed. However, transaction cost effects are limited for both smallholder farmers and service providers who own tractors.
The Social and Economic Impact of M-PESA on the Lives of Women in the Fishing Industry on Lake Victoria	White 2012 [28]	M-PESA enables rural women and farmers to save and invest in sustainable off-farm livelihood strategies like fishing. In addition, they have access to credit to purchase farm inputs like high-yielding seed varieties.
Mobile phone use is associated with higher smallholder agricultural productivity in Tanzania, East Africa	Quandt et al., 2021 [29]	In Tanzania, the use of mobile phones by farmers helped increase maize yields, agricultural profits, and reduced the costs associated with farming.
Risk Sharing and Transactions Costs: Evidence from Kenya's Mobile Money Revolution	Jack and Suri 2014 [30]	Households that use M-PESA receive more remittances and money than non-users when faced with shocks.
After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection	Janzen and Carter 2013 [31]	Upon receipt of a pay-out, insured households are less likely to sell their livestock and to anticipate reducing food consumption, unlike their uninsured neighbours.
Facilitating Savings for Agriculture: Field Experimental Evidence from Malawi	Brune et al., 2015 [32]	In Malawi, farmers with access to savings accounts increased farm investments by 13 percent and crop output by 21 percent.
Selection into Credit Markets: Evidence from Agriculture in Mali	Beaman et al., 2014 [33]	Farmers that received loans in Mali increased their investment and expenditure on agricultural inputs.
Seasonal Credit Constraints and Agricultural Labor Supply: Evidence from Zambia	Fink et al., 2014 [34]	The provision of credit to farmers in Zambia during the growing season helped boost their outputs and revenues by about 10 percent. The increase in credit was also associated with an increase in consumption and local farm wages.
Maize Productivity and Household Welfare Impacts of Mobile Money Usage in Tanzania	Kilombele et al., 2015 [35]	Farmers with access to mobile money services increased their maize productivity by approximately 124 kg/acre and reduced their poverty likelihood by nearly 25 percent.
Scaling up index insurance for smallholder farmers: Recent evidence and insights scaling up index insurance for smallholder farmers	Greatrex et al., 2015 [36]	In Kenya, Rwanda, and Tanzania, farmers insured through the ACRE program had more earnings and invested more in agriculture compared to their uninsured counterparts. In Ethiopia, farmers insured through the Rural Resilience Initiative program increased savings, grain reserves, and number of livestock owned compared to the uninsured. In Kenya and Ethiopia, farmers insured through the index-based livestock insurance program increased their herd sizes and had reduced total livestock mortality risks.

4.1. Which Financial Technologies Are Being Accessed and Utilized by Smallholder Farmers in SSA?

The results in Table 3 show that smallholder farmers from SSA have access to digital insurance, credit and savings facilities, and digital payment platforms. Digital payment platforms are the foundation upon which other financial services are provided, and in SSA, they are mainly offered through mobile money platforms. The mobile money platforms can generate transactional data, thus, developing track records for borrowers.

4.2. How does FinTech Help Finance Sustainable Agriculture in SSA and What Are the Current Challenges?

Firstly, following Mushi et al. [37] and the conceptual framework given in Section 2 of the study, this paper views sustainable agriculture as having the following three categories:

- Economic sustainability—characterized by less input costs, high farm production, good market prices, and increased incomes for farmers. This results in increased farm productivity, profitability, adaptation and strengthened food production systems in the long term;
- Environmental sustainability—characterized by mitigation activities, such as reduced greenhouse gas emissions, carbon sequestration on farmlands, use of fortified agrochemicals, and renewable energy sources by farmers; and
- Infrastructural and resource sustainability—this entails that platforms that provide financial services to smallholder farmers should continually be maintained and upgraded.

To provide long-term financial services to farmers and achieve sustainability in the agricultural sector in the digital era, the three above-mentioned sustainability concepts should be addressed. The following section presents a summary of some of the digital financial products available for smallholder farmers in SSA countries and how they are helping in financing sustainability in the agricultural sector by addressing at least one of the sustainability concepts stated above.

Most of the financial products reviewed in this study help address some of the main production and marketing challenges faced by smallholder farmers in SSA. Some of these include limited access to credit [24], the use of substandard/low-quality inputs, and unfair input/output prices in agricultural markets [38]. Emerging technologies in the financial sector can essentially help to improve efficiency in financing smallholder agriculture, thus enabling wider adoption of sustainable practices in the sector [10].

