Hohenheim Working Papers on Social and Institutional Change in Agricultural Development

Working Paper 022-2024

Silicon Savannah and Smallholder Farming: How can Digitalization Contribute to Sustainable Agricultural Transformation in Africa?

Evelyne Njuguna, Thomas Daum, Regina Birner, John Mburu

Universität Hohenheim

May 2024

Hohenheim Working Papers on Social and Institutional Change in Agricultural Development (022-2024)

Silicon Savannah and Smallholder Farming: How can Digitalization Contribute to Sustainable Agricultural Transformation in Africa?

Authors Details

Evelyne Njuguna (University of Hohenheim, Germany)

Thomas Daum (University of Gothenburg, Sweden)

Regina Birner (University of Hohenheim, Germany)

John Mburu (University of Nairobi)

Corresponding Author

Evelyne Njuguna (evelynewairimu.njuguna@uni-hohenheim.de)

Suggested citation: Njuguna, E., Daum, T., Birner, R., Mburu, J. (2024). Silicon Savannah and Smallholder Farming: How can Digitalization Contribute to Sustainable Agricultural Transformation in Africa? Hohenheim Working Papers on Social and Institutional Change in Agricultural Development. 022-2024. University of Hohenheim.

Title Picture Credit: Evelyne Njuguna

Download this working paper from our homepage: https://490c.uni-hohenheim.de/en/75736

Abstract

High hopes are pinned on digitalisation for the much-needed transformation of African agriculture, but there is little empirical evidence on the nature and impact of digitalisation on smallholder farming. Using a novel classification framework and impact pathways, we examine the landscape of digital agriculture in Kenya - Africa's *Silicon Savannah*. We find a slowing trend in the establishment of new digital start-ups since a peak in 2016, but also a shift from *generic* to *farm-specific* tools, which provide more farm-tailored advice based on data entered by farmers or obtained with sensors and improved data analytics. Reviewing all digital tools regarding the impact pathways developed, we find great potential to increase farmers' knowledge and access to inputs, services, and markets, all of which raise productivity and incomes, but limited evidence regarding food & nutrition security as well as the environmental effects and climate resilience.

Key Words

African agriculture; digitalization; farm-specific tools; generic tools; Silicon Savanna

Acknowledgments

We are very thankful to all institutions that participated in this study. We are equally grateful for the financial support from the "Program of Accompanying Research for Agricultural Innovation" (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ).

1. Introduction

Agricultural growth is key to poverty reduction, food security and economic transformation in Africa (Barrett et al., 2017; Diao et al., 2010). However, agricultural development of smallholder farmers, who form the majority in Africa (Lowder et al., 2021), is held back by several challenges. These include inadequate access to inputs (e.g. improved seeds and inorganic fertilizers), agricultural services (e.g. extension, finance, mechanization), lack of knowledge and information (e.g. related to agricultural production, markets and weather), poor linkage to output markets and more (Aker, 2011; Baumüller, 2015; Benin, 2021; Stewart et al., 2020; Van Loon et al., 2020). Digital agriculture promises to address many of these challenges, thereby optimizing agricultural production systems, enabling better connectivity to reliable markets, reducing the environmental footprint of agriculture and improving farmers' livelihoods (Akuku et al., 2019; Deichmann et al., 2016; Emeana et al., 2020; Klerkx et al., 2019).

While there are high hopes and many intriguing initiatives related to digital agriculture, there is little empirical evidence on the actual state and extent to which these tools are reducing challenges for farmers (Ayim et al., 2022). On the one hand, there are enthusiastic reports on digital agriculture in low- and middle-income countries, such as the Digitalization of African Agriculture Report (2018-2019) and the Digital Agriculture Maps Report (2020) (GSMA, 2020; Tsan et al., 2019), but they do not differentiate different tool capabilities, which inform the extent to which farmers' challenges are addressed. On the other hand, some scholars argue that digital agriculture is an overhype (Ouma & Mann, 2021), diverting attention from finding real solutions to on-the-ground challenges of farmers (Sibanda, 2019), or that Africa is not ready for a digital revolution given concerns about digital infrastructure and farmers' willingness to adopt (Jellason et al., 2021; McCampbell et al., 2021).

Using Kenya as a case study, this paper addresses two open questions. First, to what extent can and will digital solutions for agriculture in Africa take advantage of the latest technological developments in sensors, data analytics and automation, given the context of smallholder farming? Secondly, to what extent can digital solutions address the challenges of smallholder agriculture and contribute to the much-needed sustainable agricultural transformation in Africa? Answering these questions will help to develop strategies that support the further development of digital agriculture in Kenya, while providing pointers for other African countries. All with the goal of transforming agriculture.

To answer these questions, we first present a novel framework to differentiate digital tools based on advancements in sensors, data analytics, and automation. We then take a comprehensive inventory of digital tools available to Kenyan farmers and analyze them using the developed framework and insights from tool developers and the literature.

Additionally, we explore pathways through which digital tools can transform African agriculture based on the impacts observed in most of the existing studies on digital tools in Kenya. Finally, we explore untapped potentials of digitalization for sustainable transformation. Kenya is an interesting and applicable case study as it's economy is agriculture-dependent and it also pioneers digital agriculture for use in low- and middle-income countries (Kim et al., 2020), earning it the label *"Silicon Savannah"* of Africa (Akamanzi et al., 2016). 80% of smallholder farmers already own a phone, and a well-established mobile money ecosystem exists (Kim et al., 2020).

2. Methods

2.1. Classification framework of the agriculture digital tools

For the assessment of digital tools, we developed a framework that identifies key characteristics of digital agricultural tools at two different layers (see Table 1). It shows the attributes of physical devices, and their analytical capabilities. It builds on a multi-level taxonomy for digital technologies developed by Püschel et al., (2016) and Berger et al., (2018), and on a framework for classifying digital tools in agriculture by Birner et al., (2021) and Daum et al., (2022).

Table 1. Classification framework for the agricultural digital tools

Layer	Sub-layer	Characteristics				
Device	Innovation type	Embodied			Disembodied	
	Human-Machine Interface	Internet and web servers			Mobile phones (apps, SMS, voice and USSD)	
Content	Data analytics	Descriptive	Diagnostic		Predictive	Prescriptive
	Capability	Generic	Farm-specific with manual data entry	Farm-specific with sensor-based data input	Farm-specific with Autonomy	Actor-integrating

Source: Authors

Following a classification of innovations commonly used in agricultural economics, digital tools in agriculture can be classified as "embodied" or "disembodied" (Sunding & Zilberman, 2007). Embodied tools are part of agricultural equipment, as in case of sensors in a tractor while disembodied tools are not integrated into agricultural equipment, they only require a phone — as in case of advisory apps, farm management software and online platforms (Birner et al., 2021). Low levels of mechanization and limited access to capital resources makes disembodied tools attractive for African smallholder farmers. The human-machine interface enabled by internet connections and web servers allows for the actual use of digital services (Papcun et al., 2018). Apps, SMS, voice and USSD protocols are used in mobile phones.

In the content layer, value is created through data analytics. A tool can optimize operations through descriptive, diagnostic, predictive, or prescriptive analytics. Descriptive analytics records the surrounding conditions, environment and operations (e.g. history of past farming activities). It is rather simplistic but provides a quick glance to performance patterns in parameters of interest to the farmer. Diagnostic analytics examine possible causes of inefficiencies. Predictive analytics detect patterns and signal likely impediments; and prescriptive analytics suggest actions to address identified problems (e.g. opening a water gate when the water levels in the plant tissues are too low) (Porter & Heppelmann, 2015; Püschel et al., 2016).

