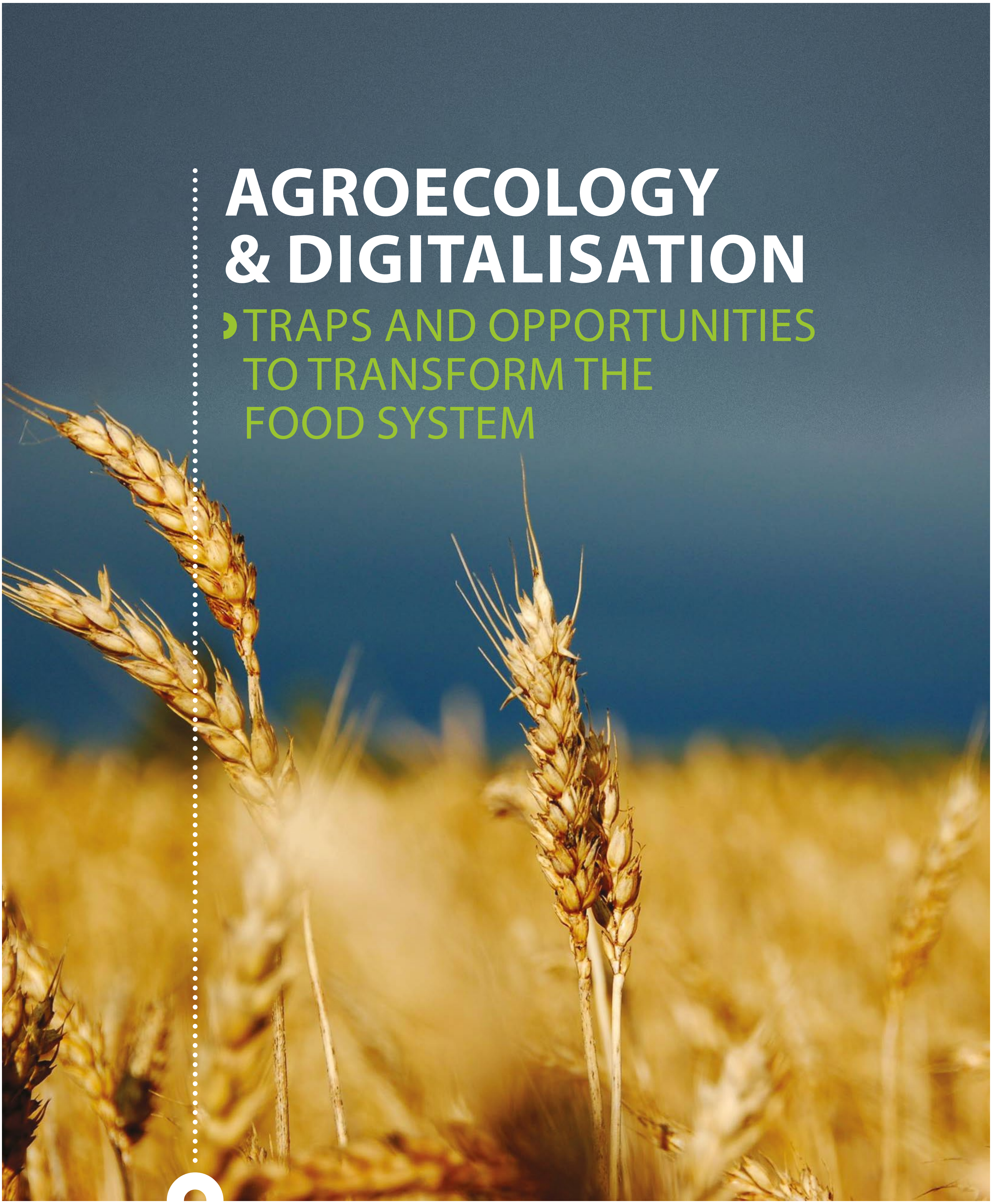
AGROECOLOGY & DIGITALISATION

TRAPS AND OPPORTUNITIES TO TRANSFORM THE FOOD SYSTEM



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FOREWORD

The EU Farm to Fork strategy acknowledges that *"food systems cannot be resilient to crises such as the COVID-19 pandemic if they are not sustainable", and that "we need to redesign our food systems which today account for nearly one-third of global GHG emissions, consume large amounts of natural resources, result in biodiversity loss and negative health impacts (due to both under- and over-nutrition) and do not allow fair economic returns and livelihoods for all actors, in particular for primary producers."*

To achieve this transition to sustainable food systems, the Farm to Fork strategy highlights a range of solutions. It calls for a reduction in synthetic pesticides and fertiliser use, and in the use of antimicrobials; it also calls for an increased share of land under organic farming, and for mainstreaming precision farming and the use of artificial intelligence.

The crisis we face, due to the impacts of climate change, the collapse of biodiversity and ecosystems, pandemics or wars, renders even more urgent a transition to agroecological food systems which are more resilient and less dependent on external inputs. The organic movement believes that, more than ever, the Green Deal and the Farm to Fork strategy remain the right policy direction to transform our food system.

This is why digitalisation should not be conceived only as a technological fix to the current input-intensive agriculture model, aimed at alleviating marginally some of its destructive impacts while increasing corporate control and further disempowering farmers. Issues of control and ownership of data are by now well-identified in the public discussion, and digitalisation and agroecology sometimes appear in the debate as two dominating and conflicting narratives on what the future of agriculture should be. But we need to go further and collectively find ways to ensure that processes of digitalisation actually contribute to this transformation of the food system, along with the principles of organic farming and agroecology. Indeed, agroecology is a way to express the four principles of organic farming (health, fairness, ecology and care). Organic agriculture and agroecology have common principles and drivers, and the organic movement sees itself as an integral part of the movement and science for agroecology. In the European context, agroecological practices are mostly applied on the ground by organic farmers.

The reflections in this report are the views of the authors and are aimed to stimulate and guide the discussion within the organic food and farming movement and beyond.

IFOAM Organics Europe is deeply grateful to Angelika Hilbeck and Bernadette Ohen for assembling such a distinguished team of scientists, researchers, thinkers and activists to deliver this collection of insightful, sometimes thought-provoking, reflections on the how digitalisation can contribute to developing agroecology. As authors and coordinators of the much-acclaimed 2015 report "Feeding the People – the relevance of agroecology for nourishing the world and transforming the current agri-food system", there could not be better-placed citizen scientists to lead us through this examination of how the principles of agroecology can be a guide to stir technical innovation in a direction that is beneficial to nature, farmers and society.

Jan Plagge
President of IFOAM Organics Europe

INTRODUCTION

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WHAT IS AGROECOLOGY?

AGROECOLOGY is gaining traction worldwide and increasingly inspiring farmers, organisations and policymakers who adopt it as a viable framework for transforming the current agro-food systems, which have been widely recognised as unsustainable (Wezel et al. 2020, IPES 2018; De Schutter 2011). Agroecology is the contextualised application of ecological principles to agriculture and, thus, entails the identification and application of the best locally adapted practices in food production. In essence, agroecology works with nature and not against it, as current dominating forms of farming tend to do (Wezel et al. 2009; Altieri 1995). Most importantly, farmers take centre stage, their role is strengthened and their knowledge, skills and participation are considered indispensable (FAO 2015; De Schutter 2011). In short, agroecology can be seen as the skill-full, situated and sustainable art of farming. As agroecological forms of farming differ substantially from conventional, industrialised farming in many aspects (Hilbeck and Oehen 2015), so does the need for technologies tailored to the tasks and goals of agroecology. In this publication, we focus on the social, economic, cultural and environmental implications of the application of information and communication technologies (ICT) to support the agroecological transformation of agro-food systems. Specifically, we propose a guideline of principles for the design, development, implementation and evaluation of agroecological initiatives that integrate ICT.

DIGITALISATION IN AGRICULTURE

Digitalisation is far more complex and has deeper implications than automation. Automation of repetitive and cumbersome processes, whether on farms or anywhere else, has been going on for well over a hundred years as technologies enabling automation emerged (electricity, machine engineering, etc.). Well-known examples that no one wants to miss ever again in agricultural production systems are, for example, ginning machines (e.g. for cotton), milking robots (for cows mainly), or harvesters to mention only a few. As electronic data collection on electronic storage devices via networked calculating machines (i.e. computers) became possible, record keeping of quantitative data captured by these machines (e.g. milk per cow and day, a ton of harvested grain per hectare) became commonplace and greatly helped farmers to keep oversight and monitor the productivity and efficiency of their operations.

However, today's widely promoted digitalisation or digitization of agriculture became only possible with the steadily increasing computing power and, more importantly, the networked technologies for data transmission across the globe. While this opened up many possibilities for the further optimising of farm operations at all levels, the most significant leap, however, did not occur on-farm but off-farm. It opened up novel business models that brought completely new actors into the field who held no stake nor knowledge in agriculture (e.g. Accenture & Vodafone 2011). These highly attractive new business opportunities aim for the full capture and vertical integration of entire agro-food systems, including their value chains from input to harvesting to processing and marketing. While the last decades of the 20th century saw the horizontal capture of specific sectors (also coined 'consolidation') like the seed, pesticide or fertiliser markets but also among the buyers and sellers of agricultural commodities produced in these production systems, the first decades of the 21st century saw the vertical convergence of these various sectors from seeds to production to selling and processing into what is being called platform capitalism.

In Switzerland, for instance, the 'cooperative' Fenaco presents a poster child example for how the vertical integration, while legally 'owned' by farmers, led to a fully integrated monopoly that looks primarily after the company's profits rather than those of its 'owners' consisting of thousands of smallholder farmers. It controls almost all input, processing and marketing entities. Globally, Bayer is a shining example of such business models. After swallowing Monsanto and its prime assets like Climate Corporation and other IT companies, the new and single biggest player sets out immediately to create an ICT platform ('Fieldview') aiming to achieve at the global level what Fenaco did at the national level. As these cases show, digitalisation tends to work far more to the advantage of players and technology providers like Fenaco than farmers. But how can we design and implement ICT initiatives that avoid the extraction of data and value and instead support agroecological transitions? The first part of our publication is dedicated to the deconstruction of digitalisation processes and power imbalances with contributions by critical actors and thinkers in this field.

THE ROLE OF ICT TOOLS IN THE DIGITALISATION OF AGRICULTURE

The potential contribution of ICT to agriculture, in general, was widely recognized for the first time in 2003, when the term e-agriculture was introduced at the World Summit on the Information Society (WSIS 2003). Originally, the aims of e-agriculture were stated as the application of ICT to dynamically disseminate accessible, up-to-date information relevant to agriculture, particularly in developing countries and to increase food production (WSIS 2003). More detailed potential contributions of ICT to agriculture were identified in subsequent studies by NGOs, ICT corporations and scientific researchers (e.g. Vodafone et al. 2011; Furuholt and Matotay 2011). A general set of policy recommendations was formulated together with the original aims of e-agriculture: 1) building on existing systems, 2) determining who should pay for access to ICT, 3) ensuring equitable access, 4) promoting local content, 5) building capacities, 6) using realistic technologies, and 7) building knowledge partnerships (Chapman et al. 2003). As with the aims of e-agriculture, policy recommendations were also progressively refined (e.g. World Bank 2017). E-agriculture experienced a rapid expansion, which culminated with its rebranding as ICT4Ag (ICT for agriculture), a term that came to be associated with the exploitation of business opportunities offered by the newly founded partnership of ICT corporations and agribusiness (e.g. Kalibata 2013). However, despite incipient policy recommendations, it is possible to argue that this turn towards monetisation contributed to emphasising the ends that ICT4Ag might serve, regardless of the means by which to reach them. Consequently, the importance of ethical, social and environmental principles for the design, development and implementation of ICTs in agriculture has largely been bypassed (Tisselli 2016). Instead, the development and implementation of result-oriented ICT platforms that tend to uncritically amplify unsustainable agro-food systems have been favoured (Tisselli 2016). Thus, in light of the lack of a principled application of ICTs to agriculture, in this publication, we propose a guideline that seeks to orient the integration of ICTs towards their contribution to context-based, farmer-centred transitions to agroecology.

While the e-agriculture and ICT4Ag models became implemented and adopted mostly in developing regions, such as Africa and Asia, the digitalisation of agriculture in Europe and other developed regions followed a different pathway under the umbrella term 'Digital Agriculture'. Digital Agriculture encompasses different fields of applications packaged by digital means. It starts with a technical engineering component of automated machinery – robotics. Further, it entails making these automated robots 'autonomous' and, thus, allowing for unmanned operations controlled remotely by joysticks or computers using either in-build cameras or camera-equipped drones for surveillance. This fundamentally aims at making farmers and farmworkers in the field redundant.

Lastly, the data generated and exchanged between robots and remote controllers are combined and mined by algorithms and repurposed or repackaged into new protocols for improved productivity – the modern-day form of 'value-addition' – which is then sold back to the farmer or farming operation owner with the promise for tailored solutions to optimised agro-economic outcomes. Digital Agriculture has included different concepts and terms, described in the following paragraphs.

Precision Farming or Precision Agriculture are the oldest terms in use, reaching back as far as the early 1990s when military GPS signals became publicly available. Initially, Precision Farming was about managing in-field variations more accurately, intending to treat each plant individually (Variable Rate Application, VRA), thus, increasing the output while reducing inputs (CEMA 2017). Similarly, Precision Farming intends to manage individual animals rather than herds, for which the term **Precision Livestock Farming** was coined. A recent publication by the European Parliament defines Precision Farming as follows: "a modern farming management concept using digital techniques to monitor and optimise agricultural production processes" (European Parliament 2016).

'Smart' Farming, on the other hand, encompasses Precision Farming but has a focus that goes beyond individual machines. It makes use of Farm Management Information Systems (FMIS) to optimise complex farming systems. With smartphones and tablets becoming widely available, farmers can access real-time data about, amongst others, weather, soil conditions or resource usage, which helps them make more informed decisions (Griepentrog, 2017).

