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Digitalizing environmental governance for smallholder participation in food systems

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A B S T R A C T

Digital technologies such as artificial intelligence, blockchain and remote sensing are increasingly used by public and private actors to improve the participation of smallholders in addressing the environmental challenges of food production. Based on an empirical mapping of 10 digital sustainability initiatives we analyse how digital technologies shape the representations of (un)sustainable production practices, the identification of sustainability targets and intervention strategies for improving environmental performance. Based on this mapping we distinguish three archetypes of smallholder participation engendered by digital technology that we label 'the tutorial', 'the dashboard' and 'the platform'. The archetypes provide a basis for understanding how digitalization, as a process of design-based governance, can overcome, replicate or even reinforce the barriers to participation faced by analog sustainability initiatives. Applied more widely we argue this typology can provide a productive means of examining the role of digitalization in contributing to more inclusive and sustainable food systems.

1. Introduction

Digital technologies are increasingly used by both state and non-state actors to address environmental challenges related to food production and trade. Sensors and satellites can make yield and environmental challenges visible (Gale et al., 2017; Jain et al., 2019), while blockchain technology and online platforms facilitate information and market exchange (Kamilaris et al., 2019; Van Wassenaer et al., 2021). Algorithms and machine learning can detect patterns in big data and generate new forms of knowledge about food production and the environment (Bronson and Knezevic, 2016; Camaréna, 2020; Wolfert et al., 2017). As argued by Rose et al., (2021), digital technologies are commonly viewed by policy makers, NGOs and the industry as a means of improving not only the efficiency, but also the sustainability and equity of food production, distribution and consumption.

The promise of digital technologies to contribute to a more sustainable and equitable food system is emphasised in the context of smallholder participation (EY and Syngenta Foundation for Sustainable Agriculture, 2020; Fairfood, 2019; Jain et al., 2019; Kos and Kloppenburg, 2019; Shukla and Tiwari, 2017; Van Wassenaer et al., 2021; World Bank, 2019). Smallholder farmers represent more than 475 million out of 570 million farms around the world (Lowder et al., 2016). Similarly, small scale fishers and fish farmers produce two-thirds of aquatic food destined for human consumption (Short et al., 2021). Their sheer number and widespread distribution, as well as their lack of resources and capabilities, remoteness and disconnectedness has limited the reach of non-digital (or 'analog') sustainability initiatives, including corporate social responsibility programmes, eco-certification, traceability and state extension services, based on costly methods involving direct sampling and documentation (Belton et al., 2010; Bush et al., 2013a,b; Lee et al., 2012; Marschke and Wilkings, 2014; Schouten et al., 2016). Digital technologies have been identified as overcoming these limitations by enabling more comprehensive, large-scale and real-time collection and communication of information on smallholder interaction with the environment (Bakker and Ritts, 2018; Gale et al., 2017; Jain et al., 2019; Shukla and Tiwari, 2017).

Recognising the potential of digital technologies, a broad range of public and private actors are applying digital technologies to engage smallholders in improved environmental performance; from multinational food companies like Unilever improving the transparency of supplier performance, to global NGOs such as WWF supporting more inclusive conservation, and technology companies like Microsoft helping "the poorest farmers gather data and increase yield" (Gates, 2018). It is increasingly recognised, however, that the use of digital technologies

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by these different food system actors does more than improve transparency and yields (Ascui et al., 2018; Bakker and Ritts, 2018; Toonen and Bush, 2020). They also redefine how (un)sustainable production practices are represented, as well as how the sustainability goals and improvement strategies of the sustainability initiatives are defined and implemented. Digital sustainability initiatives are thus not only a tool but also a site of environmental governance (Gritsenko and Wood, 2020) where programming decisions encode food system practices, goals and strategies with implications for how smallholders are engaged and participate in environmental improvement.

In this paper we explore how digital technologies shape the ways in which smallholder food producers participate in and engage with the goals and programmes of sustainability initiatives. In doing so we draw on the emerging literature on algorithmic governance, focused on the effect of computational digital technologies on social ordering (Katzenbach and Ulbricht, 2019), to examine the role of digitalization as a new and alternative means of inclusive environmental governance. We demonstrate how governance through digital technology shapes how smallholders participate in sustainability initiatives in terms of their roles and responsibilities, representations, recognition and resources (Fraser, 2007). Based on a mapping of 10 digital sustainability initiatives we analyse how digital technologies bring along changes in the representations of what needs to be governed, the identification of sustainability targets and the intervention strategies. We then examine how digital sustainability initiatives differently shape smallholder participation by distinguishing three archetypes of smallholder participation engendered by digital technology that we label 'the tutorial', 'the dashboard' and 'the platform'. These archetypes, we argue, provide a productive starting point for understanding and critically examining the implications of digitalization for inclusive and sustainable food systems.

