KNOWLEDGE BRIEF

3

Digitalisation for smallholder farmers

DeSIRA LIFT

Towards a shared research and innovation agenda for agroecological transitions of agri-food systems in Africa under AU/EU policy frameworks

Photo: Vincent Tremeau / World Bank

Introduction

Digitalisation has brought a vast array of opportunities to smallholder farmers in Africa, which, when coupled with the right investments, can help them transition to more sustainable agri-food systems. However, the diversity of services, advice and solutions provided can be overwhelming. There is often a lack of understanding about potential drivers and hindering factors and successful cases are generally context specific. To support the transition for smallholder farmers, regulations and policies must be put in place to spur responsible digitalisation. Incentives and funding facilities for the production and deployment of farmer-owned digital tools must also be prioritised. This knowledge brief outlines what digitalisation may mean for smallholder farmers in Africa and draws specific links between digitalisation and FAO's 10 principles of agroecology.

Setting the scene

Agri-food systems are in "dire need for innovative solutions, and one identified approach is through digitalisation", according to FAO (2020). One of the shortest definitions of digitalisation available says that "*Digitalisation is the ongoing integration of digital technologies and digitised data across the economy and society*"[1]. Historically, digitalisation started in the 1950s with the birth of the first computer, followed in the 1980s by the 'world wide web', then by the first 2G network used with cellular phones in the 1990s[2]. The digital 'big leap', specific to agricultural research and development (R&D) started in the year 2010 (with the increase of e.g., blogs, blockchain, drones) impacting all socio-economic sectors, invading industries but also leaving concerns about the future and impact of digital technologies (Tsan et al., 2019). In the agricultural sector particularly, the rapidly changing digital space has brought some undeniable transformations with a diversity of new technologies "that have increased efficiency and profitability to levels previously unattainable" (FAO, 2020) in some industrialised farming systems such as automated agricultural machineries, drones, Internet of Things (IoT), big data, artificial intelligence, etc. across Low and Middle-Income Countries (LMICs). The GSM Association (GSMA)[3] identified more than 700 active digital agriculture solutions in 2020 (Phatty-Jobe, 2020). After the COVID-19 pandemic, the question "to digitalise or not to digitalise" was not put forward anymore: the essence has widely been understood. However, Digitalisation for Agriculture (D4Ag) or digital agriculture -a core feature of Agriculture 4.0[4]- requires processes of responsible innovation, anticipating the potential positive and negative impacts and "where needed adjusting the direction and course of transition pathways" according to Klerkx et al. (2019).

Currently, digital technologies are embedded almost everywhere, and digitized data is generated at a staggering speed[5]. By 2025, the amount of data generated each day is expected to reach 463 exabyte[6] while as of 2021,

Box 1. A few clarifications or definitions

Digitisation: from analog to digital form (e.g., Bloomberg, 2018; Lozic, 2019)
Digitalisation: the use of digital technologies [...]; the process of moving to a digital business (see Gartner's IT Glossary)
Digital transformation: requires a much broader adoption of digital technology and cultural change. It is more about people than about digital technology (see Medium.com)

1] European Foundation for the Improvement of Living and Working Conditions, 27 June 2022, https://www.eurofound.europa.eu/topic/digitalisation
2] A brief history of digital transformation, 2019, https://supplychainbeyond.com/a-brief-history-of-digital-transformation/ 3] The industry organisation representing the interests of mobile network operators worldwide.

4] Agriculture 4.0, also referred to as the 4th Agricultural Revolution, although poorly defined comprises radical digital and biotechnological innovations (Klerkx et al, 2019).
5] How much data is created every day? 27 Staggering Stats, SeedScientific, 2021, https://seedscientific.com/how-much-data-is-created-every-day/
6] One exabyte equals one billion gigabytes.

Google, Facebook, Microsoft and Amazon store at least 1,200 petabytes (1015 bytes) of information. How much of these digital technologies and digitised data are supporting agriculture and -more precisely- the agroecological transition? Such questions require research. What is known is that in 2021, already 43% of Africans are using internet and the number of internet users increases significantly every year (13% in 2021)[7]. By April 2022, the number of Facebook users in Africa rose to 255 million, making Facebook the most used social media platform in Africa.

A snapshot of the status of digital agriculture in 47 sub-Saharan countries gives -apart from country specific facts- an overview of the current digital agriculture landscape (FAO and ITU, 2022), but this overview is still inadequate to support countries and regional bodies in identifying gaps and priorities for further investments. Since the increased use of digital technologies, however, the need for an inclusive and multi-stakeholder approach in agriculture and food has been invoked, e.g. during the 2019 Global Forum for Food and Agriculture (GFFA)[8]. Just recently, in February 2022, in the continuum of other initiatives, the EU - AU Summit ended with a joint vision of "a prosperous and sustainable Africa and Europe in 2030". Among the ambitions for 2030 were "to accelerate the sustainable transformation of African food systems, in support of Africa's agriculture, fisheries and food development agenda" as well as "to ensure the digital transition through better intercontinental and intracontinental connectivity and digital innovation bridges"[9]. Currently, the digital ecosystem in each country in sub-Saharan is evolving with new policies, initiatives, innovations and stakeholders, but a clear mapping of promising practices, innovation hubs and programmes is necessary (FAO and ITU, 2022).