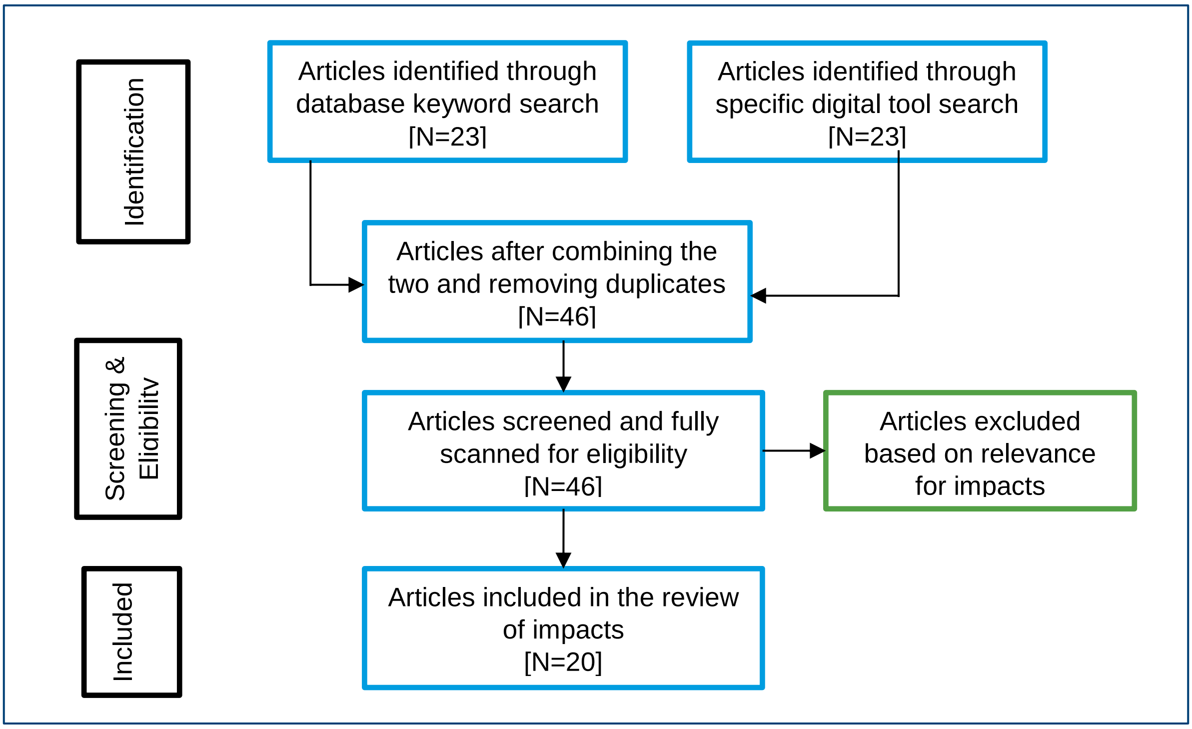
The capabilities of these tools can be distinguished as either generic, farm-specific, or actor integrating. *Generic tools* provide all-encompassing information to farmers via SMS, voice-based interfaces and apps. These tools are very common as they provide general information and are suitable for less tech-savvy mobile phone users. Examples include tools for learning, informing, and sharing information on commodity prices and weather patterns. Farm-specific tools are smart, connected and provide customized services. Within the farm-specific category are three groups, distinguished by how they gather and apply their information: manual data entry, sensor-based data input, or autonomous capabilities. *Farm-specific tools with manual data entry* allow farmers to act as "sensors", enabling more farm-tailored information without being embodied. The type of data analysis can vary. For example, they can remind farmers of farm tasks or help optimize farm production. Examples include tools that show the cycle of dairy cows and remind them of calving or deworming dates. *Farm-specific tools with sensor-based data input* rely on machine-based, animal-based, ground-based or space-based (e.g. satellites and drones) sensors (Antony et al., 2020). The sensors can monitor agricultural parameters such as weather patterns and soil mineral composition, or even cow rumination. Data analytics can include some or all of the following features: descriptive, diagnostic, predictive, or prescriptive. *Autonomous digital systems* enable automatic operation supported by artificial intelligence or rule- based mechanisms to analyze data and actuators for implementation. Examples include automatic irrigation systems and automatic animal husbandry (Liu et al., 2021). *Actor- integrating tools* encompass integration of value chain actors, including farmers, credit agencies, and commodity merchants, to create a network of digitally connected individuals. For example, a tool can work with farmer organizations to facilitate access to input and output markets and provide other services such as financial products or e-extension training.

To create a clear distinction of digital solutions within the classification framework, we use four broad categories, i.e. information & learning, advisory, financial, and market linkage services as a basis for discussion. The distinction between information & learning tools and advisory tools stems from their capabilities and the extent to which they optimize or support decision-making in agriculture. Information and learning tools are comparable to an agricultural textbook or extension material that a farmer can read to increase their knowledge. An example is reading information on the importance of soil testing. Advisory tools, on the other hand, go beyond information and offer farm-tailored instructions in case a certain outcome occurs. For example, "based on your farm location, type of soil and nutrients depletion, please use the following fertilizers at this rate and at this time for optimum production". Financial services cover all financial dimensions, including operating budgets, loans, insurance benefits and savings. Market linkages include access to agricultural inputs and services as well as output markets (including the aggregation of products for sale).

2.2. Stocktaking and impact reviews of digital tools

Stocktaking was conducted by reviewing the Google Play shop, homepages, peer reviews, and reports from organizations on digital agriculture up to July 2023. It should be noted that the results presented are a unique snapshot in a very dynamic sector. We identified a total of 70 digital tools in Kenya's agricultural value chains. Nine of these had no active websites/homepages and nine focused on services beyond smallholder farmers, so only fifty-two tools were examined in this study. To determine functionality, we downloaded and/or registered to 30% of these tools for the services they offered. We excluded tools that were developed as solutions for extension workers, consumers, supply chain management and off-farm retail. To review the potential impact of the identified digital tools, we conducted a literature search focusing on peer-reviewed journals, reports and expert opinions in the Google Scholar internet search engine and in electronic databases such as ScienceDirect, CAB Direct and IEEE Xplore. Search terms included "digital tools OR digital platforms" AND (agriculture OR farmers) AND Kenya; "smart farming" AND Kenya; "digital apps" AND (agriculture OR farmers) AND Kenya; "m-services" AND (agriculture OR farmers) AND Kenya. We expanded the search criteria to include specific digital tools in the keyword search. Figure 1 shows a flowchart illustrating the process used to select literature on the potential impact of digital tools in Kenya. Following the inclusion and exclusion process, 20 relevant articles were identified. These include 14 peer-reviewed articles, 5 reports and 1 website.