Farming 4.0 or **Agriculture 4.0** are terms that are often used interchangeably in Smart Farming and relate to the concept of 'Industry 4.0'. Whereas Agriculture 1.0 was based around labour-intensive, (supposedly) low-productivity peasant agro-food systems, Agriculture 2.0 – gaining traction after WWII building on key military technologies developed during the war (biocides and explosives becoming pesticides and fertilisers, respectively) – marks the beginning of today's 'industrial', input-oriented entrepreneurial agro-food systems. Using high-yielding varieties bred in conjunction with synthetic pesticides, fertilisers and increasingly specialised machines, farmers were able to substantially increase yields, which made the period widely known as "The Green Revolution". Agriculture 3.0 coincides with the emergence of Precision Farming in the 1990s and the gradual introduction of more advanced and mature Precision Farming technologies – mostly automation - afterwards. Finally, around the early 2010s, exponentially increasing the use of information and communication technology (ICT) in farming has led some authors to argue that these developments would constitute the next agricultural revolution (Finger et al., 2019). Thus, Agriculture 4.0 has been coined to describe this new boost in Precision Farming, based on several technologies, such as cheap and improved sensors, high bandwidth cellular communication, cloud-based ICT systems and Big Data analysis (CEMA, 2017).

Finally, **Digital Farming/Agriculture** is probably the broadest term in use and is sometimes described to integrate both Precision Farming and 'Smart' Farming, applying digital technologies to management, marketing, production and processing (Griepentrog, 2017). Its essence lays in 'creating value from data', which can mean a variety of things, from a shift in the OEMs' approach from a hardware- to a service-oriented one (e.g., enhancing the performance of their vehicles via Big Data analysis) (CEMA, 2017), but also the emergence of new, potentially disruptive players such as Microsoft, Google, various insurance companies or even retailers such as Amazon that make use of the data in various ways (also see chapter 4).

However, various stakeholders use these terms interchangeably or with different meanings. For example, the strategy consulting group Roland Berger conceives Precision Farming to also include all the latest developments around Big Data and cloud-based ICT systems, leading to platform-based whole system packages vertically integrating (i.e. capturing) entire food systems on technology platforms.

AGROECOLOGY AT A CROSSROADS

In part I of this publication, we explain how the kind of digitalisation on offer today by the same players who have led agricultural industrialisation and concentration since WWII is geared towards extending and further concentrating the industrial model of agriculture that is not in line with agroecological principles/elements. New players have joined who bring in Silicon Valley-style 'disruptive' start-up business models and platforms to capture capitalism already reaching out for agroecological systems which have been coined as 'junk agroecology' in a widely publicised report by Friends of the Earth International (Alonso-Fradejas et al. 2020). They state:

«In the current conjuncture of converging global crises, ... the main global agrifood corporations are seeking to redress their worst socio-ecological impacts through the adoption of a model of sustainable agricultural intensification with agroecological nuances. This model seeks merely to introduce some required reforms in order to safeguard the current agrifood and corporate and industrial natural resource use systems from itself. The end goal of these reforms is to ensure that big business can continue profiting, without fundamentally transforming either the unjust socio-economic, political and ecological relations on which the agrifood system is based, or the exclusionary and short-sighted ideology that legitimises it. For the purposes of 'changing everything so that nothing changes', transnational agrifood corporations find, in agroecology, a menu of extremely useful solutions that they have decided to selectively integrate into their agro-industrial model.»

Some of such useful ways to 'selectively integrate' parts of agroecological practices into their business models arise from combining various applications of digitalisation and its underpinning tools from the IT and robotics fields mined and repurposed by algorithms.

However, despite these ongoing processes, digitalisation may still hold valuable potential also for agroecological food systems. The key issue is to differentiate technology proposals that will foster agroecological and organic principles and support a transformation agenda from those that will undermine them if introduced mindlessly and when meeting an unprepared community. Therefore, in part II of this publication, we will present a case example inquiry into the preparedness of a particular Swiss organic farming community to participate in the shaping of digital technology products. And, in order to draw valuable lessons from developing regions of the world, we also present a case study on how ICT can support farmer-driven research on agroecological transitions. This publication is meant to increase the capacity of the agroecology community to sort into which category proposed digital solutions will fall. Additionally, we will propose a set of ethical principles for the design and implementation of digital tools in support of agroecology.

PART I
WHY IS THE REPORT NEEDED? DIAGNOSIS

AGROECOLOGY AND DIGITALISATION: OPPORTUNITIES & PITFALLS FOR FOOD SYSTEM TRANSFORMATION

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The digital revolution occurring across global food systems has become undeniable. From robotic tractors and spraying drones to fully integrated data-driven strategies to manage food value chains, a host of new digital technologies are now being sold as the solution to tackle a growing population, climate change and the depletion of our natural resources. Indeed, under catchy titles like "smart farming" or "agriculture 4.0" (amongst many others), the creators of these technologies are working arduously to convince farmers, policy-makers and the public alike that digitalisation will be key to the sustainable farming systems of our future.

Already, the EU Commission has frequently cited the primary role it will give to the digital transformation of agriculture and rural areas as part of food systems transformation. To meet its headline ambition to make the EU 'fit for the digital age', the Commission has stressed that "digital technologies have the potential to revolutionise agriculture by helping farmers work more precisely, efficiently and sustainably" (European Commission, 2021b). According to the Commission, the digitalisation of EU agriculture aims to make farming jobs more attractive to younger generations and offer consumers greater transparency on how their food is produced. The recently voted CAP reform intends to boost this digital revolution through significant investments into the Agricultural Knowledge and Innovation Systems (AKIS) and Farm Advisory Services (FAS), amongst other areas of investment. The new CAP also includes "digital obligations", including the mandatory use of the Farm Sustainability Tool for Nutrients (FaST)[1] by income support beneficiaries.

At the same time, agroecology, 'the application of ecological concepts and principles to the design and management of sustainable agriculture and food systems' (Gliessman, 2015), has increasingly been identified as a crucial enabler for the food systems transformation we need (see IPBES, 2018; IPCC, 2019; Global Commission on Adaptation, 2019; HLPE, 2019; UN, 2019). As an integrated approach to creating long-term social, economic and environmental resilience (HLPE, 2019), agroecology is considered capable of dismantling the structural causes of the current food systems' negative impacts and offering a solution to build just and sustainable food systems (Altieri, 2018; Gliessman, 2016; IPES-Food, 2018).

In May 2020, the European Commission published its Biodiversity and Farm to Fork Strategies, aimed at guiding the European Union (EU) towards more sustainable food systems over the next 10 years. In an unprecedented step, both strategies acknowledged the significant role that agroecology could play in underpinning a transition towards sustainable food systems. For the first time, in January 2021, the Commission also included agroecological and agroforestry practices in the draft list of agricultural practices to support its eco-schemes as part of the new Common Agricultural Policy (CAP) (EU Commission, 2021a).[2]

While the EU Commission has cited both agroecology and digitalisation as 'indispensable' in meeting the objectives of the EU Farm to Fork Strategy and Green Deal, the challenge "to maintain coherence between different policy objectives" has also been acknowledged (PubAffairs Bruxelles, 2021). On the one hand, the Commission has recognised agroecology's ability to restore the balance between human and natural processes by integrating ecological principles into agricultural systems.

On the other hand, it has extolled the digitalisation of agriculture for its ability to perpetuate a productionist paradigm under which farmers can keep "producing more, [albeit] while reducing their environmental impact" (European Commission, 2020).

A growing number of scientists, activists and farmers argue that the digitalisation of agriculture and its focus on productivity-focused technologies may only serve to entrench the logic of capital accumulation as the primary objective of food systems. If deployed under current food systems dynamics, the digitalisation of agriculture would inevitably run the risk of reinforcing social and economic inequities and drive further "natural resource degradation and exploitation of farm and food workers by landowners, governments and corporations" (see Rotz et al., 2019). This seeming contradiction begs the question of the compatibility of digital technologies and agroecology and who these pathways are meant to serve. Can the combined pursuit of digitalisation *and* agroecology unlock sustainable food systems transformation or is the attempt to simultaneously follow these two pathways an ill-considered effort to meet the interests of divergent food systems stakeholders? Below we offer a framework to consider the possible compatibility between agroecology and the digitalisation of food and farming systems and propose the United Nations' Food and Agriculture Organization's (FAO)'s 10 Elements of Agroecology as a possible assessment framework in the consideration of the new technologies. We suggest that compatibility between agroecology and digital innovation exists, but very much depends on by whom and to what end digital tools are integrated into food and farming systems.

Before an assessment can be made, however, what remains undeniable, is the magnitude of the task ahead to address today's food systems challenges. Despite global commitments to meet the Sustainable Development Goals and the Paris Climate Agreement, today's industrial food and farming systems continue to simultaneously cause and be affected by a series of severe and interconnected environmental, socio-economic and health-related impacts. Characterised by industrialisation, privatisation and exploitation, these food systems have been named a leading cause of malnutrition, the spread of communicable and non-communicable diseases, the loss of livelihood, biodiversity loss, climate change, deforestation and the degradation of land and marine ecosystems, amongst other failures (IPCC, 2019; IPBES, 2019; IPES-Food, 2016). This evidence was further corroborated in a recent Chatham House report, confirming industrial agriculture as the main threat to 86% of the 28,000 species at risk of extinction (Benton et al., 2021). And what's more, the long-term effects of the COVID-19 pandemic continue to loom large, threatening to raise already high rates of global food insecurity and malnutrition (HLPE, 2020).

It is against this backdrop that the need for an agroecological food systems transformation is being considered. To get there, the FAO's 10 Elements of Agroecology represents one recent attempt to crystallise agroecology through a comprehensive series of principles (FAO, 2018). Determined through inclusive participatory methods, the 10 Elements serve as an analytical tool to operationalise agroecology and are meant to support the planning, management and evaluation of agroecological transition. If we understand agroecology as the holistic paradigm shift we need, it could be argued that the 10 Elements present a ready-made assessment tool against which new practices, techniques and food and agricultural policies could be designed and measured – especially in assessing their overall compatibility with sustainable transition (Clément & Ajena, 2021). Indeed, in February 2021, several EU civil society and scientific organisations already endorsed the 10 Elements framework to guide the design of agricultural and food policy interventions across Europe and to support national authorities to translate agroecology into policy to meet the targets set in the EU Green Deal (EU Food Policy Coalition, 2021).

Digital technologies include a wide array of tools that can be applied across the entire food supply chain.[3] Their compatibility with agroecological principles should therefore be assessed on a case-by-case basis to ensure their relevance to the agroecosystems, contexts and communities in which they are to be applied. The diversity of criteria being considered (i.e. each of the 10 Elements) would allow for any compatibility assessment to vary significantly depending on the individual technology and its integration within the agro- and socio- ecosystem in which it operates. For example, digital tools aimed at optimising pesticide use and chemical soil fertilisation are inherently based on improving conventional agricultural production methods and less on systems transformation. As a result, the very framework from which these types of tools are developed makes them likely incompatible with several agroecological elements (e.g., Diversity, Synergies, Resilience), while remaining potentially compatible with others (e.g., Efficiency). Others, such as solar-powered weeding robots, may appear to be *ecologically* compatible within the agroecological paradigm, but may prove less suited to agroecology in certain agroecosystems, or from a *social* or *economic* standpoint if its use risks further indebting farmers and furthering dependency on external inputs (i.e., incompatibility with Resilience, Responsible governance).

Indeed, the drive to adopt 'techno-fixes' often detracts from agroecological on-farm solutions that might prove more cost-effective and ecologically sound. For example, investment in drone technology for pesticide application must be weighed against the environmental benefits and cost-efficiency of intercropping or Integrated Pest Management. Other examples of low-cost agroecological innovations to consider before the adoption of potentially costly 'high-tech' solutions include drip-irrigation (a type of micro-irrigation), nitrogen fertilisation using mycorrhizal fungi, adaptive multi-paddock grazing systems (a management system in which livestock are regularly moved from one plot to another to avoid overgrazing), bokashi composting (fermented organic matter), or the many other innovations developed through long-standing indigenous and local knowledge systems.

The 10 Elements of Agroecology also allows us to consider criteria often ignored in technological assessments. This includes an analysis of power in food systems and how knowledge and data are generated, transferred and by whom it is 'owned' (e.g. related to the Elements of Responsible governance, Co-creation and sharing of knowledge, Human and social values and Resilience). Current incompatibilities between agroecology and digitalisation are indeed largely attributed to the significant role of large private sector actors in developing high-tech solutions. To many researchers, digitalisation is being deployed to direct capital flows and autonomy further away from food and farm workers and into the hands of the agribusinesses, data processing companies and tech companies developing these tools (Rotz et al., 2019, IPES-Food & ETC Group, 2021). Simply put, to these actors, fewer profits are gained from agroecological systems, in which farmers retain more dependence on their inputs, data and livelihoods. Digital tools reliant on off-farm control and ownership of data, or that devalue diverse sources of knowledge in the analysis of data, risk the further commodification and privatisation of skills and knowledge, incompatible with a paradigm that seeks to improve participation, transparency and equity within food systems.

In contrast, digital technologies developed under the agroecological paradigm may allow for more equitable up-skilling, cooperative learning, mentorship, sharing of resources and other practices currently incompatible with current industrial food system objectives. Technologies developed using transdisciplinary and participatory research methods could respond to real users' needs. Farmer-to-farmer knowledge exchange and open-source information-sharing can be used to democratise the development of technologies and the use of data (compatible with the Elements of Co-creation and sharing of knowledge, Human & social values, and Responsible Governance). For example, Geographic Information System (GIS) technologies could provide additional services to understand complex ecosystems and support soil fertility mapping, classification of land or crop suitability, or modelling alternate inter-cropping scenarios (thereby contributing to meeting the Elements of Efficiency, Synergies, and Resilience).

With the growing availability of open-source software and data, versions of GIS technologies often exist in shareable formats and in ways that enable farmers to store data on servers that they own.

Examples of these methods include Farm Hack, a community-led approach to the development, modification and sharing of designs for farm tools; mySoil, a digital application based on crowd-sourcing soil data in their area; or the Macho Sauti platform connecting small-scale farmers and researchers in Tanzania to share successful agroecological practices using simple ICT tools. Other horizontal and bottom-up efforts include Atelier Paysan (France), social enterprises such as Farmigo (USA), Hello Tractor (Nigeria), or Farm.ink (Kenya), or public initiatives such as the Kiran Rath app (India), amongst many others. Digital apps being developed across the world are also helping strengthen relationships between producers and eaters by developing more efficient community-based agriculture systems (e.g., FarmLife in India, BeetClock in the USA, La Ruche qui dit oui in France) or by helping food companies sell their products more transparently (e.g., Almond in the UK, HowGood in the USA, OrgHive in China).

