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Review

The Revolution of Mobile Phone-Enabled Services for Agricultural Development (m-Agri Services) in Africa: The Challenges for Sustainability

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Abstract: The provision of information through mobile phone-enabled agricultural information services (m-Agri services) has the potential to revolutionise agriculture and significantly improve smallholder farmers' livelihoods in Africa. Globally, the benefits of m-Agri services include facilitating farmers' access to financial services and sourcing agricultural information about input use, practices, and market prices. There are very few published literature sources that focus on the potential benefits of m-Agri services in Africa and none of which explore their sustainability. This study, therefore, explores the evolution, provision, and sustainability of these m-Agri services in Africa. An overview of the current landscape of m-Agri services in Africa is provided and this illustrates how varied these services are in design, content, and quality. Key findings from the exploratory literature review reveal that services are highly likely to fail to achieve their intended purpose or be abandoned when implementers ignore the literacy, skills, culture, and demands of the target users. This study recommends that, to enhance the sustainability of m-Agri services, the implementers need to design the services with the users involved, carefully analyse, and understand the target environment, and design for scale and a long-term purpose. While privacy and security of users need to be ensured, the reuse or improvement of existing initiatives should be explored, and projects need to be data-driven and maintained as open source. Thus, the study concludes that policymakers can support the long-term benefit of m-Agri services by ensuring favourable policies for both users and implementers.

Keywords: m-Agri services; cell phones; smallholder farmers' livelihood; sustainability challenges; strategies for improvement; policy implications; Africa

1. Introduction

An extraordinary digital revolution has helped to drive global development with technological progress, price reduction, and infrastructural deployment resulting in improved access and connectivity for much of the world's populace [1]. The impact of this digital revolution is unevenly distributed, while many studies highlight the positive impacts and stress that these technological changes have the potential to enhance livelihoods in the global south. In Africa, for example [2–6], some studies question their impact and sustainability [2,7–11]. Digital technologies popularly known as information and communication technologies (ICTs) are comprised of various technologies that are used to aid information exchange and communication. These technologies include hardware (e.g., computers and mobile phones) and software (e.g., Internet facilities and media for information transmission) [12,13]. The use of information and communication technologies for development (ICT4D) has continued to evolve [14–17] with increasing attention on their use for agricultural development in Africa [18–23].

ICTs contribution to development varies according to the various disciplines and their intended aim [14,24,25]. However, improving the long-term impact of these technologies also requires an understanding of human-computer interactions (HCI) [26]. HCI for development (HCI4D) is a sub-discipline of HCI, which focuses specifically on the relationship between humans and computers in the context of international development [27]. In essence, while both ICT4D and HCI4D are concerned with information technology and human development, ICT4D is concerned with the process of technology development and impact as well as the design of the technology [14] whereas HCI4D focuses on the interaction between humans and information technology and the improvement of this relationship [27]. Hence, this study sits between ICT4D and HCI4D and is concerned with the sustainability and long-term impacts of future agricultural development projects.

Farmers' increasing access to agricultural information in some parts of Africa has been linked to the evolution and uptake of digital technologies [28–30]. Because agriculture is location-specific, it is important that farmers get tailored advice on agricultural practices, input use, accurate local weather predictions, and real-time prices and market information. Harnessing the growth of Internet use and associated digital technologies such as the mobile phone can help farmers retrieve the information they need as well as overcome constraints faced by the traditional agricultural extension and advisory services. Such technologies can facilitate transformative agricultural development such as collaborative agricultural knowledge exchange and learning [4,31,32].

The digital technology age has resulted in many accessible software applications aimed at farmers and other stakeholders in the agricultural sector [33]. Although many digital innovations aimed for agricultural development and ones that can help enhance the lives of rural people are developing rapidly, there is a lack of good evidence to support the impact of such technologies on development. What is needed is holistic, rigorous, and quantitative reports on the ways in which these initiatives aid development and sustainability [32]. According to Yonazi et al. [34], the strategic application of ICTs to Africa's agricultural sector offers the best opportunity for socio-economic growth of smallholder farmers. Although numerous ICT-based initiatives have been implemented in different parts of Africa for the uptake and improvement of agricultural practices, this study is focused on the mobile phone-enabled application initiative(s) for agriculture known as m-Agri services. In the context of this study, 'm-Agri service' is used to characterise any mobile phone-enabled application targeted to the needs of the agricultural sector and its stakeholders. These m-Agri services include electronic information and/or functions that are accessed through mobile phones (be they feature or smartphones). These services might include banking facilities, social networking platforms, or information such as market prices. Services can be delivered in a variety of formats including graphics, videos, images, audio recordings, and text. Smartphones specifically provide functionalities that enable users to access mobile and web applications, which can facilitate active engagement [35].

The increasing penetration of mobile networks as well as availability of mobile phones and their facilities have created significant improvements in the ability to reach remote, dispersed, and under-served farmers irrespective of their environment and social status by facilitating access to extension services, agricultural information, and financial services [11,29,31,32,36,37]. A wide range of agricultural information can be provided including data on inputs, best agricultural practices, transport, and market prices [38]. Baumüller [36] identified two key areas that can be impacted upon by m-Agri services. These are information and learning (e.g., through stakeholder networking platforms) and mobile payments (e.g., virtual markets and supply chain management). Various m-Agri services have been developed in the African region with the support of international donor agencies such as the World Bank, Food and Agriculture Organisation of the United Nations (FAO), etc. These have targeted areas that are characterised by weak infrastructure, limited access to market information, and poor transportation systems [39]. While the developers of these m-Agri services and their funders have often believed that these services hold great promise for enhancing target users' livelihoods by helping them to improve yields and provide fair market pricing opportunities, often their financial and infrastructural stability are questionable and only a very few are able to stand the test of time [39–41].

The reasons and remedies for this gap are yet unclear, with the factual evidence of their [m-Agri services] sustainability and long-term usage by the target users still being rare. Although many m-Agri apps are created, many are short-lived, and few become financially self-sustaining or widespread [39]. Some studies have focussed on the impact, effectiveness, farmers' attitude, empowerment, and challenges farmers face in using m-Agri service [42–46], while others argued from the technical or funders' perspective [39,40,47]. Baumüller [40] reported that the developers' failure to understand the context in which the farmers use these m-Agri services results in underutilisation of such services. Danes et al. [39] acknowledged that the number of successful m-Agri services is limited. Hence, concrete information is needed about the lessons learned, to inform the design and techniques of future efforts [47]. Efforts to design, produce, and evaluate appropriate m-Agri services for developing countries are naturally multidisciplinary. Thus, the research identified in this present study was obtained from a wide range of disciplines including sustainable agriculture, international development, and ICT for development (ICT4D) [39,40,48]. Furthermore, Danes et al. [39] recounted the willingness among agricultural stakeholders and application developers to collaborate more and exchange ideas on best practice. Danes et al. [39] also propose that developers should consider projects with open software, set up learning communities, develop indigenous scaled agricultural content, make existing data available, and connect the poorest to mobile networks. However, addressing the sustainability challenges requires a holistic understanding of the social, economic, and environmental impact and/or sustainability of the m-Agri services with a focus on the wider problems of designing, developing, and deploying the service(s) to the disadvantaged (rural or underserved) areas [49]. Considering this approach, more attention needs to be given to the target users' context and aspirations (e.g., their needs, social and physical constraints, etc.) [49–51].