The following section conceptualizes digital environmental governance by drawing on the literature on algorithmic governance. We then present the empirical mapping methodology used to identify and examine the 10 digital sustainability initiatives used in our analysis before presenting our results. The final two parts of the paper develop three archetypes of participation and provide conclusions on the use of these archetypes for understanding and critically examining the implications of digitalization for inclusive and sustainable food systems.

2. Conceptualizing digital environmental governance

The emerging field of algorithmic governance examines the role and consequences of applying digital technology to address both public and private societal challenges (Eyert et al., 2020; Katzenbach and Ulbricht, 2019; Yeung, 2018). A key feature of algorithmic governance is its design-based nature (Gritsenko and Wood, 2020), meaning that the goals and functions of governing social and/or environmental issues are imposed *ex ante* through code. For instance, certain rules and procedures are embedded in digital code, and thereby influence the choices and actions of smallholders. Design-based governance can thus be seen as a distinct form of governance constituted by an organizing logic of "(re-)designing actors' choice architecture rather than through adherence to laws, common interests and identities, or individual interest and self-control" (Gritsenko and Wood, 2020: 7).

Following Eyert et al. (2020), we employ three dimensions of digital environmental governance to analyse how governance through digital technologies changes how environmental issues are identified and interpreted (epistemic dimension), how sustainability targets and goals are established (normative dimension), and the strategies to reach these goals (effective dimension).

The epistemic dimension refers to how digital technologies collect information about and create specific representation of (environmental) issues. Digital technologies such as sensors, satellites and drones all hold implications for what information is collected, how environmental issues are represented, and what aspects become relevant for governance (Scott, 1998). The definition of 'data' invokes fundamental decisions about whose concerns are taken into account, how these concerns are monitored and how the data representing these concerns is interpreted (Beer, 2016; Porter, 1996). Reality is, as such, translated into data proxies based on choices and assumptions about relevance and representativeness (Latour and Woolgar, 1979) that "[subsume] contextual, indexical, symbolic or lived differences" (Mackenzie, 2015: 434, cited in Eyert et al., 2020). Data collection further abstracts reality given the parameters, materials and sensing resolution of the different digital technologies employed (Kitchin, 2014). Finally, digital technologies shape the interpretation by transforming data into a coherent representation of the world that is understandable and actionable for governing actors. For instance, using algorithms, machine learning or artificial intelligence to interpret data means that classification and interpolation become dominant forms of interpretation (Gillespie, 2014). This epistemic dimension enables us to explore what data about smallholder food production is deemed relevant to collect, what aspects of smallholder food production practices are 'made visible' by digital technologies (and what not), and how data is interpreted and made relevant for governance.

The normative dimension refers to value-based choices that affect the definition of desired outcomes related to the object being governed. This dimension places emphasis on the formalised encoding of sustainability goals and their operationalization in decision-making systems. The indicators and thresholds used in digital technologies are as such "representations […] endowed with the authority to determine whether and to which degree standards [and/or goals] have been fulfilled" (Eyert et al., 2020: 9). Consequently, digital representations may be biased in that they are geared towards goals that are computable, measurable and often rely on quantified indicators (Hildebrandt, 2018; Porter, 1996). This means that qualitative elements may be excluded or need to be made quantitative, raising again questions about digital representations as seen in the epistemic dimension. We apply this normative dimension to understand what value-based choices on what constitutes sustainability are incorporated and translated into the digital sustainability initiatives.

The effective dimension refers to the ways in which digital technologies influence the behaviour of an individual or groups of actors to achieve a desired outcome (Eyert et al., 2020). Various strategies of influence may be used, including coercion ('the stick'), inducement ('the carrot') and/or convincing ('the sermon') (Vedung, 1998). Digitalization may enhance some of these strategies, privilege one over another, or even qualitatively change their very nature (Eyert et al., 2020; Gritsenko and Wood, 2020). For instance, these strategies can include automation, with automatically generated recommendations for human decision-making, or automatically administered sanctions and rewards (Yeung, 2018). In addition, the choice architecture of digital applications can be a strategy of influence of itself by enabling certain decisions and actions while disabling others, simply by including or excluding certain options (Aneesh, 2009; Eyert et al., 2020; Gillespie, 2015). We apply this effective dimension to explore the decision-making role of different actors in digital sustainability initiatives, including whose behaviour is targeted by the intervention in the first place, and through which strategies of influence.

Together these three dimensions enable us to explore how digital sustainability initiatives *through digital technologies* engage and influence smallholder food producers to improve their environmental performance.

3. Methodology

Our analysis is based on an exploratory mapping of digital sustainability initiatives. By employing exploratory mapping we aim to structure a field of study by identifying its inherent variation rather than provide a full overview of all relevant cases by synthesizing evidence (McKinney, 1969). Exploratory mapping was also chosen because of both a potentially large number of cases and a lack of a clear set of

Table 1
Description of 10 digital sustainability initiatives.