In short, compatibility between agroecology and digital innovation very much depends on how new digital tools are integrated into food and farming systems, on the objective these tools were developed to meet in the first place and the opportunity costs in the adoption of digital technologies. If digital technologies can serve to underpin an agroecological transition and serve the common good, then the potential combination of these two approaches for food systems transformation is made more clear. Involving users in the design and training of digital agro-equipment, creating financial incentives for innovative equipment purchase, sharing costs among cooperatives and farming communities, or exchange platforms to facilitate producer-eater relationships are pivotal aspects of adapting digital tools to agroecological innovation.

As it relates to policy support, if the European Commission is putting significant emphasis on digitalisation as a way to adapt *conventional* agriculture to current challenges, then it is merely proposing a *technological fix* to (arguably) make agriculture less impactful on ecosystems and the climate with little consideration to its deeper socio-economic impacts. However, if digital tools are designed and adopted *to complement* and not *instead of* basic agroecological agronomic and socio-economic principles, they could certainly be deployed to build environmental sustainability, transparency, equity and fairness. In addition, low-tech methods need not be readily discounted, as they are often equally or more effective depending on farm size and geographic area while remaining affordable, adaptable and easy to adjust. The digitalisation of agroecology should aim to enhance synergies between these two concepts and improve resilience based on farmers' and/or eaters' needs and capacities to adopt those technologies. While beyond the scope of this short piece, further consideration must also be given to how the digitalisation of food and farming systems will serve and prioritise those actually producing our food – namely, how it will affect a growing portion of agricultural labour.[4]

The compatibility between digital innovation and agroecology is real but must be considered carefully. As it stands, the Farm to Fork Strategy highlights an active role for the financial and private sector in the development of digital food and agricultural systems, but such a focus runs the risk of promoting the further concentration of power in our food systems if it is not managed and regulated transparently. While the private sector can contribute to a just digital transition, the public sector has a crucial role to play in putting strong conditionalities on the distribution of research and investment funds to develop any technology. If public money is to be spent for the public good, the role of the public sector is not to make the digital transition possible at any cost, but to ensure it is just and equitable and goal-oriented which means in this context supports a transformation process toward more agroecological systems.

As it stands, only a very small proportion of public agrifood investments is currently aimed at supporting agroecology (Biovision & IPES-Food, 2020). Crucial to the EU's support of digitalisation will be its ability to demonstrate transparency and accountability around decision-making, funding, monitoring and impact measurement of its investments. Public funding will need to be founded on criteria meant to deliver on a much-needed agroecological transition, delivery of public goods and coherence between the EU's currently discordant agricultural trajectories. The need for inclusive and multi-stakeholder discussions will prove crucial to meet this end, as will ensuring the democratisation of knowledge. A key characteristic of agroecology – and the food systems transformation we need – is to put people before profits. If the EU wants to embrace agroecology as the key paradigm to transform food systems and leverage the potential of digital technologies in this transformation, the very Elements of Agroecology should serve to guide the research, development and adoption of these technologies, ensuring that farmers and eaters – in other words, that citizens themselves – are those who benefit first and foremost from their adoption.

THE BIODIGITAL POWER GRAB: DATA AS INDUSTRIAL INPUT AND RESOURCE FOR THE NEXT AGRIBUSINESS ASSAULT

JIM THOMAS, ETC GROUP, CANADA

In 1918 the John Deere company sold its first commercial tractors launching what was to become more than a century of commercial input agriculture. In the following years widening vistas of monoculture opened up as fossil-fueled tractors became the setting for rocketing use of synthetic fertilisers (originally developed for munitions), synthetic pesticides (originally designed as nerve warfare agents) and hybrid and patented genetically engineered seeds. Within decades a new industry discovered that it could make enormous profits selling these agricultural 'inputs' to farmers under the promise of higher yields and greater efficiency.

A century later that 'input agriculture' model, or 'agribusiness' as its better known, has transformed the face of the planet with a grossly wasteful system that drenches the soil in toxic chemicals, belches greenhouse gases, has driven a 75% loss in genetic diversity and stripped away the ecological resilience of over 70 per cent of farmland - all to feed less than a third of the global population (the rest still subsist on small farms). To an outside observer, this century-long experiment in input-based agriculture clearly deserves to be marked as a dramatic 'fail'.

Yet, the agri-giants who grew rich and powerful from this system are now combining their might with cash-rich data titans and investor-financed biotech firms to roll out an encore. This time they are reorganising around two further 'inputs': Data and DNA. This new "biodigital" mode of agribusiness is emerging as an alignment of big data and machine learning (AI) strategies, robotic automation and a wave of novel genetic engineering approaches, wrapped in thin 'green' promises of eco-efficiency. Unchecked, it will likely prove as disruptive, extractive and destructive as the last input agriculture wave or worse.

There is a counterforce. In 1924, as early tractors fanned out to the fields, Rudolph Steiner gave a series of lectures on agriculture in Koberwitz Germany preparing the ground for what was to become the Organic Agriculture movement. This movement has doggedly confronted the input model with a scientific understanding of ecological relationships and closed systems – what we today term agroecology. Organic agriculture has largely refused to accept the free ride of 'inputs' from somewhere else being added to agro-ecosystems – knowing that the real cost of health, energy, toxic leaching and fossil extraction behind input agriculture cannot be externalised. That systemic recognition of the connectedness between organisms and the processes linking them has brought organic and agroecological movements mainstream support. The input agriculture giants, now evolving into a new bio-digital model, would like nothing more than to co-opt this trusted movement and move the global ecological agriculture movement to embrace the promises of the Data and DNA input sellers. To do so would be for organic production to shift radically into the exact input-driven approach that it has rejected for almost a century.

This chapter illuminates how the new bio-digital farming model has at its heart at least two very important lies: firstly, it is simply offering the farmer a better tool to organise their own affairs. Secondly, that data is not an input but weightless, free and inconsequential. This chapter also touches on how the discussion on digital technologies should address bio-digital convergence and new financialisation strategies since 'data' is only half the business plan.

DATA AS EXTRACTION, SURVEILLANCE AND POWER GRAB

Popular imagery of digital agriculture is full of hardware kits – drones in the sky, robots in the fields, iPads mounted on tractor cabs. Yet the beating heart of the digital farming revolution, particularly in row crops, are farming data platforms that collect and combine all the data collected with these devices. Examples are Bayer's 'Climate Fieldview', John Deere's 'Operation Center' or Corteva's Granular and Encirca software – which appear light and helpful.

Of these, Bayer's 'Fieldview' and Farmrise platforms, developed from Monsanto's almost billion-dollar purchase of Climate Corporation in 2013 are the clear market leader - grabbing half of the digital farming market. Fieldview is currently used on 150 million acres in 23 countries, tying over 70 partners into a digital ecosystem of farming data "apps" that mimic Apple's "app store". Fieldview is startlingly cheap and promises to helpfully "organise" data from across farming operations, combine it with 'always-on' data about weather, soil, markets and more and, most importantly, let it be processed 'somewhere else' (in the cloud) to generate targeted "prescriptions" for increasing on-farm productivity.

Farmers who sign up for the 'BayerValue' service get Fieldview for "free" plus discounts on purchasing Bayer's chemical and seed inputs. Under new 'outcome-based pricing' schemes farmers who agree to follow the exact prescriptions generated by the Fieldview system are even guaranteed a price on market day or else Bayer pays the difference on a loss or splits the gains on any excess. It's a system built to further monopoly dominance in the input supply chain since those prescriptions inevitably recommend Bayer products. Yet, for Bayer, it is primarily a rapacious data-harvesting machine hoovering up petabytes of real-time fine-grained data about global agricultural conditions and farmer behaviour. At a time when data is feted as "the new oil", this firehose of data streaming from the fields to the data centres is the reason that every large agribusiness firm is rolling out its data platform in what has been called a wild west style grab for data dominance. Farmers may think they are receiving a service from Bayer. Bayer is in fact data-mining its operations to swell its treasure - chest of different data streams – all practically for free.

The new economy of data, as explained by digital economic theorists, is a different set of logics from the old resource economies. Unlike physical commodities that increase in value through scarcity, data increases in value as more and more is hoarded and aggregated. More like traditional commodities, data is made most valuable by processing it - particularly through artificial intelligence algorithms – into actionable economic insights – and not just for the individual farmer. Promotion for farm data platforms takes care to depict farm data as something 'belonging' to the farmer that they merely help 'organise'. They keep the visual frame tight on the entrepreneurial farmer standing in a field, iPad in hand controlling his own data. But in reality, platforms such as Fieldview are extracting - that data they receive for free and aggregating, upgrading and processing elsewhere - it in large data centres running machine learning algorithms. They can then leverage that 'processed' data to sell as a commodity to land speculators, commodity traders, hedge funds, seed breeders and more. Ultimately, it is not so much the farmer who achieves a 'field view' of his own few acres but Bayer who gets a detailed and complex aerial view of the entire global acreage and food flows: of where to make financial investment bets and how to nudge and push prescriptions to suit Bayer's corporate goals. As with the extraction of intimate knowledge about users under systems of corporate surveillance and nudging that characterise Facebook, Netflix or Google, in the same way, Bayer, Deere and Corteva are setting themselves up for 'platform supremacy' in the next iteration of industrial agriculture. Of course, they would be glad to add data from organic and agroecological farm acres into their empire as additional data points and revenue streams.

These big old agribusiness giants are in turn now being joined by the very digital titans who command over half of the value of the world's stock markets. Bayer's Fieldview system for example runs on the cloud services and artificial intelligence (AI) capabilities provided by AWS – Amazon

Web Services. Amazon is currently the world's most valuable company, approaching the first-ever two trillion-dollar market cap in history. It derives 63% of its operating profit from AWS cloud services and AWS in turn regards digital farming and processing of ag data as its next major frontier for profits. These new entrants into agribusiness further tilt the already unfair power dynamics in the food system. In 2020, Amazon's declared 13.5 billion dollar profit margin was almost double the profits of the 'big four' ag input sellers combined.[5] As Amazon connects its existing expertise and data from the consumer end of the food chain to its emerging focus on transforming the production arena, this data behemoth will likely disrupt agriculture with the same ruthless efficiency it has disrupted book-selling, clothes, shoes, grocery and every other corner of business it has stepped into. Besides Amazon, Microsoft's Azure Cloud service, Alibaba Cloud and Google Cloud are all vying to win a share of the burgeoning ag-data space. While some "Digital-organic" evangelists are advocating for organic producers to enter into digital value chains as a 'living lab' for the digital revolution it would be naïve to believe that small farmers and ethical co-ops can play in the new food data economy on a level playing field without being gamed, surveilled, extracted, abused and spat out by these data titans in the coming years.

DATA AS INPUT, RESOURCES AND ENERGY

The second big lie is that data and digital farming are weightless - that they exist in ephemeral 'clouds,' move freely through the air and consist only of light mobile devices held in the hand or mounted on a tractor cabin. Physically speaking, data is energy - the movement of electrical pulses - and so is backed by an incredible amount of very tangible electricity production. In late 2017, it was estimated that the current growing 'tsunami of data' would consume one-fifth of global electricity use by 2025 – a prediction made before the Covid19 crisis supersized data used by over 50% - thanks to billions of energy-hungry zoom calls and increased use of digital platforms and automation to provide supposedly 'pandemic proof' supply chains.

As big data goes, agricultural data (along with genomic data which will be touched on below) is particularly large data indeed. Bayer boasts that it currently has over 69 billion data points, IBM estimates that so-called 'precision agriculture' generates 500,000 data points per farm each day. It has been estimated by Monsanto (now Bayer) that its sensors on harvest equipment collect up to 7GB of data per acre may be collected from digital platforms. Looking for an example the 93 million acres of industrial corn grown in just the United States alone translates to 651 petabytes of data if it was all put under digital farming (which is a realistic goal for agribusiness). According to energy economists, the Internet uses an average of about 5.12 kWh to support the utilisation of every GB of data equal to about half a dollar of energy costs per Gigabyte. Only 38% of those costs are borne by the end-user, while the remaining costs are thinly spread over the global Internet through which the data travels. A back of the envelope calculation would therefore suggest that collecting data from cornfields in the US alone would expend 3.3 billion Kilowatt Hours of energy (that is 3.3 Terrawatt hours) – approximately the electricity consumption of a west African nation (eg Senegal). Since rural areas require high energy 5G and wireless systems and involve further miles to carry data – probably this estimate based on averages is far too low.

But even this roughly calculated cost for digitally growing just the US corn crop likely significantly undercounts real energy use since it doesn't account for either the energy costs of data storage in the cloud (possibly around 13-65 million KWH[6]) or, more significantly, the energy costs of machine learning (artificial intelligence or AI) processes that generate farming prescriptions and other datasets. AI processes, while new, are proving to be considerable energy hogs. For example, Wired Magazine recently reported that using machine learning to teach a robotic hand to manipulate a Rubik's cube puzzle required more than 1,000 desktop computers plus a dozen machines running specialised graphics chips crunching intensive calculations for several months and may have consumed about 2.8 gigawatt-hours of electricity roughly equal to the output of three nuclear power plants for an hour. Cloud service companies refuse to disclose how much power their machine learning algorithms gobble up but even beyond enabling the AI-prescriptions of data platforms like Fieldview, it is clear that the hardware side of digital agriculture, in which robots are expected to use AI systems to pick, spray, weed, pack, track, milk and manipulate crops and livestock, is full of a multitude of tasks to be machine learnt that is far more complex than manipulating a Rubik's cube.