Figure 1. Flow diagram summarizing the approach used for selecting literature



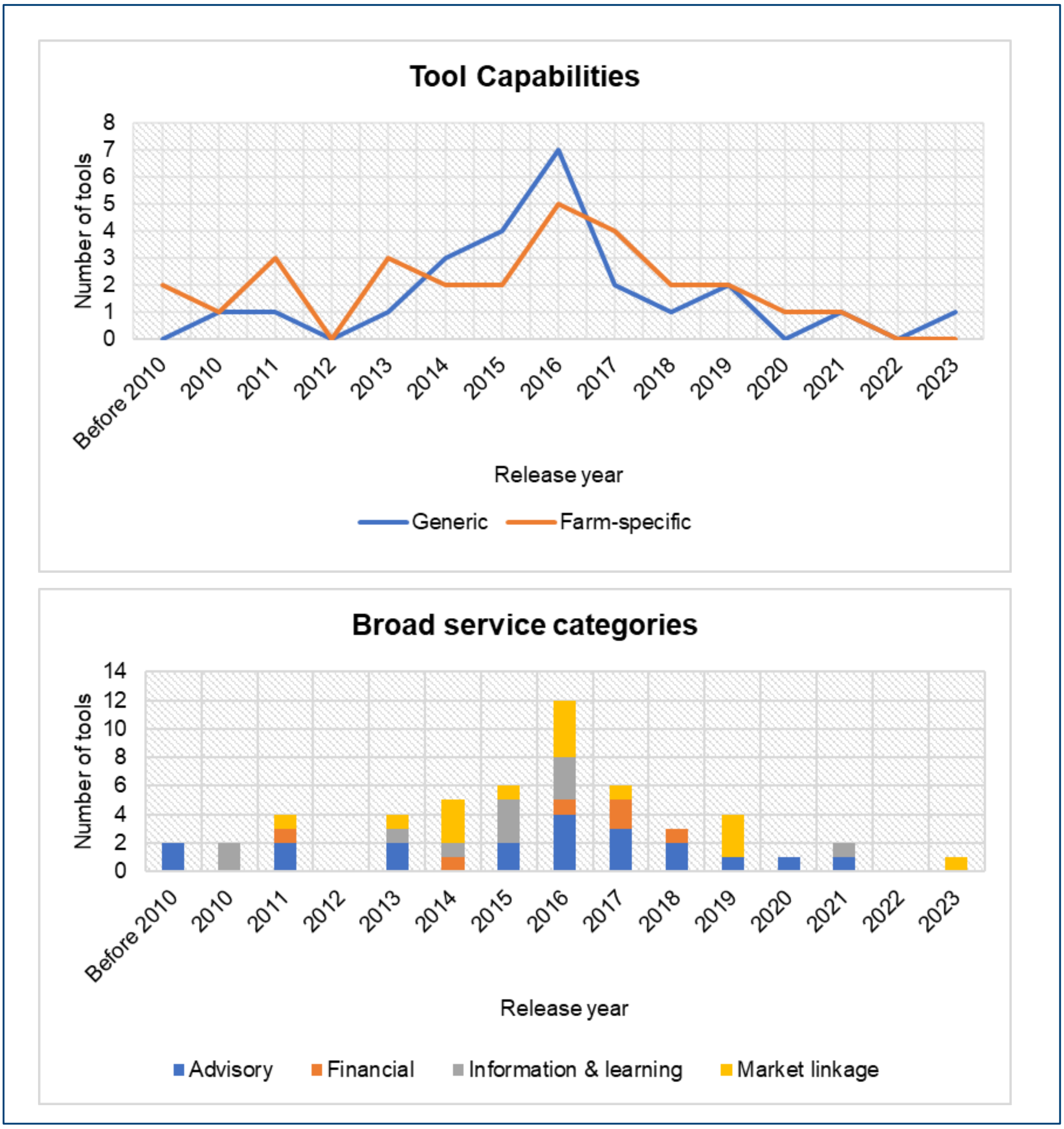
Source: Authors

3. Results

3.1. Agriculture digital landscape in Kenya

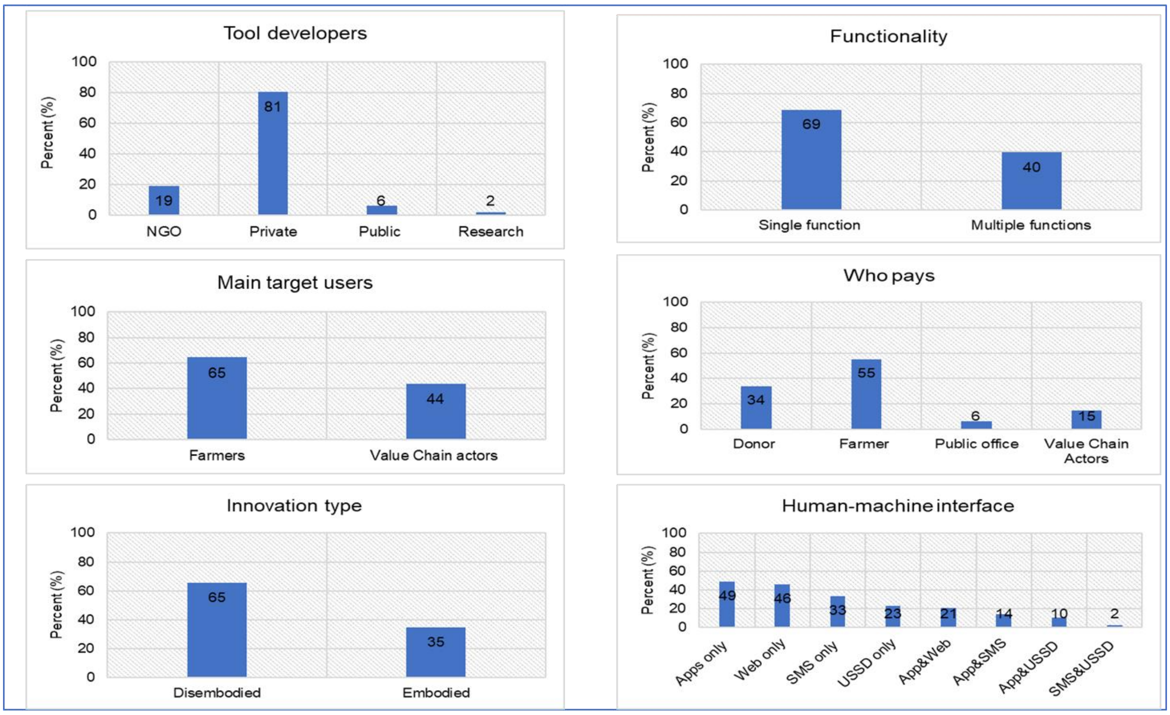
Our stocktaking showed that 52 tools were available to farmers as of July 2023 – three times as many as 10 years ago (Baumüller, 2016). The development of new tools peaked in 2016 (**Error! Reference source not found.**), possibly due to strong donor support (Abate et al., 2023) and favorable macroeconomic and political conditions, as an ICT ministry was established in 2013, followed by the expansion of internet bandwidth. However, the release rate has slowed down since, possibly due to market saturation and a shift to refining existing tools rather than developing new ones. A substantial majority of these digital tools (81%) were developed by private enterprises (**Error! Reference source not found.**) though some collaborate with government agencies. For instance, 7 tools work with public extension workers, including veterinarians and agronomists, as in the case of *iCow*, which offered free veterinary services together with the State Livestock Extension Office during the COVID - 19 pandemic. Most of these tools directly target farmers, primarily utilizing mobile phones, particularly smartphones given the ubiquity of internet/web browsers and apps as human-machine interfaces (**Error! Reference source not found.**). Additionally, "disembodied" innovations predominate and merely require a mobile device without integration into farm equipment (**Error! Reference source not found.**). However, recognizing that not all farmers possess smartphones or the requisite app-handling skills, and in cases where aggregation of agricultural produce is necessary, several companies have introduced models where intermediaries or agents facilitate connections between farmers and buyers/service providers through digital tools.

Figure 2. Agricultural digital tool development trends in Kenya based on the capabilities and service categories



Source: Authors

Figure 3. Descriptive characteristics of digital tools in Kenya



Source: Authors

As derived in the Methods and presented in Table 1, it is useful to divide digital tools according to their capabilities into "generic", "farm-specific with manual data entry", "farm-specific with sensor-based data input", "farm-specific with autonomy" and "actor-integrating", as elaborated in the next sections. Box 1 and 2 show examples of tools for each of category.

Box 1. Detailed examples of tools reviewed in the paper

ishamba: is a “generic” information and learning tool developed by a private company for farmers who grow crops and raise livestock. It was launched in 2013 and offers mainly SMS-based services. The tool has positioned itself as a call centre for agricultural extension workers, where farmers can submit their queries via SMS or call to speak to an extension worker and get immediate help. By subscribing to these services, farmers also receive tips on crops and livestock, market prices, weather forecasts and alerts on agricultural events in their area. The tool is designed for English and Swahili languages and is based on a membership business model. Here, farmers can either take out a premium membership for Kes 800 per year or a free membership with limited services.

SmartCow: is a farm-specific tool with manual data entry, and an actor-integrating tool developed by a private company to provide advisory services to livestock farmers. It was released in 2018 as a herd management tool. The tool is accessible to farmers in the form of an app on a smartphone or as a web-based service. It has several features where farmers first create an animal programme based on all animal husbandry activities, including milking, feeding, fertility, breeding, health management, and farm accounting. This enables the optimisation of key elements such as lactation cycles. Secondly, the tool gives farmers access to an integrated directory of advisors and veterinary service providers. Third, the tool connects farmers to financial services, especially credit and insurance. Fourth, it has an integrated database of agro-input shops where farmers can buy feed, disease control medicines, hay, and silage. It also has a database of milk buyers, which are all private traders or cooperatives, and an animal-sales platform. *SmartCow* has system-generated records and calendar schedules, and therefore does not allow subsequent adjustment of events to minimize potential errors or manipulation of data by farmers. The system is described as "farm-specific" because it optimizes herd management by automatically generating farm accounts and reminding farmers of critical events, such as when to look for signs of oestrus in animals for insemination, vaccination, and deworming. At the same time, the records provide collateral when taking out loans.

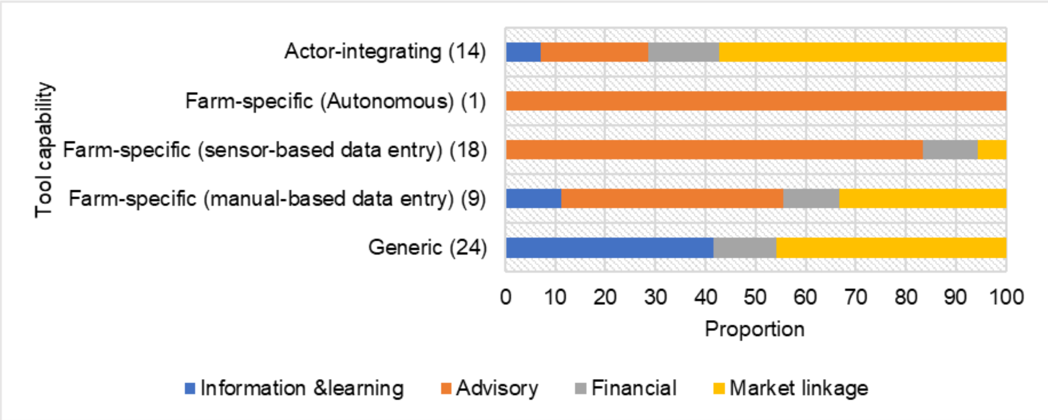
Box 2. Continuation of detailed examples of reviewed tools

AgroCares scanner: is a farm-specific, portable and sensor-based input tool developed by a private company to offer on-site soil testing to farmers. It was launched in 2016 and uses the agency model to provide these services. The agents are either private actors, public actors, or farmer cooperatives. Using near-infrared spectroscopy technology, a connection via Bluetooth and an app, the scanner connects to a global database and estimates the sampled soil health parameters (e.g. nitrogen, phosphorus, potassium, soil pH, organic carbon and soil cation exchange capacity). A fertiliser and management report is then produced with advice including soil fertility status, actual nutrient requirements, plans for soil amendments and advice on other suitable crops. Agents must purchase the scanner hardware and pay an annual licence fee to access the global database software.

FarmShield: is an autonomous digital tool that was privately developed and launched in 2013 as an irrigation and fertilizer management system for greenhouses. The tool is equipped with sensors that monitor nutrient content (NPK), soil moisture and temperature, air temperature and humidity, and light intensity, as well as a water flow metre to monitor irrigation. The tool helps control the irrigation system\and the greenhouse fans and ventilation, and it helps to notify the farmer of the soil nutrient content (NPK). The system is powered by solar energy and is connected to a cloud where the collected data is stored, analysed, and displayed on the farmer's smartphone through an app, web portal, or USSD. The tool's digital offering ranges from "Lite", "Basic", "Premium" to "Pro", with the number of sensors installed increasing depending on the package purchased.