Name	Short description	Lead actors	Location of smallholders	Digital technology used
SpiceUp	Mobile application which integrates geodata (based on satellite imagery), field observations and market intelligence to provide traceability and farm management advice to Indonesian pepper farmers.	Geodata for Agriculture and Water (G4AW) programme funded by the Netherlands Space Office (NSO) led by Verstegen Spices & Sauces BV, including an NGO, value chain actors and technology companies	Indonesia	Satellite imagery; mobile application
STARS	Research project investigating use of satellite and drone images to monitor and map smallholder farms to map land tenure and provide services for the optimization of resource use.	University of Twente, CSIRO, ICRISAT, University of Maryland, CIMMYT, Bill & Melinda Gates Foundation	Mali, Nigeria, Tanzania, Uganda, Bangladesh	Satellite imagery; drones; mobile application
FarmBeats	Project to make smart farming (precision maps to provide advisory services) more accessible to smallholders by making AI, sensors and connectivity easier and cheaper.	Microsoft	United States, India	Artificial Intelligence; sensors; connectivity technologies; drones; satellite imagery; mobile application
APOLLO	Research project aiming to support farmer decision-making through affordable satellite-based information services, to optimize resource use and increase profitability.	EU Horizon2020 funded project involving various universities, cooperatives and technology companies	Greece, Spain, Serbia	Satellite imagery; mobile application
TARA	Climate risk assessment based on satellite data and agronomic knowledge for credit scoring of smallholder farmers in Kenya.	Led by Dutch technology start-up VanderSat involving 2 partner companies	Kenya	Satellite imagery; online dashboard
TRADO	Blockchain platform used for registering smallholder tea farmer data including sustainability credentials, allowing more efficient financing.	Led by Unilever, involving technology company, financial sector actors, NGOs, social enterprise and value chain actors	Malawi	Blockchain technology
ABALOBI	Set of mobile applications in which fishers record various oceanic, atmospheric and fisheries parameters and communicate within their community and across fishing communities. Additional apps provide a digital market place, enable community catch monitoring and co-management.	NGO founded by Small-scale fishers of South Africa, University of Cape Town, South African Department of Agriculture, Forestry & Fisheries	South Africa	Mobile applications
BLOCRICE	Blockchain platform used to trace rice from and to verify adequate payments to smallholder organic rice farmers in Cambodia.	Led by the NGO Oxfam, including technology company and value chain actors	Cambodia	Blockchain technology; mobile application
FAME	Project providing small-scale vessel monitoring equipment for collecting and transmitting electronic catch documentation and traceability data, also facilitating communication with family on shore for sea safety.	Start-up partnering with USAID, SEAFDEC, WWF Philippines	Philippines	NFC; transponders; GPS; sensors; mobile application
SHRImp	Platform which is fed with data about key shrimp diseases provided by farmers, pond sensors, and the government to produce diagnostic epidemiological services to farmers.	EU-funded Thai aquaculture technology and innovation platform (ThaiTIP) involving NGOs, technology companies, value chain actors (incl. Walmart) and Thai Department of Fisheries	Thailand	Sensors; mobile application

obvious cases (Gerring, 2008). Our conceptual framework warrants a more in-depth qualitative approach that is not suited for a large number of cases.

We selected cases in an iterative process by selecting additional cases for increased variation (Marshall, 1996) across Eyert et al.'s (2020) three dimensions. To do so we applied six criteria to identify our final sample of 10 sustainability initiatives summarized in Table 1. The first criterium is that the initiatives apply a *digital technology* for the purpose of making smallholder food production more sustainable. We define digital technologies as information and communication technologies, which include a combination of hardware and software including sensors, satellite imagery, drones, mobile applications, blockchain technology, machine learning and artificial intelligence. We therefore exclude technologies such as gene editing. Second, initiatives have an explicit goal to improve the *environmental* sustainability of the process, efficiency or output of production. Third, there is an explicit intention to involve or target *smallholders,* or value chains or locations dominated by smallholder food production. Fourth, we ensured that our sample included cases from various world regions. Fifth, we included a variety of public and private actor-driven initiatives, reflecting the widespread use and global significance of digital technologies in the context of sustainable smallholder food production. Finally, there needed to be sufficient public sources of information available such as websites and reports providing details about data collection methods, the goals and ambitions of using digital technologies and strategy and aims of the initiative.

To interpret the results we identified clusters of variation, where cases sharing the same or similar characterizations along the three dimensions tend to go together (see also Korbee and Van Tatenhove, 2013). These clusters provided the basis for developing archetypes as intermediary forms of abstraction (Oberlack et al., 2019) suited to capture the diversity in how digital sustainability initiatives shape smallholder participation.