This knowledge brief will start by focusing on what digitalisation may mean for smallholder farmers in Africa (section 1) and the challenges ahead (section 2). This is followed by digitalisation opportunities for sub-Saharan Africa and more specifically its link to the agroecological transition (section 3). This brief closes by addressing knowledge and innovation gaps (respectively section 4 and 5) and few final remarks in section 6.

1 Potential benefits of digitalisation for smallholder farmers in Africa

Considering Africa's stagnant production per hectare, exacerbated by climate change and biodiversity loss (e.g., Muluneh, 2021), tremendous changes are needed in the agricultural sector. Digitalisation for smallholder farmers may provide a pathway for agri-food systems change in Africa (Tsan et al., 2019) as digitalisation is likely to play an increasingly important role in achieving the global goal of improving food and nutrition security as well as rural livelihoods (FAO, 2020). Although digitalisation boosts connectivity in the agri-food system and can reduce inefficiencies, with the internet providing access to technical information, and stimulating cooperation and connection across the value chain, digitalisation is, of course, not a panacea and it will definitely not solve all farmers' problems. But, despite the challenges of e.g., illiteracy, the cost of ICT devices and the weakness, or even lack, of coverage in rural areas, digitalisation may address some critical pain points of smallholder farmers (e.g., agricultural knowledge gaps, lack of access to finance, lack of access to markets and climate change) (Tsan et al., 2019), but only if farmer participation in research design and implementation is secured (e.g., Wittman et al., 2020) and farmers are recognised as co-creators of knowledge.

The agricultural knowledge gap prevents farmers from improving their practices and being recognised as originators of knowledge (Hillbeck and Tiselli, 2020). Financial exclusion leaves farmers without access to short-term capital for agricultural needs and long-term capital for expanding their operations. Access to markets is a challenge due to the complexity of agricultural value chains and the strong role of intermediaries, leaving many farmers highly dependent. "All these challenges are exacerbated by climate change, which is making agriculture an increasingly risky business", according to the GSMA Digital Agriculture report (Phatty-Jobe, 2020).

The GSMA has clustered digital solutions in three main groups: access to services, access to market, access to assets (and breaking them into five use cases and 24 sub-use cases).

Box 2. Examples of use cases

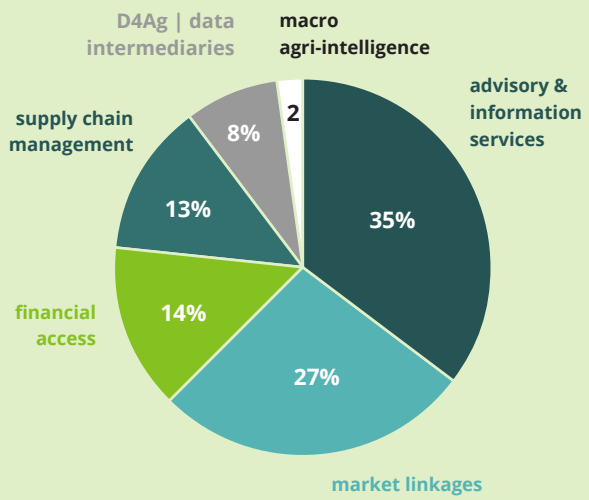
A concrete example of a digital agriculture use case is in the digitalisation of advisory services addressing the weakness of conventional extension through the dissemination of video and audio files in extension. With the low number of extension workers, videos are an easy and cost-efficient means to share knowledge and train farmers to adopt new techniques.

Another example is the use of digital systems such as SMS, web commerce portals, or mobile apps in market information dissemination and exchanges, saving time, energy and money of farmers who usually take risks trying to deliver and sell their products into the market without knowing the market prices and without purchase order. With the integration of digital tools in their market approach and transactions, farmers are more confident and secured thanks to available online market information (price, needs, offers), online exchanges with potential buyers and secured cashless mobile e-payment (e.g., the M-Pesa service that enables customers to send and receive money by using their mobile phone which revolutionised the banking economy, and became the most influential digital solution for rural areas).

7] Internet World Stats, 2021, https://www.internetworldstats.com/stats1.htm
8] In 2019, approximately 74 ministers of agriculture from around the world and high-level representatives of international organizations committed to use the potential of digitalization to increase agricultural production and productivity, while improving sustainability, efficient resource use, employment and entrepreneurial opportunities, and living conditions, especially in rural areas. https://www.fao.org/agroecology/database/detail/en/c/1264546/
9] Press releases from the 6th EU-AU Summit: a Joint vision for 2030, https://www.consilium.europa.eu/en/press/press-releases/2022/02/18/sixth-european-union-african-union-summit-a-joint-vision-for-2030/
10] An example of an 'extension platform' is https://www.accessagriculture.org
11] More information on e-payment system M-Pesa is available at ILO.org

Few examples of digital use cases[10,11], are given in box 2. In Africa, more than 400 functional digital solutions across the continent have been counted (including e.g., remote and in-situ sensing tools, weather apps, big data platforms) (Tsan et al., 2019). The nature of these digital solutions is so diverse that they have been clustered around key topics. From the data collected (see Tsan et al., 2019), most used solutions were related to advisory & information services (35%), followed by market linkages (27%), financial access (14%), supply chain management (13%), Digitalisation for Agriculture (D4Ag), data intermediaries (8%) and macro agri-intelligence (2%).