Yet the energy cost of data is only a part of the, yet again, externalised costs of data-driven agriculture – there's also the network and devices in which the data lives. The data industry has done an incredible job of hiding from view the enormous ballooning infrastructure that creates, carries, processes and stores data. Datacentres building is booming as 2.1 million new IT racks are being installed between now and 2025. A paper from 2015 estimates that some data centres use over 200 litres of water per gigabyte of outgoing data to cool their racks– equivalent to the water footprint of growing 1 kg of tomatoes or one-sixth of a kg of corn. Or to put it another way, applying digital farming to US corn acreage may potentially increase water usage equivalent to watering about 57,000 additional acres of corn.[7] The silicon, metal and plastics of the racks of servers themselves as well as the many devices being added every second to the global internet of farming things represent an ever-yawning extractive hole in the planets diminishing mineral reserves. Microchip grade silicon production transforms particularly high-quality quartz sand, of which 30,000 tonnes is mined annually in dwindling locations in China, Mongolia and the US using extremely high heat, toxic gases, hazardous chemicals and water (some experts say the world could be needing 10-100 times the available supply of chip grade silicon by 2040). At the end of their lifecycle, those same toxic chemicals leach into waterways and into the bodies of workers who are breaking and reclaiming electronic waste in West Africa, India, China and elsewhere. Millions of miles of copper and optical fibre carry data across oceans and along roadways with their own mining requirements. According to pre-pandemic estimates, the cable industry is laying fibre-optic data cables at the rate of 57,077 kilometres per hour— almost 50 times the speed of sound. The totality of this swelling data network has been described as the largest 'accidental megastructure' that humanity has ever built and the costs of this leviathan go far beyond the geophysical impacts to also the political re-arrangements of power that this infrastructure creates at all scales. Human rights violations, surveillance society, mining impacts, toxic waste streams, energy extraction, biodiversity fragmentation and water exhaustion should all be factored into the seemingly innocent 'input' of data now being added to farming systems

THE BIODIGITAL MODEL: MONETISING CARBON AND GENETIC ENGINEERING

Transforming agriculture into data not only makes the living systems that grow our food (including the people) trackable– that is, subject to surveillance capitalism as well as governments – it also makes them tractable and easier to manipulate. The flows of data amassed by Bayer, Deere and Corteva (and processed by Amazon and Microsoft) result in individual land-use prescriptions that together amount to a significant large-scale intervention in the natural world – one that can be nudged and orchestrated for non-food outcomes. This is apparent in the plans of Bayer to use their Fieldview platform to promote 'carbon farming'. The argument goes that if their AI-derived prescription can claim to sequester additional carbon in soils, farmers can apply for tradeable carbon credits as an additional 'crop' from their digitally managed lands. Whether such carbon sequestration is truly verifiable and whether it is in fact counterbalanced 'somewhere else' by the energy costs of data processing is an open question. However, Bayer and others hope to present their platform as a source of so-called 'climate-smart agriculture' insights delivering 'nature-based solutions' that can be securitised, sold and speculated on to offset 'Net Zero' promises by large emitters. As the existing limited sequestration potential of forests and conservation areas becomes apparent,[8] carbon traders will increasingly turn to agricultural soils as a source of the offsets needed to back up 'green' corporate climate claims.

As that happens, digital farming giants will manoeuvre to become key brokers not just in carbon offsets but also in other 'nature-based' financial securities (biodiversity, nitrogen, water etc) adding a lucrative revenue stream on top of farm inputs and data.

A further revenue stream that is already key for agribusiness majors will also be enhanced by the digital shift: Biotechnology. In the 1990s, firms such as Monsanto built their empire by matching new biotech seed traits like herbicide resistance to their proprietary chemicals. In the next decade, they will roll out another package of tailored crops, microbes, insects and 'gene sprays' that match the digital prescriptions of their data platforms. Consider soil: The three largest agribusiness firms have ploughed much investment into describing the "agbiome" – the specific communities of soil microbes that maintain fertility, cycle nitrogen, sequester carbon and move other nutrients and minerals. Just as health-tech startups now want to sell cocktails of probiotics tailored to individual guts so does agribusiness want to use the soil insights from digital farming to offer individualised microbe mixtures to boost specific soils, notably soils they have helped to destroy by half a century of agrotoxin use. Bayer has a $100 million joint venture with synthetic biology powerhouse Gingko Bioworks in Joyn Bio to produce genetically engineered microbes for release into agricultural soils to improve the destroyed nitrogen fixation capacities of degraded industrial agriculture soils. For Bayer, who does not have fertiliser interests as of yet, the prospect is that their digital platform will recommend microbes that could be engineered, patented, licensed and sold to precisely address specific (degraded) soil types – and if nitrogen fertiliser is displaced, maybe, they can also claim carbon credits, too. Down the line, as digital surveillance spots new diseases or environmental stresses, seeds may be rapidly gene-edited (at least so they hope) and offered to fit that niche or new RNAi sprays can be designed and sold to apply as part of digital prescriptions.

This is the perfect ultimate business model for complete capture: during the second half of the past century, these industries profited from destroying and degrading the agricultural lands and their functional biodiversity with their inputs – toxic coated seeds, toxic pesticides and destructive fertilisers – only to now profit even more from offering the pseudo-'solutions' that claim to 'fix' the failing processes and finally finish off the complete capture of the agro-food system. Needless to say that the true price for these 'pseudo-solutions' will be paid by all and future generations to come, provided humanity manages to survive this century of mad self-destruction.

THE ENVIRONMENTAL IMPACTS OF ICT

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At first glance, the apparent immateriality of data flows and the smallness of our mobile devices may lead us to think that the environmental impacts of information and communications technologies (ICT) are insignificant when compared to those of other sectors, such as agriculture. However, digital technologies constitute a massive, distributed and interconnected system of physical devices and energy-intensive processes. Although the environmental impacts of ICT are not readily perceivable upon casual observation, their magnitude is actually quite considerable, and therefore demands close scrutiny. In 2020, the estimated contribution of the ICT sector to global CO_2 emissions was about 2%, surpassing the impacts of the airline industry. However, studies indicate that the carbon footprint of ICT is systematically underestimated and that their share of global emissions could reach as high as 3.9%. This figure is certainly alarming, but how can we measure the environmental impacts of ICT more precisely? Is it possible to go beyond the carbon footprint in order to assess additional impacts in detail, such as the usage of resources or waste? Let's look at mobile devices. In 2015, the annual production of mobile devices, which included 1.9 billion phones, 60 million laptops and 230 million tablets, consumed about 1 exajoule (1018 Joules) of primary energy. But it should be clear that the life cycle of a device only begins at the stage of its production, and that many other factors should be taken into account. The average lifetime of a mobile device is about 2 years, forcing a sustained pace of production. And, before it becomes obsolete, a mobile device will consume about 4 kWh (kilowatt-hours) annually. Moreover, we should not forget that mobile devices are merely nodes in a global network of interconnected computers, some of which have the much greater processing power, and therefore a larger energy footprint. The network itself relies on powerful computers known as data centres, which only in the US consumed about 91 TWh (terawatt-hours) of electricity (about 2.2% per cent of the total national generation capacity) in 2013. This figure increased to 200 TWh in 2018, more than the annual energy consumption of countries such as Iran.

From supply chains and production, and up to the full life cycle of electronic devices, their planetary-scale interconnectedness highlights the extreme difficulty of estimating their environmental impacts with precision. Nevertheless, even a superficial overview reveals that these impacts are far from negligible. It is true that ICT may offer opportunities for reducing CO_2 emissions in other sectors through the streamlining of resource and energy-dependent processes. However, there is no evidence that digitalisation, in its current global configuration, can help the world achieve the carbon savings required by 2050. It might be argued that ICT are quickly trending toward renewable energies and that their impacts in terms of carbon emissions will be drastically reduced in the near future. In fact, from 2010 to 2015, ICT companies went from a near-zero contribution to renewable power-purchase agreements with energy providers, to account for more than half of such contracts. However, it is important not to lose sight that so-called "green" energy sources actually bring into effect considerable burdens on the environment. Paradoxically, with the progressive "greening" of ICT, we might be seeing a shift from CO_2 emissions to the various impacts caused by the mining of all kinds of minerals, which altogether constitute a significant structural element of clean technologies. Since 2010, the demand for minerals needed for a new unit of power generation capacity, such as that of the lithium-ion batteries used by all kinds of digital devices, has increased by 50%. The rising demand for minerals has brought a corresponding global increase in the negative impacts of mining, among which 90% of biodiversity loss, more than half of carbon emissions and about 100 billion tons of solid waste every year.

Additional effects of mining on ecosystems include the pollution of soils and water sources, alongside systematic human rights abuses such as dispossession of indigenous territory and labour exploitation.

In face of this overwhelming scenario, it becomes clear that most of the negative environmental impacts of ICT cannot be entirely avoided, at least not in the short term. In fact, experts agree that the ICT sector will not reduce its emissions and other related impacts without an extensive joint effort involving strong political regulation and effective corporate action. However, the damaging effects of ICT in specific contexts may be minimised through the careful application of comprehensive evaluation tools and methodologies that integrate the assessment of life cycles, tradeoffs and modes of usage. In general, researchers have identified a set of three categories that describe the various modes of interaction between ICT and the environment:

1. Direct impacts: Direct impacts refer to the effects due directly to ICT products, services and related processes. These impacts consider the resources and emissions caused by the production, usage and disposal of ICT.

2. Enabling impacts: Enabling impacts of ICT to tend to be beneficial, and derive from processes of digitalisation that reduce conventional environmental impacts across different economic and social activities.

3. Systemic (or indirect) impacts: Systemic environmental effects of ICT consider changes in production and consumption activities, as well as new patterns in user behaviour that impact the environment in far-reaching ways that may not be immediately observable.

The research field that evaluates the environmental cost of ICT largely focuses on direct impacts, which can be measured by single and simple performance indicators, such as CO2 emissions. Because of their immediacy, these indicators are preferred over more complex compound indicators, such as LCA (Life Cycle Assessment) or Green IT BSC (Green IT Balanced Scorecard). Therefore systemic impacts remain underexplored since their estimation entails variables such as changes in consumer behaviour and interrelated socio-economic, cultural and human health impacts, both favourable and adverse, which are particularly hard to measure. However, if we wish to mitigate the damaging environmental consequences of ICT, the effort must be made to identify their systemic impacts. It is only by doing so that we can provide decision-makers and the general public with actionable information on how to apply digital solutions in an environmentally responsible way.

PART II
THE WAY FORWARD - WHAT SHOULD DIGITALISATION THAT IS COMPATIBLE WITH THE VALUES AND PRINCIPLES OF AGROECOLOGY LOOK LIKE?

AGROECOLOGICAL PRINCIPLES APPLIED TO ICT

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There seems to be a growing recognition of the importance of integrating ethical principles within the field of ICT. For example, the 'Principles for Digital Development' present nine "guidelines designed to help digital development practitioners integrate established best practices into technology-enabled programs." Or, the 'Ethical Design Manifesto', which identifies human-centred principles that can be applied to the design of ICT and groups them into three categories: Human Rights, Human Effort and Human Experience. The growing interest of the technological sector in ethics should certainly be welcomed, yet it runs the risk of being used merely as a form of *ethics washing* to hide questionable or ultimately harmful practices (Piper 2019; Metzinger 2019). Therefore, true commitment from the part of the field of ICT is crucially needed.

We propose a set of principles for the development of ICT initiatives for agroecology. General principles and ethical guidelines such as those mentioned above are certainly useful and beneficial. However, we argue that it is necessary to translate them into specifically focused principles that are grounded in the values upheld by the field of practice to which they apply so that they can adequately address its particularities in meaningful and locally relevant ways. We have identified the need for a set of diversely focused principles to guide the design, development, implementation and evaluation of ICT within agroecological transitions throughout our work with farmers in developing countries. Thus, we recognise that ethical principles can cut across different fields of research and practice, yet they are fundamentally contextual and respond to diverse social situations and scenarios since ethics is necessarily grounded in agreement and experience (Lambek 2010). Nevertheless, this does not mean that ethics lacks basic underlying purposes, such as well-being, justice or solidarity. Therefore, we claim that *agro-ecological* principles and considerations are needed as guidelines for the development and implementation of ICT in the context of agroecology, to reinforce its core values and practices.

In order to draft a set of principles for ICT4AE (ICT for Agroecology), we identified the values and elements that constitute the foundations of agroecology and attempted to translate them to the design and development of ICT. We took the 'Ten Elements of Agroecology' proposed by FAO (FAO 2018b) as a starting point and translated them into corresponding principles for ICT4AE. The 'Ten Elements of Agroecology' are the result of a process that synthesises scientific studies, namely by Altieri (1995) and Gliessman (2015), with discussions held at FAO's multi-actor regional meetings (FAO 2018b) and may therefore be viewed as the consensual fruit of broad experiences and consultation processes. According to FAO, the 'Ten Elements of Agroecology' are interlinked and interdependent and are intended to serve as an analytical tool that "can help countries operationalize agroecology," as well as a guide for "policymakers, practitioners and stakeholders in planning, managing and evaluating agroecological transitions." (FAO 2018b). Similarly, the principles of ICT4AE we propose here seek to serve as a guideline for actors involved in the design, development, implementation and evaluation of ICT tools and platforms within agroecological programs.

The translation of the elements of agroecology into the principles of ICT4AE included two consecutive stages. The first one was a process of abstraction in which the essential concept of each element of agroecology was identified. This process was followed by the concretisation of each essential concept in the field of ICT. For example, the first element of agroecology refers to the biological diversity of ecosystems. Its essential concept, *diversity*, was re-contextualised in the field of ICT as the diversity of technologies or media that people living in a specific environment use to communicate and exchange information.

We considered the full technical cycle of designing, prototyping, testing, implementing and scaling, as well as the social, cultural, economic and environmental implications of ICT platforms. Our main premise is that applying ICT to support the transition toward agroecological food systems can be best achieved if ICT tools and platforms are developed according to principles that are in line with the elements of agroecology.

Here, we present the outcomes of the translation of the elements of agroecology into principles for ICT4AE. Table 1 lists the principles of ICT4AE, each of them aligned with its corresponding element of agroecology. We also illustrate how digitalisation processes that follow the logic of conventional agriculture may overlook each principle.

Table 1. Translation of the elements of agroecology into principles of ICT4AE.

PRINCIPLE	ELEMENTS OF AGROECOLOGY (FAO 2018B)	PRINCIPLES FOR ICT4AE	CONVENTIONAL AGRICULTURE
Diversity	Integrating and increasing the biological diversity of ecosystems into agricultural systems.	Integrating appropriate and relevant ICT available in a specific context and favouring their interoperation	"One size fits all"
Co-creation and sharing of knowledge	Activating participatory processes where indigenous and scientific knowledge can lead to context-specific innovation.	Creating tools that combine top-down (scientist-to-farmer) with bottom-up (farmer-to-scientist) and peer-to-peer (farmer-to-farmer) modes of communication, aimed at the co-creation of situated agroecological knowledge.	Farmers are often regarded as clients of prepackaged information coming from unknown sources.
Synergies	Enabling the combination of diverse actors, activities and conditions to build biological, ecological, economical and social synergies in food systems.	Recognising ICT as a valuable element that supports larger sets of actors and processes.	ICT as drivers of agricultural transformation, often at the expense of other actors.