While some other authors have also raised concerns about the environmental sustainability (e.g., the energy demand, material resource use, and emissions) of such initiatives [48,52], this present review explores the challenges that can impede the long-term sustainability of m-Agri services, in terms of their longevity, financial stability, and relevance, which are key issues to be addressed when scaling up from the pilot stage of pilot projects [40]. Additionally, the review identifies opportunities for policymakers to enhance the sustainable development of m-Agri initiatives in Africa. By doing so, this review answers the following research questions.

- What are the current trends and progress in the use of m-Agri services for enhancing agriculture and smallholder farmers' livelihoods in Africa?
- How can all relevant stakeholders involved in design, development, deployment and use, approach the challenges of m-Agri service(s) for sustainability?
- Are there specific functionalities for the m-Agri services that can enhance sustainability?
- What should the role of the policymakers be in promoting m-Agri sustainability?

Having outlined the specific aim and objectives of this review study, the remaining sections describe the conceptual background to the study including the concept of sustainability, the methodology adopted to identify relevant materials for the review, a summary of the key findings of the literature surveyed, and conclusions, which includes recommendations for future designs.

2. Conceptualising Sustainability in This Review

Sustainability is a widely used but contested term that has gained notable attention in recent times especially in social and technological science sectors such as policy-oriented research, human computer interaction, ICT for development, and business development [48,49,53–55]. The use of the word 'sustainability' as a broader concept implies 'meeting the needs and aspirations of the present generation without undermining the ability of nature to regenerate for future generations' needs [56]. In this context, sustainability refers to the environmental, social, cultural, technological, political, institutional, and economic consequences linked with the way development-based projects are designed and implemented [48,49,53,57]. Hence, looking at sustainability from the m-Agri services' developer,

funder, and target users' perspectives implies that they [as the actors] must ensure to enhance the socioeconomic and environmental sustainability of the given project. Additionally, the continuation of the benefits of m-Agri services after the implementation or launching need to be ensured. Accordingly, funders should be concerned about the underlying cost [social, economic, and environmental] of any intended m-Agri service and fund the services that have a well-defined sustainability plan in place. This means that integrating sustainability principles in any ongoing m-Agri project can be an efficient way of ensuring a long-term impact. However, from the implementers or developers' point of view, this means that they will need to continue to perform and deliver services to the target users (farmers and other agricultural stakeholders) even after assessing the impact of the project. In other words, from the perspective of this review, sustainability requires all stakeholders involved to continuously maintain ownership and hosting of the m-Agri services especially services that have a significant positive impact on smallholder farmers' livelihood even after the funding and other forms of intervention have ended. At the same time, ensure that the service(s) lessen their (smallholder farmers) burdens and not contribute to their poverty.

Initially, this review was conceived as an overview of the literature associated with the development and use of m-Agri services for sustainable agriculture and developing countries and was concerned with the challenges to sustainability of m-Agri services in terms of their continued functioning, their longevity, and usefulness. The interaction between humans and interactive technologies in the developing world is also a discipline in its own right, known as human-computer interaction for development (HCI4D). The literature associated with HCI4D and ICT4D (information and communication technology for development) in many respects comes to the same conclusions regarding the need for better technically and culturally appropriate designs as the literature on m-Agri apps for sustainable agriculture [58]. However, it also raises further questions about what is meant by sustainability and how the impacts of interactive technologies on sustainable development should be evaluated [38,59].

In this context, sustainability can be understood in two different ways [51,59]. First, is the m-Agri service in itself sustainable? This is described by Remy et al. [59] as 'sustainability in design' (SiD). For the m-Agri apps identified in the review the discussion of m-Agri app's sustainability was often framed in terms of its longevity, financial stability, and options for scaling up [40]. Software such as m-Agri services can be described as 'weightless.' This means they do not themselves have a direct impact on the environment, but they can be designed to be efficient for users, i.e., to work offline in regions with poor mobile coverage and power networks [58]. The second way in which sustainability should be considered is the effect or impact that an m-Agri service can have on sustainability [48,59]. Does it encourage more sustainable behaviours? Is there any impact on the sustainability of real-world practices in the agricultural system targeted [51,59]? This is described as 'sustainability through design' (StD) by Remy et al. [59].

Although sustainability should be evaluated in a holistic manner incorporating environmental, economic, and societal impacts, this is not often the case [60]. Incorporating these three pillars into an evaluation is time-consuming, and, more often than not, evaluations focus on one pillar only, and most frequently on environmental sustainability [53]. Although several authors including Toyama [61] and Remy et al. [59] have produced frameworks for evaluating the sustainability of ICT interventions, there is still considerable debate on the approach to evaluation in a human-computer interaction for development (HCI4D) [51,53,59]. One of the key issues with evaluating sustainability of ICT in the developing world is the question of who decides which criteria should be used for evaluation and which values are important. Ideas and interpretations of sustainability depend on culture and context [62]. This may be why evaluation of impact on sustainability is often missing in HCI4D/ICT4D research [59]. In their review, Brynjarsdottir et al. [51] found that almost half of the HCI studies included no evaluation whatsoever.

3. Methodology

This analysis adopts a scoping review methodology as described by Arksey and O'Malley [63] and focuses on published literature that relates to mobile phone-enabled applications for agricultural development and smallholder farmers' livelihood improvement in Africa. The scoping review method is less restrictive than a systematic review. It allows the redefinition of the literature search criteria as the researcher becomes familiar with the existing literature on the subject area [63]. During the review process, searches were made through the Web of Science, Scopus, AgEcon, JSTOR, Science Direct, ASSIA, Google, and Google Scholar to identify relevant publications using the following terms.

- 'mobile phone application' AND 'agriculture development' OR 'digital innovation';
- 'smartphone application' AND 'sustainability' OR 'agriculture';
- 'mobile or smartphone' AND 'farmers' OR 'smallholder farmers' livelihood';
- 'agriculture information' AND 'farmers' livelihood development';
- 'smart farming' AND 'smallholder farmers' OR 'm-Agri';
- 'mobile application' AND 'm-Agri finance' AND 'services';
- 'mobile application' AND 'm-Agri' AND 'challenges';
- 'ICT for sustainability' OR 'ICT4S' AND 'ICT for development' OR 'ICT4D';
- 'Human Computer Interaction for development' OR 'HCI4D' AND 'sustainability'.

After skimming through the published titles and their abstracts, only relevant articles published in English within an African context were selected for further review. Articles that excluded human interaction and focused on non-human involvement such as management of equipment and connecting to the Internet of things were not included for detailed review. Articles included were published after the year 2000, as that was when mobile and Internet facilities began to expand significantly in Africa. Furthermore, articles that specifically cover m-Agri services that disseminate agricultural information, provide financial services, and facilitate access to input and output markets for agricultural stakeholders in Africa were included. In addition, a snowball strategy based on a thorough review of each article's references was used to identify other relevant peer-reviewed literature. However, because of the limited number of relevant peer-reviewed literature, none covered the sustainability aspect of the m-Agri services. Grey literature was also included, which presented m-Agri services that have impacted on farmers' livelihoods, provided they were within the year of publication range and geographic coverage.