Figure 1. The nature of digital solutions



Source: Tsan et al., 2019

2 Digitalisation for smallholder farmers in Africa: challenges ahead

Digital technology and digitisation of data can be used to contribute to agri-food system transformation due to the diversity and the potential power and impact magnitude of digital technologies. Undeniably, digitalisation presents enormous possibilities and opportunities. Also for smallholder farmers (FAO, 2020). Apart from the examples in the previous sections, FAO (2020) refers to the benefits that big data can offer by improving insights for improving productivity and for decision making through real-time alerts, such as when coping with natural disasters. Besides, "open sharing of information also helps to increase transparency and trust between otherwise disparate stakeholder groups in the global agri-food system" according to FAO (2020). At the same, different publications, including FAO (2020), but also e.g., Ajena et al.(2020) and Gkisakis and Damianakis (2020), warn about potential challenges for smallholder farmers and highlight that particularly "data extraction, surveillance and power grab" might be embedded in the digitalisation of agriculture. Few of the challenges that particularly smallholder farmers face, partly inspired by the Digital Transformation Strategy for Africa[12], are listed below and all underline -directly or indirectly- the risk of a digital divide. Part of these challenges may also be referred to as innovation gaps, which will be discussed in more detail in section 5.

- **Weak enabling environment and infrastructure**
  The first challenge is linked to a lack of infrastructure and political will and coordination when it comes to the enabling environment for digitalisation for smallholder farmers in Africa. Lack of or weak infrastructure (internet connectivity, mobile coverage, sometimes electricity) are often mentioned by disadvantaged farmers, as these are especially huge challenges in more remote rural areas. The so-called digital divide (lack of access to digital infrastructure and hardware, and lack of digital literacy) can further exacerbate inequality and thus needs to be addressed. Furthermore, farmer communities are vulnerable to potential negative consequences of digital technologies as they have fewer resources and (digital) rights to counteract changes caused by digitalisation (McCampbell et al., 2022). This requires a strong institutional environment that can deal with issues around access, power, ethics and justice.

- **Illiteracy and economic constraints and lack of contextualised content**
  Another challenge in digitalisation for smallholder farmers is illiteracy and lack of contextualisation. Although quality digitized information is becoming more and more accessible in audio-visual format (thus accessible also to illiterate farmers), production of these contents, especially with participation of the final end-users, contextualised for the diversity of needs and conditions of farmers across the continent, requires attention, time and money. Access requires also more bandwidth, thus more financial resources. We live in the information age, overwhelmed by the volume of information bombarding us every day (and accessible at a click). Particularly remote smallholder farmers – exacerbated by socio-cultural conditions, perhaps illiteracy and often economic constraints – may need guidance in the filtering of what information actually benefits them (e.g., weather apps, market data).

- **Data extraction**
  It often happens that data is collected from farmers by development actors but at the end they don't receive any transparent feedback about the use of these data, neither any compensation or profit from the process; on the contrary, the data can even be used against them, to take more control of their future with a "system built to further monopolise dominance in the input supply chain (...)" (Ajena et al., 2020). Ajena et al. (2020) therefore also highlight the issue of pseudo-solutions for smallholder farmers as digitalisation can be used to serve the interest of a minority (big corporations).

12] Digital Transformation Strategy for Africa, AU, 2020: https://au.int/sites/default/files/documents/38507-doc-dts-english.pdf

- **Digital rights**
  The ethical landscape is still fragmented as most digital rights exist in guidelines and voluntary standards, making smallholder farmers poorly protected against (intentional or unintentional) harm of third parties when extracting data or disseminating information. General digital rights include access to information, free expression, data security and privacy, transparent governance and accountability. Digital rights that are specifically recognized for LMICs and vulnerable people include data ownership and control, access to personal data, data minimisation and purpose definition, informed consent, and protection from direct or indirect harm (McCampbell et al., 2022).

- **Lack of genuine collaboration between farmers and 'experts'**
  In rural areas, it is assumed that e.g., the scientific expert (perhaps a digitalisation expert) and the development agent are more enlightened and know everything including what is good or bad for the farmers. This is the foundation of digitalisation project failures, a situation where digitalisation is more technology-driven rather than demand-driven (e.g., Wittman et al, 2020). Inclusion of smallholder farmers and ensuring local ownership of projects and data, are essential if an initiative is to be sustainable and upscaled.

