

Beyond the digital divide: A multi-dimensional approach to enabling digital inclusivity in food, land, and water systems

Felix Ouko Opola, f.opola@cgiar.org, International Water Management Institute, Pretoria, South Africa

Simon Langan, s.langan@cgiar.org International Water Management Institute, Colombo, Sri Lanka

Indika Arulingam, i.arulingam@cgiar.org, International Water Management Institute, Colombo, Sri Lanka

Charlotte Schumann, charlotte.schumann@fu-berlin.de, Freie Universität Berlin, Berlin, Germany

Niyati Singaraju, n.singaraju@irri.org, International Rice Research Institute, New Delhi, India

Deepa Joshi, deepa.joshi@cgiar.org, International Water Management Institute, Colombo, Sri Lanka



Date: 18th October 2023

// Work Package:2

Summary

In what is proclaimed as the 'fourth industrial revolution', digital innovation is thought to have the potential to provide solutions to key challenges facing food production and consumption together with the support of sustainability of the underpinning support of land, and water systems. Nowhere is this more the case in less-industrialised countries, which largely have agrarian based economies. Applications of digital innovations include faster and more reliable communication, better collection, analysis, and storage of data, enhancing democratic processes and transparency in governance, affordable financial services and can provide the basis for decision support. However, there is a risk that people with less formal education and skills and little resource endowments as well as particular groups of people such as women will be excluded from participating or benefiting from digital innovation, the so-called digital divide. In addition, there is a risk that people, communities, and societies may be disadvantaged or harmed by digital innovation processes. Digital inclusivity within food, land and water systems are approaches in digital innovation need to include the differing needs and resources of men, women, youth, indigenous communities who produce most the world's food in smallholder land holdings. Here we provide the state-of-the-art evidence from peer reviewed literature and other literature in support of these statements. On the basis of this and our wider anecdotal experience we present, a holistic multi-dimensional framework for digital inclusivity. The aim of the digital inclusivity index (and supporting tools) is to provide a resource to guide to transform and change development and application of digital innovations. Specifically, it provides governments, funders, researchers, and development agencies a framework on how to assess, minimise and lessen exclusion from digital innovation. This is achieved through increasing awareness of the characteristics of digital exclusion, recognising the needs of the actors that they target with digital interventions which are more inclusive, making interventions more participatory and mitigating any potential harm that can be caused by digital innovation. We also argue that the approach to digital innovation needs to be set within the context of a wide ranging 'digital ecosystem' where different actors contribute knowledge and resources, and digital innovation goes beyond the adoption and use of technologies to include changes in preexisting social arrangement and institutions.

Opola, F. O.; Langan, S.; Arulingam, I.; Schumann, C.; Singaraju, N.; Joshi, D. 2023. *Beyond the digital divide: a multi-dimensional approach to enabling digital inclusivity in food, land, and water systems.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Digital Innovation. 29p.

This publication has been prepared as an output of the **CGIAR Initiative on** <u>Digital Innovation</u>, which researches pathways to accelerate the transformation towards sustainable and inclusive agrifood systems by generating research-based evidence and innovative digital solutions. This publication has not been independently peer reviewed. Responsibility for editing, proofreading, and layout, opinions expressed, and any possible errors lies with the authors and not the institutions involved. The boundaries and names shown, and the designations used on maps do not imply official endorsement or acceptance by IWMI, CGIAR, our partner institutions, or donors. In line with principles defined in <u>CGIAR's Open and FAIR Data Assets Policy</u>, this publication is available under a <u>CC BY 4.0</u> license. © The copyright of this publication is held by <u>IWMI</u>. We thank all funders who supported this research through their contributions to the <u>CGIAR Trust Fund</u>.