Digifarm: is a “generic” and an actor-integrating tool launched in 2017 and privately developed by the largest network provider in East Africa. The products and services enable farmers to procure, trade, and learn through generic-feature phones. Through integrated services and collaboration with service providers, farmers have access to inputs from vetted agricultural input dealers, and they have access to credit for these inputs in the form of a code used in the dealers' shops. A 20% down payment is required to obtain credit for inputs. Crop insurance is also offered, either together, with a credit for inputs as compulsory insurance, or separately for farmers who buy inputs in cash. The tool also offers farmers market connections through its own e-market platform called *Digisoko* and other partners who have signed up. Finally, *DigiFarm* offers interactive learning in collaboration

Figure 4. Digital tool categories based on the capability and broad service types



The number of tools that can be classified as "farm-specific" is cumulatively higher (28) than that of "generic" tools (24)

Source: Authors

3.1.1. Generic digital tools

Twenty-four out of the 52 digital tools are classified as "generic", being limited to exchanging information. While less technologically sophisticated than "farm-specific" tools, "generic" tools also address agricultural development challenges. The majority of these tools (45%) focus on market linkages to connect farmers with input and output markets, with 75% being multifunctional and enabling produce aggregation for offtake markets. Almost all "generic" market linkage tools offer the possibility of posting products online. Others focus on input markets, for example by allowing farmers to access services like artificial insemination using USSD code. 14% of the "generic" tools focus on financial services, enabling farmers to borrow, save, or pay for inputs. Some tools condition payment services to prevent diversion to non-agricultural expenses, a long-standing problem in agricultural development projects (Oboh & Ekpebu, 2011). 40% of the "generic" tools facilitate information and learning services, using e-extension components based on apps, SMS, video, or interactive voice (Figure 4). This includes participatory peer-to-peer learning where farmers share information among themselves, which may be more effective in innovation diffusion than top-down recommendations (Eitzinger et al., 2019). However, as these tools do not collect farm-specific information unless shared by farmers, no farm-specific advice is given. In many cases, a basic version is free of charge but farmers must pay for additional services. For instance, *iShamba,* an e-extension tool with a call center, restricts access to advisors to premium members.

3.1.2. Farm-specific (manual-based data entry) tools

Nine of the reviewed tools were classified as "farm-specific" with manual-based data entry functionality (Figure 4) using web, apps and SMS as human-machine interfaces. Most such tools are advisory tools. Based on data entered by farmers; such tools can provide customized advice to farmers. For example, *iCow Kalenda* offers farmers personalized livestock calendars with reminders for important activities like vaccinations, deworming, and insemination. Manual data entry also allows farmers to use such tools for documentation and monitoring. Other services such as information and learning, financial and marketing are often integrated within such tools. For instance, *SmartCow* includes an information and learning component on herd management, connects farmers to buyers and input/service providers, and provides access credit.

3.1.3. Farm-specific (sensor-based entry) tools

Eighteen tools are "farm-specific” due to sensor data, which 15 of them use to provide better advisory services (Figure 4). These tools have diagnostic, predictive and prescriptive capabilities. Satellite imagery is a commonly used data source. For example, *AfriScout* uses satellite-based vegetation maps to show the grazing and water conditions, helping pastoralists to make movement decisions. Other tools provide more direct optimization recommendations. *MyAnga* provides pastoralists with weekly weather forecasts and suggests actions to optimize production (e.g., when to destock animals). Some tools combine sensor-based data from satellites with manual data entry, such as *FarmDrive,* a credit-scoring tool, which combines manually-entered socio-economic data with satellite data and weather forecasts to assess performance patterns. There are also tools using ground-based sensors. *AgroCares Scanner* uses in-field soil sensors to test soil pH, nutrients, and organic content and provides tailored recommendations based on soil and crop needs. Several tools are integrated with an existing system or send notifications to farmers when action is needed. For example, *CropNuts IoT Sensors* monitors soil moisture along with an existing irrigation schedule and *SunCulture* uses sensors and sends notifications to farmers when water pumping is required. One tool (*RioFish*) uses water-based sensors to monitor fish feeding needs based on changes in water temperature.

3.1.4. Farm-specific (autonomous) digital tools

FarmShield is the sole tool with autonomous capabilities. It is an intelligent, networked and autonomous device for greenhouse management using remote mobile phone control (see also Box 2). *FarmShield* employs a range of sensors and actuators to control irrigation, ventilation and fans, while also providing alerts on primary soil macronutrients.

3.1.5. Actor-integrating digital tools

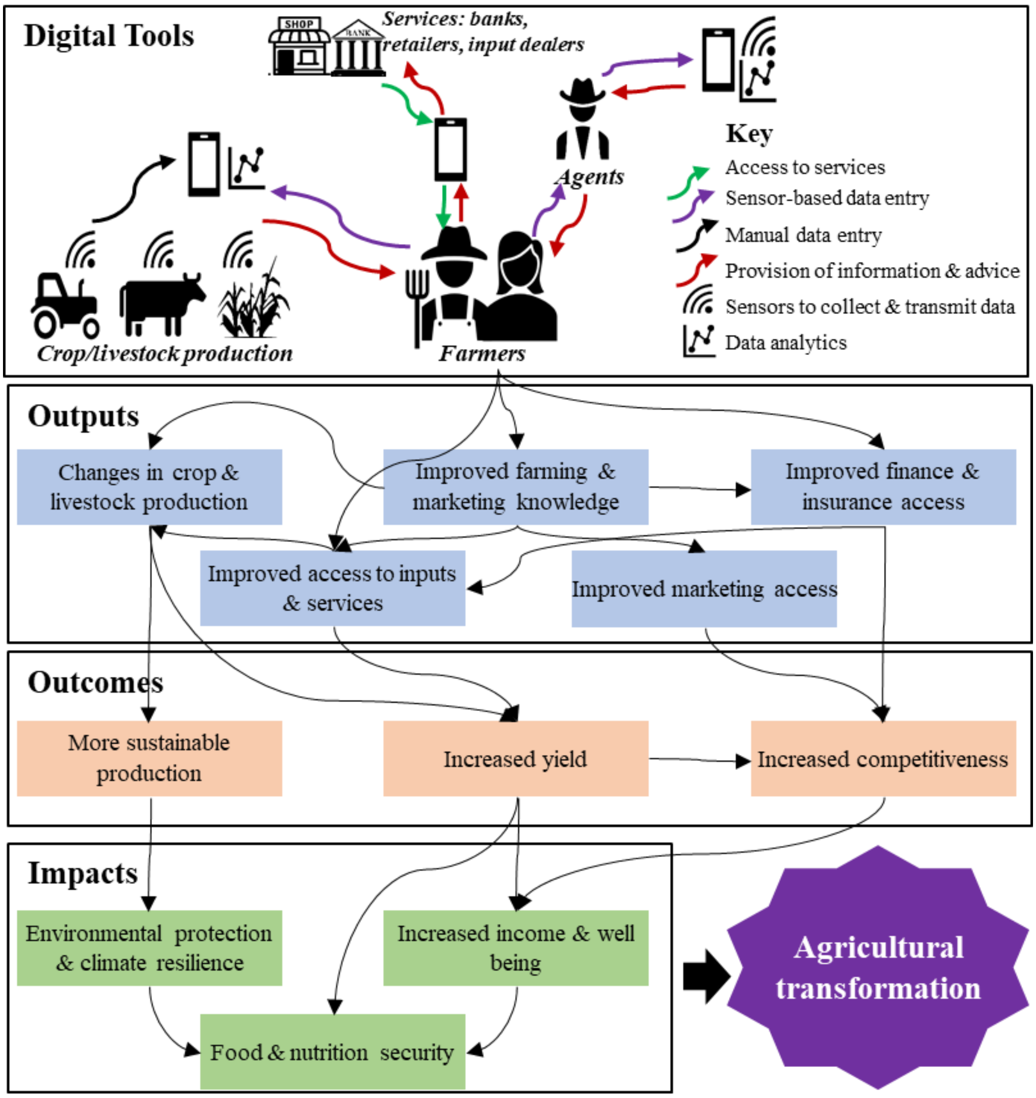
Fourteen tools are actor-integrating, with market linkage being a key element in most (57%) (Figure 4). These tools facilitate connections between farmers and one (or various) value chain actors, ranging from input suppliers to buyers. *DigiFarm,* for example, connects farmers with input supplier and buyers while providing credit services. In addition, through collaborations with other tools, *DigiFarm* is also an information and learning platform that provides data on commodity prices and weather. However, this model has faced criticism for potentially locking farmers into legible systems to ensure debt repayment, reduce investment risk and ensure stable or predictable demand and supply for actors (Mann & Iazzolino, 2021).

3.2. Potential impact pathways of digital tools in Kenya

In Figure 5, we show potential impact pathways of digital tools, based on our novel classification framework and insights from the literature. Digital tools can enhance the provision of information to farmers, improving their knowledge and access to inputs, services, and marketing options. Consequently, this can lead to changes in crop and livestock production (outputs), promising to increase yields, competitiveness, and sustainability (outcomes). This can impact societal outcomes such as food and nutrition security, farmer income and well-being, and environmental protection and climate resilience. This can ultimately enable the transformation of agriculture, which is the long-term goal. We have identified five major outputs and their potential impacts based on the literature are summarized in Table 2 and further examined below.