- **New forms of dependence**
  Digitalisation can result in new forms of dependency through gadgetism. Leaving smallholder farmers with new gadgets or digital content that may not actually serve their entrepreneurial needs, even merely overload them with posts and advertisements 'popping up', as digitalisation, without responsible governance, may be orchestrated by big corporations.

- **Contamination and environmental impact**
  Ajena et al. (2020) particularly question the environmental impact of the increased number of ICT applications resulting in larger energy consumption -and thus CO2 emissions- and the growth of the ICT manufacturing industry, including the mainly linear nature of the life cycle of ICT hardware, from mine extraction to disposal and/or recycling. This will indirectly -maybe even directly- affect smallholder farmers.

3 Zooming in on Digitalisation for Agriculture (D4Ag): opportunities for smallholder farmers in the agroecological transition in Africa

Two major agricultural transformations are currently being promoted worldwide: digitalisation and ecologisation (Schnebelin et al., 2021). These two transformations are in literature sometimes indicated as convergent, but rarely studied together (Schnebelin et al., 2021). This section attempts to see where digitalisation can meet agroecology and specifies digitalisation developments and trends, as well as tools and technologies, in support of agroecology.

Agroecology offers an alternative approach to conventional agriculture that considers the complexity of farming systems within their social, economic and ecological contexts (e.g., Anderson et al., 2019; IPCC, 2022) and an approach that gradually increases documented evidence of advantages, benefits and impacts (e.g., Andersen et al., 2020; HLPE, 2019). Agroecology is more complex than the conventional mono-cropping agriculture (e.g., Wezel et al., 2020; Altieri, 2018) and this is why a well-planned and fuelled transition towards this new holistic knowledge and practice, with its 13 principles (HLPE, 2019) and 10 elements (FAO, 2019)[13], is necessary. For some experienced farmers, this might mean a come-back to some earlier applied practices, but for the majority of farmers especially young farmers, agroecology is a totally new area where digitalisation might be of great help.

Focusing more on the Digitalisation of Agroecology (a more complex concept compared to Digitalisation of Agriculture) IFOAM Organics Europe (see Ajena et al., 2020) presented the opportunities and pitfalls of digitalisation with deep perspectives and historical analyses. The objective of this deep dive is therefore not about the question "to digitalise or not to digitalise", but rather about how to support the agroecological transition of agri-food system transformation with a digitalisation engine. Inspired by Ajena et al. (2020), the table below shows how a specific digitalisation – in this case one that integrates digital tools and digitised data - can serve the agroecological transition with its elements and principles.

Table 1 shows that digitalisation could facilitate the agroecological transition among smallholder farmers, although clear steps are required to manoeuvre responsibly, including being aware of the risks digitalisation may carry, and being responsive and reflective to emerging effects (whether positive or negative) and where necessary adjust the direction or the course of transition pathways (Klerkx et al., 2019).

13] FAO's Agroecology Knowledge Hub, https://www.fao.org/agroecology/en/

Table 1. *Specific digitalisation conforming to agroecological principles/elements*

Elements / Principles	Digital technologies and data that can be used for the agroecological transition
Diversity 	Digital technologies and digital data have exploded in the last decades. While digitalising, there is no 'single solution fitting all'. The farmers' challenges and problems are different from one geographical location to another and for each period of the year. Digital solutions can be very complex addressing the granularity of diverse needs across time, space, culture and audience (farmers, extension workers, researchers, policy makers, women, youth, etc). An inventory of the GSMA report of 2020 shows that, in sub-Saharan Africa, 42% of digital agriculture services are related to advisory services providing accurate and timely information and advice to farmers, 25% are related to digital finance service, 16% are related to agricultural e-commerce and 13% related to digital procurement. The remaining 4% are related to smart farming. Digital advisory services are the most used with the highest number of active services because of the high demand for advisory services and due to the low extension to farmers' ratio. Digital advisory services present a huge diversity of solutions, combining data and information 'pull-push' from different sources, including from satellite data and farmers' daily tasks. While data is becoming a new gold extracted by digital service developers and providers, farmers can also benefit from the output of big data usage when it is used in a fair and just objective: information and data intelligence will provide valuable information and guidance to farmers, e.g., on the timing of crop activities, where to buy inputs or in having better insight in market prices. Integrated sophisticated solutions or standalone e-market solutions will help farmers to link with buyers while knowing the market prices and trends. Datasets and information intelligence is becoming a profitable resource for both digital service providers and farmers. The challenge is to help farmers access the right information on agroecological solutions at the right time that is appropriate for his or her specific context, while valorising and appreciating the (diversity of) local knowledge and farmer-led innovation.
Co-creation & sharing of knowledge 	Digital platforms (such as Github) can particularly support digital solution co-creation, as all good developers know that robust digital solutions must be designed with the end-users in mind. Sharing of agroecological knowledge can already easily be done, e.g., through different open-source solutions, crowdsourcing and open data platforms. However, digitalisation will be able to provide different possibilities of actor relations and linkages, e.g., farmer-to-farmer, extension specialist-farmer, researcher-farmer, researcher-extension, etc.
Synergies 	Digital technologies like communication tools, groupware, social media, and collaborative platforms can create clarity, transparency, and visibility about agroecological science, its practice as well as the movement and thus enhance synergies and collaboration (breaking silos) across the diversity of actors.
Efficiency 	At scale, digital technologies can offer at least a triple advantage in the agroecological transition in terms of cost-efficiency, time-efficiency, and energy-efficiency (although, again, depending on context and scale). For example, crucial information (related to agroecological science, practical advice or alerts) can be disseminated in a fraction of a second for a few cents at the speed of light (fibre optic cable vs wave) potentially reaching all farmers at any point of the globe.
Recycling 	Recycling, re-use, re-sharing and repackaging, re-contextualisation of agroecological information and knowledge is facilitated by digital technologies such as word processing, graphical, audio and video editing software. For example, the same factsheet can be re-packaged into a poster, a cartoon, a video or an audio file. But any digitalisation developments and transitions should also consider the recycling of hardware infrastructure, investing in durable devices and apps.