Cover photo: IWMI

Table of Contents

List of figures	4
List of tables	4
Introduction	5
Methodology	7
A preliminary framework for digital inclusivity	7
Sampling and analysis of literature	9
Findings: Indicators of digital inclusivity	10
Enabling access to digital innovations	11
Ensuring desirable and long-term impacts	13
Fostering participation in digital innovation processes	15
Creating inclusive social structures	16
Towards a digital inclusivity index in food systems	
Next steps in the index development process	
Concluding remarks	
References	21

List of figures

Figure 1. The ladder of inclusive innovation (Heeks et al., 2014)
Figure 2. Dimensions of digital inclusivity11

List of tables

Table 1. Indicators of access	12
Table 2. Indicators of impact	14
Table 3. Indicators of participation	16
Table 4. Indicators of structural inclusion	17

Beyond the digital divide: A multi-dimensional approach to enabling digital inclusivity in food, land, and water systems

Felix Ouko Opola; Simon Langan; Indika Arulingam; Charlotte Schumann; Niyati Singaraju; Deepa Joshi

Introduction

Digital innovation, which includes the development and application of new or improved digital information, technologies, skills, and services, as well as the associated rules and social arrangements that govern it, is considered to have a huge potential to transform food, land, and water systems (Benfica et al., 2023; Koo et al., 2022). In less-industrialized countries, which are largely depended on food, land, and water systems for livelihoods, income and economic development, digital innovations can provide solutions to some of the social, economic, and environmental challenges related to food production and distribution, water use, and natural resource management (Benfica et al., 2023; Tsan Michael et al., 2019). These applications range from simple tools such as mobile phones and phone-based applications that enhance communication and knowledge sharing between various actors (Onsongo & Schot, 2017) to more sophisticated innovations such as sensors, robots, computer simulations, and artificial intelligence (Benitez et al., 2020; Klerkx et al., 2019). In natural resource management, applications include the monitoring of land and water bodies, collection, storage, and use of data and decision support (Mehta et al., 2013; Ng et al., 2021).

Despite this promise and potential, there is a growing concern that large groups of people are excluded from accessing, benefiting from, or participation in the digital transformation of food, land, and water systems (Ng et al., 2021). First, there still exists stark inequalities regarding access to and use of digital technologies and services as revealed by the Covid-19 pandemic (Aissaoui, 2021; Boggia et al., 2022; Zheng & Walsham, 2021). Secondly, particular groups of people such as women are unproportionally excluded from accessing and using digital innovations (Hilbert, 2011; Khoza et al., 2021; Ragetlie et al., 2022). Thirdly, evidence of tangible benefits of digital innovations to smallholder farmers, who are the predominant food producers in less-industrialized countries, as well as many communities living in rural areas remain scant and speculative. Kudama et al. (2021) for example point out that out of all smallholder farmers that register for digital agricultural extension services, less than 30 percent remain active users. Finally, attention has been drawn to risks and potential harm such as surveillance or misuse of data that can be caused to people are especially exposed to the effects of such risks due to lack of sufficient safety nets (Klerkx et al., 2019; Ng et al., 2021; Stone, 2017; van der Burg et al., 2019).

Many countries and organizations, including development agencies, civil society organizations, and knowledge institutions have been vocal about the need to make digital innovations inclusive to marginalized groups of people, including people with little resource-endowments, marginalized women, smallholder farmers in rural areas, and people living in remote and arid lands (African Union, 2020; lizuka & Hane, 2021; World Bank, 2016). Given the multiple aspects of social inclusion pointed out above, digital inclusivity will require a holistic approach that addresses a variety of issues such as access, participation, and risks in order to not only 'leave no one behind' but also 'cause no harm'. However, current understandings and interventions on digital inclusivity focus on a linear technocratic approach emphasizes adoption and use (or lack thereof) of digital technologies or services (Lajoie-O'Malley et al., 2020). As a result, available guidelines, and metrics for promoting digital inclusivity are based on this top-down linear approach, which ignores other aspects of inclusion that are equally important (Holmström, 2022; McCampbell et al., 2021). The aim of this work is to provide a holistic guideline and metrics for promoting digital inclusivity, that indicates all aspects of

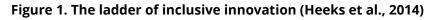
enabling a socially inclusive digital transformation process. Based on a systematic review of published studies and reports on digital inclusivity in food, land, and waters systems, we propose and present a multi-dimensional framework for digital inclusivity. Such a holistic index for digital inclusivity currently lacks in research, policy, and practice on digital inclusivity (Lioutas et al., 2021).