In reporting these review findings, the information retrieved from the literature was grouped into themes that correspond to answering the research questions. After the inclusion and exclusion exercise, a total of 64 relevant artefacts were identified. They include 26 journal articles, 29 reports [grey literature], and 9 webpages as listed in Table 1. To complement this literature search, a search for m-Agri services currently available in Africa was also carried out using the main iOS and Android app stores. This first aimed to authenticate the m-Agri services reviewed in the literature search and also retrieved other English language applications targeted for farmers and agriculture. The m-Agri services identified are shown in Table 2. Each application's platform was searched to identify the specific location of such an application and the user reviews were checked to determine whether or not the application was still functioning. Those m-Agri services that appeared to be functional were compiled in Table 2 with a summary of their purpose and their location indicated. Although the two most popular app stores were investigated, this list may not be exhaustive as there may be other applications available that were not present in the databases accessed. Examples of m-Agri services from Table 2 discussed in the text are shown in italics. Table 3 provides further data for those apps for which this could be found. This includes the date of the launch, number of downloads, and number of average reviews. These data give a crude measure of longevity and user satisfaction. Without full access to the m-Agri services, it was not possible to evaluate other measures of quality and sustainability.

Table 1. List of materials accessed.

Materials Used	Number of Materials	References
Peer-reviewed journal articles	26	[13,29,36,64–86].
Reports/Grey literature	29	[32,35,38,87–112]
Webpages	9	[113–121]

Scoping survey 2018/19.

Table 2. Survey of currently functioning mobile phone-based m-Agri services available in Africa in 2018/19 (accessed between January 2018 and October 2019).

Mobile Apps	Inventor/Founders	Country/Location of Use	Description
iCow	Kenyan farmer, Su Kahumbu	Kenya	SMS and voice-only mobile app. Farmers are sent information on the best dairy practices. Allows farmers to register their cows, and to receive individualised text messages on their mobile phones, including advice for veterinary care and feeding schedules, sends prompts to farmers to collect and store milk within the days of a cow's cycle, a database of experts, and updated market rates on cattle prices [64,87].
Vet Africa	A Scotland based tech company—Cojengo, founded by Craig Taylor and Iain Collins in partnership with Microsoft	Kenya, Ethiopia, Uganda and Tanzania	An image-based user interface app provides diagnostic tools and disease surveillance data for livestock disease and recommends appropriate medications for farm animals. Helps farmers monitor and record animal data [87].
M-Farm	Kenyans: Linda Kwamboka, Susan Oguya, and Jamila Abass are co-founders	Kenya and Ghana	Delivers price transparency and access to markets. Provides updates to farmers on current prices of goods across the country and a networking platform for farmers to sell their produce wholesale. Connects local farmers directly to suppliers and provides access for farm inputs [87].
Esoko	A team of local and international professional in Ghana	Nine African countries	Connects projects, non-governmental organisations (NGOs), businesses, and the government to farmers. Formerly known as TradeNet provides agricultural content, marketing, advisory, and monitoring services for farmers and potential investors [65–67].
Agro-Hub	Agro-Hub was developed by a Cameroonian business venture	Cameron	Agro-Hub employs social network, short messaging service (SMS), and the Internet to source, manage and disseminate information on all areas of agriculture [65,113]
Agri-wallet	Dodore Kenya Ltd. founded by Ad Rietberg and Sijmen de Hoogh	Kenya	Agri-wallet is a mobile purse that smallholder farmers use to manage their business finances and can borrow money to spend on agricultural inputs such as fertiliser and seeds [87].
Cocoa Link	Developed by Farmerline, which promotes entrepreneurship in partnership with Hershey and World Cocoa Foundation	Ghana	Delivers farming practice information from agricultural experts to farmers in English and local languages at no cost [13,65].
Kilimo Salama	Syngenta Foundation for Sustainable Agriculture and Kenyan telecom operator, Safaricom	Kenya	Provides up-to-date and full climate and weather information to farmers and sustainable agricultural practices to increase productivity, ensure food security, and protect their crops during bad weather [68].
Kuza Doctor	Backpack farmers in Kenya	Kenya	Provides access to information on crop growth, soil, and answer to general farming questions to help farmers grow better crops by employing environmentally-friendly practices [87].
Modisar	Agric Software Development Start-up Company located in Gaborone, Botswana	Botswana	Enable farmers to keep and access their farm records, cattle herds, farm costs, and sales. Provides advice to farmers on animal vaccinations, feed, nutrition, and finance [87].
Hello tractor	A team of business entrepreneurs	Nigeria	Provides access to low-cost tractors that farmers can buy or rent using their mobile phones [114].
Haller app	Haller foundation	Kenya	Provide farming instructions to the farmers on how to manage soil fertility and maintain beehives [69].

Table 2. *Cont.*

Mobile Apps	Inventor/Founders	Country/Location of Use	Description
M-Shamba	M-shamba social enterprise	Kenya	Provide information about crop and poultry management practices for the small-scale farmers. Allows farmers to track farm activities such as their revenues and expenses [69].
WeFarm	Originally created by Kenny Ewan, Claire Rhodes, and Jim Rhodes, and was developed as a pilot project from within the Cafedirect Producers' Foundation (now called Producers Direct)	Kenya, Tanzania, and Uganda	Provides free crop and livestock management practices. Especially advice on how to manage diseases and new practices [69,115].
M-Samaki	No details	Kenya	Provides advice on fish farming about how to manage pond health and feed as well as harvest and marketing [69].
Senekela	Established by Orange-Mali	Mali	Provides advice on available agricultural products, weather forecast, and market prices, which allow farmers to market their produce in better conditions and improve their productivity [116].
e-Wallet	Established by the Federal Ministry of Agriculture and Rural Development	Nigeria	Provides information about where and how to buy fertilizer and the exact amount sold, which allows farmers to compare prices [70].
Tigo Kilimo	Provided my mobile network operator Tigo	Tanzania	An agricultural value-added service that provides information for 10 crops through unstructured supplementary service data (USSD), SMS, voice, and helpline for the farmers.
EZ-Farm	IBM Research—Africa Dr Kala Fleming	Kenya	Provides farmers with information on facilities for remote farming water management.
AgroTech	A programme run by Grameen Foundation and its partners Digital Green	Ghana	Enables the government and private company field personnel to understand and analyse farmers' needs and crop history quickly and timely, to deliver agricultural advice, and to procure loans to purchase farm supplies such as fertilisers and seeds.
Lima Links	SANGONet, a South African NGO, and International Development Enterprises (iDE), with $200,000 in initial funding from the Gates Foundation.	Zambia	Provides a sort of 'live' market price information on horticulture and connections to markets for smallholder farmers.
AGMIS (Infotrade)	Infotrade	Uganda	Aggregates market price information from 35 major districts in Uganda for 48 agricultural products, trends, and price movements. Price data is collected three times a week, analysed, and disseminated to the farmers.
Crowdyvest (Farmcrowdy)	Team of individuals with experience and expertise in information technology management, e-commerce and financial management supported by Syngenta and ASTC (Agricultural Training Centre), Vom and Plateau State Notore Seeds	Nigeria	Supports small farm sponsorship, provides improved seeds, farm inputs, training on modern farming techniques, and also provide a market for the sale of farm produce for farmers.
Crop Monitoring Service (CROPMON)	Developed by Geodata for Agriculture and Water Facility, Netherlands with four Dutch and five Kenyan partners	Kenya	CROPMON develops and makes available information that help farmers to make improved farm management decisions during the growing season. The information given is based on real-time satellite imagery informing them of the growth and growth status of their crops.