Improved farming and marketing knowledge: The majority of the reviewed tools are “information and learning” tools that disseminate farming- and marketing-related knowledge with e-extension components (Table 2). Many are “generic”, providing all-encompassing information, however, they are easily accessible, associated with minimal costs, and can help to reach farmers in regions underserved by formal extension. For example, *Precision Development* internal evaluation in 2021 reports an average cost of $1.61 per farmer and a 36% success rate (defined as per attempted interaction two-way SMS: Average percent of messages where an SMS was received and responded to) in engaging with 630,000 farmers through SMS and phone calls (Precision Development, 2022). Similarly, 75% of *iShamba* users accessed extension services for the first time (Mercy Corps, 2020) through the tool. E-extension tools are attractive because they reduce the transaction costs associated with seeking information and improve the convenience of learning, as was reported in an evaluation of *iShamba*(Etchells, 2019). A study on *Afriscout,* a pasture optimization tool, revealed that pastoralists are willing to pay for access to various information, including on pastures, water, livestock diseases, and markets. Access to information, in turn, is associated with improved farming and marketing knowledge in areas such as cultivation methods, seeds and fertilizer use, pests and diseases, and market prices, which can help to minimize exploitation. Table 2 also shows that improved knowledge can enable higher yields and incomes.

Figure 5. Potential impact pathways of digital tools



Source: Authors

Changes in crop and livestock production were documented in five studies (Table 2). For example, *iShamba* users adopted higher-yielding seeds and improved the precision and timeliness of input application, enabling higher yields (Etchells, 2019). Of particular relevance were "farm-specific" tools with manual data entry, which help farmers to schedule and optimize activities based on the recorded data. Users of *iCow*, another such tool, reported positive changes in herd management, including improvements in hygiene (57%), feeding (55%), mastitis control (37%), and deworming (35%)(Marwa et al., 2020). This positively affected milk production, revenue, and income, which increased by 13%, 29%, and 22% respectively (Marwa et al., 2020). Importantly, the evaluation of *iCow* considered only the e-extension aspect and no other functions such as lactation cycles for registered animals. These latter functions explain its classification as a "farm-specific" tool with manual data entry (Table 1). In many cases, it remains unclear to which extent customized services are used even if tools promise such services. *CropIn*, a tool integrated within *Digifarm*, claims to provide farm-tailored advice based on satellite and weather data (Mercy Corps, 2021). However, in a recent study, farmers expressed dissatisfaction with its services, citing a lack of farm-tailored messages and a focus on general weather conditions (Mercy Corps, 2021). However, our review also shows that there are truly “farm-specific” tools. Using sensor data, *AgroCares scanner* reliable estimates soil nutrients, allowing farmers to align fertilizer use with soil and crop needs, thereby reducing production costs and contributing to production sustainability (Amasi et al., 2021). Five tools provide climate-related advice, including in areas frequently affected by droughts. For example, *AfriScout* helps pastoralists locate pasture and water resources, resulting in improved livestock condition, although a recent study reports no causal effects on herd size (Machado et al., 2020).

Improved access to inputs and services: Various digital tools increase farmer’s uptake of certified seeds and fertilizers, enabling higher yields (Bulte et al., 2020; Etchells, 2019). *Precision Development* and *SmartCow* connect farmers with input dealers and service providers through SMS agro-dealer directories, reducing input market frictions and saving farmers’ time and money on physical visits (McKee, 2023). Other tools focus on quality assurance, thereby addressing the long-standing issue of widespread input counterfeiting, which can undermine crop yields. For example, *Digishop* employs a micro-franchising model with an integrated traceability system; however, actual usage evidence for this tool is scarce (Figure 5).

Improved marketing access: Digital tools promise to transform agriculture from a fragmented and unorganized subsistence-oriented economy to a more structured and market-oriented economy, thereby establishing a foundation for scaling up production (Duncombe, 2018). *M-Farm*, an e-marketing tool, allows produce aggregation with other local producers, strengthening their bargaining power and facilitating their access to medium- and high-value markets, thereby enhancing their competitiveness (Baumüller, 2015; Duncombe, 2018). Aggregating products resulted in faster sales, reduced transportation costs, minimized uncertainty, and higher farm-gate prices (Baumüller, 2015). *Twiga Foods*, a food distribution platform, demonstrates direct online marketing feasibility using real-time data to match market demand with farmers’ produce and streamline transportation and logistics (Moyer et al., 2022). However, eliminating intermediaries may come with downsides in regions that lack transport and digital infrastructure and, where farms are fragmented and supply chains are patchy (Moyer et al., 2022). Reports of *M-Farm* highlight concerns about power abuse by aggregation agents who may dominate decision making on whether to sell through the platform, and may even engage in side sales of produce (Duncombe, 2018).

Access to financial services can help farmers to access inputs, services, and markets, enhancing their competitiveness (Figure 5). In the case of *DigiFarm* (Mercy Corps, 2021), farmers considered the offered credit service to be the most valuable component, as it enables them to purchase inputs on time, optimizing sowing or fertilization. The service's flexible repayment terms and assurance of input quality make it attractive. Insurance is also gaining importance, especially with the climate crises. *AcreAfrica* addresses this by offering bundled insurance with inputs, meeting latent demand (Bulte et al., 2020). 89% of *AcreAfrica* users had previously lacked access to crop insurance (Mercy Corps, 2020). However, lacking knowledge on how bundled insurance works can undermine usage, as shown in a study on *DigiFarm* (Mercy Corps, 2021). Combining finance and insurance – or using others ways to make lending to farmers less risky for banks such as saved budgets (*Budget Mkononi)*, credit scores (*FarmDrive*) and performance records – appears promising. For example, *SmartCow* offers dairy farmers loans of at least Kes 20,000 (USD 200) if they have well-maintained records and a livestock insurance policy from the tool.

Actor-integrating tools promise to integrate farmers into value chains, improving access to information, inputs, markets, finance, and insurance - thereby enhancing competitiveness. The perceived impact of *DigiFarm* (Mercy Corps, 2021), for example, increased with the number of integrated services to which the user had access/experience. These integrated services included access to credit, markets, and farm management advisory across parameters such as capacity, resilience, and farm outcomes (Mercy Corps, 2021). Users of the *Arifu chatbot*, an interactive training tool for farmers within *DigiFarm*, perceived strong impacts on resilience (the ability to cope with external shocks and risks) due to increase farming knowledge from continuous access to information and learning resources. The perceived impact on agricultural outcomes within *DigiFarm*, including production and income, was highest among users of the *Arifu chatbot* and *DigiFarm* market services. The latter is attractive due to the provision of fair prices and an effective payment structure.

Table 2 shows that most digital tools focus on improving farming and marketing knowledge (10/15 studies), changing crop/livestock production (8/15), and improving market access (5/15). The tools have shown success in improving yields (7/15) and farmers' competitiveness (5/15), while their focus and impact on environmental sustainability agriculture remains limited(1/15). These efforts appear to increase farmers' income and well-being (7/15) and, to a lesser extent, improve food and nutrition security (2/15) and environmental protection and resilience to climate change (2/15). These findings align with those of Porciello et al., (2022) who also found limited data about outcomes related to environmental sustainability and climate resilience. Although digital tools are no panacea, there clear evidence of their potential in addressing several challenges of agricultural transformation

Table 2 Documented impacts of selected digital tools

Tool name	Study and source	Output 1: Improved farming and marketing knowledge	Output 2: Change in crop/livestock production	Output 3: Improved access to inputs & services	Output 4: Improved marketing access	Output 5: Improved access to financial services	Outcome 1: Increased yield	Outcome 2: Increased competitiveness	Output 3: More sustainable production	Impact 1: Increased income & improved well being	Impact 2: Environmental protection & climate resilience	Impact 3: Food & nutrition security
Arifu Chatbot (**within DigiFarm) (generic tool)**	Mercy Corps, 2021. Panel study survey (N=1439) and in-depth interviews (N=52)	Increased convenience of learning farming techniques; crop planting most useful learning content	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DigiFarm **(generic and actor integrating)**	Mercy Corps, 2021. Panel study survey (N=1439) and in-depth interviews (N=52)	Average 90% of users had improved farming knowledge	NA	NA	Stable & reliable channel for selling	Credits for seed, fertilizer, & pesticides (average amount borrowed: Kes 7300 -USD 73); limited utilization of insurance component due to lack of understanding	NA	Better market experience and prices compared to local markets	NA	Improved standard of living and ability to provide for basic needs such as food & school fees	Average 75% of users improved resilience	Increased households food sufficiency
iShamba **(generic tool)**	Etchells, 2019. In-depth interviews (N=33)	Reduced transaction cost of information. Improved knowledge on price	Changes in fertilizer & pesticide application. Shift to high quality seed, set up irrigation systems	Increased access to quality input	Shift from subsistence to agribusiness; increased bargaining power	NA	Increased maize yields	Increased produce quality	NA	Increased income through risk avoidance strategies	NA	NA