Continued >>>

Elements / Principles	Digital technologies and data that can be used for the agroecological transition
Resilience 	The development and dissemination of well-packed and comprehensive agroecological information (for farmers, extension workers and agroecology adopters) in an energy-efficient device can empower the smallholder farmer, minimize dependencies and enhance their autonomy.
Human & social values 	Human and social values must be considered and put at the centre of each digitalisation initiative. Inclusion, participatory approaches are highly encouraged, and the usage of digital technologies must be done carefully to respect the privacy, safety and integrity of humans and the society through policies and regulations.
Culture and (food) tradition 	Culture and traditions shape humanity. Digital technologies have invaded all aspects of our life and are now embedded in our culture and tradition. Especially the last decade we may also observe technology 'addiction' and to some extend dependency. A sound agroecological transformation requires that all humans: • take control of digital technologies and its implications; • are well informed and have the opportunity to reflect; and • have the choice to use or not to use different digital technologies ICT initiatives should be adapted to each context, integrating local cultural values, including language, rules, regulations and religious considerations into the core of their tools and methodologies
Responsible governance 	Digital technologies can be seen with two lenses regarding responsible governance: **1. Digital technologies enhancing governance, including:** • Participation and inclusion are facilitated by digital networks and platforms; • Taking informed and responsible decisions are also facilitated by the wealth of digitized data and information available on the web thanks to the culture of sharing; • Promotion of justice and equity through digital networks, platforms and various digital interactive means, such as campaign tools; • Traceability with blockchain technology. **2. Digital technologies must also be governed in a responsible way, including:** • Integration of stakeholders in decision, choice, design, development and evaluation of digital technologies and digitized data for agroecological transition; • The issues of privacy, safety, justice, equity must be re-questioned and considered frequently.
Circular & solidarity economy 	Open-source development (co-creation), open data sharing and re-use are part of a circular and solidarity economy. Circular economy is not only applicable to software and data, recycling of hardware (often from rich to poor countries) is also common, although sometimes questionable. Digital technologies can be used to enhance solidarity, synergy and efficiency among agroecological value-chain actors.

Source: Adapted from and inspired by Ajena et al. (2020)

4 Digitalisation for smallholder farmers in sub-Saharan Africa: Addressing knowledge gaps

Section 3 shows the possibilities and the compatibility of digitalisation integration into the agroecological transition. However, while - on the one hand - digitalisation can be a powerful and efficient option to enhance and accelerate the agroecological transition of food systems transformation, it can also be - on the other hand - a bad option regarding broad socio-economic development when it becomes a tool in the hands of a minority, in particular large private firms.

Digitalisation can support information-based governance (Ehlers et al., 2021), but only if digitalisation is centred around the end-user (in this case smallholder farmers) and co-designed by and specific to the needs of smallholder farmers, it can support agroecological transition. In other words, it requires "organising participation at multiple levels and taking advantage from collective intelligence and organisational structure in a non-exclusive manner" (Gkisakis and Damianakis, 2020). Keywords here are user-friendly, user-developed or, according to Gkisakis and Damianakis (2020), a user-innovation process, which redirects the development and application of digital technologies towards an approach that stimulates horizontal transfer of innovative knowledge among stakeholders. In such a digitalisation movement, availability and sharing of data and knowledge are expected to be the main source of profit for all stakeholders (farmers, consumers, brokers, etc.).

In that light, few specific topics or themes relevant to digitalisation have been addressed below, each of them complemented by suggested or potential knowledge questions. Specifically, current research questions that need to complement a shared research and innovation agenda for agroecological transitions of agri-food systems in Africa under AU/EU policy frameworks are highlighted. The selection of topics is a non-exhaustive one, requiring further discussion. Also, the complementing research questions suggested may appreciate a deeper dialogue.