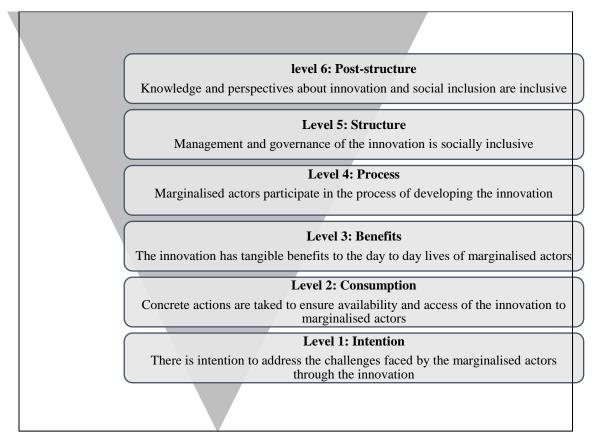
Methodology

We use the critical interpretive synthesis method, a qualitative approach to a systematic review and meta-synthesis of literature. To guide the review process, we use the ladder of inclusive innovation as a preliminary holistic framework of social inclusivity in innovation processes. This framework applied to digital inclusivity literature and modified based on concepts and themes that emerge from the analysis.

A preliminary framework for digital inclusivity

The ladder of inclusive innovation (Heeks et al., 2014) is a suitable preliminary framework for a holistic understanding of digital inclusivity given its multi-faceted and holistic nature. This ladder was adapted from work done in the 1960's by Sherry Arnstein on how to include urban residents in the design and implementation of urban planning interventions (Arnstein, 1969). As per this framework (outlined in figure 1), there are six levels in succession that indicate whether an innovation is inclusive. At the lowest level, an innovation is inclusive when there is an intention by those promoting it to reach out or benefit marginalized groups of people, even if no further steps are taken to realize this goal. This can be through the organization's goals and missions or the presence of a social inclusion staff or department. At the second level, concrete steps are taken to ensure access and utilization of the innovation being promoted by the people that are targeted for inclusion. At the third level, innovations are evaluated for their benefit to the day to day lives of the targeted actors. This can be indicated by the continuous or repeated use of the innovations by these actors. At the fourth level, the targeted people are included as active participants in the design and implementation of innovations. This level therefore goes beyond the dichotomy between producers and users of an innovation or technology and promotes participation in innovation processes by people that are targeted for inclusion. At the fifth level, marginalized actors are included in the making of rules and policies that govern the innovation process such as policy making processes and stakeholder networks. At the sixth and highest level, innovations are inclusive when targeted actors contribute to discourses and knowledge about what innovation is and what makes it socially inclusive.





This framework, and the 6 proposed levels of social inclusivity is suitable as a guide to developing a holistic framework that captures all the dimensions of digital inclusivity in food, land, and water systems.

Sampling and analysis of literature

Sampling, review, and synthesis of literature followed a critical interpretive synthesis methodology, a qualitative approach to systematically reviewing and synthesizing literature (Brunton et al., 2020; Dixon-Woods et al., 2006). This involved the following procedures:

- a) Using the ladder of inclusive innovation as a guide for a preliminary scope and analysis of literature
- b) Sampling and analysis of additional literature based on concepts and themes that emerge from the initial analysis.
- c) A thematic analysis of the sampled literature to cluster emerging concepts on digital inclusivity into dimensions.
- d) Modification of the ladder of inclusive innovation into a holistic framework of digital inclusivity in food, land, and water systems.

We employ this approach because literature on digital inclusivity is large, diverse, and addressed from different academic disciplines (Lythreatis et al., 2022; Van Dijk & Hacker, 2003). In such instances, an approach that interprets and synthesises this literature is more appropriate compared to systematic review methods such as meta-analysis that aggregate and summarise all the available literature on the topic (Dixon-Woods et al., 2006; Noblit & Hare, 1999). Our analysis is therefore mainly inductive, focussed on developing themes and concepts that emerge from literature. However, we first select a preliminary framework on digital inclusivity to guide the search for literature to avoid 're-inventing the wheel' as suggested by other authors (Dixon-Woods, 2011; Strauss & Corbin, 1990). The ladder of inclusive innovation framework helped in selecting broad research questions and key words to start the search and analysis with.

The following were our inclusion criteria for selecting literature:

a) Peer reviewed journal articles, government and multi-governmental policy documents, books, and project reports.

- b) Studies, reviews, policy recommendations and project reports that are aimed at making digital innovation socially inclusive.
- c) Literature focussed on the food, land, and water systems of less industrialised countries.