	Mercy Corps, 2020 Survey (N=256)	Improved knowledge on: farming cycles and planning of farm activities	Enhanced timely planting	Average 75% of users accessed extension services for the first time.	NA	NA	Average 74% of users increased farm production	NA	NA	Average 46% of users increased household income	NA	Average 30% of users increased consumption of food from farm
M-Farm **(generic tool)**	Baumüller, 2015. Survey (N=115), key informant interviews, focus group discussions	Information shared encouraged expansion of crops grown	Average 79% of users changed cropping patterns & 90% changed sales channels	NA	Faster sale at lower transport cost	NA	Average 87% of users increased maize & 56% in bean production	Better price negotiation ; switched to traders with better offers	NA	Inconclusive evidence related to income effects	NA	NA
	Duncombe, 2018. Case study- observations, key informant interviews,	NA	NA	NA	Encouraged collective action		NA	Observed substitution effects for top-down role of state and bottom-up role of farmer collective action	NA	NA	NA	NA
Precision Development **(generic tool)**	Precision Development (PxD) (evaluation report dashboard, 2022) https://precisiondev.org/pxd-	NA	NA	E-extension to 630,000 farmers; increased access to local agro-dealers; access to	NA	NA	NA	NA	NA	NA	NA	NA

	global-dashboard/			fall armyworm control								
Twiga Foods **(generic tool)**	Moyer et al., 2022. Qualitative conversations	NA	NA	NA	Shift to direct online marketing using real-time data; facilitated transportation & logistics	NA	NA	Increased coordination of market demand with farmers	NA	NA	NA	NA
AcreAfrica **(farm-specific-sensor based)**	Mercy Corps, 2020 Survey (N=241)	Average 48% of users improved knowledge on land preparation & planting methods & use of high quality seeds & fertilizers	Average 42% of users optimized planting methods; 20% improved land preparation; 23% adopted higher quality seed varieties & fertilizers	NA	NA	Average 89% of users accessed crop insurance for the first time	Average 40% of users increased farm production	NA	NA	Average 32% of users increased crop revenue; 45% improved life quality	Average 20% of users improved resilience to shocks	NA
	Bulte et al., 2019. Randomized control trial (N=780)	NA	Increased demand for complementary inputs (fertilizer, machinery, hired labour & land)	Greater uptake of certified seeds	NA	Insurance best utilized bundled with inputs	NA	NA	NA	NA	NA	NA
Afriscout **(farm-specific-sensor based)**	Machado et al., 2020. Randomized control trail (N= 2573)	Improved knowledge on pasture and water sources	Optimization of pastoralists migration decisions	NA	NA	NA	Improved animal condition (but no effects on herd size)	NA	NA	NA	NA	NA
	Banerjee et al., 2018. Key informant interviews (N=25), focus	Improved knowledge and willingness to pay for information on pasture, water,	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	group discussions(N= 4)	livestock diseases & markets										
AgroCares scanner **(farm-specific-sensor based)**	Amasi et al., 2021 Experiment: (N=9)	Demonstrated direct impact on soil organic matter and soil aggregate stability from land use change	NA	NA	NA	NA	NA	NA	Established that unsustainable land use change increases risk of erosion	NA	NA	NA
CropIn **(within DigiFarm) (farm-specific-sensor based)**	Mercy Corps, 2021. Panel study survey (N=1439), in-depth interviews (N=52)	NA	Average 95% of users adjusted farming practices, with 19% changing planting methods, 17% crop types, 14% fertilizer types, & 17% farm planning	NA	NA	NA	Average 99% increased yield and/or income	NA	NA	Average 99% increased yield and/or income	NA	NA
iCow **(farm-specific-manual based)**	Marwa et al., 2020. Propensity score matching (N=457)	Improved knowledge on fodder, feeding, hygiene, mastitis, diseases, vaccination, deworming, calf rearing, & management practices, among others	Changes in hygiene (57%), feeding (55%), mastitis control (37%), & deworming (35%) practices	NA	NA	NA	Average 13% increase in milk yield	NA	NA	Average 29% & 22% increase in revenue & income	NA	NA
All		***10/15***	***8/15***	***4/15***	***5/15***	***3/15***	***7/15***	***5/15***	***1/15***	***7/15***	***2/15***	***2/15***

NA: means the particular output, outcome, or impact was ***Not Assessed*** in the study/source

4. Discussion

It is clear that both "generic" and "farm-specific" tools are relevant and offer new opportunities to meet farmers' needs. "Generic" tools, using mobile phones and SMS interfaces, are low-cost tools for disseminating agricultural information, intended to complement but not replace the sparse public extension services. This evidently leads to an improvement in agricultural knowledge and marketing. The increasing trend towards "farm-specific" tools shows the appreciation of additional capabilities based on data entered by farmers or obtained with the help of sensors. For example, farmers have used descriptive capabilities (monitoring and documentation) to adapt their farming practises, resulting in increased productivity, income and overall well-being. The use of diagnostic, predictive and prescriptive data analytics, as demonstrated by the tool to support livestock farmers' migration decisions, also illustrates the optimisation potential of customised services for agriculture. Where the level of mechanisation is limited, 'farm-specific' digital tools focus on disembodied solutions where farmers act as 'sensors' (Mehrabi et al., 2021) or where data comes from satellites or is entered by agents. However, accurate data input is required and developers should consider this carefully when designing tools. In addition, tools with optimisation features are not widely available and need to be further explored.

Although the potential of customized data generated by most farm-specific tools is recognised, there is little quantifiable, attributable and documented information on the impact of these tools on farm productivity or farmer behaviour change. Due to the large number of tools, their different functions and evaluation methods, much remains unknown about their performance. The few evaluations available are often project-based surveys, which can mean that the scope of evaluation is limited compared to larger projects. Such evaluations are also subject to biases, such as small project bias and evaluator bias. Of the literature reviewed, only four studies aimed to quantify impacts. Two of these had a baseline, two used statistical methods to control for sample selection bias and one study used a randomized control trial design. Therefore, the full benefits of these tools in terms of affordability, ease of use, accessibility and interaction of technology with elements such as traditional knowledge are still unknown. This validation is important given the heterogeneity of the tools, which range from "generic" to "farm-specific" and multifunctional.

The private sector plays a pivotal role in the development and use of these tools. This is happening amid skepticism about the potential risk of "platformazation" and 'lock-in' for farmers, especially in the case of actor-integrating tools. However, by and large, these tools ensure access to a wide range of services that increase competitiveness and full participation in markets. The risk of lock-ins can be averted through measures such as close monitoring by farmers` umbrella organizations and government regulation. We recognize that farmers may face data governance issues from the outset, as data collected on private farms is often stored and processed by third-party software (Jouanjean et al., 2020). In three cases, intervening agents keep digital records on behalf of farmers, raising questions about who should have control over, and benefit from, the data. Another problem is the scientific and practical validity of agricultural information. This is mainly because digital structures eliminate the need for physical contact and therefore mechanisms to verify the skills of these agricultural experts are largely lacking. To exploit this potential, partnerships between private service providers and public extension services could be strengthened to create complementarities in e-advice and market information. This can also solve the trust problem with farmers once the source of information and advice is clear (Emeana et al., 2020).

5. Conclusion

In conclusion, digital tools have the potential to address several of the thorny challenges faced by smallholder farmers. The availability of a large variety of digital tools, driven primarily by the private sector, is encouraging. As shown in this review, it is beneficial to disaggregate digital tools by type and impact pathways. Therefore, the public sector and academia could help realise the full potential by investing in research to assess the extent to which these tools optimize farming operations, taking into account the different capabilities identified and potential impacts on food and nutrition security, environmental sustainability, and climate change resilience.

6. References

Abate, G. T., Abay, K. A., Chamberlin, J., Kassim, Y., Spielman, D. J., & Paul Jr Tabe-Ojong, M. (2023). Digital tools and agricultural market transformation in Africa: Why are they not at scale yet, and what will it take to get there? *Food Policy*, *116*. https://doi.org/10.1016/j.foodpol.2023.102439

Akamanzi, C., Deutscher, P., & Guerich, B. (2016). Silicon Savannah : The Kenya ICT Services Cluster. In *Microeconomics of Competitiveness*.

Aker, J. C. (2011). Dial 'A' for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Akuku, B., Haaksma, G., & Derksen, H. (2019). *Digital farming in Kenya. Opportunities and challenges for Dutch ICT companies in agriculture in Kenya*.