Table 2. *Cont.*

Mobile Apps	Inventor/Founders	Country/Location of Use	Description
FarmDrive	Rita Kimani and Peris Bosire	Kenya	Connects smallholder farmers to loans and financial management tools through their mobile phones. Closes the critical data gap that prevents financial institutions from lending to creditworthy smallholder farmers.
MyAgro (One Acre Fund)	Anushka Ratnayake, One Acre Fund	Mali, Senegal	Helps the farmers save money gradually in smaller amounts to cover the cost of their basic farm needs such as buying seeds, fertiliser, and training.
Fertiliser Optimiser Tool (FOT)	CABI's OFRA programme, funded by the Alliance for a Green Revolution in Africa (AGRA)	13 countries in Africa	Provides free access to advice on fertiliser use for farmers and extension workers. The app runs in an offline mode allowing users to perform optimisation calculations in the field and utilises data on crops grown, area planted, fertiliser cost, management, and expected crop sales, etc. to calculate the most profitable combinations of fertilisers to use.
NARO beans, Common Cassava Diseases & Control, NARO Maize Production	National Agricultural Research Organisation (NARO)	Uganda	Provides information on: (1) bean cultivation, (2) common cassava diseases and control, and (3) maize production for the farmers.
Pannar Sprout	Developed by Pannar Seed, a South African seed group founded in 1958, which is one of the largest field crop seed producers and suppliers in Africa	South Africa and some other African nations	Provides technical advice for grain farmers. A new function has been added, which is known as PlantDr for help with crop diseases.
Khula	South African digital company in Randburg	South Africa	Provides mentorship for farmers and connects them to customers, better access to logistics, and source for low cost farm inputs through a group purchase.
Agripredict	Developed by three individuals (Patrick Sikalinda, Cassandra Mtine, and Mwiza Simbeye)	Zambia	Provides information that help farmers to identify crop diseases, predict pest infestations, and weather conditions.
uLima	uLima Limited	Kenya	Provides access to crop and livestock management information, weather and market price information, and customised crop and livestock calendars for farmers.
AgTag	Magazine app	South Africa	Provides written articles, videos, and audio on crops, livestock, equipment, water, and soil management as well as agro-processing.
Nuru (Plant Village)	Developed by Penn State University researchers in collaboration with UN FAO and Consultative Group of International Agricultural Research (CGIAR). Nuru is incorporated into the Plant Village app.	Many African countries	Helps farmers to diagnose crop diseases of crops like cassava, maize, wheat, and potatoes in the field without an Internet connection. The app interfaces with the FAMEWS app to upload data collected from the field. For example, the app help farmers to validate data on fall armyworm to the national fall armyworm focal points and database.
RiceAdvice	Developed by AfricaRice and CGIAR under the name RiceAdvice.	22 African countries	Provides farmers with field-specific crop management guidelines for rice production
Agrix Tech	No details	Cameroon	Detects crop diseases at a primary stage and proposes treatment with the use of artificial intelligence.
Labaroun Kassoua	Labaroun Kassoua in Niger is one of the mAgri services supported by Orange in Africa	Niger	Offers information and advice on agricultural techniques, weather, and access to markets and financial services for farmers.
mAgri, Côte d'Ivoire	mAgri in Côte d'Ivoire is one of the mAgri services supported by Orange in Africa	Côte d'Ivoire	Provides information and advice on weather, agricultural approaches, access to markets, and financial services.

Table 2. *Cont.*

Mobile Apps	Inventor/Founders	Country/Location of Use	Description
Naafa Buudu	Supported by Orange in Africa	Burkina Faso	Offers farmers advice on weather, market prices, financial services, and agricultural techniques.
Cow Tribe	Cow tribe technology company based in Ghana	Ghana	Provides subscription based and on-demand animal vaccines and other services to last mile farmers.
Connected Farmer	Produced by the Connected Farmer Alliance, a public-private partnership between U.S. Agency for International Development (USAID) and Vodafone	Kenya, Tanzania, and Mozambique	Targets to address the value chain management inefficiencies and increase productivity of both the agribusinesses and the smallholder farmers who supply them.

Survey 2018/19.

Table 3. Launch date, user reviews, and downloads of m-Agri services available in Africa in 2018/2019 (accessed between January 2018 and October 2019).

M-Agri Service	Year Launched	App store/Google Play Metrics			Other Data
		Average Reviewer Score (Max Score = 5)	Number of Reviews	Number of Downloads	
Esoko	2008	no data	no data	no data	
Agrohub	2009	4.7	7	1000+	
M-Farm	2010	no data	no data	no data	
Kilimo Salama	2010	4.7	21	1000+	
M-Shamba	2010	4.9	38	100+	Reports 685,460 farmers reached
iCow	2011	3.6	5	100+	
MyAgro	2011	no data	2011	no data	Reports 45,000 downloads
Senekela	2014	no data	no data	no data	Reports 37,333 users
WeFarm	2014	no data	no data	no data	Reports 1.9 million farmers joined
Farmdrive	2014	4.2	5	500+	
mAgri, Côte d'Ivoire	2014	no data	no data	no data	
HayVokra (HNI)	2014	no data	no data	no data	
Bazar.mada	2014	no data	no data	no data	
Hello tractor	2015	2.9	44	5000+	
M-Samaki	2015	none	no data	no data	
EZ-Farm	2015	no data	no data	no data	
Pannar Sprout	2015	3.7	35	5000+	
Crowdyvest (Farmcrowdy)	2016	3.8	221	50,000+	Reports 25,000 users
Cow Tribe	2016	no data	2016	no data	Reports 29,000 farmers in 119 communities
Fertiliser Optimiser Tool (FOT)	2016	5	5	1000+	
Murimi Umlimi	2017	none	0	no data	
uLima	2017	4.8	29	1000+	Reports 20,000 users
Agri-wallet	2018	none	no data	50+	Reports 4000 farmers, 14 suppliers, and 25 buyers
CocoaLink	2018	5	16	5000+	
Agripredict	2018	no data	no data	22,000	
Plant Village Nuru	2018	4.4	18	1000+	
NARO beans	2018	4	1	100+	
Common Cassava Diseases & Control	2018	none	none	100+	

Table 3. *Cont.*

M-Agri Service	Year Launched	App store/Google Play Metrics			Other Data
		Average Reviewer Score (Max Score = 5)	Number of Reviews	Number of Downloads	
NARO Cage Aquaculture	2018	none	none	500+	
NARO Maize Production	2018	3.7	6	1000+	
Agrix Tech	2019	no data	no data	n/a	
Labaroun Kassoua	2011 (SMS)	no data	no data	no data	
LimaLinks	2011–2013, 2016	no data	no data	no data	Pilot in 2011–2013 scaled up in 2016
CROPMON	2015–2019	no data	no data	no data	
RiceAdvice	c. 2016	4.6	23	1000+	Reports 20,000+ users
Modistar	c.2014	no data	no data	no data	
AgTag	c.2014	4.5	74	5000+	
Vet Africa	no data	3.5	11	1000+	
Kuza Doctor	no data	no data	no data	no data	
Haller app	no data	no data	no data	no data	
AgroTech	no data	no data	no data	no data	Reports 500,687 users
AGMIS (Infotrade)	no data	no data	no data	no data	
Khula	no data	no data	no data	2000+	

No data = no data found in app store, Facebook, Twitter, or website searches. none = no reviews or downloads recorded in app store. c.Year = indicates that the app is documented at this date, but the launch date is not known.