Digital technologies to support the agroecological transition

While transformation of agri-food systems calls for novel approaches that are able to bring together a diversity of actors' and institutions' knowledge and visions (Lamine, 2018), food systems are relatively slow in adopting innovative technologies, particularly in developing countries (World Economic Forum, 2018). Digitalisation is able to address the fragmented production landscape, but also operational complexities across value chains. Digitalisation can play an important role in the light of agroecology's knowledge-intensive nature, particularly in providing more transparency in the way knowledge is constructed or produced, and in how knowledge is shared and mobilised. Digitalisation could therefore complement some of the aims of alternative agricultural and food system concepts such as agroecology, but how digitalisation fits "into the already crowded conceptual landscape of sustainable agriculture" requires reflection (Klerkx et al., 2019).

'Digital agroecology': putting farmers at the forefront of design

Data-driven agroecology, from the ground up (Wittman et al. 2020), requires assessing what the relationships are between peasant and indigenous innovations, practices and knowledge and digital technologies. This means that "farmers need to be at the forefront of designing digital tools that work for them and that respect local cultural contexts and conditions" (Wittman et al., 2020). Human-centred design approaches can facilitate participatory design processes that take into account the four dimensions of responsible innovation: anticipation (defining possible scenarios for and consequences of innovations), inclusion (participation of stakeholders with diverging concerns and perspectives), reflexivity (reflecting on activities, commitments and assumptions) and responsiveness (adapting the digital design or intervention in response to demands or values of the stakeholders). However, care must be taken that systemic issues such as data security and power dependencies are not overlooked (McCampbell et al. 2022).

The LiteFarm Platform (www.litefarm.org) provides an example of a digital tool (a web application) that is open-source and community-driven (designed by farmers, researchers, designers, software professionals, donors, open-source enthusiasts). The app currently generates insights, in real time, for farmers based on the collected data, including data on profits and costs of production, market prices (relative to other local farmers in the network), fertilizer and water use efficiency, soil health, biodiversity conservation and even data on worker satisfaction and labour quality and the number of consumers (Wittman et al, 2020). Creating software that is of direct use to farmers that also provides evidence of the value of agroecology can at the same time support data sovereignty, in terms of ownership, access and control, and in that respect the development of better policies.

Digital content and applications for farmers to support agroecology

If digitalisation is to support the agroecological transition, farmers will be required to manipulate and interact with digital contents and tools. However, often farmers are not even aware of the wealth of knowledge available at a click across the digital space. Digitalisation will transform not only exchanges of information and farmers' decisions, but potentially the knowledge and actors of the agricultural innovation system as a whole (Schnebelin, 2021).

Digital content and applications for advisory services to support agroecology

Digital advisory services systems are identified as the most used in the D4Ag space studies across Africa (e.g., Tsan et al. 2019; Phatty-Jobe, 2020). This is probably due to the recent development of new social digital platforms coupled with the lack of human resources in the field of extension and advisory services during the recent decades. Despite the massive existing global digital divide in access to digital infrastructure, a broad range of community-, government-, and NGO-driven initiatives have emerged to utilize new digital technologies to design and deliver data-driven farming advisory services (such as digital extension, climate services, market information, and access to finance (e.g. Wittman et al., 2020). The importance of ownership, access and control of data needs to be understood and stimulated by CSOs and farmer organisations. Besides, they can play a role in supporting the management of digital services.

From digitalisation across scales to digitalisation to connect scales

Digitalisation has the incomparable advantage of being an enabler to reach and connect different levels across different scales: i.e., household, community, landscape/territory, national and international (Anderson et al., 2019). Digital agriculture specifically needs to integrate territorial connections, relations and practices, within the context of a multi-scale governance framework. Digitalisation developments currently lack the inclusion of such a multi-scale perspective and mainly focus on farm or household level, national or even international level, but lack explicitly the community or territory perspective as referred to by Anderson (2019).

5 Innovation to support digitalisation: addressing innovation gaps

A lot is digitalised and digitised worldwide, but surely not enough in the agricultural sector according to final recommendations of Tsan et al. (2019), which is specific on the need to develop human capital, the need to create greater impact by bringing agricultural development to lesser-served populations, the need to invest more in a research agenda for agricultural development and the need to create strong alliances and partnerships. Ehlers et al. (2021) analysed the extent to which digital technologies can trigger different choices of agricultural policy instruments but also novel design specifications that address problems of sustainability in farming more effectively and possibly more efficiently. The analysis suggests that institutional constraints and interests, as well as the capabilities of the actors involved require attention.

In order to further discuss these and other institutional constraints and innovation gaps, the following focus areas have been identified, namely: Enabling environment and infrastructure; Digital skills and human capacity; Supporting

Suggested research questions include:

Digital technologies to support the agroecological transition:

- *As agroecology emerges through processes of community self-organisations in territories (Anderson et al., 2019), to what extent is digitalisation able to contribute to the collective agency of food producers?*
- *To what extent can digitalisation support the agroecological pathway of agri-food systems transformation, especially among smallholder farmers?*
- *Which digitalisation options/characteristics need to be considered to be able to model best-fit solutions for the diversity of contexts in Africa? What disruptive technological fixes are needed?*