4.2.1. Digital Credit

For a sustainable agricultural sector, SSA needs well-designed and functional credit markets. The main constraint to the adoption of sustainable agricultural practices by smallholder farmers, especially women in the region, is the lack of capital/funding to purchase improved/high-quality inputs [24]. Agricultural investments are capital-intensive, and for farming to be more efficient and productive, smallholder farmers require financial support in the form of credit. Traditionally, in SSA, microfinance has led as an alternative source of credit to agricultural finance [4]. Though important, agricultural loans from microfinance institutions are expensive to smallholder farmers due to high transaction costs.

A study in Zambia by Fink et al. [34] found that the provision of short-term loans to farmers helped to boost output and revenues among the farmers. This was due to an increase in labour hiring and food consumption. Many challenges among smallholder farmers in SSA are a result of reliance on rain-fed agriculture and the high cost of inputs. In another study by Beaman et al. [33] in Mali, farming households that had access to loans increased their investments and expenditure in agricultural inputs. Through the AgroTech platform, smallholder farmers in Ghana have access to hybrid seeds that have significant resistance to droughts, resulting in efficient production [24]. They also receive information that helps them respond to pest and disease outbreaks. Another digital credit platform accessed by smallholder farmers in Ghana is RiMFin. Through the service, rice producers in Ghana found it easier to hire farm laborers for harvesting, land preparation, and other

farm activities [39]. Rainfed/irrigation outgrower farmers also received training on pest and disease control, seed and fertilizer placement, and water management, through the service, thus improving their productivity.

In Kenya, M-SHWARI helps farmers to access credit/capital for purchasing fertilizers, quality seeds, and farm machinery [40]. This increases farm productivity and incomes. M-KOPA also supports smallholder farmers in adopting renewable energy sources, irrigation, and purchasing inputs. For example, small livestock farmers in Kenya use solar-powered LED bulbs to keep their poultry warm, increasing productivity [25,41].

Results from the review have shown that digital credit products like AgroTech [24] and RiMFin [39] in West Africa, and M-KOPA and MSHWARI [25] in East Africa are helping to finance agricultural sustainability among smallholder farmers. The products provide farmers with funding at a lower cost to the lenders. This ensures a level playing field for those living in rural areas, where there is poor access to traditional sources of finance.

4.2.2. Digital Savings

In recent years, FinTech has caused an upsurge in the number of savings applications all over the world [12]. Because smallholder farmers in SSA do not produce enough food for their own consumption, they often tap into savings to buy food. With access to savings, farmers can make bigger agricultural investments, increase their income security, and create a buffer against shocks, leading to better household nutrition. In SSA, mobile money accounts have become a popular method of saving money formally. A study by Brune et al. [32] found that Malawian cash-crop farmers who used a commitment savings product increased farm-level investments in addition to having their crop output boosted.

Another savings product is MyAgro—an input retailer in West Africa that helps farmers to develop savings habits. Smallholder farmers can save small amounts of money that they can invest in their farms in the future to boost production. It also offers smallholder farmers a convenient method of paying for inputs like certified seeds and fertilizers that help improve farm profits and harvests [42]. In East Africa, there is M-PESA, which enables rural women and farmers to save and invest in sustainable off-farm livelihood strategies like fishing. In addition, they have access to credit to purchase farm inputs like high-yielding seed varieties. M-PESA also provides farmers with fast money to finance farm-related activities, such as early planting, casual labor, purchasing of improved breeds for livestock, etc. [26,28,43].

4.2.3. Digital Insurance

To enhance sustainability in the agricultural sector of African countries, the African Union (AU) established an index-based weather insurance program known as the African Risk Capacity (<https://www.arc.int/about>, accessed on 2 September 2022), which is being piloted in AU member states. Index-based insurance products are more affordable to smallholder farmers than indemnity-based insurance products [8]. They allow poor farmers to access affordable insurance packages to de-risk their enterprises and build their resilience to climate-related shocks. Technological innovations used in this case include remote satellite sensing and picture-based monitoring of crop/livestock health. If insured crops/livestock show damage/injuries, farmers receive insurance pay-outs through digital payment features on their smartphones. A study in Ghana found that farmers with access to rainfall-index-based insurance had more revenue and spent more on harvest expenditure compared to the uninsured ones [44].

