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A Sustainable Future for Small-Scale Farming? Qualitative Research on Agroecology and Digitalization

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Abstract

There is a great deal of agreement amongst farmers, environmentalists, scholars, and policy-makers that the current agri-food-system is unsustainable. Debates about the future of an agriculture that can cope with the challenges of climate change and at the same time feed many people well revolve, among other things, around a digitalization of agriculture, but also around alternative agricultural practices and sciences. Agroecology represents one such alternative. However, in view of the processes toward digitized agriculture, the question arises as to whether digitization and agroecology are compatible. This working paper approaches this question from the perspective of environmental and development NGO activists as well as academics researching these topics. Based on qualitative interviews, the paper shows the multiple challenges and partly diverging perspectives on (possible) costs and benefits of digitization for agroecological practices and those who practice them.

Keywords: agroecology, digitalization, environment

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1. Making sense of digital agriculture and agroecology

It is a growing consensus amongst activists, politicians, and academics that the current agri-food system is unsustainable and not apt for coping with the challenges of climate change. According to IPCC estimations, between 2007 and 2016 the agricultural sector accounted for 13% of CO2 emissions, 44% of methane emissions, and 82% of nitrous oxide emissions. The global food chain caused 21 to 37 % of total GHG emission[1] (Friends of the Earth Europe 2020). Further, policy makers and research agree on the impact of agroindustry on biodiversity loss and soil degradation (e.g. UNCTAD 2013; Newell & Taylor 2017; Arancibia & Motta 2019). Critical food regime research stresses that the agri-food system is further characterized by a domination of a few crops as cash crops for the global market, the concentration of control over seed reproduction, fertilizers and

1 The entire food chain includes input, production, processing, distribution, and preparation of food (Friend of the Earth 2020, p.2).

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machinery, transport and processing in the hands of a few transnational companies (Prause et al. 2020), and, partly as a consequence of this, a decline of the total number of (small-scale) farmers[2]. This affects the social structure of rural communities and food sovereignty (see also McMichael 2012), because, as different actors – from the World Bank to social movements like Vía Campesina – emphasize, small-scale farmers are central to food production in different parts of the world, with a central importance to food-systems in peripheral regions (e.g. Vía Campesina 2012).

In the light of debates on the impacts of climate change, international organizations like the World Bank (2020) and the FAO (2020) consider the digitalization of agriculture a crucial pillar for both mitigating climate change, adapting agriculture to its impacts, and addressing the necessity to provide food for an increasing world population, which is estimated to reach 10 billion by 2050. Digital farming or smart farming is the process of integrating advanced digital technologies such as big data, sensors, robotics, etc. into the farm production system (Lioutas et al. 2021). Tech, seed, and chemical industry as well as international organisations promote it as a solution to the food problem that will reduce poverty and help farmers to increase yields.

Research has pointed to the ambivalences of digitalization of agriculture or digital farming. Scholars have been drawing attention to the fact that digitalization processes are spearheaded by large corporations and governments of the Global North (Prause et al. 2020). Further, and in light of this, research discusses forms of digitalization and its impacts on labour or commodity chains as well as the tendency to increase control over data, knowledge, land, and value chains via the merger of tech-companies with seed companies, machine manufacturers, and agricultural traders that are already dominant in the respective global commodity chains (Prause et al. 2020; Newell & Taylor 2017). For labour relations, Louisa Prause (2021) points to possible benefits for precarious (migrant) farm workers and middle-scale farmers alike. Hannah Wittman et al. (2020) and Zia Mehrabi et al. (2021) debate impacts of digital and climate-smart agriculture on the control of (small-scale) farmers over knowledge on farming practices, crop varieties, local markets, and the persisting digital gap, particularly in regions of the Global South. Research discusses possible contributions of digitalization to deploy resources efficiently and enable farmers to yield comparatively larger, healthier harvests; Yet, there is also some discontent among scholars, policymakers, and activists as digitaliziation could pose a threat to small-scale farmers by creating monopoly systems in agriculture (Lioutas et al. 2021).

In sum, digitalization as both sociotechnical imaginary (Jasanoff & Kim 2013) and process with different and contested sociospatial repercussions is becoming an essential element of critical academic and political debates on what is referred to as climate-smart agriculture (Newell & Taylor 2017), sustainable agriculture, or – in some cases – organic farming (Le Coq et al. 2020).

In these debates, agroecology as science, practice and movement, is often depicted as an holistic approach to agriculture which respects both humankind and the environment (Maurel et al. 2022), as a way of practicing an ecologically sound, socially just, and economically inclusive form of agriculture (Le Coq et al. 2020) and thus an alternative to different forms of corporate-dominated food commodity chains, or agrobusiness. Hence, according to Altieri (1989), it includes both technical and socio-economic aspects, that is, what is produced, how it is produced, and for whom (Maurel et al. 2022, p. 77). Research has pointed to the economic, ecological, and social importance of this form of agriculture (Altieri & Toledo 2011; Martínez-Torres & Rosset 2014) and not least, international organizations such as the FAO[3] or the EU (see Levidow et al. 2012) dedicate research, funding, and consultancy budgets to agroecological practices.