An initial search was conducted in Scopus and ProQuest using the following key words: Digital divide, gender digital divide, digital inclusivity, ICT for development, agriculture, food, water, land, developing countries, data rights, data justice. The search yielded 81 journal articles, government policy documents and project reports. 12 of these were identified to be most relevant and were analyses through a thematic analysis (Nowell et al., 2017) to developed key concepts and themes. Additional literature was sampled and analyzed based on these emerging themes and concepts. Eventually, 54 sources of literature, published between 2003 and 2023 were included in this review and synthesis.

Findings: Indicators of digital inclusivity

Based on our analysis and findings, we propose the following as key dimensions of digital inclusivity in food, land, and water systems: Access, impact, participation, and social system. Access refers to refers to whether groups of people that are targeted for inclusion such as Indigenous communities, smallholder farmers of marginalized women or the youth are aware of, can afford, and can use the promoted digital innovations. The dimension of impact refers to the positive outcome of digital innovation to the day to day lives of the groups of people targeted for inclusion. This includes amplifying the positive impacts and mitigating any potential risks. The dimension of participation is broader than the first two and relates to inclusion in the design and development of digital technologies and services. Finally, the dimension of social system is the broadest in scope and refers to including the knowledge, meanings, and perspectives of the targeted groups of actors on what constitutes digital innovation and how it should be realized and governed. Each of these four dimensions contains several processes and situations that can be used as criteria for determining the inclusivity or exclusivity of a

digital innovation. These are outlined in figure 2 below and explained in the subsequent text.

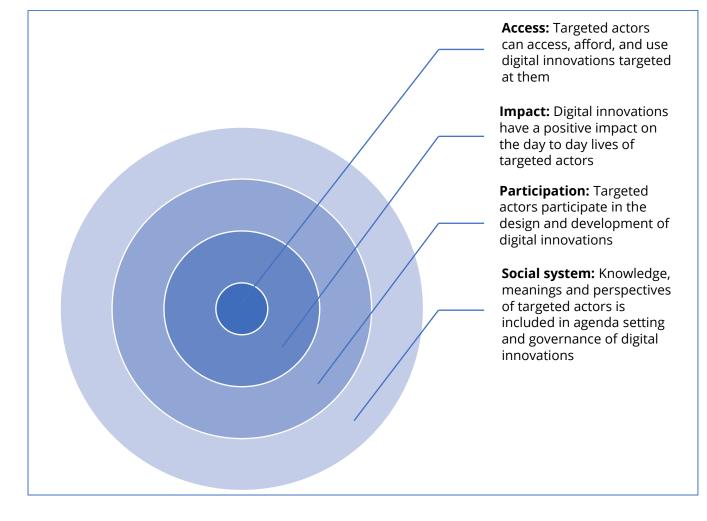


Figure 2. Dimensions of digital inclusivity

Enabling access to digital innovations

Access to digital innovations is determined by material factors such as whether the targeted actors (TA) for digital inclusivity can afford and use the digital technology or service as well as immaterial factors such as whether the TA have a desire for and are motivated to repeatedly use the digital innovation (Acilar & Sæbø, 2021; Lythreatis et al., 2022; Vassilakopoulou & Hustad, 2021). Table 1 below outlines five indicators of access that are elicited from literature.

Table 1. Indicators of access

 innovation and its benefits? Are targeted actors motivated to repeatedly or User-centere continuously use the digital innovation? Is the digital innovation package intentionally made affordable to the targeted actors? Do targeted actors have the skills and capacity to use the digital innovation? Is the digital innovation designed to align to the technology 	Dimension	Indicators	Examples of approaches
continuously use the digital innovation? design Is the digital innovation package intentionally made affordable to the targeted actors? Do targeted actors have the skills and capacity to use the digital innovation? Is the digital innovation designed to align to the technology	Access		Agent-based modelling
affordable to the targeted actors? Do targeted actors have the skills and capacity to use the digital innovation? Is the digital innovation designed to align to the technology			User-centered design
digital innovation? Is the digital innovation designed to align to the technology			
use habits and daily routines of the targeted actors?		Is the digital innovation designed to align to the technology use habits and daily routines of the targeted actors?	