Smallholder farmers in East Africa have access to insurance products offered through the Agriculture and Climate Risk Enterprise (ACRE). ACRE insures smallholder farmers' loans for buying certified/improved seeds and fertilizers, improving their adoption of insurance and quality seeds, as well as farm productivity [8,38]. Kenyan smallholder farmers, for example, have access to bundled insurance services. After purchasing certified seeds, the farmers receive a free hybrid crop insurance service. This improves the uptake of certified seeds and the willingness to pay for insurance in the area under cultivation [17].

4.2.4. Digital Payment Platforms

Most of the transactions across agricultural value chains in SSA occur through informal cash-based channels, which are typically slow, costly, risky, and unreliable. FinTech is revolutionizing agricultural value chains across the region. It provides services to marginalized populations and makes payments and money transfer processes cheaper, quicker, and simpler through automation [10,45]. MNOs are leading in providing clients with digital platforms for transferring money/making payments using smartphone applications. For example, M-PESA, Africa's largest and most successful FinTech platform, has active agents operating in Kenya, Tanzania, South Africa, and other African countries [7]. In Kenya, many farmers sell and receive payments for their agricultural goods through mobile-phone-based accounts. This is important and beneficial to smallholder farmers across SSA, considering that they live in areas that are poorly served by traditional financial systems [46].

In other cases, commercial banks are digitalizing/partnering with start-up firms that provide FinTech packages to expand their financial services to the banked and unbanked parts of the population by offering branchless banking services. Evidence from the adoption and utilization of these innovations indicates that FinTech has the potential to stimulate growth and transform the livelihoods of smallholder farmers in SSA. According to the Global Findex Database, smallholder farmers' interest in mobile money can be improved if digital payment platforms also offer services that allow farmers to purchase farm inputs and access credit [21]. In addition to using their mobile phones as digital payment platforms, farmers can use them to access information about input/output markets, prices, business opportunities, etc., through digital marketplaces, thus improving spatial arbitrage.

In southern Africa, there is the SmartFarmer innovation, a digital payment platform that was launched by the Riskflow Development Bank of Southern Africa in 2019. It seeks to connect agricultural actors, such as funders, farmers, input providers, and government departments, to agricultural value chains [13]. The innovation also provides agricultural producers with extension services and information on best agricultural practices and general agricultural information that helps them adapt/mitigate climate change. The information supports farmers in farm-level decision-making, leading to improved profits and agricultural productivity.

Another digital payment platform that has revolutionized African agriculture is the Hello Tractor platform. It is also known as the 'uber of tractors.' This innovation addresses the challenge of under-cultivation of arable land by small-scale farmers who have small plots of land. Due to increased mechanization, farm productivity increases [27,42,47]. In addition, small-scale farmers are provided with information that helps them optimize input usage and manage other resources on their farms.

There is also M-CASH, a mobile-based product that facilitates the issuance of subsidized inputs from agro-input dealers to smallholder farmers in Uganda. Through this product, farmers have access to farming goods and services that are certified by the industry and are also cheaper. In addition, farmers do not have to travel long distances/incur costs in trying to access input providers. Inputs will be delivered by the agro-input dealers to the agreed points nearest to the farmer. This enhances the adoption of good-quality inputs by smallholder farmers.

4.2.5. Current Challenges

Although FinTech has enabled the expansion of financial services to groups of people that traditionally fell outside formal services, it is still unable to meet the unique needs of smallholder farmers. Most of the services are offered through mobile-based platforms and require access to electricity, the internet, and ownership of smartphones. This is still a challenge in many rural areas in the SSA region [10]. Smartphone ownership is still limited among smallholder farmers in SSA, and the farmers who own phones use them for calls and messaging applications only. They have little or no awareness of mobile finance platforms. Agricultural payments are still cash-heavy across SSA, with agricultural

producers generally preferring cash to digital wallets [38]. They have no confidence in performing digital transactions due to low digital literacy [7] and adoption.

However, the World Bank [48] showed that between 2014 and 2017 there was a decrease in agricultural payments that were made in cash only in SSA. This is illustrated in Figure 5. There may be a possibility that the decrease in cash payments was caused by an increase in public debt and not an increase in the FinTech industry.