4. Results and Discussion

This review explored the progress of m-Agri services in contributing to the improvement of livelihood of smallholder farmers and the challenges for their sustainability in Africa. In this section, the findings that answered the fundamental questions that emerged from the study's aim and objectives are outlined into four overarching themes and are discussed accordingly.

4.1. An Overview of Current Trends in m-Agri Services

The increasing expansion and use of m-Agri services have created a trend in the agricultural digital ecosystem, which consists of software platforms, thousands of developers, and millions of users. Some such m-Agri services are available and distributed through platforms such as the app stores for mobile and web apps and databases for short message and other related services. Table 2 below highlights existing functional m-Agri services in the African region. The list was correct at the time of writing, even though it is acknowledged that, in the time taken for publication, some of the available applications may no longer be fully functioning.

Globally, m-Agri services' contribution has been to enhance the efficiency of the agricultural value chain, as information delivered through m-Agri services can help farmers' access to new technology or inputs and assess its suitability as well as facilitate farmer-to-farmer/buyer relationships, how to manage financial and production risk, and where to sell their produce [36,38]. Similarly, the m-Agri services identified in this review had a positive contribution to improved smallholder farmers' livelihood by facilitating their access to financial services, which enables them to access and source agricultural information as well as input and marketing services [71,72,88,89]. Thus, the following sub-sections highlight the trends and progress made in these categories. The key trends include m-Agri financial services, information and sharing, and input and marketing services. These are discussed in more detail below.

4.1.1. M-Agri Financial Services

According to Mercy Corp [88], the transitioning to and use of m-Agri financial services by smallholder farmers has increased safe and convenient transactions in many African countries. These kinds of services open up opportunities for many smallholder farmers who are excluded from mainstream financial services such as banking and insurance. Furthermore, the availability of loans and repayment via such platforms increases farmers' ability to manage their finances and investment in agriculture as well as improve their relationship with bankers and other relevant agricultural stakeholders [29,73,90]. For instance, farmers in Western Kenya with the help of One Acre Fund can access *Agri-Wallet*, which is an m-Agri financial service that allows them to borrow money to spend on their agricultural inputs and pay back their loans digitally. Thus, saving travelling costs to extension offices and banks as well as improving time management and reduced cash carrying [91]. Significantly, digitising agricultural payments via mobile phones has the potential to improve security, efficiency, and transparency. Particularly, there is an increasing number of initiatives, which aim to enhance the m-Agri financial services' value chain, especially in sub-Saharan Africa with major attention in Kenya, Rwanda, Tanzania, and Uganda, and other dynamic markets such as Ghana and the Ivory Coast [35]. Examples of m-Agri finance apps include *Labaroun Kassoua* in Niger and *FarmDrive* in Kenya. Accordingly, Mercy Corps [88] reported that more than 46% of farming households use an m-Agri financial service product in Uganda and attested that this had resulted in an increase in household incomes. This service can support the creation of economic identities for the farmers through the transactional reports and records from their produce sales as well as for geolocations and farm size, which creates full financial inclusion for their access to credit, savings accounts, and insurance facilities [90].

4.1.2. M-Agri Information and Knowledge Sharing Services

According to Bedi [71], m-Agri services play a significant role in enhancing farmer access to information because of their ability to support the retrieval of information from its repository at the farmer's convenience. Specifically, information and knowledge sharing can support better agricultural practices and skills development among farmers, which results in increased productivity as well as enables easier access to product certification requirements [74,90]. Baumüller [29] pointed out that advice on farming practices is the most easily provided agricultural information for farmers through mobile phone services. In addition to this, information on the weather forecast, monitoring, and crop diseases can then better equip them in understanding and managing risks. Thus, this helps them save and improve their productivity. For instance, the *Senekela* Orange initiative is a service established in Mali that provides farmers' access to updated agricultural advice such as stock availability, product market prices, and weather predictions. Crowdsourcing information through mobile phone applications, such as that provided by *Nuru*, a digital early warning network is helping farmers to prevent the outbreak of cassava diseases in Tanzania [92]. In a CTA (Technical Centre for Agricultural and Rural Cooperation) report, a similar service allows farmers to access real-time, location, and specific information regarding their farming queries and providing advice regarding crop and livestock management during the critical stages of development, which also aids learning [93]. Training is the cornerstone of future agriculture and capacity building for farmers, with training information content and research contributing to a rise in agricultural innovations. Potentially, innovations can be disseminated and promoted among farmers more rapidly through m-Agri information and knowledge-sharing platforms [29,94]. In an evaluation of the m-Agri service *Tigo Kilimo* in Tanzania, carried out by GSMA [89], the attitudes and behaviour of users of the app were compared to non-users. The results showed that *Tigo Kilimo* users were more willing to change their farming practices by shifting from one cropping system to adopting diversification approaches in growing more varieties of crops.

4.1.3. M-Agri Input and Marketing Services

Increasing globalisation and market deregulation in developing countries often results in pressure on smallholder farmers to lower their prices. For farmers, greater awareness about the politics of agricultural products' pricing, marketing, and trade allows them to better deal with these pressures. M-Agri services can provide them with timely access to information and better access to input and output services [72]. Basically, farmers tend to be more receptive when information is tailored to specific contexts to support their needs with the view of reducing cost as well as increasing efficiency and productivity [72,75]. M-Agri services can facilitate the dissemination of information about input suppliers and input prices as well as provide platforms for input trading and bargaining, which can help farmers evaluate the profitability and obtain higher prices for produce [29,76]. Furthermore, access to market pricing information is helping farmers improve their harvest planning. For instance, the app *m-farm* helps farmers in Kenya to make informed decisions about the best harvest, selling times, and pricing [36]. Besides allowing farmers to obtain market price information, the *m-farm* also enable suppliers to publicise product information on special offers to the farmers [32].

Some studies in the African region affirmed that m-Agri interventions led to greater savings, increase in produce sales, increase in household income, farmers' confidence and trust, financial security, farm management, increased access to inputs, increased bargaining power, and social cohesion for smallholder farmers [29,36,76–78]. However, the type of solutions, range, and complexity vary, as some providers offer complete platforms with multiple functionalities and others target single or specific issues with the aim of improving smallholders' livelihoods. The maintenance of these acclaimed positive impacts requires a consistent and unified approach by the project initiators, service developers, funders [public and private investors], implementers, researchers, Internet providers, non-government agencies, policymakers, and the farmers. Hence, it is imperative to understand

the challenges that affect such initiatives as well as to comprehend the strategies that can improve their sustainability.