Amasi, A. I. M., Wynants, M., Kawala, R. A., Sawe, S. F., Blake, W. H., & Mtei, K. M. (2021). Evaluating Soil Carbon as a Proxy for Erosion Risk in the Spatio-Temporal Complex Hydropower Catchment in Upper Pangani, Northern Tanzania. *Earth (Switzerland)*, *2*(4), 764–780. https://doi.org/10.3390/earth2040045

Antony, A. P., Leith, K., Jolley, C., Lu, J., & Sweeney, D. J. (2020). A Review of Practice and Implementation of the Internet of Things (IoT) for Smallholder Agriculture. *Sustainability*, *12*(9), 3750. https://doi.org/10.3390/su12093750

Ayim, C., Kassahun, A., Addison, C., & Tekinerdogan, B. (2022). Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature. *Agriculture and Food Security*, *11*(1). https://doi.org/10.1186/s40066-022-00364-7

Barrett, C. B., Christiaensen, L., Sheahan, M., & Shimeles, A. (2017). On the structural transformation of rural Africa. *Journal of African Economies*, *26*, i11–i35. https://doi.org/10.1093/jae/ejx009

Baumüller, H. (2015). Assessing the role of mobile phones in offering price information and market linkages: The case of M-Farm in Kenya. *Electronic Journal of Information Systems in Developing Countries*, *68*, 1–16. https://doi.org/10.1002/j.1681-4835.2015.tb00492.x

Baumüller, H. (2016). Agricultural service delivery through mobile phones: Local innovation and technological opportunities in Kenya. In F. W. Gatzweiler & J. Von Braun (Eds.), *Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development* (pp. 1–435). https://doi.org/10.1007/978-3-319-25718-1

Benin, S. (2021). *Policy drivers of Africa's agriculture transformation: A CAADP biennial review account* (Issue November). https://doi.org/10.2499/p15738coll2.134837

Berger, S., Denner, M. S., & Röglinger, M. (2018). The nature of digital technologies - Development of a multi-layer taxonomy. *26th European Conference on Information Systems: Beyond Digitization - Facets of Socio-Technical Change, ECIS 2018*, *June*.

Birner, R., Daum, T., & Pray, C. (2021). Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. *Applied Economic Perspectives and Policy*, *December*, 1–26. https://doi.org/10.1002/aepp.13145

Bulte, E., Cecchi, F., Lensink, R., Marr, A., & van Asseldonk, M. (2020). Does bundling crop insurance with certified seeds crowd-in investments? Experimental evidence from Kenya. *Journal of Economic Behavior and Organization*, *180*, 744–757. https://doi.org/10.1016/j.jebo.2019.07.006

Daum, T., Ravichandran, T., Kariuki, J., Chagunda, M., & Birner, R. (2022). Connected cows and cyber chickens? Stocktaking and case studies of digital livestock tools in Kenya and India. *Agricultural Systems*, *196*, 103353. https://doi.org/10.1016/j.agsy.2021.103353

Deichmann, U., Goyal, A., & Mishra, D. (2016). Will digital technologies transform agriculture in developing countries? *Agricultural Economics (United Kingdom)*, *47*, 21–33. https://doi.org/10.1111/agec.12300

Diao, X., Hazell, P., & Thurlow, J. (2010). The Role of Agriculture in African Development. *World Development*, *38*(10), 1375–1383. https://doi.org/10.1016/j.worlddev.2009.06.011

Duncombe, R. (2018). Mobile for agriculture (m4Agric) services: Evidence from East Africa. In R. Duncombe (Ed.), *Digital technologies for agricultural and rural development in the Global South* (1st ed., pp. 104–110). CABI International.

Eitzinger, A., Cock, J., Atzmanstorfer, K., Binder, C. R., Läderach, P., Bonilla-Findji, O., Bartling, M., Mwongera, C., Zurita, L., & Jarvis, A. (2019). GeoFarmer: A monitoring and feedback system for agricultural development projects. *Computers and Electronics in Agriculture*, *158*(June 2018), 109–121. https://doi.org/10.1016/j.compag.2019.01.049

Emeana, E. M., Trenchard, L., & Dehnen-Schmutz, K. (2020). The revolution of mobile phone-enabled services for agricultural development (m-Agri services) in Africa: The challenges for sustainability. *Sustainability (Switzerland)*, *12*(2). https://doi.org/10.3390/su12020485

Etchells, E. (2019). *Are mobile phone-based information services making a positive difference to the livelihoods of Kenyan smallholder farmers?*

GSMA. (2020). *Digital Agriculture Maps 2020 State of the Sector in Low and Middle-Income Countries*. www.gsma.com

Jellason, N. P., Robinson, E. J. Z., & Ogbaga, C. C. (2021). Agriculture 4.0: Is Sub-Saharan Africa Ready? *Applied Sciences*, *11*(12), 5750. https://doi.org/10.3390/app11125750

Jouanjean, M., Casalini, F., Wiseman, L., & Gray, E. (2020). Issues around data governance in the digital transformation of agriculture. *OECD Food, Agriculture and Fisheries*, *146*, 10–23. https://doi.org/http://dx.doi.org/10.1787/53ecf2ab-en OECD

Kim, J., Shah, P., Gaskell, J. C., Prasann, A., & Luthra, A. (2020). Scaling Up Disruptive Agricultural Technologies in Africa. In *Scaling Up Disruptive Agricultural Technologies in Africa*. https://doi.org/10.1596/978-1-4648-1522-5

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS - Wageningen Journal of Life Sciences*, *90–91*(October), 100315. https://doi.org/10.1016/j.njas.2019.100315

Liu, Y., Ma, X., Shu, L., Hancke, G. P., & Abu-mahfouz, A. M. (2021). From Industry 4.0 to Agriculture 4.0: Current status , enabling technologies and research challenges. *IEEE Transactions on Industrial Informatics*, *17*(6), 4322–4334. https://doi.org/10.1109/TII.2020.3003910

Lowder, S. K., Sánchez, M. V., & Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? *World Development*, *142*, 105455. https://doi.org/10.1016/j.worlddev.2021.105455

Machado, E. A., Purcell, H., Simons, A. M., & Swinehart, S. (2020). The Quest for Greener Pastures: Evaluating the Livelihoods Impacts of Providing Vegetation Condition Maps to Pastoralists in Eastern Africa. *Ecological Economics*, *175*. https://doi.org/10.1016/j.ecolecon.2020.106708

Mann, L., & Iazzolino, G. (2021). From Development State to Corporate Leviathan : Historicizing the Infrastructural Performativity of Digital Platforms within Kenyan Agriculture. *Development and Change*, *52*(4), 829–854. https://doi.org/10.1111/dech.12671

Marwa, M. E., Mburu, J., Oburu, R. E. J., Mwai, O., & Kahumbu, S. (2020). Impact of ICT Based Extension Services on Dairy Production and Household Welfare: The Case of iCow Service in Kenya. *Journal of Agricultural Science*, *12*(3), 141. https://doi.org/10.5539/jas.v12n3p141

McCampbell, M., Adewopo, J., Klerkx, L., & Leeuwis, C. (2021). Are farmers ready to use phone-based digital tools for agronomic advice? Ex-ante user readiness assessment using the case of Rwandan banana farmers. *The Journal of Agricultural Education and Extension*, *0*(0), 1–23. https://doi.org/10.1080/1389224X.2021.1984955

McKee, C. (2023, February 28). *Research in Review: 2022*. Https://Precisiondev.Org/Research-in-Review-2022/#more-3286.

Mehrabi, Z., McDowell, M. J., Ricciardi, V., Levers, C., Martinez, J. D., Mehrabi, N., Wittman, H., Ramankutty, N., & Jarvis, A. (2021). The global divide in data-driven farming. *Nature Sustainability*, *4*(2), 154–160. https://doi.org/10.1038/s41893-020-00631-0

Mercy Corps. (2020). *ACRE Africa Farmer Insights Kenya*. 60decibels.com

Mercy Corps. (2021). *DigiFarm Panel Study*. www.mercycorpsagrifin.org

Moyer, D., Ostertag, M., & Gershenson, J. (2022). Mitigation Intermediary Transactions within Kenya's Agricultural Supply Chain. *2022 IEEE Global Humanitarian Technology Conference, GHTC 2022*, 250–256. https://doi.org/10.1109/GHTC55712.2022.9910996

Oboh, V. U., & Ekpebu, I. D. (2011). Determinants of formal agricultural credit allocation to the farm sector by arable crop farmers in Benue State, Nigeria. *African Journal of Agricultural Research*, *6*(1), 181–185.

Ouma, M., & Mann, L. (2021, April 15). *On the ground the reality is different: policymakers in Kenyan agriculture should beware limits to platform knowledge*. Https://Blogs.Lse.Ac.Uk/Africaatlse/2021/04/15/Policymakers-Kenya-Agriculture-Beware-Limits-Platform-Tech-Knowledge-Colonisation/.

Papcun, P., Kajati, E., & Koziorek, J. (2018). Human Machine Interface in Concept of Industry 4.0. *2018 World Symposium on Digital Intelligence for Systems and Machines (DISA)*, 289–296. https://doi.org/10.1109/DISA.2018.8490603

Porciello, J., Coggins, S., Mabaya, E., & Otunba-Payne, G. (2022). Digital agriculture services in low- and middle-income countries: A systematic scoping review. *Global Food Security*, *34*, 100640. https://doi.org/https://doi.org/10.1016/j.gfs.2022.100640

Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard Business Review*, *2015*(October).

Precision Development. (2022). *PxD Global Dashboard*. Https://Precisiondev.Org/Pxd-Global-Dashboard/.

Püschel, L., Röglinger, M., & Schlott, H. (2016). What's in a Smart Thing? Development of a Multi-Layer Taxonomy. *2016 International Conference on Information Systems, ICIS 2016*, *4801*.