PRINCIPLE	ELEMENTS OF AGROECOLOGY (FAO 2018B)	PRINCIPLES FOR ICT4AE	CONVENTIONAL AGRICULTURE
Efficiency	Optimising food systems to produce more using less external inputs and resources.	Taking advantage of the full potential of the different ICT platforms available in a specific environment, regardless of their level of sophistication, to maximise their usefulness, as well as favouring energy-efficient technologies.	Privileging sophisticated (and often costly or largely untested) ICT for the sake of efficiency, while energy efficiency is not necessarily considered.
Recycling	Imitating and supporting biological processes to minimise waste of resources in food systems.	Reusing and repairing ICT to extend their lifespan and usefulness as much as possible.	Recycling is not always emphasised since business models are often based on replacing obsolete ICT.
Resilience	Increasing biological diversity and maintaining the functional balance of agricultural systems to enhance resistance and recovery in adverse conditions.	Designing sustainable ICT capable of withstanding adverse conditions, as well as minimising farmers' dependency on prepackaged information, monetised loops and external inputs.	Business models are often based on farmers' dependency on external inputs, including data, energy, devices and connectivity.
Human and social values	Protecting and improving rural livelihoods, equity and social well-being.	Respecting the integrity of farmers and their communities by placing them at the centre, avoiding disruptive practices such as surveillance or non-consensual extraction of data and supporting farmers' full ownership of ICT.	Farmers are often considered inefficient and unreliable, therefore replaceable by algorithms or machines and are also regarded as mere sources in data extraction and surveillance schemes.
Culture and food traditions	Supporting healthy, diversified and culturally appropriate diets.	Developing ICT initiatives that integrate local cultural values, including language, rules, regulations and religious considerations, into the core of their tools and methodologies.	Farmers must adapt to ICT, regardless of cultural constraints and conditions, since local culture and traditions are not necessarily considered.

PRINCIPLE	ELEMENTS OF AGROECOLOGY (FAO 2018B)	PRINCIPLES FOR ICT4AE	CONVENTIONAL AGRICULTURE
Responsible governance	Designing and implementing local, national and global political mechanisms that support sustainable agriculture and food production.	Complementing ICT platforms with corresponding governance provisions that ensure their appropriate usage by integrating a wide range of local actors, organisations and institutions.	ICT are often aimed at individual farmer-entrepreneurs or operators, while governance is often delegated to "smart" algorithms.
Circular and solidarity economy	Creating virtuous cycles that connect producers and consumers, prioritise local markets and support economic development, as well as optimising food systems by redesigning them according to the principles of the circular economy.	Embedding the principles of circular and solidarity economy into the design of ICT tools and methodologies, such as implementing locally relevant and solidary business models, orminimising and sustainably managing waste related to ICT usage.	Business models often follow the startup paradigm: "move fast and break things" and waste related to ICT usage is not necessarily considered.

In the following paragraphs, we discuss each of the principles for ICT4Agroecology.

1. **Diversity:** In the context of ICT and media in general, the notion of *diversity* may be understood as the multiplicity of means through which people communicate and exchange information in a specific environment. In order to respect such diversity, an ICT4AE initiative must start by examining how ICT are used in the particular context where it will be implemented and what are those technologies' affordances[9] and limitations. Instead of narrowly focusing on solutions that are based on a single technological platform, ICT4AE programs can be designed to integrate a diversity of locally relevant media. In ICT4AE, diversity also entails the examination and possible assimilation, of previously existing sociotechnical strategies in support of agroecology, such as radio broadcasts or the dissemination of printed media, that may complement and enhance the implementation of ICT.

2. **Co-creation and sharing of knowledge:** Agroecology recognises the need for bottom-up, participatory approaches to the co-creation of knowledge (Altieri 2002). Thus, a crucial aspect of ICT4AE is the combination of vertical and horizontal modes of co-creation and sharing of knowledge, which contrasts with the top-down mode often found in conventional agricultural extension programs (Rivera-Ferre 2012) and, correspondingly, in digital initiatives developed in the context of conventional agriculture that tend to deliver prepackaged *solutions* or *expert recipes* to *passive* farmers (Tisselli 2016). By harnessing the full interactive potential of digital technologies and networks, ICT4AE can enable and harmonise vertical, that is, bottom-up (farmers to experts) and top-down (experts to farmers) and horizontal (peer to peer) modes of communication, co-production and dissemination of knowledge. Farmers may, thus, be fully recognised as co-creators of knowledge, which can be fruitfully enhanced through co-development with other actors. Farmers are also considered co-designers, co-implementers and co-evaluators of technological platforms in the context of ICT4AE, by including their input and participation at every step of the ICT life cycle.

3. **Synergies:** In ICT4AE initiatives, ICT are regarded neither as substitutes for human skills, knowledge or cooperation, nor as stand-alone solutions or drivers, but instead as strongly contextualised elements that act in synergy within a broader set of social, political and economic actors that jointly seek to strengthen agroecological food systems. Therefore, ICT4AE programs should recognise and tie their efforts together with the other actors and forces that operate in their environments, such as farmer associations and cooperatives, policies, institutions, or governmental and non-governmental organisations. Moreover, agroecology as a social movement seeks to build cohesion between its different stakeholders (Wezel et al. 2009). Cohesion relies on relationships of mutual trust, which are built mainly through physical interaction, rather than through "smart" contracts such as blockchain[10] transactions or the remote modes of connectivity provided by ICT, which often result in superficial and detached communication that can further separate people from each other (Turkle 2011; Kendall and Dearden 2017). Therefore, ICT4AE considers ICT as supporting tools to enhance face-to-face communication and cooperation.

4. **Efficiency:** Often, simple and widely accessible technologies, such as printed media, radio or SMS messages prove to be the most effective and cost-efficient tools in helping to strengthen the principles, practices and value chains of agroecology. Consequently, ICT4AE programs reject empty visions of technological innovation, in which the *new* is pursued and implemented for its own sake, typically as a standalone business model and is often described as *revolutionary* or *disruptive* (Walter et al. 2017). Instead, ICT4AE initiatives make the effort of examining their particular contexts to identify and eventually integrate the most accessible, efficient and effective technologies available, regardless of their novelty. In addition, ICT4AE initiatives will favour energy-efficient technologies, as well as renewable sources of energy.

5. **Recycling:** Recycling in ICT4AE is guided by the principles of reusing and extending the usefulness of ICT, as well as limiting waste and the unnecessary expenditure of resources, such as technological artefacts or energy sources, both for economic and environmental reasons. Recycling entails making use of ICT that are already present and useful in the specific context of an ICT4AE initiative, as well as repairing, reusing and sharing the devices that are involved in such initiative.

6. **Resilience:** In the context of ICT4AE, resilient projects are those that can adapt and thrive in challenging sociotechnical and environmental settings, such as those with unreliable internet connectivity, limited or non-existent possibilities of repairing or replacing a broken device, or adverse weather conditions. But ICT4AE initiatives also aim to encourage resilient agroecological practices and this may be achieved by enhancing the participating farmers' abilities to acquire and share knowledge, carry out autonomous research and strengthen their social networks. Consequently, ICT4AE initiatives will avoid creating or increasing farmers' dependency on prepackaged information, monetised loops and external inputs.

7. **Human and social values:** The careful design of an ICT4AE initiative entails a detailed examination of the ethical principles practised in its specific social context, as well as local cultural values and the integration of those principles and values into its tools and methodologies. ICT4AE respects the integrity of farmers and their communities, as well as their ecosystems, by placing them at the centre. Consequently, ICT4AE avoids socially and ecologically disruptive practices, such as the introduction of technologies and methodologies that disturb or contradict local ethical and cultural values, the digital surveillance of farmers' communication and activities, the monetisation of farmers' data and metadata through non-consensual extraction, or the implementation of ICT programs with contents that encourage decontextualised

or poorly modelled practices that may result in the mismanagement of land, crops or livestock. ICT4AE promotes farmers' full ownership of tools, methodologies and data, by integrating their views, ideas and values at every step of the ICT cycle.

8. **Culture and food traditions:** In connection to the above principle, ICT4AE initiatives that integrate culture and food traditions are those that incorporate local cultural values and traits, such as laws, religious constraints, visual representations, languages and other cultural manifestations at the very core of their respective tools and methodologies. In the same vein, ICT4AE seeks to develop technological platforms and contents that give support to locally relevant crops, foods and methods of cultivation, preparation and exchange.

9. **Responsible governance:** ICT4AE initiatives will include contextualised governance guidelines, workflows and methodologies, co-designed and led by farmers and their representatives, aimed at providing frameworks for responsible, locally relevant and accountable usage of ICT platforms. Additionally, ICT4AE governance frameworks will pursue alliances and partnerships with a wider range of local, regional and global actors, including governments, organisations and institutions.

10. **Circular and solidarity economy:** By reusing and recycling ICT tools and through the minimisation of technological resources and the maximisation of their potential, ICT4AE initiatives can integrate the principles of the circular economy. Moreover, by practising the co-creation and sharing of agroecological knowledge, ICT4AE will seek to emphasise solidarity, understood as a reciprocal, non-competitive mode of communication and collaboration in which the well-being of farmers, communities and ecosystems is always the overriding concern.

The translation of the 'Ten Elements of Agroecology' into principles for ICT4AE can be a fairly straightforward process. However, integrating and applying the principles of ICT4AE into agroecological transitions is a complex task that needs to carefully consider local environments and contexts at every step. It also requires rethinking the role of ICT, traditionally described as context-independent, primary or single *drivers* of *progress* (Feenberg 1999; Pinch and Bijker 1987), as one of support that aims to contribute to the flourishing of agroecology, as well as its scaling up and out. [11] Consequently, ICTs in support of agroecology need to assume a different function, as well as a different integration model. The choice of ICT platforms and the way in which they are implemented can serve to strengthen (or weaken) the impact of a specific agricultural model (Kendall and Dearden 2017). Thus, we argue that ICT in agroecological programs should not be chosen based on their novelty, their efficiency to solve a predefined problem or their potential to deliver quick, measurable results, but rather on the degree to which they may agree with the principles of ICT4AE.

The principles we have proposed here are not necessarily meant to be used as a checklist to evaluate the extent to which a specific ICT component may or may not be in line with agroecology. Instead, the ICT4AE principles are intended as a guideline for the design of ICT in support of agroecological programs that address specific aspects of agroecology. An agroecological program aimed at training farmers, for example, may include a supporting ICT component that follows the different ICT4AE principles to varying degrees, but with a special emphasis on co-creation and sharing of knowledge, human and social values and culture and food traditions.

CASE EXAMPLES: HOW COULD DIGITALISATION SERVE THE AGROECOLOGY AND ORGANIC FARMING COMMUNITIES?

PREPAREDNESS OF THE ORGANIC FARMING COMMUNITY TO ENTER THE DISCOURSE ON DIGITALISATION OF ORGANIC FARMING - EXPLORATORY SURVEY AMONG SWISS ORGANIC FARMERS

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BACKGROUND

While digitalisation is currently being pushed as yet another technology to fix the problems caused by conventional agriculture, the agroecology and organic farming community appear to be still relatively unprepared to engage in this debate. Several publications with ties to the food sovereignty and agroecology movement have recently begun to address digitalisation (e.g., Anderson et al., 2020; ETC Group, 2018; Global Network for the Right to Food and Nutrition, 2018; Idel & Beste, 2020; IPES-Food, 2017; Nyéléni newsletter, 2019). Nevertheless, there seems to only exist a comparably small body of literature covering concepts of digitalisation in support of agroecology. While the potential impacts of digitalisation on agricultural sustainability are still difficult to assess (Moschitz & Stolze, 2018), a recent review reaffirms agroecologists' concerns that digitalisation could unravel in two extreme scenarios, one with open, collaborative systems – or one with closed, proprietary ones (Wolfert et al., 2017b). Still, the role of digital technologies as a transformative force in transitioning to sustainability remains understudied (Klerkx et al., 2019). For example, research gaps exist concerning digital technologies' relation to different paradigms in agriculture such as agroecology, as well as the technologies' role as a change agent (ibid). For example, empirical questions are left to be answered regarding digital technologies' role in enabling actors in the food system to foster change, supporting alternative niches, or reinforcing incumbent food regimes (ibid). We consider the involvement of agroecological farmers imperative in this debate.

Therefore, we explored if and to what degree Swiss organic farmers are prepared and informed to enter the discourse about digitalisation in support of organic farming and are empowered to effectively contribute and shape technological development. More specifically, we wanted to understand whether farmers understand and articulate positions and arguments that have recently been put forward by various stakeholders and actors in the debate, incl. corporate and academic proponents, critical scientists and social movements (references for this can be found in other chapters of this publication). If that were not the case, farmers would find themselves in vulnerable positions, potentially making uninformed decisions and entering path dependencies they were not aware of.

APPLIED METHODS

An exploratory survey was conducted that only serves as an illustration of the range of positions that we believe characterize the state of understanding in organic farming communities, certainly in Switzerland but probably also beyond. A total of seven Swiss organic farmers were interviewed in a semi-structured way. The sample group of farmers were chosen to represent different farming segments. Therefore, farmers holding leading positions with expertise in different product segments of the Swiss organic association 'Bio Suisse' were contacted and agreed to participate. These farmers not only have specific knowledge about their respective farming segments but also about the (Swiss) food system level. The interviewees represented the following expert groups: 'Arable crops', 'Poultry and eggs', 'Meat', 'Viticulture', 'Vegetable/potatoes', 'Fruit', 'Dairy'.

Interviews: Farmers agreed to be interviewed following a specific questionnaire and also gave their consent to cite their responses in an anonymized way. The semi-structured interviews were explorative and covered three thematic fields following a brief presentation of own farming operation and professional background: A) Overview: terminologies used in the field of digitalisation, (future) usage of digital tools, perception of colleagues' attitudes; B) Perceived potential benefits and risks: Anticipated positive or negative effects on the three dimensions of sustainability (social, economic and ecological); C) Conditions: Governance-related questions, perceived sense of urgency for digitalisation. Part B received the most attention during the interviews, farmers elaborated on the pros and cons of digitalisation concerning the three dimensions of sustainability.

OUTCOMES AND DISCUSSION

"We in organic farming, in particular, … have an absolute opportunity here; we can and must get fully involved now with these technologies" versus *"If [going digital is] what the organic movement wants, let them, we're a democracy. But then I certainly won't label my produce like you anymore".*

These two quite different opinions illustrate digitalisation's potential for division among the agroecological/organic community. Farmers were divided over the question of how much digital 'Hardware' to use, with issues concerning 'Software' still being largely under the radar. 'Digitalisation' is much more perceived as a continuation of past trends of intensification through automation, i.e. 'hardware' technologies associated with Precision (Livestock) Farming. On the other hand, 'Software' – Big Data analysis systems, farm management and information systems, proprietary software, etc. – encompasses a wide spectrum of actors (e.g., Bayer AG, 2018; ETC Group, 2018; Roland Berger Strategy Consultants GmbH, 2019) who create 'value from data' while shifting to outcome-based and/or service-oriented business models instead of the formerly input-based business models.