4. Digital food sustainability initiatives

4.1. Representation through digital technologies (epistemic dimension)

Our data demonstrates that the use of digital technologies to generate and interpret information about smallholder food production leads to specific types of representations of environmental issues related to food production. The type of digital representation depends on choices about what information is collected, the technologies used for information collection, and subsequent interpretation to make the information useful for a particular purpose (for more detail see supplementary materials). From the 10 cases we synthesise three ways in which digital technologies represent their object of governance.

First, several of the initiatives included in our sample use digital remote sensing technologies such as satellites, drones and sensors to establish a set of *environmental representations* (see Fig. 1) based on data related to e.g. soil moisture, crop size, weather conditions and tree coverage. These remote technologies measure and represent the object of governance in terms of (bio)physical environmental parameters, often coupled with automated interpretation of those parameters through algorithms or other computational methods. Examples include projects that use satellite data to provide farm management recommendations such as Verstegen's SpiceUp project with pepper farmers in Indonesia, Micrsoft's FarmBeats in the US and India, and the EU's APOLLO project. The TARA project uses environmental data to estimate droughts and expected harvests to make climate risk assessments that inform calculations of smallholder credit worthiness to provide access to finance. For fisheries, there are several initiatives that collect data about the location and quantities of capture using vessel monitoring systems (VMS) and scanners for NFC tags attached to fish (e.g. FAME in The Philippines).

Second, some initiatives create *behavioural representations* by collecting and processing social and economic data on those actions and decisions of smallholders that are deemed relevant for environmental sustainability. These initiatives sometimes also include analog methods such as questionnaires. For example the TRADO project in Malawi generates a sustainability score based on data related to smallholder production practices gathered through interviews by a social enterprise. The data covers a wide variety of aspects of smallholders and their practices, including demographic, economic, financial and agricultural data. This examples shows a much broader representation of smallholder production practices compared to initiatives that rely on automatically interpreted satellite imagery.

Third, in some initiatives smallholders co-construct representations because they are provided with, and therefore represented by, a *digital identity*. This digital identity enables smallholders to present their production practices and products to buyers and gain access to market information. For example, the BLOCRICE project in Cambodia enables smallholders to use their digital identity on a blockchain application to check whether they were paid the agreed price for their produce, on time and in accordance with the volume specified in the contract. This information is made accessible to all actors in the supply chain, including consumers, which means that the data entered by smallholders creates leverage over other supply chain actors. Other examples include digital market places on which smallholders can make a profile to sell their produce or catch, such as the NGO-led ABALOBI application for small-scale fishers in South Africa. Although these digital identities are often based on pre-defined parameters (such as yes/no answers to questions about payment for the BLOCRICE project), the data is generated, entered and in some cases owned by smallholders, which provides them with a degree of control over how they are digitally represented.

4.2. Sustainability objectives through digital technologies (normative dimension)

Sustainability initiatives typically set normative goals which are operationalized and translated into the design and workings of digital technologies. General goals such as making food production more sustainable are operationalized to address specific issues, such as a reduction of water use and an increase in productivity. In digital sustainability initiatives, normative objectives are encoded in digital technologies through the creation of numerical indicators, standards and thresholds. This has implications for the way in which sustainability objectives are set, implemented and monitored. We identify three ways in which digitalization shapes the process of setting, implementing and monitoring sustainability objectives.

First, digital sustainability initiatives set, implement and monitor goals through *thresholds and standards* that support the goals and activities of organizations such as government authorities, banks and buyers. A threshold is created and programmed into the technology to inform decisions and actions by a governing actor based on measurable indicators. As such, it functions as a 'judgment device' (Chiapello and Godefroy, 2017) for determining, for instance, whether something is sustainable or not. For example, the TARA initiative enables banks to evaluate the credit worthiness of Kenyan smallholders based on a threshold that determines whether a smallholder is expected to pay back the loan or not. In the case of TRADO, Unilever uses an automatically calculated sustainability score based on five indicators as a standard to evaluate the sustainability of smallholder tea farmers in Malawi. These examples show how new standards for sustainability are created specifically for these digital initiatives. These standards are based on what can be measured and analysed by digital technologies (e.g. soil moisture measured by satellites to determine credit worthiness), which generates a particular definition of sustainability that may rule out other interpretations. Other initiatives, in contrast, couple existing sustainability standards with digital judgment devices. The NGO-led BLOCRICE project, for example, determines whether a standard of 'living income' has been paid to Cambodian smallholder rice farmers based on entries in a blockchain application.