First, inclusivity is indicated by whether the right channels have been used to inform marginalized actors about the innovation and its benefits. For example, people living in rural communities might prefer or trust audio visual channels such as radio and television over text-based channels such as newspapers or SMS (Dey & Ali, 2016). Secondly, digital innovations are accessible if the TA desire them and is motivated to continuously use them. Digital technologies such as smart phones might be considered too complex and induce anxiety and stress among the targeted users (Aissaoui, 2021; Van Dijk & Hacker, 2003). In addition, use habits vary among different groups of people. For example, research done in Malawi and Zambia indicate that there are differences in perceptions between men and women regarding the ease of use, value and risk associated with adopting a new digital technology or service (Khoza et al., 2021). In Indonesia, it was pointed out that within smallholder communities, farmers who had an entrepreneurial mindset were more likely to experiment with new digital technologies compared to farmers who were practicing agriculture for subsistence (Fahmi & Savira, 2021). A key aspect of enabling access is therefore ensuring the digital innovation is desirable and usable. Approaches such as user-centered design for example focus on understanding the specific needs and interests of targeted groups of people in order to design technologies or services that are appropriate and usable for them (Molina-Maturano et al., 2022; Müller et al., 2022). Third, the digital innovation package, including digital infrastructure such as internet connectivity and electricity as well as digital technologies and services should be affordable to the TA and areas where they live, which as often neglected in public and private investments in digital innovation packages (Deichmann et al., 2016; Tsan Michael et al., 2019). Fourth, TA should have the necessary skills to use the digital innovations. Across less-industrialized countries, level of education is cited as the most important factor causing the digital divide (Abdulai et al., 2022; Lythreatis et al., 2022; Ng et al., 2021). For instance, a cross sectional survey done in Northern Ghana revealed that 69% of people cannot send an SMS and 83% are not able to browse the internet (Abdulai, KC, and Fraser 2022). Enhancing the capacity and skills of TA to use the digital innovation is therefore an important aspect of enhancing access (Fahmi and Savira 2021).

Ensuring desirable and long-term impacts

Collecting, storing, and using data for processes such as monitoring the quality and content of soil, water bodies and weather patterns is not new and has been done since ancient civilizations (Maru et al., 2018). Digitalization of this data is a relatively recent innovation that aids in making these processes faster, more efficient, and more reliable, especially within marginalized groups of people such as those in arid areas where this information has needed them most. Tools such as index-based livestock insurance for example has utilized digital data such as satellite imagery to signify, predict and compensate losses caused by unreliable climate and in the absence of data on the actual losses that is difficult to measure among pastoral communities (Carter, 2022). Such aspects relating to tangible benefits and solutions in the day to day lives of marginalized actors are an important dimension of social inclusion since adoption and access to digital innovations may not necessarily translate to benefits for the targeted actors (Dey & Ali, 2016). However, digital innovations do not inherently lead to positive outcomes and the

untended negative outcomes need to be mitigated as a key aspect of making digital innovation impactful and inclusive. Table 2 outlines four indicators of impact elicited from literature.

Dimension	Indicators	Examples of approaches
Impact	Is the solution offered by the digital innovation to the targeted actors effective and reliable?	Data stewardship plans
	Are there opportunities to adapt the digital innovation based on emerging and changing needs of the targeted actors?	Sustainable business models
	Can the benefit of the digital innovation be sustained in the long run?	
	Are there standards and procedures in pace to guide on ethical collection, use, and analysis of data?	

Table 2. Indicators of impact

First, it is pointed out that though digital innovation is promising to transform the food, land, and water systems in less industrialized countries, evidence of tangible and verifiable benefits for marginalized groups of people such as farmers in rural areas remain scant and speculative (Adenle et al., 2019; Maru et al., 2018). The solution proposed and offered by the digital innovation in addressing a challenge faced by targeted actors should therefore be effective and verifiable as a key aspect of making it inclusive. Secondly, impact of a digital innovation takes time and key part of inclusivity is investing time and resources to monitor the digital innovation over time and ensure that the solutions it provides can be sustained in the long run (Utami et al., 2021). Third, the needs and interests of targeted actors vary with time and to be impactful, digital innovations need to have the capacity to respond to these changes (Dey & Ali, 2016). Finally, there may be negative outcomes associated with the digital technology or service and these impacts are more severe for vulnerable groups of people (Stone, 2022). For instance, the use of smart phone-based applications for digital agricultural extension services may expose targeted actors to surveillance by the government for informal economic activities (Gurung, 2018). Additionally, data collected from marginalized actors for use in digitalization processes (exported data) may be commercialized by companies such as input and service provides through profiling of users for market segmentation (Gurung, 2018; van der Burg et al., 2019). Technologies such as remote sensing and drones (imported data) may also infringe on the rights and privacy of marginalized groups of actors (Maru et al., 2018; van der Burg et al., 2019). The establishment of guidelines for ethical collection, use, and processing of data in digital innovation processes is therefore one of the key indicators of digital inclusivity.