'Digital agroecology': putting farmers at the forefront of design

- *How can digital agroecology significantly shift power dynamics within the agricultural innovation ecosystem and in food systems in general?*
- *What are the minimum human capital requirements to enable a wide digital transformation of agroecology?*
- *How do we need to conduct agroecological digitalisation in the African context?*
- *Are there sensitive aspects that need to be considered at an early stage and during development?*

Digital content and applications for farmers to support agroecology

- *How do we create awareness and readiness among smallholder farmers to unleash the potential of the digital space?*
- *How are existing digital content and applications used and how are they impacting the livelihoods of smallholder farmers?*

Digital content and applications for advisory services to support agroecology

- *Is the digitalised advisory services system serving farmers better compared to conventional non-digital systems?*
- *Considering the agroecological principles, how do we model advisory services to achieve agroecological transformation objectives in the future?*

From digitalisation across scales to digitalisation to connect scales

- *At which level and at what scale should digitalisation be initiated, (and with which time frame) to make impact (in different circumstances to be identified)?*

digital innovation and entrepreneurship; Developing a healthy digital ecosystem; Governance, including policies and regulations. This selection of focus areas, which is (also) inspired by the African Union Digital Transformation Strategy for Africa[14], including the suggested innovation gaps and questions raised, is a non-exhaustive selection, requiring further discussion.

Enabling environment and infrastructure

The AU Commission developed **a Comprehensive Digital Transformation Strategy for Africa**[15]. Some of the proposed recommendations and actions in the strategy include those highlighted in the AU-EU Digital Economy taskforce report[16].

Considering the following specific objective put forward in the strategy "*By 2030 all our people should be digitally empowered and able to access safely and securely to at least 6Mb/s all the time where ever they live in the continent at an affordable price of no more than USD 0,01/Mb through a smart device manufactured in the continent at the price of no more than USD 100 to benefit from all basic e-services and content of which at least 30% is developed and hosted in Africa*", requires discussing a few innovation gaps. Because, in order for hardware and networks to reach each village in Africa and in order to reach the objective of "at least 30% of basic e-services and content to be developed and hosted in Africa" what actions need to be considered now if we think of infrastructure (electricity, internet connectivity and mobile coverage)? Complementary and aligned innovations in neighbouring systems such as health, education and the environment can accelerate the impact of innovations in food systems (e.g., World Economic Forum, 2018).

Digital skills and human capacity

In order for digitalisation to support agroecology, it requires some new digitally-enabled 'species' both from the technicians' side and from the users' side. Technical experts should be oriented in agroecological standards such as open-source solutions, open data standards and online collaboration and crowdsourcing. Digital capacity of the end-users (for example farmers) also need to be strengthened in order to allow their effective participation in the design of digital solutions. Explicit attention for shaping inclusiveness while dealing with conflicting interests and power imbalances is required (see McCampbell, 2022). For that to happen, innovation must take place and that requires -in turn- addressing digital capacity gaps, including those of public and private advisory services, farmers' organisations and NGOs.

Support to digital innovation and entrepreneurship

The number of start-ups in the different areas of agricultural digitalisation has risen during the recent years. This is following the development of new technologies in ICT hardware and software, cloud services, artificial intelligence, blockchain and internet of things to name some of the fast-developing areas. Africa needs to be and to get ready, to evaluate, adopt and adapt depending on discussed scenarios, trends and potential circumstances. However, responses to digitalisation are often ad-hoc, starting with adapting capabilities, practices and services, rather than a strategic approach of innovation networks allowing for more flexibility of roles and processes, and changing business models (Rijswijk et al., 2019).

Development of a healthy digital ecosystem adapted to smallholder farmers

Digitalisation needs to be developed with specific target groups in mind, for example smallholder farmers (e.g., Gkisakis and Damianakis, 2020; Wittman, 2020). When it comes to putting in place a digital ecosystem for smallholder farmers, parameters such as connectivity, hardware availability, affordability, culture and literacy must be considered. In this regard, investment in strategic grassroots-led digitalisation initiatives (check e.g., litefarm.org) should and can multiply efficiency and profitability along the agricultural value chain. Digital technologies in the agricultural sector are likely to influence Agricultural Knowledge and Innovation Systems (AKISs). AKISs, in turn, need to better support agricultural knowledge providers (putting farmers at the centre as a knowledge provider) and anticipate on possible futures and scenarios (Rijswijk et al, 2021). Identifying the AKIS for digitalisation can provide an entry point for the development of a healthy digital ecosystem that supports agroecology.

Governance, including policies and regulations

Digitalisation is relatively new in Africa and requires the readiness of policy makers (and private sector). It requires the development of good policies and regulations and clear steps towards responsible governance in support of the digitalisation transition. Policy makers across Africa still need to get ready for the digitalisation era and for the digital transformation (e.g., Tsan, 2019) and this includes being informed about the implication of non-digitalisation. As underlined in Table 1, digitalisation can support pathways towards good governance, but digital technologies and digitalisation also explicitly require the integration of stakeholders in decision making about (as well as the development, design and evaluation of) digital technologies and digitized data for agriculture and the agroecological transition. The issues of privacy, safety (e.g., cyberattacks), justice, equity must be considered carefully and continuously, which requires already new ways of governing. Data-driven agroecology, from the ground up, requires a healthy digital ecosystem.