Sibanda, T. (2019). *Digital Transfomation of Africa-Hype or reality*. https://archive.uneca.org/sites/default/files/uploaded-documents/CoM/2019/presentations/20190326_digital_transformation_of_africa_-_hype_or_reality_tawanda_sibanda_response.pdf

Stewart, Z. P., Pierzynski, G. M., Middendorf, B. J., & Prasad, P. V. V. (2020). Approaches to improve soil fertility in sub-Saharan Africa. *Journal of Experimental Botany*, *71*(2), 632–641. https://doi.org/10.1093/jxb/erz446

Sunding, D., & Zilberman, D. (2007). The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector. In Bruce L. Gardner & Gordon C. Rausser (Eds.), *In Handbook of Agricultural Economics: Vol. Volume 1A* (pp. 207–261). North-Holland.

Tsan, M., Totapally, S., Hailu, M., & Addom, B. K. (2019). *The digitalisation of African Agriculture Report 2018-2019*. CTA.

Van Loon, J., Woltering, L., Krupnik, T. J., Baudron, F., Boa, M., & Govaerts, B. (2020). Scaling agricultural mechanization services in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia, and Latin America. *Agricultural Systems*, *180*(December 2018), 102792. https://doi.org/10.1016/j.agsy.2020.102792

Appendix 1. Reviewed agricultural digital tools

1. Generic digital tools

Digital Tool name	*Short description of the goal and function*	*Provider*	*Launch year*	*Broad Service type*	*Device Technology*
Agri-wallet	Provide payment and savings functions for the value chain actors	Private	2016	Financial services	Disembodied
DigiFarm	Extension, access inputs &services, sell products	Private	2017	Financial services	Disembodied
Mobigrow	Access to mobile money	Private	2018	Financial services	Disembodied
Arifu chatbot	Interactive farmer training on, farm, business, finance, and digital skills	NGO	2015	Information & learning	Disembodied
FarmKenya	Extension services through videos and live TV coverage	Private	2021	Information & learning	Disembodied
iShamba (Agritips)	Extension	Private	2015	Information & learning	Disembodied
KALRO Apps (58)[1]	Extension/agricultural information	Public	2016	Information & learning	Disembodied
MbeguChoice	Specifies seed information and verities to be planted	Public	2016	Information & learning	Disembodied
M-shamba	Extension services via interactive voice services, sms. Market access	Private	2010	Information & learning	Disembodied
Precision Development	Extension reaching farmers through their mobile phones	NGO	2016	Information & learning	Disembodied
WeFarm	Information sharing platform amongst farmers, market place	Private	2015	Information & learning	Disembodied
iCow	Extension, sell products	Private	2010	Information & learning	Disembodied
Haller Farmer App	Farmer training through video	NGO	2014	Information & learning	Disembodied
DigiShop	Online farmer shop	Private	2016	Market linkage	Disembodied
Digital AI	Dial USSD code to access AI. Timely reminders on important dates	Private	2019	Market linkage	Disembodied
Digital Vet Systems	Dial USSD code to access vet.	Private	2019	Market linkage	Disembodied
e-GRANARY	Aggregates farmers for input and output markets and financial and extension	NGO	2016	Market linkage	Disembodied
M-Farm	Platform for buyers and seller to post produce for sale or orders.	Private	2011	Market linkage	Disembodied
Mifugotrade	Display livestock information for selling and buying	Private	2014	Market linkage	Disembodied
Mkulima Young	Platform for buyers and sellers to post produce /products for sale	Private	2015	Market linkage	Disembodied

[1] *KALRO (Kenya Agricultural and Livestock Research Organization) has developed 58 different mobile applications with learning materials for farmers covering livestock, crop production and aquaculture. Included is information on diseases and pests and different seed varieties*

Tinga Rental store App	Tractor renting services for registered farmer groups	Private	2016	Market linkage	Disembodied
TruTrade	Produce aggregation and traceability	Private	2017	Market linkage	Disembodied
Tupande	Procurement and last mile distribution of inputs to farmers	NGO	2023	Market linkage	Disembodied
Twiga Foods	B2B technology enabled food distribution platform	Private	2014	Market linkage	Disembodied

2. Farm-specific tools with manual data entry

Digital **Tool name**	**Short description of the goal and function**	**Provider**	**Launch year**	**Broad Service type**	**Device Technology**
DigiCow Dairy App	Record data, monitor breeding, feeding and milk production	Private	2016	Advisory services	Disembodied
iCow (Kalenda)	Livestock records and calendar keeping for crucial dates	Private	2011	Advisory services	Disembodied
SmartCowApp	Record data, monitor and optimize breeding, feeding and milk production	Private	2018	Advisory services	Disembodied
Usomi Lulu App	Record data, monitor animal health and economics, value chain integration	Private	2019	Advisory services	Disembodied
Budget Mkononi	Planning, record keeping and budgeting of farming activities	Private	2017	Financial services	Disembodied
FarmDrive	Farmer data collection for credit scoring	Private	2014	Financial services	Disembodied
G-Soko App	Provides a grain transaction platform for farmers and traders	NGO	2016	Market linkage services	Disembodied
iProcure	Procurement, last mile distribution and warehousing	Private	2013	Market linkage services	Disembodied
Usomi Rubi App	Farm produce aggregation and sale through bidding process	Private	2019	Market linkage services	Disembodied

3. Farm-specific tools with sensor-based data entry

Digital Tool name	***Short description of the goal and function***	***Provider***	***Launch year***	***Broad Service type***	***Device Technology***
AgroCares scanner	In-field soil testing with immediate recommendations	Private	2016	Advisory services	Embodied
CROPMON	Monitoring actual crop condition to determine probable growth limiting factor	Public	2015	Advisory services	Embodied
AfriScout	Provide water and vegetation location to optimize pasture management	NGO	2017	Advisory services	Embodied
CropNuts IoT sensors	Soil moisture sensors monitor water use in green houses	Private	2017	Advisory services	Embodied
CropNuts FARMLAB	Onsite soil testing with immediate recommendations	Private	2021	Advisory services	Embodied
CropIn (Farm-specificFarm Plus)	Farm management with analysis of crop health, growth, input management with actionable insights	Private	2020	Advisory services	Embodied
cropHQ	Monitoring and collection of farm data using sensors	Private	2016	Advisory services	Embodied

MyAnga	Monitor agri-weather and forage conditions using satellites	NGO	2013	Advisory services	Embodied
Plantvillage Nuru	Crop disease diagnosis and pests scouting	Research	2018	Advisory services	Embodied
RioFish	Water sensors to monitor fish feeding	Private	2017	Advisory services	Embodied
Scarab precision	Scouting of pests and diseases	Private	2005	Advisory services	Embodied
SunCulture	Sensors to monitor water requirements in irrigation systems	Private	2011	Advisory services	Embodied
Ujuzi Kilimo SoilPal	In-field soil testing with immediate recommendations	Private	2016	Advisory services	Embodied
Vipimo App	Sensors monitor water, temperature, soil moisture, humidity and light intensity	Private	2009	Advisory services	Embodied
WeatherImpact	Agri-weather information	NGO	2015	Advisory services	Embodied
ACREAfrica	Agricultural insurance	Private	2011	Financial services	Embodied
Hello tractor	Tractor booking agency model with GPS enabled tracking, fuel and driver management	Private	2014	Market linkage	Embodied

4. Farm-specific tools with autonomy

Digital Tool name	***Short description of the goal and function***	***Provider***	***Launch year***	***Broad Service type***	***Device Technology***
Farmshield AI-Powered Sensors	Greenhouse management and optimization	Private	2013	Advisory services	Embodied

5. Actor integrating tools

Digital Tool name	***Short description of the goal and function***	***Provider***	***Launch year***	***Broad Service type***	***Device Technology***
Agri-wallet	Provide payment and savings functions for the value chain actors	Private	2016	Financial services	Disembodied
DigiFarm	Extension, access inputs &services, sell products	Private	2017	Financial services	Disembodied
WeFarm	Information sharing platform amongst farmers, market place	Private	2015	Information & learning	Disembodied
DigiShop	Online farmer shop	Private	2016	Market linkage	Disembodied
SmartCowApp	Record data, monitor and optimize breeding, feeding and milk production	Private	2018	Advisory services	Disembodied
Usomi Rubi App	Farm produce aggregation and sale through bidding process	Private	2019	Market linkage	Disembodied
Mkulima Young	Platform for buyers and sellers to post produce /products for sale	Private	2015	Market linkage	Disembodied
G-Soko App	Provides a grain transaction platform for farmers and traders	NGO	2016	Market linkage	Disembodied
Twiga Foods	B2B technology enabled produce distribution platform	Private	2014	Market linkage	Disembodied
e-GRANARY	Aggregates farmers for input and output markets and financial and extension	NGO	2016	Market linkage	Disembodied
Mkulima Young	Platform for buyers and sellers to post produce /products for sale	Private	2015	Market linkage	Disembodied

iCoW	Extension, sell products	Private	2010	Information & learning	Disembodied
Budget Mkononi	Planning, record keeping and budgeting of farming activities	Private	2017	Financial services	Disembodied

Social and Institutional Change in Agricultural Development
Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)
Universität Hohenheim
Wollgrasweg 43 | 70599 Stuttgart | Deutschland
T +49 (0)711-459-23517 | **F** +49 (0)711-459-23812
E regina.birner@uni-hohenheim.de | https://490c.uni-hohenheim.de/en