It is in this context, that we see the necessity to assess the relationship between agroecology and digital agriculture. While some scholars see possible compatibilities and benefits of digital technologies for small-scale peasant farmers (Wittman et al. 2020), other research has hinted at the challenges of digital agriculture for those actors (Prause et al. 2020), and at the tendency that the necessity of "going 'digital' or 'smart' [as] hegemonic model of economic and social development" (ibid., p. 12) legitimizes financial resources for new digital technologies in the context of the persisting exclusive structures of the agri-food sector (see also Lajoie-O'Malley et al. 2020). This rearrangement of the sector particularly challenges concepts such as agroecology and the practices of peasant movements, especially in the Global South. Just as scientific interest in digitalization and agroecology overall increased in the past years, so too has it regarding regions of the Global South such as Latin America. Latin America is the "world's largest net food exporting region" (World Bank 2020, p. 21), and its food exports determine international product flows and prices. The region's agricultural sector comprises both large-scale agribusiness and peasant subsistence farming. Increasingly, Latin American ecosystems face large-scale destruction while simultaneously playing an important role in global climate change mitigation (World Bank 2020; McKay et al. 2021). This dichotomy might cause disruptions to global food chains and ecosystems in the future. Digitalization of agriculture and changing dynamics caused by emerging technologies are considered drivers of productivity growth (World Bank 2020). While acknowledging a digital gap, the World Bank (ibid., p. 162) emphasizes the advantages of digitalization for every actor along the commodity chain in its report on

2 The FAO defines small-scale farmers as those who farm less than two hectares.

3 See e.g. https://www.fao.org/agroecology/home/en/.

Future Foodscapes in the LAC region: "Technology penetrates deeply into every aspect of the agriculture and food system. The percentage of farmers using data systems to inform production decisions in real time increases dramatically. Further downstream in the value chain, new technologies improve coordination, enhance transparency, and reduce transaction costs. Food loss and waste decrease dramatically, encouraged by policy incentives." At the same time, Latin America has a history of peasant movements struggles, of agroecological practices (Astier et al. 2017; Gazzano & Gómez Perazzoli 2017) of and policy support for different forms of organic, sustainable, and agroecological farming (McKay et al. 2014; Le Coq et al. 2020).

That is why in this paper, we will explore the implications and challenges of digitalisation in agriculture and discuss the repercussions of digital farming on small-scale farmers. Research for this paper revolved around the following questions: 1) What opportunities and challenges does digitalization pose to small-scale farmers who often belong to socially structurally disadvantaged social groups, such as indigenous groups or afrolatinxs? 2) In what way could digital tools complement and/or support agroecological practices? Hence, we seek to contribute to the growing literature that discusses the convergence between agroecology and digital technology (Biradar et al. 2019; Caquet et al. 2020; Grieve et al. 2019; Maurel et al. 2022).

To approach these research questions, we conducted semi-structured online interviews with experts, that is people that hold somehow formalized expert knowledge (see e.g. Döringer 2021; Flick 2015) – although we are aware that being attributed an expert position is embedded in power relations in knowledge production. The result show that all interviewees shared a rather sceptical view about the potential digitalization of agriculture for agroecology, food sovereignty, and independence from agribusiness, resilience towards climate change ramifications, and data sovereignty from big tech companies. However, their evaluation varies in detail, which calls for comprehensive research on different actors' perceptions on digital agriculture and socio-spatial repercussions of digital technologies. In the following, we will lay out our methods and then turn to the results in the remainder of this paper.

2. Method

To approach the research questions, we conducted semi-structured interviews with five experts and practitioners based in Canada, Germany, Ghana, Greece, and the Netherlands between December 2021 and January 2022. The interviews varied in length between 30 minutes and one hour, were conducted and recorded online via Zoom, and later transcribed. We selected interviewees according to the following criteria:

a) Fields of expertise: The interviewees are engaging with the fields of food sovereignty, sustainable agriculture, agroecology, and environmental justice, and are familiar with the contradictions of agribusiness and agriculture in Latin America or other regions of the Global South.

b) Affiliation: As our research focus lies on the impacts of agricultural changes and digitalization on small holders, local peasants, indigenous communities, and other marginalized groups, we selected interviewees who were rather associated with these groups than with large agribusiness companies. We are aware that they tend to have critical views towards the approaches of the large agribusiness companies to digitalization and the existing system of industrial agriculture.

c) Availability: The selection of interviewees was largely dependent on their availability between December 2021 and January 2022. After five experts responded to our request for an online interview, we complemented our insights from the semi-structured interviews with a focus group interview along the same set of questions on 9 February 2022 with two practitioners from cooperatives of community-supported agriculture (*Solidarische Landwirtschaft* in German) to get insights into practices within Germany.