A second group of initiatives is focused on setting, implementing and monitoring *location- or farm specific objective*s, for example the optimizing of resource use. These applications usually rely on location-specific data and quantifiable indicators such as soil moisture, which is then processed into tailored farm management advice for smallholders. For example, the SpiceUp project calculates optimal water and fertilizer use for Indonesian pepper farmers by processing satellite imagery using software applications. Applications that make use of machine learning algorithms are even more flexible and location-specific. Microsoft's FarmBeats, for instance, uses machine learning to interpolate data and provide advice on how to increase productivity with minimal input use for smallholders in the US and India as they tend to operate in remote areas where data is scarce. As a result, specific standards may emerge from local situations rather than being defined by external thresholds.

Third, in various cases normative goals are not explicitly translated into standards and thresholds. These initiatives instead provide information to smallholders, including market intelligence and environmental data based on voluntary self-monitoring. These initiatives do not standardise normative goals such as efficient sustainable production. They instead adopt what we term an *open normative approach* of providing information that smallholders or other actors can use to set their own objectives. In the case of ABALOBI, for example, the collection of market intelligence (e.g. prices, potential buyers) enables South African small-scale fishers to make decisions on where and to whom to sell. At the same time, ABALOBI collects catch data (location, species, fishing method) which fishers can pass on with the fish to the digital market place. This data enables government and market actors to access information on the source, practices and status of the fishery without a pre-interpreted sustainability threshold or score.

4.3. Influencing decisions and actions through digital technologies (effective dimension)

Our examination of the effective dimension demonstrates how digital sustainability initiatives employ technologies and interfaces to influence the decisions and actions of smallholders. From our 10 cases we identify three main effective strategies employed by these sustainability initiatives.

First, the most commonly used strategy of influence in our sample is the collection and processing of information into an advice that can *inform smallholders* about how to improve the sustainability of their production practices. These initiatives provide their advice through technologies ranging from text messages to digital interfaces. Digital interfaces are often comprised of a 'dashboard' displaying information on the amount and timing of key inputs such as water or fertilizer. For example, the SpiceUp initiative provides Indonesian pepper farmers with a smartphone application which provides automated advice on water and fertilizer use based on satellite data on their farm.

A second strategy observed uses *rewards and sanctions* to entice

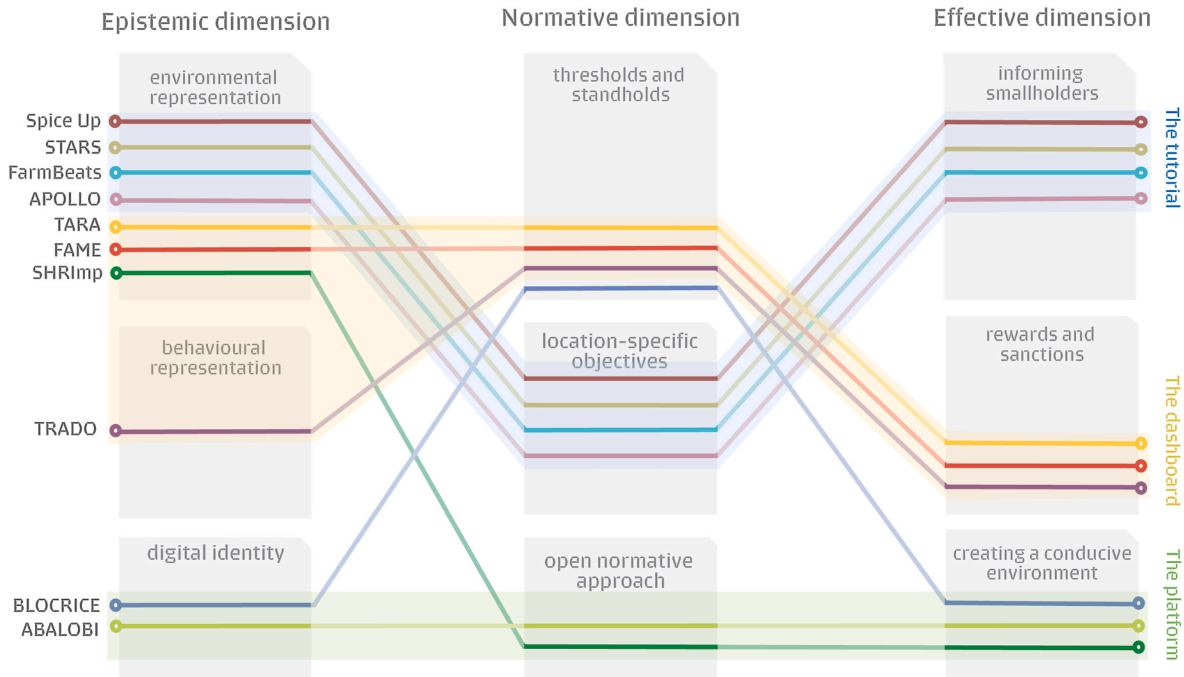

Fig. 1. Archetypes of smallholder participation by design based on variation of sustainability initiatives along the three dimensions of digital environmental governance. Note: Each case is categorized per dimension, indicated by the lines linking the categories identified through mapping 10 sustainability initiatives applying digital technologies (section 4 of this paper). More detailed analysis of the empirical results of this mapping per case can be found in Tables S-1, S-2 and S-3 in the supplementary materials.