4.2. The Challenges for M-Agri Services in Africa

This review further revealed that, despite the positive impacts and opportunities for m-Agri service initiatives toward the enhancement of smallholder farmers' livelihood in Africa, the reality is that not all of these m-Agri apps are sustainable over the long term. According to Laurey's [92], lessons show that exaggerated expectations placed on such services can lead to frustration and abandonment. If they are not well designed, clearly integrated into, and adapted to their prospective users' life processes, they will not survive. Furthermore, complementary investments in electricity and literacy programs can affect the scaling up of initiatives for smallholder farming. For example, the adoption and use of the *e-Wallet* service that enables farmers to make more informed farm management decisions (where and how to buy fertiliser and seeds) in Nigeria was constrained by a poor electricity supply resulting in many farmers abandoning its use [70,79]. Applications that failed to consider their target users' literacy level were also likely to be abandoned, where the target farmers have a low literacy level and struggle to interact with the app. A text-based application may be severely limited to succeed despite the good intentions if the target users find it difficult to read and understand the content [89]. An example is n'kalô in Côte d'Ivoire, which provided market information to cashew producers. This was forced to close down eventually because the target users found it difficult to engage with the content [95]. Beyond basic literacy, skills such as the Internet skills needed for some of the m-Agri services are sometimes lacking, which was estimated in 2016 by the World Bank reporting that 7 in 10 people in Africa who do not fully utilise their Internet account affirmed that they do not know how to use it effectively, while four in five mobile phone owners have simple phones that are not capable of browsing the Internet [32], bearing in mind that farmers are among these people.

The one size fits all approach can sometimes be a distraction that can cause the implementers to focus more on the technology and ignore the specific demands and priorities of the proposed users [80,96]. For instance, many users of *Tigo Kilimo* reported that there was limited information on a wider variety of crops on agronomy information. In addition, they echoed that financial information should be incorporated into the service [89]. The neglect of integrating the deep understanding of the target users' culture when designing or adapting m-Agri initiatives is part of the challenges that affect sustainability as users tend to lose interest in such initiatives [41,53,70]. Scaling-up the initiative can be challenging when there is a lack of relevance in the content for the target users or the effectiveness of the communication style [81]. For example, the use of foreign languages such as English in non-English speaking countries may neglect the appropriate cultural context of the host community [66,69]. M-Agri services may also be doomed to fail if the implementers do not consider the cost for sustainability right from the beginning of the project. Services provided free of charge to farmers in the pilot stage could prove difficult to continue after the donors left without revenue. A typical example is the M-Kilimo, a Kenyan farmer helpline (no longer functioning), where the service is aimed to address the weaknesses in the availability of extension services using available networks in Kenya, which charged a standard network rate. The service was initially successful after the first three years (2009–2011), but was abandoned due to the high cost of the operation as farmers found it difficult to bear the cost for a longer time [93,97].

Trust has proven to be a critical factor in determining the success of any given project. The farmers tend to be skeptical with trusting an external organisation such as the government or those in the private sector [82]. As Baumüller [36] and Aker et al. [80] point out, getting the farmers to trust the information provided to them can be difficult. This can affect the progress of such services as well as the contents and could present a suspicious notion in a way that is either reliable and understandable. In addition, given that smallholder farmers' income is often low especially among farmers living in the rural areas, such farmers can be unwilling to pay for m-Agri services as well as pay for the costs associated with using the application [41,80]. A comprehensive business model both for-profit

and non-profit m-Agri services, which can guarantee such services to exist independently of external funding in the future is sometimes ignored. By so doing, it can affect the development [36]. In addition, data security and privacy, i.e., the fear of digital crime and identity theft can be a concern for the farmers in their continuous use of m-Agri initiatives, especially with the services that are supported by smartphones, which generally have the tendency of collecting varied sensitive data. Moreover, poor commitment and collaborative efforts of the governments in implementing adequate policies that support the varied stakeholders poses a significant challenge to such initiatives [98].

Certainly, some of these challenges to m-Agri services are more difficult to overcome than others. However, many of these issues can be addressed by taking a more participatory approach, in which key stakeholders combine forces to identify and adopt strategies that can support the development and design of m-Agri initiatives. Some of the strategies that were adopted by various m-Agri services to improve their relevance, longevity, and sustainability are discussed below.

4.3. Strategies Adopted by Some of the Existing M-Agri Initiatives

Although agricultural development activities continue to focus on more technologically advanced systems, which are knowledge-intensive, there is also demand for more sustainable initiatives. For smallholder farmers who are the target users of many such interventions, sustainability for them means placing their needs at the centre of every m-Agri service initiative [69,99]. Some of these m-Agri service providers have already begun to implement some strategies that can enhance the sustainability of their project. In the situations where digital literacy may be low among the target users, the developers and their funders may have to work directly with the target users to enhance their skill in using the application. For instance, *m-farm*, which is a Kenyan m-Agri service, co-opted a team of content managers who directly work with the farmers who do not fully understand the use of the application. They act as mentors to the farmers and teach them the step-by-step process of the application so that they become conversant with it and are able to use it independently in the future. Where the main issue is an unreliable electricity power supply, the One Acre Fund provided the target users with solar-powered phone chargers on credit to help address this [117].

Similarly, *WeFarm*, which operates in Kenya and Uganda, adopted the strategy of using crowdsourced knowledge through a message service to give remote farmers access to agricultural information without using Internet facilities [115]. This method has enabled the application providers to connect to more than 1.1 million users across Kenya and Uganda. This service also allows the farmers to ask questions in any language, and, therefore, directly addresses one of the barriers to long-term usage by the farmers. This is where the farmers are not conversant with the language used for the service.

The sustainability of a given project also needs to consider the economic aspects. The question of whether or not to charge end users fees is the subject of debate and depends on the business model [80]. Many m-Agri services take a business-to-customer approach with a business-oriented perspective, this is where charging the end users a fee for a given service seems reasonable to maintain the initiative. Services that rely on direct revenue from target users can only attain fiscal sustainability by scale [83,84]. Some of these m-Agri services adopted this strategy to enhance the sustainability of their service. For example, the '*Connected Farmer*' that operates in Kenya, Tanzania, and Mozambique, which offers combined services such as agronomic information, a weather forecast, and marketplace services, adopted the service bundle model through the generation of income from selling products and services for agribusinesses as well as selling data and market research survey. In this case, the agribusiness clients pay a monthly charge to access farmer data [100]. Similarly, *iCow* charges its users KES9 ($0.09) to receive three short message service tips per week. This means that the service's fiscal sustainability is ensured with a regular recurring revenue of $150,000 from its regular users [101]. In this case, the higher the number of users, the more the service becomes financially sustainable. However, the business-to-customer approach can be difficult to achieve in practice as many farmers have low disposable incomes. Many times, their ability and willingness to pay does not always translate into

real payment [80]. An example of such a dilemma is the *Tigo Kilimo's* experience when new users and repeat users of the service increased after their short message service fee was removed. Even though the farmers who used the service expressed their willingness to pay a small amount in a survey, the majority did not sign up until the fee was removed [89].