Our research method of semi-structured interviews was chosen to enable interview partners to raise questions, problems, and contradictions that have been omitted from reports and academic discourse. An interview guide was developed from the aforementioned questions that allowed interview partners to talk freely and raise previously neglected issues that require further investigation. The elaboration of the interview guide as well as the evaluation was a joint work and done in the context of a seminar on qualitative research methods (winter term 2021/2022) at Heidelberg University[4]. Interviews were transcribed and analyzed through qualitative content analysis (see Mayring 2000, Gray 2004, Flick 2015). These methods guarantee that theoretical knowledge deducted from academic research and interviewees' knowledge in their respective fields can generate a more diverse and differentiated picture of digitalization and agroecology. Yet, our study can only be exploratory in nature. It aims to offer insights into how practitioners and experts from NGOs and research institutes are engaging with the contradictions and dilemmas of agribusiness and agroecology mainly in Latin America, and how they perceive and evaluate smart farming and agroecology. That said, we need to point to the limits of the study: Assessing challenges, possible benefits and/or problems related to digitalization of agriculture in particular for small-scale farmers certainly would need to include the voice of the latter. Yet, the context in which we intended to realize the study (University seminar located in a German university and and measures

4 The seminar was titled "Qualitative Research Methods: semi-structured interviews on agrarian change in Ibero-American contexts" and was taught in the Master Programme Communication and Society in Ibero-America by Jun.-Prof. Dr. Rosa Lehmann.

to combat the covid pandemic, which prevents or impedes travel) did shape the research design of the study and we decided to explore and approximate the topic "from the distance" and by interviewing people that could be considered as "formalized" expert in the field (for a discussion on what is an "expert" in guided interviews see e.g. Döringer 2021; Meuser & Nagel 1991; Flick 2015).

3. Results

In the following sections, we present our research results. We briefly describe our interviewees' perception of the current agricultural regime and digitalization and their understanding of agroecology. We then depict more comprehensively the challenges of digitalization they consider pertinent – in particular for small-scale farmers and those that work with organic and/or agroecological practices – and possible ways of complementing agroecology with digital tools and services. We close the result section by outlining the interview partners' evaluation of future scenarios.

a) Agricultural regime and digitalization

All of the interviewed experts agree that the status quo of the agricultural regime globally is dominated by an industrial, profit-oriented agriculture scheme. Given the economic model of the agroindustry, the interviewees perceive an overall simplification and commercialization of agro-ecosystems, associated loss of adaptability, and centralization of land in the hands of a few farmers and corporations. Additionally, the rural-urban divide was a reoccurring topic in the interviews. Interviewees related dynamics of a rural exodus and inequalities between rural and urban areas to the centralization of control of land. Hence, a new generation of younger farmers would lose interest in agriculture and move to urban centres in search for better employment opportunities. This dynamic facilitates market entry of big industrial players, and, as one interviewee emphasizes, rising land-prices, even in Germany, and tendencies of what has been debated under the concept of 'land-grabbing' in the Global South: the transference of control over and property of land to foreign investors (private companies or states) via purchasing or leasing contracts. Agricultural productivity on these land plots serves the purpose of producing crops for food, feed, fuel, or fibre primarily for export, thus enforcing tendencies of land concentration and loss of local food production (see Borras & Franco 2012). In line with studies on changes in the agricultural regime, interview partners mostly agree that in agricultural politics there is a rising emphasis on 'productivity,' implying an intensification of agriculture and the strengthening of big agribusiness, for which regions like Latin America are considered as promising markets.

As documents by international organizations show (World Bank 2020), digitalization is considered as one important pillar of future agricultural developments in Latin America. When talking about 'digitalization', interviewees did not only refer to robotics, mechanization of processes in agriculture, big data, communications platforms, drones and sensors (e.g. for precise spraying of pesticides) but emphasized that digitalization is in itself a contested term and has different meanings and challenges depending on the socioeconomic context (see below).

The majority of interviewees agrees that agrobusinesses define what "digitalization in agriculture" means and how it is facilitated. Agrobusinesses, however, are no longer limited to the agrarian industry, but today also include companies like BAYER, BASF and ChemChina who merged several corporations in order to control and concentrate profits from bringing digitalization to their existing markets and using the collected user-data. In the case of ChemChina (since 2021 Sinochem Holdings Corporation Ltd.), the Chinese state-owned company took over Syngenta, an agrotechnological company, and KraussMaffei, a manufacturer of machinery, thus combining various large companies, related and unrelated to agriculture, under the term agribusiness.

Besides the purely economic dimension, digitalization of the agricultural sector must also be viewed from a regional political and economic-political vantage point. As one interviewee pointedly states, there is no need to reject digitalization per se, but a "digitization of agriculture in general and for agroecology in particular that generates new forms of exclusion, paywalls, right, indebtedness" (Interview 1). Other interviewees mentioned that governments like Brazil rather invest in export-oriented infrastructure than providing rural internet access and communications technology for the farmers. Thus, there is a perceived risk that profit-oriented digitalization under the current agricultural regime will deepen power asymmetries.