certain behaviour by smallholders. These rewards come in different forms. For instance, some digital applications apply a so called 'data-for-benefits' approach that incentivise the disclosure of data by smallholders in exchange for different services. For instance, some applications such as Unilever's TRADO offer price premiums in exchange for data. Other applications, such as FAME, build benefits into their mobile application, such as communication functions for fishers with their family on shore in exchange for fishing data. These incentives to provide data are coupled with attempts to enhance the trust from buyers, banks and government in individual smallholders. The digital interface thus provides a tool for these actors to administer sanctions and rewards. The scope of these tools goes beyond influencing the behaviour of individual smallholders. For instance, FAME helps governments monitor the cumulative impacts of fishing, while TARA provides financiers with data to finance smallholders and TRADO targets buyers to pay premium prices. This group of initiatives have made preliminary steps to automate decisions and actions, such as the evaluation of credit worthiness in TARA or the sustainability score developed in TRADO, which have direct consequences for the decision to provide loans or premium prices respectively.

Third, the initiatives use digital technologies to *create a conducive environment* to directly empower smallholders with information that allows them to better manage external risks such as disease and payments. The SHRImp initiative, for example, facilitates information exchange between smallholder shrimp farmers in Thailand to prevent the spread of diseases. The ABALOBI application goes further by allowing small-scale fishers to transmit data on their products that they maintain ownership over on a digital marketplace and the BLOCRICE project provides smallholders a certain degree of leverage over the buyers by enabling them to verify payments. So, similar to the strategy of using sanctions and rewards, the creation of a conducive environment extends beyond smallholders to affect other actors. However, these initiatives additionally intend to improve the position of smallholders vis à vis these other food system actors by providing a two-directional information exchange, either among smallholders or between smallholders and other actors.

5. Archetypes of digital smallholder participation

Our results show considerable variation in the way that digital sustainability initiatives represent environmental issues, establish improvement targets and employ strategies for influencing the practices of smallholders. We now explore the consequences this variation holds for how smallholders participate in governing food system sustainability. We do this by identifying bundles of cases with similar characteristics as defined by the aspects identified above under epistemic, normative and effective dimensions (see Fig. 1). This results in three archetypes of smallholder participation, i.e. 'the tutorial', 'the dashboard' and 'the platform'.

5.1. The tutorial

A first bundle of initiatives is characterized by (1) the representation of (un)sustainable production practices based on remotely sensed and automatically processed environmental data (epistemic); (2) optimizing location- or farm-specific objectives on the bases of this data (normative); and (3) strategies to change behaviour of smallholders through automatically generated information and advice (effective). We characterise the way these initiatives engage smallholders as 'the tutorial' – reflecting their role in guiding and advising their users on how to perform sustainably.

Initiatives characterized by a tutorial form of participation rely on context-specific representation of smallholder food production in order to provide advice based on location-specific data. This approach is therefore generally more relevant for the context and realities of smallholders than more generic 'one-size fits all' initiatives (Vellema and Van Wijk, 2015). Smallholders are instructed how to make required changes by these initiatives through interfaces such as mobile or web-based applications, as seen in the SpiceUp, APOLLO and STARS projects. These initiatives can complement in-person extension services by providing more rapid and often free advisory services (Fabregas et al., 2019; Genius et al., 2014). As noted by Gale et al. (2017), they can also compliment private sustainability initiatives such as certification schemes, which are often critiqued for providing limited support to smallholders to conform to their prescribed standards (Belton et al., 2009; Bush et al., 2013a,b; Schouten et al., 2016). These digital advisory services can also enable greater efficiency, with a potential for higher yield and lower reliance on inputs (Fabregas et al., 2019), as noted by Jain et al. (2019), can be more scalable than their analog counterparts because of the lower cost of scaling them to a wider audience of smallholders.

At the same time, the location-specific data provided by these initiatives appears to rely to a large extent on remotely measured biophysical and environmental parameters – such as satellite and drone imagery of leaf cover and crop size in the STARS project and satellite-derived data on soil moisture in the SpiceUp project. While efficient, the risk of such remotely sensed data is that it relies on data proxies and categories that create narrow representation of sustainable smallholder food production (cf. Rothe, 2017). In addition, by focusing on the production-level these proxies may not capture the wider eco- and food system drivers underpinning unsustainable behaviour (Béné et al., 2020). As a consequence, these digital technologies may reify the perceived responsibility of smallholders for environmental improvement. In practice smallholders continue to be the focus of advice, while other actors in the food system avoid the same level of scrutiny and responsibility. In that sense digitalization risks replicating existing forms of and barriers to participation in analog public and private extension services and certification schemes (see Bush et al., 2019).