HARDWARE

It could be argued that Swiss organic farmers are already in the midst of an ongoing debate that revolves around intensification and automation. Digitalisation has been described to be part of a wider trend of those organic farmers who produce for mass markets, fuelling a conflict between those farmers who are ready to use new technologies such as automatic hoes or weeding robots to replace costly manual labour ('Digital Organic') and others, 'Artisanal Organic' farmers, who adhere to a vision of small-scale farms that rely more on manual labour and pursue goals related to agrarian culture and artisanal craftsmanship (see Gottwald et al., 2019). Hence, there was disagreement among farmers, including ethical and philosophical questions about preserving small farms, replacing human workers and which agricultural tasks could and should be automated for what purpose. For example, farmer O. highlighted that "*after all, the robot doesn't observe*", indicating that robots may see and process data – but still couldn't observe with the cognitive capacity of humans. Further, farmer L. stated that he would rather transport his bales of straw manually instead of having to go for a run in the evening. Similarly, farmer H. stated that he wouldn't want to discontinue sweeping the floor if he then had to replace this meditative task with yoga.

Notably, farmers who associated more with 'Artisanal Organic' ideas often displayed some degree of fatalism and saw their way of farming as an economic niche, rather than as a vision for the entire food system. In fact, farmers proposing more fundamental change (e.g., concepts of food sovereignty) were at the same timeless optimistic that this could be achieved via politics or the organic association. Generally, there was the notion that the Swiss organic association 'Bio Suisse' has already become too large and established 'mainstream', representing too big a spectrum of farmers as to openly demand more fundamental systemic changes. Hence, especially the more 'Artisanal' farmers were appealing to each farmer's self-responsibility of joining in or not. At the same time, some were contemplating maybe creating an additional or even independent 'Artisanal Organic' label if, following further the path towards 'ecologically inspired conventional',[12] digital technologies were to be widely adopted by organic farmers. Consequently, this raises the question of whether the discourse may already be slanted towards a more 'ecologically inspired conventional' paradigm, although digitalisation does not seem to have evolved that far yet.

Nevertheless, there were some important nuances regarding the relevance of digital automation, nuances that may also correlate with the respective farming segment. Firstly, several farmers argued that some segments like poultry production or cultivation of standard fruit orchards may not experience far-reaching automation because of their inherent boundary conditions (e.g. limits of numbers of chicken) and also their small size. This argument is partially supported by a recent publication by Groher et al. (20202), who reported very low adoption rates of digital technologies in Switzerland compared to other countries. Secondly, there was disagreement among farmers about to what extent automation could reinforce structural change and foster path dependencies via price pressure and debts, which may depend on a) the efficiency gains realised, b) the relative costs of these digital technologies compared to existing machinery and c) the general political and economic environment (e.g. the subsidy systems). Thirdly, especially in the case where automated solutions (e.g. automatic milking systems) may not offer significant cost benefits, the availability of workers could be a decisive element, with some farmers stating that there is already a shortage of workers. They also pointed to tedious, repetitive work that may just not be worth preserving.

Although there seem to be many new entrants to agriculture – with 40% of them stating that they want to farm organically – they are currently struggling to find a farm to rent or buy (Dyttrich, 2015). Competing directly with a majority of farmer's successors who adhere to a logic of increasing their parents' farm to increase competitiveness (Lips, 2010) which is favoured by the current political conditions, such new entrants into organic farming have a difficult stand (Dyttrich, 2015).

For these reasons, it is hard to say whether a coexistence of both 'Digital' and 'Artisanal Organic' will be possible, or whether there could be significant spillover effects impeding the latter – or the other way round. Similarly, this raises the question of whether it is possible for organic farming to just digitalise to some extent without entering a path of dependency that could impede transitioning to 'Artisanal Organic'. In any case, the influence of political and economic framework conditions should not be underestimated. Also, there are important mechanisms that may already today subtly shift organic more towards sustainable intensification, whilst hampering the emergence of a stronger 'Artisanal Organic' faction. Most notably, this concerns the issue of institutional framework conditions, which did not receive a lot of attention during the interviews. For example, without internalising conventional farming externalities, e.g. via a pesticide tax and without addressing the huge potential of reducing food waste (e.g. Beretta & Hellweg, 2019), there will understandably be pressure on organic farmers to intensify, e.g. by deploying (digital) technologies, in order to reach price and productivity parity with conventional farming. In other words: instead of making the economic system compatible with agroecological forms of production, 'organic' is forced to be compatible with conventional economic logic, leaving framework conditions unchanged. However, these issues have hardly been brought up by farmers, as did the issue of opportunity costs in terms of research funding for the development and promotion of

truly sustainable low-tech innovation that may be more adequate in tackling agriculture's pressing challenges.
In conclusion, embarking further on the current track of automation could equate to giving in to productivism, with detrimental effects for 'Artisanal Organic' and the environment, especially in the long run. This is particularly relevant when looking at Software.

SOFTWARE

The structural transformation debate may not even be the most important element concerning the crossroads discourse. Digitalisation entails additional disruptive potential on both farm and food system levels that may, as the interviews suggest, be still underestimated by farmers. Still, there was some degree of scepticism, especially regarding the prospects of delegating decision making to algorithms. Indeed, when asked whether they would make use of prescriptive advice, all farmers negated, often referring to nature's inherent complexity and unpredictability and stressing the importance of retaining farmers as stewards and bearers of tacit knowledge. Even the one farmer most enthusiastic about digitalisation stressed that farmers' experience would even become more important with increased automation, as he expects to have more time at hand which he would then spend observing the operation. Conversely, many farmers expressed concerns that a big proportion of their colleagues may be susceptible to prescriptive planting if it is allowed to reduce risk. Some interviewees related this to existing models of contract farming, or farmers' reliance on pesticide spray plans. Additionally, a majority of farmers brought up higher consequential costs associated with digital technologies, mostly due to higher maintenance costs, e.g., for updates. However, apart from a clear reluctance to give away decision-making autonomy and some wariness about higher consequential costs, there was limited awareness of other important mechanisms that may foster a digital path dependency:

Firstly, there was only a little awareness about the software component of automated or autonomous machinery like automatic milking systems, autonomous weeders or hoes, with farmers mostly focusing on these technologies' more palpable social and economic impacts (e.g. unemployment). For example, only one farmer explicitly mentioned the machinery industry's change in business models to more service and support packages (e.g., CEMA, 2017), although some also brought up issues of repairability. This is likely owed to some degree of naiveté and lack of experience and knowledge among farmers regarding the demands on software development, update requirements and access and licensing contracts coming along with these business models.

Secondly, related to this, neither issues of data collection by machinery nor farm management and information systems received a lot of attention. Only two farmers identified the growing importance of data collection, with others questioning or even entirely dismissing the relevancy of their data: *"[Data collection] is not a danger, there's far too much data and I really don't know what they would do with all of it. I don't see so much danger in tha*t" (farmer S.). Often, privacy concerns were more related to potential state surveillance, i.e., the creation of the 'transparent farm' to authorities.

Consequently, there was only little enthusiasm to support, e.g. via Bio Suisse, the construction of open-source alternatives. However, with one farm management and information system, developed by Barto, potentially close to establishing a market-dominating position in Switzerland, this should be of particular interest to the organic association, as Barto is backed by Switzerland's largest agricultural company fenaco (Schweizer Bauer, 2018). Notably, Barto is also supported by the publicly funded Identitas AG, leading even the Swiss Federal Audit Office to question Identitas' support of this platform, which the Audit Office considers to be clearly motivated by the prospect of making economic use of the data (Swiss Federal Audit Office, 2019).

In its report, the office also prompts questions on why the Swiss government would not rather support a market independent alternative (ibid). This issue also clearly relates to the issue of opportunity costs where public resources are being used to support the construction of private, proprietary technology, instead of market-independent, open-source solutions. Swiss agroecologists may want to pay more attention to this subject. Particularly when taking into account the winner-takes-all dynamics of such platforms, there may be only a small window of time left to establish an attractive independent alternative solution (Barthelmess, 2020; Srnicek, 2017).

Thirdly, with farmers stressing the importance of self-reliance and a conscious approach to digital technologies, there has only been little debate about the potential of disruption and coercion related to digital platform dynamics. For example, a process of deskilling about farming advice has only been brought up once and the importance of pathways of closed solutions (e.g., incompatible software) seems to also have gone largely unnoticed until now. Similarly, both NGOs (e.g., ETC Group, 2018), as well as industry consultancies (Roland Berger, 2015, 2019), stressed the importance of disruptive business models and the associated race to occupy strategic control points among incumbents and new entrants, almost no farmer articulated concerns that digitalisation may unravel quickly and unpredictably. This seems to be largely owed to a lack of awareness and information about these developments taking place in entirely different and decoupled professional business domains.

Lastly, food-system level developments such as data-driven merger activity could soon lead to powerful new cross-sectoral monopolies that may drastically reduce choices for farmers while increasing corporate power in political decision making (ETC Group, 2018, 2019), as well as increase PR activity by agribusinesses to portray digital technologies as saviour technologies to build sustainable food systems (Mooney, 2020), have not been mentioned by farmers. Consequently, proposals to create political framework conditions to counteract these trends, i.e., via stringent data protection and a 'right to repair', publicly owned digital infrastructure, or even stricter competition laws were rarely or not at all brought up.

It is difficult to predict whether and how decisive such mechanisms will play out exactly. For example, how could acquiring an autonomous hoe already entail a dependency on proprietary software and closed solutions? Or could the high investment costs for digital technologies result in increasing farm sizes, which may end up becoming too big and complex for farmers to manage without digital service packages? Still, our small survey illustrates that these dynamics do not yet receive the attention they deserve in the organic farming communities despite their massive potential for disrupting current organic farming businesses. Consequently, there was no informed, vocal opposition against today's uncritical public research push and promotion, support and subsequent adoption of digital technologies, even though it looks like their social, economic and ecological impacts can so far hardly be sufficiently assessed (e.g., Moschitz & Stolze, 2018). Hence, with a board member of Bio Suisse admitting that they had no real digital expertise within the association, it can be concluded that especially Bio Suisse may want to improve on this matter.

CONCLUSIONS AND RECOMMENDATIONS

Arguably, the current technology push for digitalisation in organic farming meets a fairly unprepared community and bears potential for division between 'Artisanal Organic' farmers – a term coined already by observant organic farmers reflecting on these developments – and their 'Digital Organic' colleagues. Remarkably, a majority of interviewees were expecting digital farming to prevail in the long run, seeing approaches related to food sovereignty as mere niche strategies. However, this fatalism, or rather, lack of agency and political activism may prove decisive – especially regarding the disruptive nature of digital platform capitalism, which requires rapid, coordinated action on part of the agroecological/organic community.

The well-known 'winner-takes-all' phenomenon of digitalisation should be a sufficient incentive for the agroecological/organic community to engage with the subject thoroughly and critically. Indeed, instead of moving into niches, it may prove key for sceptical farmers to recognise the potential of collaborative action in both demanding political change, as well as in building open-source alternatives.

A first step would be to raise the awareness and level of education on this theme among the organic farming community. Furthermore, the organic farming community needs to develop its positions on what type of digitalisation they would embrace and which one they would reject. Boundary conditions for developers of digital tools as well as farm management and information systems for the organic sector need to be defined. Bio Suisse could profit from its German counterparts, who have already started to critically engage with digitalisation in various ways, including a series of workshops (AgrarBündnis, 2020, 2021; INKOTA-netzwerk, 2020).

We expect that the level of capacity and empowerment of organic farmers in other European countries to engage in this debate and shape the development of these technologies to their needs will not differ much from the situation in Switzerland, in which case we would extend our recommendation for investing in acquiring expertise and competence to the European level. IFOAM may be the best-suited actor to kick-start such an awareness-raising and self-empowerment process.

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UGUNDUZI– A CASE EXAMPLE OF THE CO-CREATION OF AN ICT APPLICATION WITH SMALLHOLDER FARMERS IN TANZANIA

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INTRODUCTION

Farmer-led research and on-farm record-keeping are valuable activities that can support smallholder farmers in their transition towards agroecological food systems. Here, an ICT platform for farmer-led research and record-keeping is proposed as both a methodology and a strategy to encourage farmer-led research and on-farm record-keeping among farmers in Tanzania. The platform, named Ugunduzi, was co-developed with a group of smallholder farmers who were in the process of adopting agroecological practices.

ON-FARM RECORD-KEEPING

On-farm record-keeping is a decision support system based on records generated by farmers, in which the different activities related to food production and their associated data are registered. Recording farming activities and transactions enhance systematic thinking and allow farmers to compare the performance of crops between years. However, record-keeping is almost non-existent under small-scale, subsistence production. The general absence of record-keeping in small-scale farming is recognised as a problem, since it prevents a systematic analysis of farm dynamics and, therefore, reduces the ability of smallholder farmers to accurately evaluate the benefits of new agricultural practices.

FARMER-LED RESEARCH

The principle of farmer participation in agricultural research is a response to the critique of top-down technology transfer models, which often minimize active farmer participation in research processes and tend to consider farmers as mere recipients of technological innovation, rather than its co-designers. In contrast, the participatory approach in agricultural research seeks to empower farmers by integrating their knowledge into research programs and giving them greater control of decision-making. Farmer-led research, a type of on-farm participatory research in which trials are designed and managed by farmers, has been recognised as a particularly well-suited strategy for favouring the uptake of new practices and technologies, as well as identifying and encouraging farmer innovation, particularly within agroecological farming systems.

DESIGN AND DEVELOPMENT OF THE UGUNDUZI ICT PLATFORM

BACKGROUND

The development of the Ugunduzi platform in 2018 came after eight years of interaction and joint work with Tanzanian farmers. In 2011, we coordinated the Sauti ya wakulima[13] project, in which a group of ten smallholder farmers from the region of Bagamoyo shared smartphones to document their observations of the effects of climate change and post them to a collaborative website.