However, one expert highlights the importance of differentiation: The tensions are not only between small-scale farmers and corporations but also amongst different classes of farmers. Similarly, not all companies are equally problematic. Some, being subject to scrutiny of international watchdog NGOs, are paying attention to environmental and humanitarian standards while others, usually oligarchic local elites, do not. In the following subsection, we will adopt this differentiated lens to look in particular at agroecology, challenges of digitalization, a combined approach of the two, as well as potential future scenarios.

b) Agroecology

The literature highlights that the meaning of agroecology is contested and negotiated in different approaches towards more environmentally friendly agriculture among different bodies and groups in the sector. Le Coq et al. (2020, p. 130-131) identify three

main approaches: organic agriculture, agroecology, and sustainable agriculture. Organic agriculture has developed since the 1920s and is maintained through certification processes that are regulated by national and international institutions. Organic food production allows the use of certified inputs instead of chemical non-organic inputs and is not intended to challenge the existing agricultural production and distribution system. Agroecology has developed since the 1970s especially in Latin America. It aims not only to avoid chemical inputs, but also to change the agricultural system profoundly to secure food security and sovereignty, more direct distribution processes, and a greater autonomy of producers. The transformations should not be limited to the environmental aspect, but should also include social, economic, and cultural dimensions in the agricultural production and distribution systems. In contrast, sustainable agriculture tries to adjust the conventional production system to a more environmentally friendly one with more technological inputs.

This distinction between agroecology and sustainable agriculture echoes the ways that some of our interviewees define and distinguish the agroecological practices they use or support from those used in connection with sustainable agriculture. One interviewee describes the distinction between sustainable agriculture and agroecology as a contrast between "weak" and "strong" ecological transformation. Weak transformation, which he also calls "sustainable intensification," covers attempts to redress some problems in agriculture, but it does not cope with more fundamental and structural problems such as the use of pesticides (Interview 2).

Overall, interviewees highlight, that the type of agriculture is related to the actors endorsing them. Sustainable agricultural intensification tries to respond to environmental challenges that the current agricultural system faces, and it is mostly promoted by those who endorsed agricultural practices that caused those environmental distresses in the first place. Apart from the modifications in ecologically most unsustainable practices, this approach intends to "keep going business as usual" (Interview 1) without transforming social and economic inequality in the existing food system. This resonates with the literature that identifies different approaches to implement more environmentally-friendly agricultural models and portray sustainable intensification or weak transformation (corresponding to sustainable agriculture of Le Coq et al. 2020) as lacking provision for redressing social and economic inequality.

In contrast to sustainable intensification approaches, agroecology has developed as a sort of counter-movement against the conventional agricultural and food system. Agroecological approaches aim to transform the entire conventional agricultural system including social and economic dimensions, treat the environment holistically, and protect its diversity instead of pursuing maximum efficiency. Agroecology first emerged in Latin America in the late 1970s and early 1980s in the form of social movements to resist agribusiness and address the right to food and food sovereignty. Agroecological approaches can be described as efforts to restore the diversity in food production and the adaptabilities to diverse environmental and social contexts, which have been lost by simplified production processes of the conventional agricultural system. Here, interviewees emphasize the aspect of social justice, hence the relation between changes to more sustainable agricultural and food systems and the need to achieve the transformation of social structures that maintain unfair distribution of economic and environmental resources. Agroecology tends to involve bottom-up movements of practitioners instead of being implemented from above. Agroecology is mostly referred to as "holistic" approach and seeks to transform the entire agricultural system from the conventional one. As an example, one interviewee mentions the method of keeping agricultural inputs to manage soils and pests and diseases on crops at a minimum level in order to preserve biodiversity.

Based on these descriptions by the interviewees, agroecology can be understood as efforts to counter inequalities and negative impacts on the environment that are inherent in the conventional agricultural system. Instead of seeking solutions with minimum changes as practiced by the sustainable intensification approaches, practitioners and supporters of agroecology try to ensure social justice and biodiversity that have been hugely neglected in the pursuit of efficiency in the conventional agricultural system.

c) Challenges of Digitalization

In this research process, four main challenges small scale farmers encounter with digitalization were identified, namely access, control, ownership, and participation. Each challenge entails different elements (Table 1) that will be further explored in the following paragraphs.

The first challenge, i.e. access, starts with having access to digital tools. According to some interviewees, a lot of

Access	Digital tools, Internet connection, financial resources
Control & Ownership	Data, dependencies, resources
Participation	Top-down approach / lack of participatory approaches

Table 1.: Main challenges of digitalization for small-scale Farmers.

farmers, especially the younger generation, are very interested in accessing digital tools, e.g. smartphones, that they can configure for their own needs and utilise on the farm. Access to these tools, including smart phones, as well as to stable internet connection, however, starkly varies across regions of the Global South. According to one interview partner, "having access to a phone is not generally the issue because somebody in your network has a phone. […] And so, it's not the hardware that seems to be the challenge. It's the connectivity" (interview 3). Furthermore, interviewees mentioned that governments like Brazil rather invest in export-oriented infrastructure than providing rural internet access and communications technology for the farmers. Thus, there is a perceived risk that profit-oriented digitalization under the current agricultural regime will deepen power asymmetries.

Insufficient financial and educational resources are other hurdles for digitalizing the agricultural sector. Some interviewees see high costs associated with new digital solutions which small-scale farmers can hardly afford. In addition, advancing technology but not promoting farmers' skill levels about these technologies can cause dangerous co-dependencies; interviewees warn against technology that can no longer be fixed within the community but requires special skills and computers, and thus enters farmers into a dependency from higher-skilled and better-equipped personnel and companies. In addition to heightening dependency, this weakens community resilience as knowledge and practices can no longer be passed on to future generations. In summary, the main challenge related to access is, thus, how to equip small-scale farmers with an affordable, sustainable, and user-friendly technology that empowers them instead of pushing them into dependencies.