Given that m-Agri services can be a complex system of technologies, it is important to clearly and distinctively define the design and management of the technologies. It is often difficult for implementers of these m-Agri services to understand the exact needs of the farmers and to assess how best is best enough for the applications' everyday use. This may, in the short-term, lead to advances that fail to tackle the major areas of farmers' need or deliver over-performing interventions that may be unnecessarily exorbitant [80]. Therefore, a closer relationship and continuous communication with the end users and other key stakeholders will help to ensure that the value is gained from the initiative. This can be achieved by drawing insight from the principles for digital development and adapting to the following strategies and functionalities, as discussed below.

4.4. Strategies and Functionalities that can Enhance the Sustainability of M-Agri Services

4.4.1. Designing with the Users in Mind

The success of m-Agri services should be deep-rooted in a clear understanding of the user characteristics, their needs, dynamics, and challenges, as well as potential changes in the future. This could be achieved by getting to know the target users or potential users through dialogue, observation, and collaboration. During the engagement process, the information gathered is, therefore, used in building, testing, and redesigning the service until it effectively meets the users' need. This approach can address the specific context, culture, behaviours, and expectations of the users who will directly and interact with the service. This means that the service providers will continue to partner with the target users throughout the lifecycle of the project, co-creating solutions for identified problems as well as continuously obtaining and incorporating the feedback from the users [80,92,96,100–102]. The m-Agri implementers should focus on engaging the farmers at all stages of the product development, from identifying the opportunities and generating concepts during the early stage, to develop stages of product realisation, execution, and scaling-up [79]. The m-Agri, initiatives can be impeded if the perceived problem that the service aims to address, the availability, affordability, and accessibility of such services are not thoroughly analysed or evaluated before creation and implementation [80,96]. This strategy could answer the question of whether the application should be free, text-based, or Internet connection free [80,98].

4.4.2. Analysing and Understanding the Existing Environment

In maintaining a given m-Agri service, the initiators need to consider the structures and needs that exist in the target community, country, or region. The time and resources set aside to understand the culture, political environment, technological infrastructure, gender norms, economy of the target location, and other factors that can influence target users' ability to access and use the service, can enable the implementers to ensure that a relevant m-Agri service that will attract long-term use is chosen. This recounts that the m-Agri services that do not account for the ecosystem challenges are more likely to fail to achieve the desired objectives or become sustainable [92,100,103–105]. This may imply that the implementing organisations must identify whether the target community have significant experience in a certain mobile device to be used for the m-Agri service rather than creating and imposing it on them. Furthermore, implementers need to understand the socio-cultural circumstances of the female target users and design m-Agri services that aim to close the digital gender divide [106,107]. This could mean that m-Agri services that consider women's lived realities and working conditions should be encouraged and supported.

4.4.3. Designing for Scale and Sustainability

Achieving scale is an objective that always seems ambiguous for many m-Agri service development practitioners. That is the practitioners' inability to move such initiatives beyond the pilot stage, such that requires the adoption of the initiative beyond the pilot's population. Designing the m-Agri services for scale means planning beyond the pilot and considering the factors that will enable the extensive adoption later as well as proposing what will be affordable and useable beyond the pilot group. The design for the scale of an m-Agri service project from the onset can guarantee that the project will expand more easily to markets, new users, or locations if the service meets target users' need and has an impact. In addition, ensuring that the m-Agri services are embedded in the existing policies, users' daily activities, and workflow, can help to improve the services' sustainability [105]. Additionally, institutionalising such a service with a private company, government, or non-governmental organisation as well as incorporating a business model that has a sustainable revenue generation strategy can enhance the ultimate achievement of a sustained positive impact [105,107,108,118]. Seeking for scale and sustainability requires that implementers should ensure they understand their target users' changing behaviour, expectations, and willingness to pay for the m-Agri service.

4.4.4. Addressing Privacy and Security through Collaboration

This approach implies that the m-Agri service providers need to ensure individual users' sensitive information is secured while adhering to strict transparency of how data will be collected and used as well as minimising the amount of personal and sensitive information collected. As such, all related data policy should be followed stringently. The m-Agri service providers have the duty of care to ensure that they define data ownership, declare who has access to the data and who decides what to do with the data, and determine the use and where the data will be stored before embarking on data collection process. A risk-benefit analysis should be carried out throughout the data collection cycle to identify the individuals who benefit from the process and who are at risk [109]. The initiators or implementers should consider the impact of data theft or inefficient data management to ensure they assess the risks of leakage and unauthorised access to any stored data [119].

Furthermore, it is imperative for the implementers to work collaboratively with the target users to ensure that they [target users] understand the risks associated with sharing their data for their informed decision about whether to participate or not to participate [120]. At the same time, the users need to be made aware of what their data will be used for, how it will be stored, for how long it will be stored, and who can access the data. The best practices for security and privacy protection may include encryption of files, secure cloud storage services, use of two-factor authentication, and validation of data-sharing agreements with all the potential data-sharing associates [110]. The adherence to these principles is vital to uphold the ethical implementation of m-Agri services and evasion of negative outcomes that may result from security breaches. Hence, this will help secure the interest of the users/participants and, at the same time, promote trust between all the stakeholders [end users, implementers, funders, and others].

4.4.5. Reusing and Improving the Existing Initiatives

Innovation does not only mean building something new, but it can also mean repurposing an existing initiative/tool in a new way and/or adding more features or functionality. This strategy, therefore, means that the implementing organisations can explore ways of adapting and improving on the exiting m-Agri services. The term 'reuse' in this perspective means evaluating the resources that are currently available and using them to meet the aim of any proposed initiative, while 'improve' means modifying the existing resources to improve their quality, applicability, and impacts. This approach could be achieved by identifying the relevant methods, software platforms, or codes, digital content, technology tools and standards that have been tried and tested [111]. As such, the implementers should learn about m-Agri initiatives that have been piloted or scaled through blogs, conferences, project

evaluations, and digital development community. This can be realised by collaborating with other digital development practitioners and partaking in technical working groups and other knowledge sharing events to be informed of the existing services and to establish relationships that could lead to the future improvement and/or reuse of the proposed one [53,112]. Although, an existing initiative may not exactly fit all the requirements for reuse, improving and upgrading it rather than creating an entirely new one should be considered. It is also important to identify what works and what does not work before embarking on a given project. Hence, this approach can reduce the amount of time needed for the development and testing as well as reducing the costs of the m-Agri service.