The farmers took ownership of this project and transformed it into a space for sharing agricultural knowledge with their peers. In 2016, a consortium of local NGOs led by Swissaid Tanzania applied the tools and methodologies of Sauti ya wakulima as means to provide backstopping to farmers who were receiving training on agroecology, as well as allowing them to document their practices. The new project was named Macho Sauti and, at the time of writing, had reached about 8,000 smallholder farmers, most of them living in the Masasi region.[14] Sauti ya wakulima and Macho Sauti may be regarded as ICT initiatives that emphasise the centrality of peer-to-peer exchange and the co-creation of knowledge in agroecology.

Ugunduzi is an ICT platform, consisting of a smartphone app supported by an online database, that aims to assist smallholder farmers in their record-keeping and self-driven research tasks. Ugunduzi is the fruit of a guided process that engaged a group of farmers as co-designers. We identified a group of 10 farmers from three different regions of Tanzania (Bagamoyo, Morogoro and Masasi) who met any or all of the following criteria:

- Expressed interest in doing research at their farm
- Experimented with crops and agroecological treatments
- Practiced record-keeping for decision-making
- Had a basic familiarity or experience with smartphone apps

When the group of 30 farmers was formed, a series of iterative co-design workshops, facilitated by the author of this paper and aided by local farmer organisations, was launched.

FIRST CO-DESIGN WORKSHOP

The goal of the first workshop was to identify the concepts, elements and tasks relative to research and on-farm record-keeping according to the farmers' perspectives and actual experiences. The main research questions of this initial round were:

- How do farmers represent their farms visually?
- What is the farmers' understanding of research
- Why do they find research important?
- How, if at all, do they carry out research?
- What data, if any, do they record or would be interested in recording?

The conceptual model derived from the answers to these questions would subsequently be used to design and develop the first prototype of the ICT platform which, at that time, had no name.

During the workshop, farmers were asked to draw their farms without following any predetermined model. This activity was inspired by rich picture drawing, a technique associated with the practice of soft systems methodology. The drawing activity was also inspired by a prospective approach to drawing, regarded as an engaged practice of description that couples perception and action and that may yield significant insights into a specific matter. Subsequently, different variations of brainstorming, a key technique of design thinking, were used to delineate the farmers' understanding of research and its perceived importance, as well as the practical ways in which farmers carried out the research.

The drawing activity directly addressed the question of how farmers represented their farms visually. Two trends were detected: farms drawn with clearly differentiated and delimited plots, drawn as a grid and farms drawn in a freestyle with no clear delimitations. Overall, 27 out of 30 farmers represented their farms as a grid.

Figure 1: A farm drawn as a grid of plots

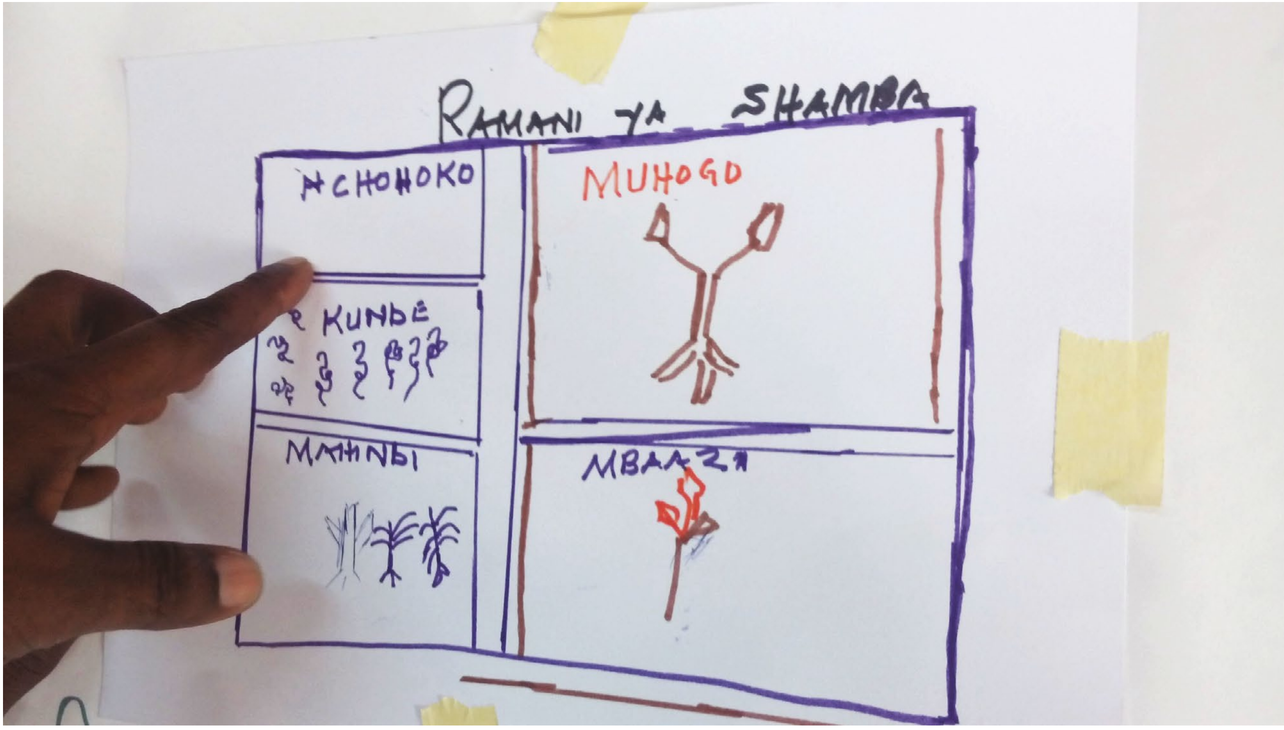
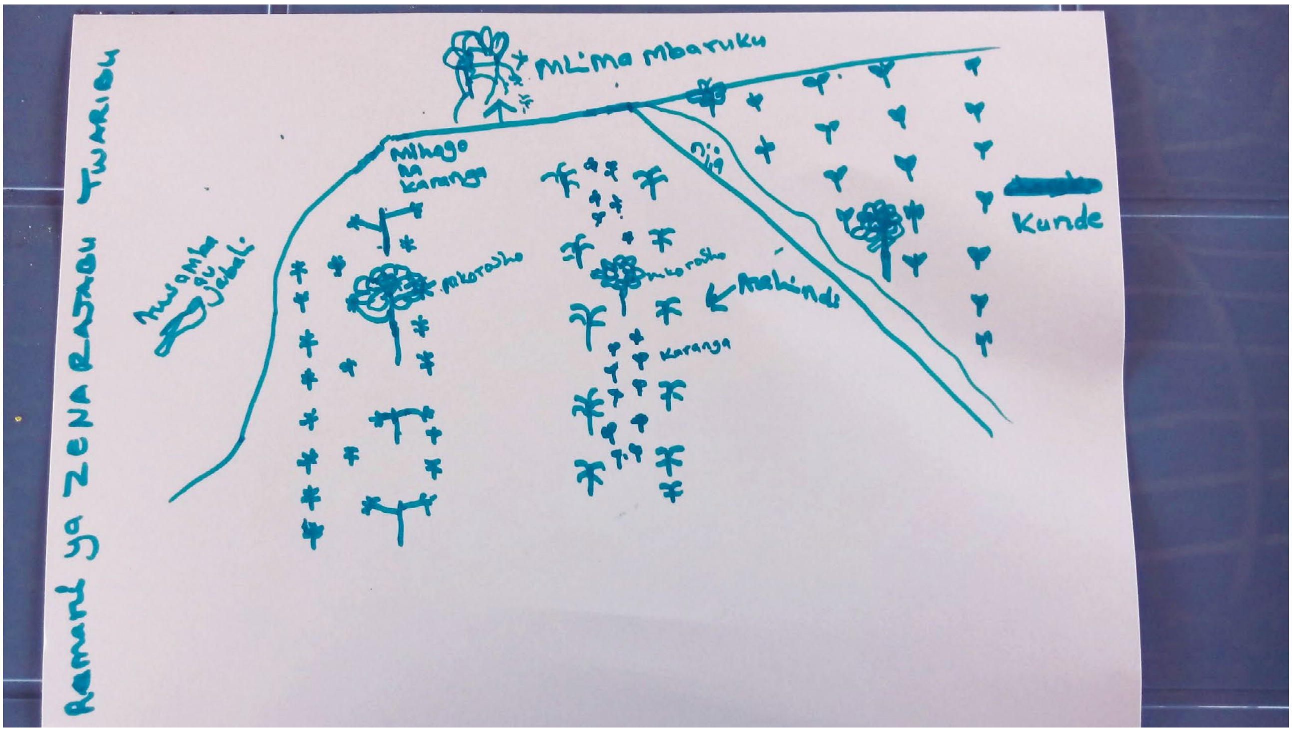


Figure 2: A farm drawn in free style



The understanding of research shared by the farmers was essentially a practical one. Farmers defined research as a way to solve problems and practised it through observation and the application of advice offered by peers or trainers. However, research was also defined as discovery, translated in Swahili as Ugunduzi. Discovery, thus, became the name of the ICT platform.

Regarding record-keeping, the outcomes of the workshop confirmed the findings of previous studies: most farmers did not keep records, but most saw their usefulness and were willing to test new means other than paper or memory.

The first workshop gave way to a phase of prototyping, a crucial element of design thinking. The first prototype of the Ugunduzi app included the following functionality:

- **Creating a farm**: starting from an empty space, plots could be added, moved and resized. Imitating the visual representations made by most farmers, plots were placed on the screen as a grid of up to 16 variably-sized rectangles.
- **Defining the contents of the plot**: each plot could contain one or two (intercropped) crops and one or two agroecological treatments, namely pest control and soil management, or none.
- **Entering plot records**: two types of records could be entered at the plot level: qualitative, consisting of a combination of a picture and a voice recording, or quantitative. Quantitative records were based on the different kinds of activities, processes and transactions identified by farmers during the workshops (for example land preparation, planting, or the cost of seeds)
- **Reviewing previously entered records**: records for a specific plot or for the entire farm could be viewed in chronological order.

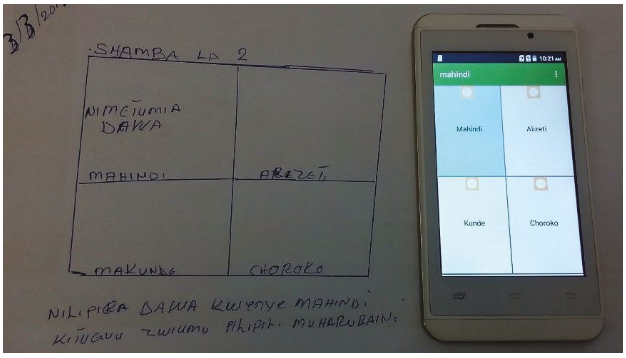
SECOND CO-DESIGN WORKSHOP

Four months after the first workshop, a second one took place. The main goal was to test the prototype of the Ugunduzi app. To this end, all 30 farmers received a smartphone with a pre-installed version of the app. The main research questions of the second workshop were:

- How do farmers interact with the app?
- What is missing or needs to be modified?

The workshop was structured around a series of hands-on exercises that allowed farmers to test the app and identify its strengths and weaknesses, as well as potential modifications. As in the previous workshop, the farmers were invited to draw their farms on paper. However, this time they were also asked to reproduce their drawings digitally, using the Ugunduzi app. Of all 30 farmers, 28 successfully completed the exercise of reproducing their farms using the Ugunduzi app.

Figure 3: A farm copied from paper to screen



When finished, farmers finally had to enter qualitative and quantitative records relative to crops, treatments and other activities on their digitized farms. After the exercise, farmers provided their feedback on the Ugunduzi app.

The workshop facilitators guided the discussion towards identifying the challenges and shortcomings of the prototype of the Ugunduzi app, as well as improvements to be made. The farmers requested the following changes to the Ugunduzi app:

- Adding the possibility of editing previously created farms
- Specifying the ingredients of agroecological treatments and not just their type.
- Keeping track of financial transactions and breaking down costs and benefits per crop, treatment and other activities
- Adding more than two crops per plot

The farmers faced several challenges when interacting with the app, mostly having to do with aspects of the user interface, such as identifying the operation and function of its elements (e.g. buttons or text fields), or performing specific gestures, such as scrolling. Consequently, the farmers declared that they would need an extensive training period in order to feel more confident with the app.

A second prototype of the Ugunduzi app was developed after the workshop. The new version corrected previous limitations and wrong assumptions and integrated the modifications suggested by the farmers. Moreover, changes and adjustments to minimise the challenging aspects of the user interface were introduced.

FINAL CO-DESIGN WORKSHOP

The third and final workshop took place four months after the second one. The main purpose of the final workshop was to test the second prototype of the Ugunduzi app. The testing phase consisted of a series of guided, sequential exercises:

1. Copying the layout of the farm from paper to screen
2. Adding records to a plot
3. Reviewing the records and consulting the farm's financial balance
4. Modifying the layout of the farm
5. Backing up the farm's records online

After these exercises were completed, a final round of discussion, questions and feedback was opened.

Overall, farmers expressed a good level of acceptance of the Ugunduzi prototype. All of them completed successfully the guided exercises, which were also meant to function as a first round of training on the app's usage. However, some farmers needed more assistance than others when it came to the usage and navigation of the app's different functionalities.

Finally, the workshop was closed with the delivery of the smartphones with the Ugunduzi app to the farmers, who would subsequently test it in the real-world scenario of their respective farms.