The second problematic aspect is control, particularly control over data and resources. Conventional digital agriculture is highly consolidated in the development of tools, software, and equipment. Entering into digital agriculture comes with contracts over data collection and management for farmers. In particular, two interview partner raise concerns that the data sovereignty of small-scale farmers jeopardized by the status quo of digitalization as usually all the data gathered will be used solely by the company who sold the equipment. For the farmers, however, this means that they do not have rights to enact control over their data and the data collection process. Here, control, ownership and access are interelated. Or, as one interview partner puts it: "a lot of farmers' data is being held hostage in order to access technology that might benefit [farmers]" (interview 3).

The third challenge for small-scale farmers is that of ownership, particularly data ownership. In the case of native farming communities, ownership concerns particularly revolve around indigenous knowledge, e.g. on medicinal plants, that would then be handed over to and potentially exploited by agribusinesses in order for farming communities to profit from the company's technologies.

Additonaly, ownership questions are related to storage of data and security. One interview partner emphasizes problems related to data storage and security. Trade agreements with other countries (e. g. the U.S. or China) make uniform data protection and storage regulations impossible; countries can access the data while farmers are not allowed to save them on their own devices. An another interview partner raises the issue of using data to access funding. E.g. in Ghana, most digital services come from young start-ups who are dependent on development funds and grants by international organizations; in most cases, these start-ups use information about their customer-farmers to get grants but not to benefit the farmers themselves.

Tying up on that, the last digitalization challenge we identified in our research is participation. Interviewees stress stress asymmetries in online negotiations and meetings, for in digital meetings and conferences, it is much easier to side-line critical people, a practice that is much harder when being in the same room. Also, having direct talks and informal conversation before negotiations or decisions are made is more difficult. Benefits from digital meetings are gained by people/companies who already have a lot of influence on state policy and/or financial resources, like large agribusinesses. Indigenous people, grassroot activists, or people from rural communities are usually at a disadvantage on multiple levels, i.e. in regards to the lack of access to digital tools, a stable internet connection, and power asymmetries. Along this line, one interviewee stresses the importance of the analogue space and criticizes the push towards digitalization as "the new normal" (interview 4). He instead proposes an analogue system that is fine-tuned by digital tools but still enables in-person interactions, negotiations, etc.

Top-down approaches and/or lack of participatory approaches was a main concern for most of the interview partners agreeing on the fact that farmers are not really integrated in the whole process of innovation development. Instead, the digital farming industries develop solutions in an exclusive, not inclusive, user-oriented way. Participatory approaches to co-create and share knowledge are not integrated. One interview partner, a farmer himself, stresses that digital solutions are mostly driven towards large-scale intensive farming and the needs of small-scale farmers are usually not considered.

As the previous paragraphs have shown, digitalization comes with complex challenges along the lines of access, control, ownership, and participation. The possibilities that agroecology offers to address those challenges will the explored in the following subsection.

d) Combining Agroecology and Digital Agriculture

This section addresses if and how agroecology and digitalization can be combined. The interviewees agree that the agroecological approach does not

generally oppose the use of digital technologies. Some interview partners emphasize that agroecology is not against digital technologies per se – as long as digital tools are used to meet farmers' needs, to increase sustainability, and to complement traditional ways of farming. Yet, interviewees agree that digital agriculture is an ambivalent phenomenon that comes with certain benefits, but also many risks and challenges. If not carefully and consciously implemented, digitalization poses a serious threat to agroecological values and principles. The compatibility of digital farming and agroecology therefore depends on the way digital technologies are integrated.

Since our data offered complex and, in part, contradictory insights, we structured this part accordingly. First, it will be shown what advantages respondents see in a combination of agroecology and digital agriculture approaches. Subsequently, the prerequisites and possible strategies for integrating digital tools in an agroecological farming system will be discussed, followed by some best-practice examples. Finally, the current limitations of 'digital agroecology' will be addressed.

Benefits of Combining Agroecology and Digital Agriculture

The interviewees believe that – under certain conditions – the use of digital tools and services can bring various benefits to smallholder farmers as well as to the agroecological movement in general.

First of all, digital tools can provide important agricultural information. As one interviewee points out, technologies such as sensors can collect data about air temperature, humidity, soil moisture, crop health, the presence of pests, etc. – key information that support farmers in making good farm management decisions. As a result, the efficiency of the farming system can be increased and the use of external inputs such as pesticides can be reduced. The rise of efficiency and reduction of external inputs is an important first step on the path to an agroecological food system.

For some interview partner, digitalization can also improve access to off-farm information and different kinds of services. For instance, farmers in Ghana can register to agricultural messaging services in order to receive SMS alerts on market prices for crops, which enables them to make targeted decisions on when and where to sell their crops. Since this kind of service is not only accessible on smartphones but also on the more basic feature phones, it is a viable option for low-income and remote-area farmers. Another example is online tractor hiring services that allow farmers to connect to nearby tractor owners and rent machinery they might not be able to afford on their own – a new concept that is sometimes referred to as Uber for tractors.