4.4.6. Open and Data Driven

An open approach to m-Agri services can help increase collaboration among the relevant stakeholders as well as help to reduce the duplication of the initiative that is already in existence. Many times, huge resources are spent for investing in new tools, content generation, and developing of software codes for specific m-Agri solutions that are locked away under licensing fees with restricted access to data. Moreover, programmes can judiciously use their resources and achieve impact by being open. However, what being open means for a particular initiative may depend on practical or technical limitations, privacy, and security concerns, as well as the dynamics of the stakeholders and networks in the target environment. Being open in this perspective means that the implementers need to adhere to publicly available standards and policies such as Open Data Commons license, Open Source license, and Creative Commons license, which allow them to freely share their data, while maintaining users' privacy protections [121]. For instance, the extent to which m-Agri service providers use any open source software is dependent on the needs identified within the context and assessment of the available options that fit the needs. Hence, it requires that the implementers/developers need to collaborate with other counterparts who have done a similar initiative to identify opportunities for making such initiatives more open. Moreover, no amount of data collected will manifest an accelerated impact if not used to inform a decision-making process. When an m-Agri service is data driven, quality information is made available to the right target users when it is relevant and when they can use it to solve their perceived problems. Hence, the users should drive the process of determining the best data needed for their decision-making, appropriate time, and in what format.

However, dealing with these approaches and concepts for ensuring m-Agri services' sustainability requires good governance and the active involvement of the policymakers to facilitate the process. The following section, therefore, highlights some of the perceived role appropriate policy and governance can play in promoting sustained long-term impact of m-Agri services.

4.5. Policy and Governance

This review suggests that policymakers and/or government/non-government organisations can play a key role in enhancing the sustainability of m-Agri services in Africa by creating an enabling environment for all the stakeholders through the implementation of favourable policies or programmes. Thus, this could be achieved by supporting affordable access to mobile handsets, networks, and Internet facilities, and promoting universal digital literacy as well as grassroot innovation skills [80,85]. Furthermore, it requires that security policies should be implemented to protect individuals' data and uphold their privacy and dignity, as well as instituting an end-of-life post-project data management policy and ensuring that the implementers abide by strict data protection policies. Given that agriculture is increasingly becoming knowledge-intensive and high technology-driven, a key task for the government and policymakers could be to enact policies that support m-Agri services that enable illiterate farmers to interact with such services using analogue components. More so, the government can support by hosting m-Agri services at subsidised rates or free for the target users and, by so doing, ensure an improved long-term impact [80].

4.6. Summary of Key Findings and Recommendations for the Future

This review set out to examine the current landscape of the m-Agri app use in Africa, and provide an overview of the challenges that currently impede the establishment and sustainability of m-Agri services and identify opportunities for policymakers, designers, and developers to enhance the development and sustainability of m-Agri apps in Africa. Smallholder farmers in Africa produce the majority of food consumed. For many of these smallholder farmers, m-Agri services could revolutionise their access to information and extension services, and, ultimately, improve their livelihoods [86]. Currently, these smallholder farmers are not always best served by the m-Agri services available and this should be improved. This requires input from policy makers and government to improve provision. The questions posed at the beginning have been addressed in detail in the previous sections, the key findings are summarised, and recommendations based on these findings are presented in Table 4.

Table 4. Key challenges for wider m-Agri use, opportunities for improvement, and policy recommendations to improve m-Agri provision for smallholder farmers.

Challenges to Wider Use of M-Agri Services	Opportunities/Potential Remedies	Policy Recommendation
Uneven and unsteady electricity power supply for charging mobile phones and Internet access	Provision of solar chargers and infrastructure improvements	• Provide support for infrastructure development in rural areas [e.g., free Wi-Fi] • Provide solar chargers at low or no cost for target users
Uneven network coverage	Improve access in rural and distant regions	• Policy to encourage telecoms companies to widen coverage, financial, or legislative incentives
Cost of subscription to m-Agri services	Free access, low-cost access, sponsorship by NGO, Business, or Government	• Government support for service start-up and maintenance of the service
Cost of equipment	Low-cost handsets, or free handsets	• Provision of free handsets to disadvantaged users (women farmers, isolated villages) • Subsidy for low-cost handsets
Failure to understand farmers use of m-Agri services results in underutilisation	Understand the needs of users, content, and language, engage in development needs analysis	• Encourage developers to engage with end users • Provide access through extension services • Engaging the extension agents may result in cost savings for extension services
Accessibility, language, and skills needed for smartphone access	Provide training, understand user's language, education, and technological skill levels	• Provision for the training of users, options for peer-to-peer learning and mentorship
Bridging the research-farmer disconnect	Encourage participatory research involving farmers	• Provide facilities for knowledge exchange • Provide extension agents with funding and facilities to engage • Policy to require researchers to engage with end users • Funding for research to bridge this disconnect
Trust issues on privacy and data security	Ensuring standards for data privacy and protection	• Privacy and data protection policy that can ensure that the data subject has a right to access and understanding of what his/her data is used for and how long the data is stored
Unsustainable business models	Diversified income sources to maintain a long-term impact of the service Revenue models that involve institutions covering the cost of marginalised users' [e.g., smallholder farmers, women, and young people] access to the m-Agri service	• Provide facilities for maintaining a user feedback loop • Provide standards for business models to adapt to users' needs and expectations
Digital gender divide	Identify and engage with the gatekeepers [husbands, parents] Encourage services that are tailored to the needs of women	• Provide facilities that promote women and girls' participation in m-Agri services • Funding for an e-skill acquisition
Unsustainable practices towards m-Agri service(s)	A sustainable approach to the design, development, deployment and use Participatory approach to understand specific and genuine problems	• Regulatory policies that can ensure sustainable practices

5. Conclusions

M-Agri services have proven to bring significant benefits such as access to financial facilities, agricultural information, and sharing, supply, and marketing services to smallholder farmers with the enabling penetration of mobile phone and Internet facilities. Despite the documented positive impacts, such initiatives sometimes face challenges for their sustainability. This review identified that some of the m-Agri services in Africa encountered challenges such as a lack of trust about the content by the target users, the one-size-fit-all approach by the service initiators, and reduced attention for providing the necessary infrastructures before embarking on the development of the initiatives by the developers/implementers. The infrastructures may include appropriate contents, sustainable business models, provision of mobile and Internet skills, and investment in grassroot assessment to understand specific users' need. However, it was revealed that there were various strategies adopted by some of the existing m-Agri services in overcoming some of the challenges, which include reasonable service charges, offline messages that use no Internet for delivery, providing alternatives for grid electricity-powered mobile phone chargers, as well as co-opting intermediaries between the providers and users to help improve users' skills. Following the review of varied literature and available m-Agri services, this study highlights that, to enhance the sustainability of m-Agri services, the initiators/implementers should adapt with the various functionalities, which include designing with the target users in mind, understanding the target environment, and planning and executing the service beyond the pilot stage. They should ensure the users' privacy and data security and explore other innovative strategies such as reusing and improving existing initiatives, operating within open data and open source policies/standards, and utilising a user-led initiative approach. It is also important that m-Agri service(s) providers ensure truly sustainable initiatives by adopting a holistic approach for sustainability in the design, development, deployment, and evaluation of any m-Agri service(s). They should consider the long-term social and economic impact as well as efficiency for the users and encourage sustainable behaviour through the design. This can be achieved through a participatory approach to identify the needs of the target users and requirements for sustainable m-Agri service(s). Also, a peer-to-peer model among implementers and users should be encouraged to enhance the sharing of ideas and initiatives. As such, these recommended strategies for improved long-term impact of future m-Agri projects are derived from the key findings of this review. Hence, each country's government and policy makers can enhance the actualisation of these recommendations.

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