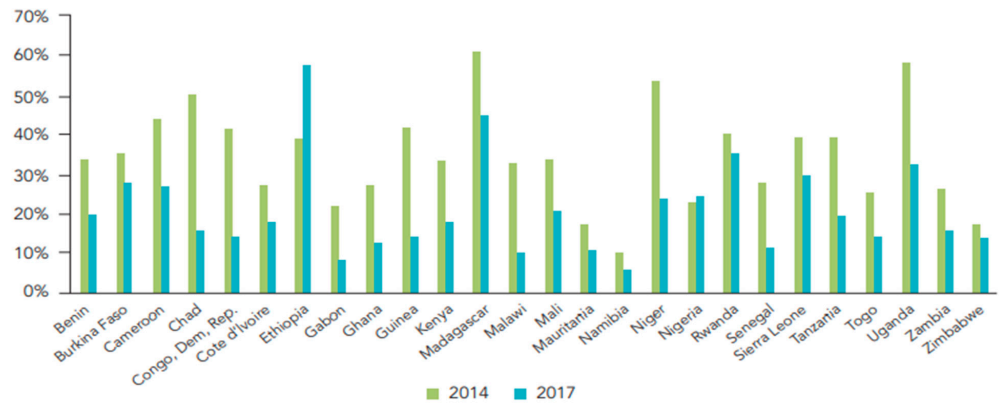


Figure 5. Decrease in cash agricultural payments across SSA between 2014 and 2017 (Source: World Bank Group [48]).

There is, however, evidence that in countries like Kenya, where mobile money services have been successfully adopted, economic growth is greater [49]. Figure 6 shows an estimation of Kenya’s GDP per capita with and without mobile money services. M-PESA was launched in 2007 and over the years the number of users of the service increased. As shown in Figure 6, Kenya’s GDP per capita was around USD 1600 in 2019. In the absence of mobile money services, the figure would be around USD 1450, implying that mobile money services have a positive effect on economic growth.

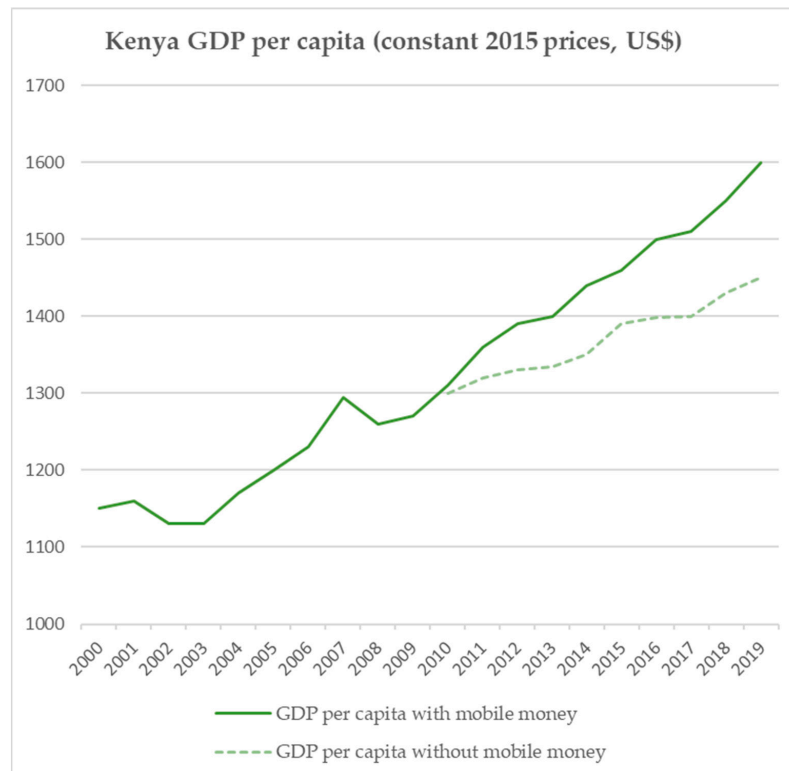


Figure 6. Effect of FinTech on GDP growth in Kenya (Source: Lopokoiyit and Mitha 2022 [49]).

As the primary service providers of mobile money services, telecommunications companies ensure that their services satisfy the needs of the poor. For example, M-PESA enables customers to deposit, save, transfer or withdraw money. The platform has positively impacted the Kenyan economy by enabling easing transactions, enabling higher savings, increasing per capita incomes, and helping to solve the temporary liquidity problems of the households.