A final concern with digital technologies aligned with this tutorial approach is that, contrary to their initial goals, they may disempower smallholders. This could happen when the initiators of digital sustainability initiatives use it to increase control over the productivity and efficiency of smallholder food production (Dauvergne, 2020; Prause et al., 2021). In this way digital technologies can perpetuate the same means of control through value chains observed in analog sustainability initiatives (Bush et al., 2015; Vandergeest and Unno, 2012). Whether or not digital sustainability initiatives can enable smallholders to negotiate their own knowledge and practices with the digitally enabled advice remains unclear (Bronson, 2018; Carolan, 2018; Jakku et al., 2019; Klerkx et al., 2019). With developments in smart farming (Wolfert et al., 2017) slowly entering the domain of smallholder farming, the decision-making role of smallholders is increasingly supported by, and may even risk being replaced by digital technologies programmed by external actors, including software developers. As argued by Prause et al. (2021: 641), this may “introduce new forms of control and value extraction based on the use of data and pave the way for large tech companies to take over market shares in the agri-food sector”.

Overall, this form of participation enables context-relevant, timely and cost-effective advice to potentially large numbers of smallholders to produce more efficiently and thereby decrease resource use. However, the individualized production-level focus may neglect eco- and food-system drivers of unsustainable practices, reifying the perceived responsibility of smallholders for environmental improvements and potentially enabling increased external control over productivity. If these digital advisory services are used as part of a broader strategy that aims to address these challenges, they may play an important role in fostering more inclusive and sustainable food systems.

5.2. The dashboard

A second bundle of initiatives is characterized by (1) representations of issues based on both environmental and behavioural data (epistemic); (2) other food system actors using digital indicators and thresholds to evaluate smallholder performance (normative); and (3) strategies to influence the behaviour of smallholders through the use of rewards and sanctions to ensure transparent compliance with standards (effective), with a particular focus on convincing other actors to trust in the sustainability of smallholder food production. We characterise the way these initiatives shape the roles, responsibilities, resources and representation of smallholders as ‘the dashboard’ – reflecting their function as centralized means of monitoring.

‘The dashboard’ represents forms of participation in which a set of indicators and thresholds are combined and used as a centralized means of monitoring, analysing and acting upon relevant information by governing actors. Initiatives falling under this category support the decision-making of actors beyond the farm or fishery through dashboards with relevant indicators. This is seen, for example, in the indicators used to determine creditworthiness of smallholders by TARA or the data captured by fishers to meet information demands from national and international buyers in the FAME project. Even so, in the dashboard-form of participation, smallholders are made responsible to meet standards set by other actors such as buyers, banks, governments or NGOs. Similar to analog standards (Cashore, 2002; Hatanaka et al., 2005), the goal of these initiatives is to set measurable normative goals for sustainability surveilling compliance with these goals and providing assurance for buyers, consumers, financiers and the state. The application of these standards at production level puts smallholders in the spotlight. If these digital standards also address and monitor the wider food system, and the role of other actors and their decisions and actions (e.g. as in the BLOCRICE project), they can play a more transformative role in promoting inclusive food systems. Also similar to analog initiatives, dashboard forms of participation do not appear to overcome the challenges of delivering enabling *ex ante* resources that can support improvement rather than *ex post* reward for compliance (Belton et al., 2009; Ponte et al., 2014).

Standards, consisting of numerical indicators and thresholds, are either created specifically for these digital interventions based on what can be measured and computed (e.g. sustainability scores), or based on existing standards translated into a digital form (e.g. digitalized certifications). Initiatives falling into this category, however, risk applying indicators as targets of themselves (Goodhart, 1984; Strathern, 1997). For example, the sustainability score calculated by TRADO risks becoming a substitute for general sustainability ambitions. This is problematic because, as seen in the case of the ‘tutorial’ archetype, digital monitoring of standard compliance makes technical and environmental issues visible in a way that does not necessarily reflect eco- and food system dynamics. Although digital monitoring can decrease the costs of assurance (Gale et al., 2017; Shukla and Tiwari, 2017), digital technologies displace on-site interpretation, explanation and interaction by auditors or extension agents. Although behavioural data is included in monitoring dashboards, for instance through household surveys and economic indicators in the TRADO project, it remains unclear whether it is possible to represent the contextualized, lived experiences of those people who are digitally monitored (Boas et al., 2020).

This archetype also captures attempts to implement automated rewards and sanctions for standard (non-) compliance on the basis of digital monitoring of indicators and thresholds, such as automated premium pricing for smallholders that reach a certain sustainability score in the TRADO project. This means that in addition to monitoring, the human factor in evaluations is also replaced by digital technology, which is – as argued by Gillespie (2014) and Mittelstadt et al. (2016) – less sensitive for alternative interpretations, negotiations and unintended adverse consequences. Compared to in-person monitoring through audits, digital monitoring lacks social interaction in the process of evaluating performance.