Digital technologies can further be used for education and knowledge exchange. In contrast to conventional agriculture, agroecology "does not offer fixed prescriptions – rather, agroecological practices are tailored to fit the environmental, social, economic, cultural and political context" (FAO 2018, p. 4). Agroecological farming therefore requires comprehensive and context-specific knowledge. As some interview partners emphasize, a large proportion of the world's farmers have been separated from this kind of knowledge. However, one interviewee in particular asserts that digitalization may help to solve the problem: Digital technologies such as online platforms allow farmers from all over the world to gather and share knowledge about agroecological farming and to discuss and exchange labour practices. This way, the ability to manage complex systems can, to some extent, be recovered, and farmers wanting to convert to agroecological farming can be supported. Agroecology movements in Latin America are already using digital networks to communicate and exchange experiences.

Finally, the integration of digital technologies might help to raise interest in agroecological farming. Interivew partners mention that the agroecological approach is sometimes perceived as low-tech or even as a 'backward', which is why it may not seem appealing to many people. When combining agroecology and digital farming, however, farmers, especially young ones, might be more inclined to enter and stay in the agroecological farming sector.

Prerequisites and Strategies for Combining Agroecology and Digital Agriculture

As shown in Section 2c, the potential advantages of digital agriculture are countered by several challenges and risks, especially for small-scale farmers. This section discusses the preconditions and strategies for implementing digital farming in a way that is compatible with the agroecological approach and does not harm small-scale farmers.

A first challenge concerns the development of digital technologies. As has been shown, digital innovations are almost exclusively developed by manufacturers of the digital farming industry. Agroecology, however, "has been traditionally based on co-producing knowledge with farmers, scientists, indigenous communities and technicians" (Arancio et al. 2016, p. 1). Interviewees emphasize the necessity to integrate farmers and other stakeholders of the food system into the innovation process, in the sense of a "user innovation process" (interview 2): Since farmers (i.e., the end-users) know their needs best, they should be able to participate in technology development and also innovate for themselves.

A second challenge concerns ownership and access to digital farming technologies. As described in Section 2c, digital technologies are mostly owned by private companies. For smallholder farmers, the

usage of these technologies is often accompanied by dependencies and a lack of control. To avoid this, several interviewees suggest following the principles of open source and open access. This means that digital innovation should be shared and made available to the public for free, creating a common pool of sharing innovative knowledge and tools. Such a peer-to-peer process, as one interviewee points out, requires the establishment of non-hierarchical relationships that enable actors to collaborate and exchange the value generated by technology. The interviewees expect that access to the knowledge surrounding technologies and tools will increase farmers' autonomy, for example, by improving their ability to repair defective tools.

Ownership is a critical issue not only in relation to the actual tools and services, but also with regard to the data collected by them. As discussed in Section 2c, farmers often need to give up rights to their personal data in order to get access to certain tools and services. This not only entails considerable risks such as data abuse, but also contravenes agroecological principles, since agroecology is a rights-based approach. According most interview partners, it is therefore necessary to base digital agriculture on the principle of data sovereignty. Data sovereignty means that personal farm data belongs to the farmer and that farmers are in control of how their data is used. Suppliers should only use or sell farm data when explicit consent is given by the farmer, and there should be full transparency about how the data is disseminated. Some farmers might, in fact, want to share their data, but it should not be a requirement to access a certain technology. One interviewee emphasizes the need for basic laws on data security and privacy protection in order to avoid the misuse of personal data.

To be in line with the agroecological approach, digital technologies should also be designed for the right purpose. To give an example, digital services offered by big tech companies often tend to simplify farming systems, e.g., by offering generalized solutions. Agroecology, on the other hand, promotes locally adapted and knowledge-based solutions. According to one interviewee, digital technologies should thus be tailored to support knowledge complexity rather than simplification. Similarly, another interview partner points out that digital tools are often advertised as a means of enhancing the efficiency of pesticide use, e.g., via drone-based spraying. From an agroecological viewpoint, however, the final goal is not to maximize efficiency, but to completely replace pesticides with biological control methods – an aspect that should be kept in mind when designing digital tools.

Another point concerns the individualistic nature of digital agriculture. Agroecology places a strong emphasis on community and collaboration. In contrast, digital solutions are mostly tailored to the level of the individual farm. One interview partner anticipates that the integration of digital tools might fail in certain areas of the world if they are designed solely for individual use. This is because many rural farmers depend heavily on group-based networks and information exchange with their peers, and due to factors such as illiteracy, some might not be able to make use of digital tools when on their own. To ensure that all farmers can benefit from digitalization, it is necessary to take account of such local conditions and to put a stronger focus on technologies that work at the community level.

Moreover, several interviewees point to the importance of considering the environmental impact of the production of digital tools. Since agroecology aims to reduce the negative impact of agriculture on the environment, the tools used in agroecological farming should also be produced in an environmentally friendly way. This applies in particular to the extraction of resources, such as the mining of metals.