14] Digital transformation strategy for Africa, African Union, 2020 available at: https://au.int/sites/default/files/documents/38507-doc-dts-english.pdf 15] Idem
16] More about the New Africa-Europe Digital Economy Partnership available at https://digital-strategy.ec.europa.eu/en/library/new-africa-europe-digital-economy-partnership-report-eu-au-digital-economy-task-force

Identified innovation gaps

Enabling environment and infrastructure

Promoting national, regional and intra-continental connectivity, boosting investment in the telecom sector and taking into consideration smallholder farmers; Promoting measures that increase affordability of broadband connections for rural communities; Stimulating affordable and 'green' devices and services for smallholder farmers.

Digital skills and human capacity

Reviewing education curricula in accordance with the evolving needs and trends in the digital economy and society; Ensuring that equipment and connectivity is available for rural schools, training centres, telecentres, knowledge hubs, rural information centres, etc. It also includes raising awareness about online risks, rights, safety and security, focussed on smallholder farmers.

Support to digital innovation and entrepreneurship

Providing incentives facilitating access to finance and funding for digital innovations; Having an enabling ecosystem that addresses interrelated barriers and needs (e.g., by improving advisory services to stimulate digital entrepreneurship in rural areas); Establishing and strengthening partnerships among actors inside the Agricultural Innovation System to harmonise efforts related to the digitalisation of agroecological food system transitions.

Development of a healthy digital ecosystem adapted to smallholder farmers

Having a thorough understanding of the mandates and activities of AKIS actors that are involved in digitalisation for agroecology and how they interact; Fostering the development of digital agriculture or digital agroecology at farm level, including the access to digital equipment, services and goods (such as provision of reliable market information to enlarge farmers' market intelligence, including access to information on where to find potential buyers for their produce and to strengthen their bargaining power).

Governance, including policies and regulations

Understanding the digitalisation landscape as the actual volume of digital content and the number of agricultural digital applications across Africa is largely unknown, and new tools or technologies are emerging on a daily basis; (Linked to previous) Having systems or mechanisms in place to be able to have an exhaustive mapping and recording of existing knowledge and digital applications related to the agroecological transition in Africa that are at the same time benefitting smallholder farmers; Stimulating and making clear steps towards a responsible digitalisation governance, including digitalisation transformation strategies and policies by and with the participation and inclusion of smallholder farmers; Avoiding power imbalances and data dependency and stimulate data sovereignty, in terms of data ownership, access and control; Consolidating the fragmented landscape of guidelines and regulations to safeguard the digital rights of all stakeholders and protect vulnerable groups from harm.

6 Final remarks

Finally, the popularity of digitalisation now should not mask other dimensions of the Agricultural Innovation System that need urgent attention, e.g., amplifying grassroot voices and enhancing informed decision making and policy development (Schnebelin et al., 2021) as these areas are as critical to consider in advancing, scaling and amplifying agroecological transformations[17] (Anderson et al, 2019). The deep dive dialogue on digitalisation made clear that currently an -even confusing- array of different opportunities for farmers to access inputs, advice, credit and markets through providers with digital capabilities exists, often providing different or even contradictory advice and solutions. In itself, the number of digital apps can be overwhelming: "Before you master a tool, there is already a new one". Digital technologies need to focus on frugal tools and be based on media and tools farmers are already using. The deep dive dialogue also made clear that many new digital offerings are tied to short-term pilots, that rely on donor funding. Supporting and (further) stimulating a good investment climate, regulations and policies to spur responsible digitalisation for smallholder farmers supporting the agroecological transition is seen as pivotal. This includes having incentives and funding facilities for the production and deployment of farmer-owned digital tools that can be supported.

General agreement exists that a lot is happening in the field of digitalisation in Africa, but a strategy to harness the efforts of all these initiatives is lacking. Creating a space where experiences can be shared may be the most urgent next step to enhance understanding about successful cases and drivers behind them across the different sub-Saharan regions. An online platform will support the sharing of enabling and hindering factors for digitalisation, thus accelerating the learning and understanding about the benefits of digitalisation, its link with analogue advisory services and the opportunities it provides for the agroecological transition.

17] Specific reference has to be made to figure 4 of Anderson et al., (2019), indicating that, when domains start to overlap and enabling conditions in each domain become more robust and aligned, a greater potential for durable, widespread and deep agroecological transformation is ensured.

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For further reading

Digitization, Digitalization, and Digital Transformation: What's the Difference? by Colleen Chapco-Wade-Safina | Medium

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DataReportal (www.datareportal.com), by Simon Kemp and Kepsios, designed to find data, insights, and trends, reports yearly on 'the status of digital' globally, by country, by theme etc.: e.g. https://datareportal.com/reports/digital-2022-ghana.

Country specific data have been used for FAO and ITU's 2022 report: *Status of digital agriculture in 47 sub-Saharan African countries.*

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