4.3. How does FinTech Help Promote Financial Inclusion in SSA

There is growing evidence that FinTech evolution in the financial sector can help drive financial inclusion in African economies [46]. FinTech evolution has helped the financially excluded groups of African economies to overcome most of the binding constraints on formal financial services. Some of these constraints include low incomes, transaction costs, and collateral requirements. By eliminating these constraints, FinTech turned financial exclusion into financial inclusion [50]. This section of the paper presents a review of how FinTech helps promote the financial inclusion of smallholder farmers in SSA. In addition, the role of associations in governing the FinTech companies and applications is also discussed.

4.3.1. M-PESA in Kenya

Several studies have shown that mobile financial services, such as M-PESA in Kenya, promote financial inclusion [50]. According to Ndungu (2018) [46], the first step to financial inclusion is the use of digital platforms or electronic banking services in transacting. Digital payment platforms form the foundation upon which other financial services, such as credit, savings, and insurance [8], are provided. In SSA, they are mainly offered through mobile platforms like M-PESA.

M-PESA was launched in 2007 by Safaricom, a local MNO. Through M-PESA, smallholder farmers have access to mobile savings accounts [51] and digital loans [52]. For instance, Vodafone developed the Connected Farmer Alliance [52], a mobile-based platform that facilitates digital payments and communication services between smallholder farmers and agribusiness companies in Kenya, leveraging on M-PESA and AgriVAS. However, a study that was conducted by Parlasca et al. (2022) [26] in Kenya to analyse the use of digital services, such as credit and savings, among farmers found that about 80% of farmers used mobile money, but only 15% used mobile services for agriculture-related payments, and less than 1% of the farmers used mobile phones to access digital loans.

M-PESA has also led to the lowering of the gender financial inclusion gap in Kenya. In addition to providing female farmers with digital loans, M-PESA enables rural women and farmers to save and invest in sustainable off-farm livelihood strategies like fishing. The women have access to savings products that are more private, secure, and tailored to their needs. This has led to women's empowerment as it allows women to manage household finances with less control by the males.

Through automation [53], FinTech initiatives like M-PESA have helped to solve the inefficiency problems that were associated with traditional financial services. For example, in Kenya, according to Ndungu (2022) [50] before M-PESA, the average distance to the nearest bank was 9.2 kilometres. After M-PESA, the average distance to the nearest M-PESA agent was 1.4 kilometres [50]. As a result of its success in Kenya, M-PESA has expanded to other countries in SSA like Tanzania, South Africa, Lesotho, etc.

4.3.2. The Agriculture and Climate Risk Enterprise (ACRE) Africa

ACRE is an insurance intermediary that helps protect smallholder farmers in selected SSA countries against climate change vulnerabilities. ACRE has offices in Tanzania, Kenya, and Rwanda. Through its projects in Senegal, Ghana, Uganda, Zambia, Malawi, and Mozambique, ACRE is making agricultural insurance products more accessible, available and affordable to smallholder farmers, thus promoting financial inclusion [8,54]. ACRE insures smallholder farmers' loans for buying certified or improved seeds and fertilizers,

improving their adoption of insurance and quality seeds, as well as farm productivity. For example, in the Horn of Africa, ACRE provides de-risking and financial services to pastoralists/farmers through index-based livestock insurance (IBLI) [55]. In addition, the pastoralists are given access to savings accounts to help them address shocks.

4.3.3. MyAgro

MyAgro is an input retailer in Mali, Senegal, and Tanzania that promotes financial inclusion by helping farmers to develop savings habits [56]. Smallholder farmers can save small amounts of money that they can invest in their farms in the future to boost production. It also offers smallholder farmers a convenient method of paying for inputs like certified seeds and fertilizers that help improve farm profits and harvests. In African rural areas, female farmers have less access to formal savings accounts than men. This limits their ability to manage shocks and to invest in agriculture. According to Varangis et al., 2021 [56], women have limited access to financial services like savings accounts because they tend to be time-constrained. FinTech has the potential to unlock financial services for women in agriculture, promoting financial inclusion. In an effort to lower the gender inclusion gap, MyAgro targeted more female farmers from Tanzania [56].

4.3.4. FinTech Associations in Africa

As the number of FinTech companies, applications, and entrepreneurs in Africa continues to grow, country and regional level associations that support the creation of innovative financial technologies have been created. Firstly, there is the Africa FinTech Network, a regional FinTech association that unites FinTech leaders/entrepreneurs, organizations, and stakeholders in Africa. It does so through country-level associations (https://findexable.com/wp-content/uploads/2022/03/V2-Africa-Fintech-Radar_FINAL_10Sep21-1.pdf, accessed on 5 February 2023), e.g., the FinTech Association of Kenya, the FinTech Association of Nigeria, Mozambique FinTech Association, and many others. The country-level associations help foster connection and communication among FinTech companies/start-ups in their respective countries, thus promoting financial inclusion.