For some interview partners, the transformation of the digital farming sector towards more sustainability requires the cooperation of various actors. Not only farmers and ranchers, but also stakeholders from other sectors (e.g., engineers, programmers) should be involved in the transformation process and provided with incentives to participate in alternative non-top-down approaches. Ideally, there should be horizontal and synergistic collaborations between political actors, farmers, and other stakeholders.

In this context, one interview partner stresses that the ability of digitalization to be compatible with agroecology would depend largely on the main funders of agricultural digitalization (e.g., the World Bank, or the Bill & Melinda Gates Foundation). If these actors have an ideal image of agriculture that corresponds to intensively managed conventional farms, then digitalization is unlikely to be compatible with the agroecological approach. Hence, the challenge is to convince political and economic players of the benefits of agroecological farming and to encourage them to invest in digital solutions that comply with agroecological principles. Unfortunately, agroecology is often still perceived to be less productive than conventional farming. However, a growing number of studies suggest that agroecology is the more effective approach as economic, social, and ecological aspects are equally considered (see above). Interviewees point out that due to its socio-ecological services, the agroecological approach has a high potential to support sustainable development – a fact that political and economic players should be made aware of. As one interview pointedly suggests: "increasing the recognition of the power and potential of agroecology to support global Sustainable Development Goals […] theoretically should stimulate policy and investment towards protecting that kind of farming" (interview 3).

Best-practice examples

To show how some of the above-mentioned criteria can be implemented in practice, this section will briefly present the "best-practice projects" mentioned by the interviewees. 'Best practice' here means that

these examples seek to meet the challenges and critique raised by our interview partners concerning digitalization of agriculture. The examples are mostly community-based initiatives that meet the criteria of user involvement, co-creation, open source and open access, and integration of different stakeholders. The depictions rely on insights from the interviews and the focus group as well as on other external sources.

OpenTEAM, or Open Technology Ecosystem for Agricultural Management, is a collaborative community of farmers, scientists and researchers, engineers, programmers, farm service providers, and food companies. Based on a co-development approach, OpenTEAM has designed a series of free and open source digital tools that provide farmers of all scales with knowledge to improve their soil health and combat climate change (OpenTEAM, n.d.).

Similarly, Farm Hack is an online community of farmers and other stakeholders committed to developing and sharing open source tools of all kinds – digital and non-digital ones – with the aim to create resilient agricultural systems. Farm Hack consists of a tool library where users can document and share tool designs, a blog, and forum for community discussion (Farm Hack, n.d.).

L'Atelier Paysan is a French cooperative comprised of small-scale farmers, engineers, and agricultural development organizations. Following a user innovation approach, L'Atelier Paysan assists farmers in designing tools and machinery appropriate for small-scale agroecological farming. The aim is to reclaim farming skills and achieve self-sufficiency with regard to agricultural equipment (L'Atelier Paysan, n.d.).

The EU research and innovation program Horizon 2020 (2014–2020) is an example of a synergistic collaboration between formal institutions – in this case, the European Union – scientists, and farmers. Horizon 2020 has financed research for the development of alternative digital farming approaches and digital innovations that meet open technology and sustainability criteria. One of the funded research projects is the CAPSELLA project, which aims to develop community- and demand-driven ICT (Information and Communications Technology) solutions for actors engaged in biodiversity (EIP-AGRI, n.d.).

A further example is cost effective rainfall sensors developed by the Delft University of Technology, Netherlands (DW, 2013), which rely on open-source software. One interview partner has participated in a project along similar lines, developing open platforms that allow olive and grape wine producers to calculate their energy use and greenhouse gas emissions (see Gkisakis et al., 2020).

Limitations of "Digital Agroecology"

As has been shown, the integration of digital technologies into an agroecological farming system is principally possible and can even be accompanied by certain benefits for small-scale farmers, provided certain preconditions are met. However, some interviewees express doubts as to whether the digitalization of agroecology will actually lead to more sustainability in the food system.

When bringing the interviewees' statements in line with Gliessman's (2007) "Five Levels of Transition towards Sustainable Food Systems," the path to a sustainable and agroecological food system consists of five steps (see Figure 1). The first step is to increase the efficiency of input use and to reduce the use of environmentally damaging inputs. As has been shown, digital technologies can indeed support farmers during this initial phase. According to some of our interview partner, however, digital technologies – at least in their current form – are not suitable to support the remaining four steps aimed at a more profound transformation of the food system. In other words, digital tools can support the transition towards a sustainable food system up to a certain point, but they cannot be the main drivers of this transition.

Figure 1. Gliessman's Five Levels of Transition towards Sustainable Food Systems. Adapted from: Agroecology Europe (n.d.).

Already mentioned earlier but important to include here is the tension between analogue and digital space: Digitalization does not replace the analogue system; it is merely an addition to what is already there. So, while digital technologies do have the ability to improve certain aspects of the farming system, they cannot bring about sustainability if the non-digital basis of the farming system is already unsustainable. One interviewee concludes that people should thus look for ways to improve the 'analogue world' instead of relying on digital technologies for change. In this context, it is

also important to ask whether there are alternatives to digital farming that come with less risks.