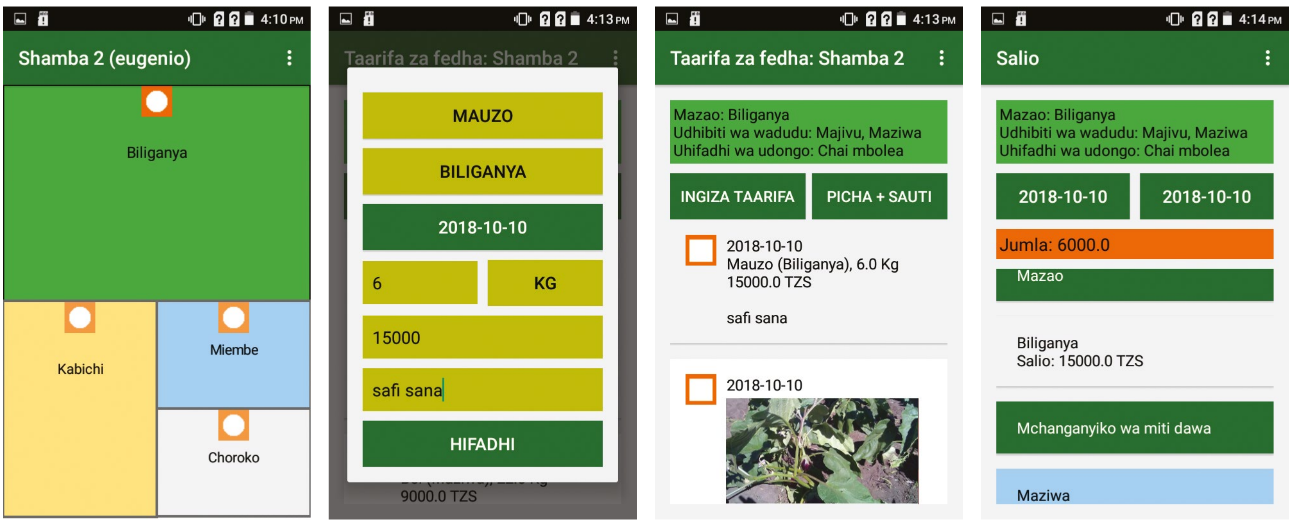
DISCUSSION

Ugunduzi was designed as a self-reflexive application integrated into the tasks of daily farm labour and through which farmers could keep track of the performance of their farms over time by looking at records and using them as a basis for decision-making. The co-design workshops that led to the development of the Ugunduzi app were planned and executed as a series of iterative processes, which were guided by participatory principles and grounded on specific techniques of soft systems methodology and design thinking. This transdisciplinary approach was applied in order to properly capture the farmers' perspectives, needs and aspirations and integrate them into the development of a functional ICT platform.

The main challenge found throughout the co-design process consisted in striking a balance between the farmers' understanding of research, based on practical problem-solving approaches and the more systematic scientific method.

Figure 4: Farmers at the final workshop

Figures 5-8: Screenshots of the final version of the Ugunduzi app



Indeed, one of the key findings of the workshops was that farmers had diverse perspectives on the nature, importance and practice of research and that, by the end of the co-design process, only 10 out of 30 farmers claimed that they had truly grasped the principles and techniques of scientific research. Carrying out research according to scientific methods, such as the establishment of a test plot to compare the performance of crops or agroecological treatments to untreated control, may yield a higher degree of certainty than unsystematic, ad-hoc problem-solving. However, throughout the workshops, it became clear that the different ways in which farmers carried out the research needed to be considered and accounted for since they are embedded in the farmers' culture (i.e. oral exchange of information and advice).

Therefore, the Ugunduzi app was designed in a way that allows farmers the choice between following a systematic approach analogous to scientific research or by simply drawing a map of unrelated plots and tracking their progress through basic record-keeping over time.

The Ugunduzi platform attempted to follow the lessons learned through farmer-led approaches in agriculture, which suggest that the acceptance, impact and dissemination of a new technology may be increased through farmer participation. However, the platform could be criticised on the basis that it may potentially benefit only a select group of advanced farmers while leaving behind other farmers who are unable to improve their practice due to unfavourable socioeconomic conditions or lack of access to smartphones. Ugunduzi was indeed co-designed with a small group of farmers who were regarded as leaders in their regions. However, Ugunduzi is currently in its pilot phase and is being tested against the real-life scenarios of the farms of the 30 participants. The actual levels of acceptance, usability and usefulness of Ugunduzi are presently being monitored and evaluated by independent researchers.

It is foreseen that, if monitoring and evaluation ultimately yield a positive outcome, the Ugunduzi platform may be subsequently made available to a wider user base in Tanzania. It is also true that the rate of smartphone ownership among Tanzanian farmers is low and this is why devices had to be distributed during the co-design workshops. Nevertheless, such a rate is projected to increase in the near future, since the Tanzanian population covered by 3G networks has expanded from 41% in 2017 to 61% in 2018, the cost of subscription to mobile broadband has consistently decreased and cheaper devices have become widely available.

In the face of these considerations, it is realistic to expect that, upon completing its pilot phase, the Ugunduzi platform may be disseminated and adopted by a larger number of smallholder farmers in Tanzania at a later stage.

In what we consider a novel transdisciplinary approach, the co-design process of the Ugunduzi platform was guided by the participatory principles that characterise farmer-led research, as well as the social elements of agroecology, namely the co-creation of knowledge and structured according to specific techniques of soft systems methodology and design thinking.

This approach attempted to stand in contrast to the conventional model of top-down technology transfer in agriculture by integrating farmers as co-designers of an ICT platform that seeks to support and enhance their farming practices.

Thanks to the participatory nature of this approach, it is expected that farmers will not only claim ownership of the Ugunduzi app but also of the practices of on-farm record-keeping and self-led research.

CONCLUSIONS AND RECOMMENDATIONS FOR THE ORGANIC SECTOR AND AGROECOLOGY

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SUMMARISING – AGROECOLOGY AT A CROSSROADS

While Agroecology has been introduced already four or more decades ago, decidedly as an alternative concept to the dominant input-based, industrial farming systems, it has only been gaining traction globally for roughly a decade.

Reasons for this recent rise of agroecology, we believe, are, for one, that the long-predicted destruction of ecological systems has begun to reach a point where it is affecting everybody and denial is becoming increasingly impossible. Secondly, this undeniable ecological destruction along with documented or suspected impacts on human health has fueled a wide public debate about the dysfunctionality of our current, dominant agro-food systems. Thirdly, and also, increasingly, citizens and civil societies are questioning the at times aggressively promoted technology-based saviour strategies proposed by those industries that have been instrumental in establishing the dysfunctional current systems without accepting their share of responsibility.

It becomes increasingly clear that these are just the latest attempts by those industries to maintain their business concepts and market power by co-opting the counter-proposals, at least rhetorically. Among those cooptation attempts are what some call 'Junk Agroecology' and their saviour technologies integrated into digital platforms capturing all inputs on offer by these industries, ranging from genetically engineered seeds to synthetic pesticides and fertilisers, coupled with the use of specifically tailored robotic machinery and licensed cultivation protocols.

This will lead to more – not less - path dependency and will tie farmers even more – not less - to service and extension packages of these industries and their products, while their claimed environmental benefits are questionable, undocumented and likely transient.

Corporations "take what is useful to them – the technical part – and use it to fine-tune industrial agriculture, while conforming to the monoculture model and to the dominance of capital and corporations in structures of power" (Nyéléni newsletter, 2016, p.1). Hence, proponents of agroecology are facing a serious dilemma whether to make concessions, i.e., abolishing certain principles, in order to finally go mainstream – or whether to "take the political opportunity to advance agroecology as a tool for transforming the current hegemonic, agroextractivist model" (Nyeleni, 2015). Similarly, Altieri et al. (2017) argued that establishing a "lukewarm" definition of agroecology aims at stripping agroecology of its political content and goals and erasing its history: "**Agroecology is now at a crossroads**, facing a major struggle over its possible co-optation by the mainstream and to be further subordinated to conventional agriculture (...)" (Altieri et al., 2017, p.3).

This publication, therefore, brought together experts to explain and deconstruct the conceptual logic of digital solution proposals, notably, without dismissing that digital tools also hold great potential for agroecological food systems if applied consciously and thoughtfully. Examples for the latter are described. Technologies are not neutral but rather traversed by values that are inscribed at their core (Feenberg 1999). However, these values are often rendered invisible precisely by technology's supposed neutrality (Feenberg 1999).

This also applies to digital tools and technologies developed for agriculture. Hence, to make the best use of digital technologies in support of agroecology, it is paramount to understand the non-neutral, contextual nature of technology introduction in any field of human activity including the transition towards agroecological food systems.

WAY FORWARD…

Development of different speeds. While recently some political commitment for agroecological/organic forms of farming has been pledged by the European Commission and some Member State actors representing the least common denominator outcome of a messy political battle, the push for digital techno-solutions is disproportionally larger and much more unified. Western technophile countries and transnational corporations invest vast amounts of funding into techno-solutions without proper contextualisation with its intended field of application, e.g. top-down, without or with minor stakeholder participation. In contrast, public and private investment in transforming current destructive agro-foods systems into non-destructive agroecological systems makes up only a tiny fraction. Consequently, we are faced with a highly advanced technology field with many ready-to-go digital gadgets and platforms promising big benefits for farmers, albeit with little evidence, while the transformative processes necessary for fostering the agroecological transition are still in their infancy - their path to rise being cluttered with stumbling blocks strewn strategically by those powerful actors who stand to lose. While technology is going full speed ahead, the sectoral side is lacking way behind.

SYNCHRONISING TECHNOLOGY DEVELOPMENT WITH SECTOR TRANSFORMATION

These asymmetrical development pathways – push for digitalisation without proper guidance and commitment to agroecological transformation - must be brought into more synchrony and balance. The relevant actors of agroecology ranging from farmers to scientists to civil society and beyond must become aware of the pitfalls and different narratives underlying the promotional claims and promises of current digital tools. In order to empower these actors, they must be offered guidance enabling them to differentiate between digital proposals that are useful and support agroecology, and those that undermine and capture agroecology to maintain global dominance and dependencies.

- Agroecological farming communities need to be informed and educated in the underlying strategies and framing of proposed technological solutions, in particular those with saviour claims. Their participation in technology development is essential.

- Agroecology support organisations must have dedicated personnel that follow the technological, political and scientific developments and represent legitimately the interests of agroecological farmers and their support communities. To make their voices heard, they must be empowered and enabled to separate useful from damaging digital proposals and insist that proposed principles for ICT development in support of agroecological transformation are met.

- The proposed principles for ICTs in support of agroecology should be put forward for wider discussion and consensus-building in the relevant communities, so they can serve as legitimate guidance for technology developers – public and private - in the digital domain.

- A wider discussion is necessary to learn where and what regulations should be developed to encourage digital technology developers to meet the goals of agroecological transformation. Currently, these developers – public and private - enjoy large public funding support largely free of regulations, guidance, oversight and critical discourse.

- The true costs of digital tools must be assessed and means to do so developed to avoid that we simply only shift from fossil fuel-based strategies to those based on rare earths and metals. All are limited resources and, to date, their extraction follows the same old destructive, capitalist exploitation model of nature and humans.

We have to unite behind a transformation agenda at all relevant levels from farming to science, politics and economy and make sure that technology development gets in sync with sustainable transformation. Some efforts are underway to meet these wider needs, but very little attention is paid to the agro-food sector, although this sector is key for a successful transformation to overall sustainability – whether climate change, land use or biodiversity. All relevant global industries of the agro-food sectors and also the newcomers to this field have understood this and are pouring massive resources into their sustainability models. The agroecology circles must catch up fast if they want to get ahead of the curve and, for once, shape the technologies to their needs – not vice versa.

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CONCLUSIONS

Alonso-Fradejas, A., Forero, L.F., Ortega-Espèse, D., Drago M. and Chandrasekaran, K. (2020). *'Junk Agroecology': The corporate capture of agroecology for a partial ecological transition without social justice*. Friends of the Earth International, The Transnational Institute, Centro Internazionale Crocevia.

ENDNOTES

[1] "The FaST tool aims to facilitate a sustainable use of fertilisers for all farmers in the EU […] The digital tool provides information on the parcels selected, including crops, the number of animals on the farm and the amount of manure generated by them. Additional data will also be available for nutrient management such as data on soil, the proximity of protected areas and legal limits on the use of nutrients. Accessible via mobile phones, PCs or tablets as a digital tool, the user can accept or edit the data provided. From this, the tool will propose a nutrient management plan, which gives customised recommendations on crop fertilisation for the farm selected."
https://ec.europa.eu/info/news/new-tool-increase-sustainable-use-nutrients-across-eu-2019-feb-19_en

[2] Eco-schemes are a new instrument under the EU Common Agricultural Policy designed to reward farmers whose practices support environmental stewardship and climate action.

[3] For more on the scale and scope of digitalization of the food system see, IPES-Food & ETC-Group, 2021 (Section 3).

[4] While digitalization may contribute to the creation of higher skilled, higher paid jobs and less transient employment opportunities for some, it is equally likely to further exploit lower-skilled workers who will be forced to operate under greater surveillance, scrutiny, and productivity pressures or be replaced altogether (Rotz et al., 2019). If food systems undergo digitalization under the current productivist – rather than agroecological – paradigm, this shift will likely do nothing to change food systems' underlying labour inequities around access to training, better wages, and more sustainable livelihoods, particularly for low-skilled labour, migrant workers, and already marginalised groups.

[5] In 2020 Bayer, Corteva, Syngenta and BASF reported a total of 7.8 billion dollars in pre-tax income - bayer - 5.3 billion USD, corteva - 0.68 billion use, syngenta - .85 billion use, basf - .97 billion.

[6] This figure for storage is based on calculations provided by Jean Pau Calderone. He estimates that a 1.5TB HDD in a data centre uses 3.4W when idle and 5.9W when operating which scales to an energy storage cost for data of approx. 20,000-100,000 kWh per petabyte.

[7] Total water use required to cool 651 PB of data, data derived from 93 million acres of US corn would be approx. 130,200,000,000 litres equivalent to the direct water use for growing 57,325 acres of corn. High yield industrial corn uses 600,000 gallons of water per acre (2271274 litres). In 2018 500 million km of optical fibre were installed worldwide, in 2019 it was 480 million km – see For 2018 figures that are equivalent to installing 57077 km of cable per hour. Sound travels at 1238 km/h.

[8] The IPCC reports that the maximum sustainable CO_2 removal in 2050 by new forests is somewhere between 500 and 3,600 Mt per year. The combined Net Zero pledges of just a handful of large transport and fossil fuel companies could overshoot that theoretical capacity.

[9] In the context of ICT, the notion of *affordance* "reflects the possible relationships among actors and objects." (Norman 1999, p. 39). In other words, the affordance of a specific technological artifact describes the modes of usage and the possibilities for extended agency that it enables.

[10] Blockchain is a technological innovation that consists in an open, distributed ledger that records transactions safely and permanently and has been proposed as a way to ensure the trustworthiness of all contracts made through a digital platform (Wüst and Gervais, 2018).

[11] Scaling up can be understood as the process by which a system grows in scale, increasing its size and production capacity. On the other hand, a system scales out when it grows horizontally in a networked fashion through its replication. We argue that both kinds of scaling processes are necessary in agroecological transitions.

[12] Other points of conflict may include the ongoing debate on genetically modified organisms, but also the recent referendum battle on pesticides, which has led to significant tensions within Bio Suisse (SWI, 2021).

[13] Sauti ya wakulima (translated as "the voice of the farmers" in Swahili).

[14] Macho Sauti (translated as "eyes and voice" in Swahili).


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