5. Conclusions

This paper reviewed the linkages between innovative financial technologies and sustainability in the context of smallholder agriculture to shed light on their usefulness in driving new financial products and services. The experiences from the SSA countries reviewed in this study have shown that FinTech is a critical component for productivity and sustainability in the agricultural sector. The financial technologies being accessed by smallholder farmers help in addressing one or more of the SDGs. Some of these include SDG 1, SDG2, SDG 8, and SDG 13. In addition, the review has shown that with FinTech, some countries in SSA (e.g., Kenya) are global leaders in mobile money services, offering a wide range of financial services and products to smallholder farmers. Other African countries can learn from the Kenyan experiences and scale up/replicate the FinTech models that successfully financed smallholder agriculture in Kenya.

FinTech enhances farmers' access to financial services, such as credit, savings, and mobile money. This results in higher productivity and profitability of farm enterprises, higher incomes for smallholder farmers; improved access to high quality/certified inputs, improved quality of produce, improved access to input and output markets, strengthened resilience of food production systems, adoption of sustainable land use management practices, and other co-benefits and multiplier effects on non-farm sectors of the economy. Concerning insurance products, experiences from countries studied in this review have shown that the uptake of insurance products among smallholder farmers can be promoted if the products are either subsidized or bundled with inputs such as certified seed varieties or agro-advisories. This provides additional utility to smallholder farmers. Such initiatives present great partnering opportunities for input agro-dealers, government agencies, and insurance providers to provide bundled financial products to African smallholder farmers.

FinTech offers African countries a great opportunity to leapfrog inclusive economic growth and development. It challenges the limitations and shortcomings of traditional financial institutions as it provides financial services with better accountability, accessibility, and efficiency. However, smallholder farmers' limited access to electricity, internet/network in rural areas, and poor adoption of digital products, especially among older farmers, are serious limitations to financing smallholder agriculture through FinTech. To promote the financing of sustainable agriculture at scale among smallholder farmers there is a need to train the farmers about the functionality of digital/mobile platforms. Policymakers also need to address challenges, such as the gaps in infrastructure, between the urban and rural areas in SSA as they deepen socio-economic inequalities in the communities.

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Appendix A

Table A1. Review of FinTech and sustainable agriculture in SSA.

Category of Product	Product Name	Country	Description	Source
Digital Savings	MyAgro	Senegal, Mali, and Tanzania	MyAgro is an input retailer in West Africa that helps farmers to develop savings habits. Smallholder farmers can save small amounts of money that they can invest in their farms in the future to boost production. It also offers smallholder farmers a convenient method of paying for inputs like certified seeds and fertilizers that help improve farm profits and harvests.	[42]
Insurance	Bundled Insurance	Kenya	After purchasing certified seeds, smallholder farmers receive a free hybrid crop insurance service. This improves the uptake of certified seeds, and willingness to pay for insurance in the area under cultivation.	[17]
Digital Credit	AgroTech- Digital platforms for trust in credit provision	Ghana	Through the AgroTech platform, smallholder farmers in Ghana have access to hybrid seeds that have significant resistance to droughts, resulting in efficient production. They also receive information that helps them respond to pest and disease outbreaks.	[24]

Table A1. Cont.