In this regard, it is again important to emphasize that a lot of peasant communities in peripheral areas in Latin America and other regions of the Global South do not have a lot of access to and availability of internet connection, and it is questionable if this should even be a goal. Pointedly, a renowned expert in the field of agroecology responded to an email request for an interview: "[…] in the poor rural areas of Latin America I don't perceive a need of digitalization, nor will this technology be accessible for peasants in decades. In addition, if it is, what would be the usefulness of it? The goal of agroecology is [to] make farmers autonomous and not dependent on privatized technology."

e) Future Scenarios for the agricultural sector

Debates on current problems of the agri-food regime, on digitalization, and possible forms of a more sustainable farming system are inextricably bound to envisioning impending developments. Accordingly, in our semi-structured interviews, we asked the interviewees about their point of view on future scenarios concerning the agricultural development in the next 30 years. The interviewees offered visions around the topics of agroecology and the role of digital tools.

Imagining the future of agriculture and agroecology and interview partners differ in their perspetives. Most interview partners stress conflicts concerning land concentration and dominance of agribusiness, a centralisation of property where through an intensification of farming, increasingly fewer farmers are involved. This environment is especially hostile for young small-scale farmers because new land has become very expensive and is often controlled by big corporations.

For Latin America, one interviewee has a rather pessimistic vision on the development of agroecology in the next 30 years. He predicts that corporate mega plantations are going to transform into smaller plots of land that are going to be cropped with organic fertilizers, thus, presenting a shift towards certain technologies that promise a so called climate-smartagriculture. Further, agricultural corporations that adopt a so called 'green image' – an image that meets the discourse on sustainability – are going to control these small-scale plantations. Challenges and conflict revolve around(increasing) pressures on water rights whereas reforms might contribute to inclusiveness, since agribusiness is able to adapt and use methods for sustainable intensification, yet, this form of inclusiveness does not echo the dimensions of justice that are central to agroecology.

Another interview partner highlights the necessity that more people, especially young people, adopt agroecological approaches to face environmental challenges in the following decades. He specifically points towards changes required in the academic and educational sector so farmers can benefit from training in the areas of agroecological practices and sustainable cultivation. Of central importance is also the support of states and organisations like the EU for young farmers in the adoption of agro-environmental measures. This way, environmental pressure could be reduced and the rural exodus limited as a young generation with an environmentally conscious background enters and redesigns the farming sector.

Concerning the future role of digital tools, interviewees showed different assessments here, agreeing mostly on the right of everyone to the internet. Pointedly, one interview partner argues that

"that not everyone needs to pursue agroecological digitalization. Many people are very happy not doing that, and that's totally fine. But they should have that choice" (interview 3).

By ensuring public access to the internet, she further argues, farmers would have better opportunities for dynamic interactions of technology and knowledge generated directly by them. This would decrease the need to sell their own data to be able to access and get technology, thus reducing a kind of "hostage" (interview 3) dynamic.

More critical voices echo this argument, not only concerning the often assumed relation between digitalisation and positive effects on the environment including the reduction of the CO2 footprint which lacks evidence, but also concerning power relations and benefits big companies can reap from digitalization. One interviewee explicitly contrasts how leadership in big companies and organizations determines their alignment towards agroecology or agribusiness: e.g. the most powerful players, mostly from China and the US, impose their interests upon the whole agricultural sector exemplified by the leading heads of the FAO. This emphasis on the power of big corporations pressing for further centralisation and intensification of the farming sector with the use of digital tools and thereby reducing scopes of action for agroecological farmers is shared by many interview partners.

5. Discussion and Outlook

This paper has discussed digital farming and agroecology and the perceptions of experts from NGOs and think tanks on challenges and opportunities in light of the necessity to cut GHG and provide food security, if not sovereignty to a growing world population. The perceptions interviewees displayed rhyme with current research debates. They indicate that the digitalization of agriculture and agroecology must be considered as highly contested fields – the terminologies as such, as well as the political, social, and economical processes and actor constellations that are interrelated with the implementation of both concepts. So is the possible connection between using digital tools and working

with agroecological practices. If the attempts of developing open source and/or affordable digital tools that break with the economic model of accumulation or the dominance of tech-, seed- and/or chemical firms of generating surplus by gathering and selling data users collect have a chance to scale up and compete with tools offered by the latter actors, seems to still be not the focus of agroecological debates[5] and presents an open research field to debates on the agrifoodsystem, on agroecology, and a sustainable food production. Further research could investigate more in detail companies' practices in the field of digital agriculture and the repercussions and interrelations with agricultural producers taking into account different size of farms, a variety of practices to work the land, and heterogenous sociocultural, political, and economic contextes; discourses on digitalization of agriculture and how they are taken up and reproduced by different actors in the agricultural sector; and attempts to the digitalization of agriculture from the perspective of small-scale farmers working with agroecological methods.

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Interview 2: with an agronomist and farmer, conducted on the 20 December 2021, online

Interview 3: with a sociologist, conducted on the 10 January 2022, online

Interview 4: with a agriculturalist, member of a NGO, conducted on the 10 December 2021, online

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