Overall dashboard forms of participation enable interventions beyond individual smallholders, especially if standards are used to address and monitor other actors in the wider food system. However, the cases also demonstrate the importance of understanding what is made legible and what is left obscured when using dashboards for steering environmental improvement by smallholders.

5.3. The platform

The third bundle of initiatives is characterized by (1) providing a *digital identity* to smallholders shaped by the data they enter and own without predefined interpretation (epistemic), (2) an open normative approach allowing actors to set their own goals to a certain extent (normative) and (3) creating a conducive environment for information exchange on the platform to manage external risks (effective). Building on Kloppenburg and Boekelo (2019) and Plantin et al. (2018), we characterise the form of participation in this third cluster of initiatives as 'the platform' – reflecting their role in exchanging information and/or resources and facilitating interactions between distributed users.

The more open normative approach in the platform type appears to provide a conducive environment for smallholders to take responsibility for environmental improvements. These initiatives achieve this by more loosely defining goals while at the same time ensuring that other actors are made responsible for empowering smallholders through, for instance, fair payment. These platform initiatives thereby intervene in the wider context of the food system by providing market intelligence that allows smallholders to make strategic decisions about when, where and to whom they sell their produce. Platforms also facilitate information exchange (Belk, 2014) among smallholders, decreasing dependency on private and public experts.

These platform initiatives also provide smallholders with a digital identity that enables them to co-determine how issues are represented through entering their own data. These digital identities refer to a set of data about a smallholder that she or he has control over (Weitzberg et al., 2021), for example through a profile on a platform. These identities afford smallholders the right to 'exist' as they can 'act' in food markets through the digital realm. The open normative approach and absence of automated applications supporting farm-level management means that the agency of smallholder to decide on the direction and means of environmental improvement is respected – be it within the architectural limits of the digital application (Gillespie, 2015). At the same time, it also means that the effectiveness of environmental improvements is more unclear and uncertain compared to the tutorial and dashboard archetypes of smallholder participation; environmental improvements are not monitored based on a set of predefined indicators. This highlights an inherent trade-off identified in other studies (see for example Bush et al., 2013) between promoting ambitious sustainability standards and empowering smallholder participation.

Overall, this form of participation provides more options for smallholders to be seen and heard, connect with other food system actors to achieve their livelihood and environmental goals, and share and collect information to collectively learn (Belk, 2014; Keen et al., 2005). However, given platforms remain programmed by the interests of those creating and owning them (Gillespie, 2015; Srnicek, 2017), questions remain on whether they can enable and constrain smallholders to achieving nutritional, social and environmental goals. And while the platform approach might seem most desirable for smallholder participation, the open normative approach and less stringent strategy to influence behaviour means that there is less certainty and clarity about the environmental improvements.

6. Conclusion

By analysing digital food sustainability initiatives, we have distinguished three archetypes of smallholder participation that overcome simplistic binaries of opportunities and risks. Instead of uncritically welcoming digital technologies as a panacea for smallholder participation or warning for the risks of digitalization to exacerbate inequalities and environmental damage, the archetypes we present offer a nuanced understanding of how smallholder participation is always already shaped in particular ways through design-based governance.

Our three archetypes of participation - the tutorial, the dashboard and the platform - show that digital technologies can enable participation in sustainability initiatives through information exchange and collaboration. They allow for context-relevant information collection and thereby make visible what was previously invisible. In addition, smallholders can be connected digitally to other food system actors and can, through their digital identities, play a role in shaping sustainability transitions. However, we also see that existing barriers to participation in analog governance arrangements, such as extension services, voluntary certification and multi-stakeholder platforms, can be replicated and even strengthened through digital technologies. This is especially the case when the optimization of and compliance with numerical indicators become goals in themselves, without proper reflection on the limitations of such digital metrics. Although these metrics can and do play an important role in environmental management, they risk placing the responsibility for environmental improvements with smallholders, without affording them the authority and resources to change their production and/or trading practices. Furthermore, the increased reliance on metrics also raises questions around the ownership and protection of data gathered by digital technologies.

Finally, our three archetypes of participation should not be seen as mutually exclusive categories, but rather as concurrent tendencies in digital environmental governance. They present the first step towards understanding the ways in which digital technologies can either contribute to or obstruct more inclusive and sustainable food systems. Further research is needed on how these different technologies both individually and in combination affect the practices of smallholders. Attention should also be given to actors and interests that drive and shape the digitalization of environmental governance. For instance, how and by whom are the initiatives governed and what effect does more or less private control have over smallholder participation in sustainability? In addition, although our research focusses on the distinct challenges of and implications for smallholder participation, we believe the archetypes may also hold relevance in the context of large-scale or industrial food production.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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