Category of Product	Product Name	Country	Description	Source
Digital Payments and Digital Credit	SmartFarmer	Botswana, Malawi, Zambia, Zimbabwe, Tanzania, Lesotho, South Africa, and Mozambique	The SmartFarmer innovation was launched by Riskflow DBS in 2019. It seeks to connect agricultural actors such as funders, farmers, input providers, government departments, etc. to agricultural value chains. The innovation also provides agricultural producers with extension services and information on best agricultural practices and general agricultural information that helps them adapt/mitigate climate change. The information supports farmers in farm-level decision-making, leading to improved profits and agricultural productivity.	[13]
Digital Credit and Digital Savings	M-SHWARI	Kenya	Through M-SHWARI, farmers have access to credit/capital for purchasing fertilizers, quality seeds, and farm machinery. This increases farm productivity and incomes.	[40]
Digital Credit	M-KOPA	Kenya Tanzania and Uganda	M-KOPA supports smallholder farmers in adopting renewable energy sources, irrigation, and purchasing inputs, e.g., small livestock farmers in Kenya use solar-powered LED bulbs to keep their poultry warm, increasing productivity.	[25,41]
Insurance	NWK Agri-Services/ Farmershield weather	Zambia	Farmershield trained smallholder cotton farmers on yield improvement. Through this, the area cultivated under cotton production in Zambia increased.	[39]
Digital Credit	Rice mobile Finance RiMFin	Ghana	Through RiMFin, rice producers found it easier to hire farm laborers for harvesting, land preparation, and other farm activities. Through the service, rainfed/irrigation outgrower farmers also received training on pest and disease control, seed and fertilizer placement, and water management, thus improving their productivity.	[39]
Digital Credit	DigiFarm	Kenya	Through a partnership with Mezzanine, DigiFarm provides smallholder farmers with information on affordable/discounted inputs and technical advice on best farm practices for sustainable agriculture. Farmers are trained in planting, application of agrochemicals, and post-harvest management.	[42]
Digital Credit	MobiGrow	Kenya and Rwanda	MobiGrow is a financial innovation that supports farmers and pastoralists with credit. In addition to providing credit in Kenya, MobiGrow supports farmers with a mobile-based platform that gives farmers information on sustainable crop and livestock management practices to improve farm productivity. Farmers are also trained in financial literacy and business management.	[42,57]

Table A1. Cont.

Category of Product	Product Name	Country	Description	Source
Insurance	ACRE- Agriculture and Climate Risk Enterprise	Kenya, Rwanda, Tanzania, Zambia, Malawi, Mozambique	ACRE insures smallholder farmers' loans for buying certified/improved seeds and fertilizers, improving their adoption of insurance and quality seeds, as well as farm productivity.	[8,38,54]
Digital Payments	Hello Tractor	Nigeria, Kenya, Mozambique, Senegal, South Africa, and Tanzania	Hello Tractor is also known as the 'uber of tractors.' Hello Tractor addresses the challenge of under-cultivation of arable land by small-scale farmers who have small plots of land. Due to increased mechanization, farm productivity increases. In addition, small-scale farmers are provided with information that helps them optimize input usage and manage other resources on their farms.	[27,42,47]
Digital Credit	ECLOF- Climate-Smart Lending Platform	Kenya	Under the ECLOF climate-smart lending platform in Kenya, lenders ensure that the credit provided to smallholder farmers has the intended sustainable land use management practices. The adoption of climate-smart farming by smallholder farmers is monitored through a mobile-based technology, in compliance with the loan requirements, and this forms the basis for credit scoring.	[58]
Digital Credit	Apollo Agriculture	Kenya	In addition to supporting smallholder farmers with credit for the purchasing of inputs, Apollo provides tailored agronomic advice through mobile phones.	[42]
Digital Payments and Insurance	AgUnity	Papua New Guinea, and Kenya	AgUnity is a mobile-based platform that uses blockchain technology to enable farmers to remotely contact and connect with each other and coordinate/organize sustainable farming activities such as crop rotation programs, harvesting, equipment hiring, etc.	[59]
Digital Savings and Digital Credit	M-PESA	Kenya	M-PESA enables rural women and farmers to save and invest in sustainable off-farm livelihood strategies such as fishing. In addition, they have access to credit to purchase farm inputs such as high-yielding seed varieties. M-PESA also provides farmers with fast money to finance farm-related activities such as early planting, casual labour, purchasing of improved breeds for livestock, etc.	[26,28,43]
Digital Savings and Digital Credit	FarmDrive	Kenya	FarmDrive supports financial institutions in Kenya to use machine learning algorithms to develop small-scale loans for smallholder farmers. With these loans, farmers purchase quality inputs to improve farm productivity	[60]

Table A1. Cont.

Category of Product	Product Name	Country	Description	Source
Digital Payments, Digital Savings and Digital Credit	M-CASH	Uganda	M-CASH is a mobile-based product that facilitates the issuance of subsidized inputs from agro-input dealers to smallholder farmers in Uganda. Through this product, farmers have access to farming goods and services that are certified by the industry and cheaper. In addition, farmers do not have to travel long distances/incur costs in trying to access input providers. Inputs are delivered by the agro-input dealers to the agreed points nearest to the farmer. This enhances the adoption of good-quality inputs by smallholder farmers.	[61]

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