Fostering participation in digital innovation processes

Digital technologies are no longer strange to marginalized groups of actors and these actors are increasing demanding to participate in processes that affect their lives (van Bruggen et al., 2019) It is also realized that groups of actors that are usually considered marginalized are not passive users of technology and services but have valuable knowledge, skills, and other resources that can be instrumental in digital innovation processes (Cozzens & Sutz, 2014; Nyadzi et al., 2020). A key dimension of digital inclusivity is therefore the extent to which it includes, acknowledges, and compensates the knowledge, initiatives, and expertise of marginalized groups of actors that are usually targeted with digital technologies and solutions. These are indicated by the three aspects outlined in table 3.

Table 3. Indicators of participation

Dimension	Indicators	Examples of approaches
Participation	Are targeted actors partnered with as co-innovators?	Participatory modelling
	Are opportunities created for targeted actors to re-adapt the digital innovation to their contexts through secondary innovation?	Grassroots/informal sector innovation
	Are the knowledge, initiatives and technologies developed and shared by targeted actors acknowledged and adequately compensated?	

First, targeted actors can contribute their knowledge and resources as active partners in the co-development of digital innovations. Approaches such as citizen science and participatory modelling for instance have attempted to include citizens such as rural communities in the design and development of digital innovations (Bhawra, 2022; van Bruggen et al., 2019). This is not only ethical, but can also reduce the cost of developing digital solutions to targeted actors and make them more acceptable to these actors (Timmermann, 2020). Secondly, digital technologies are sometimes used by targeted actors in ways that were not envisioned or intended, and a key aspect of making them inclusive is giving opportunities to these actors to redesign and adapt the innovations targeted at them to their contexts and needs (Daum et al., 2022; Mabaya & Porciello, 2022). Finally, targeted actors can be independent digital innovators despite or even due to their limited formal skills and education and resources (Abdulai, 2022b; Cozzens & Sutz, 2014; Mabaya & Porciello, 2022). From an inclusivity perspective, these initiatives need to be acknowledged and compensated as legitimate forms of innovation.

Creating inclusive social structures

Digital technologies and services do not just provide solutions to technical problems such as access to information. They also interact with people and as a result, change routines, practices, and meanings that people attach to their day to day lives (Abdulai, 2022b; van der Burg et al., 2019). An important aspect of inclusivity is therefore the extent to which the meanings and narratives about food, land, and water caused by the digital innovation are desirable to the targeted actors and do not disrupt alternative meanings in a negative way. This dimension of inclusivity is indicated by the three aspects outlined in table 4.

Dimension	Indicators	Examples of approaches
Inclusive social structures	Are changes in meanings, skills, norms caused by the digital innovation to the targeted actors analyzed, communicated to them, and consented to?	Responsible research and innovation
	Are pre-existing socio-economic inequalities within the groups of actors targeted with digital inclusivity interventions known and mitigated?	
	Are targeted actors included in the making of rules such as policies and legislations that govern digital innovation processes?	

Table 4. Indicators of structural inclusion

First, the changes in folk wisdom, skills, and meanings attached to food, land, and water systems by the targeted actors should be known and communicated to the targeted actors for consent. For example, the shift from milking by hand to the use of milking machines may change the relationship between a farmer and their cows and the meanings through which issues such as animal health are understood (Abdulai, 2022a). Digitalization of manual processes may also lead to loss of the manual skills and knowledge (Klerkx et al., 2019) and may be misaligned to other narratives about agriculture such as agro-ecology (Béné et al., 2019; Carter, 2022). Regarding inclusivity, targeted actors need to be informed of these changes. Secondly, Digital innovations may unintentionally multiply inequalities that already exist within the marginalized groups of actors that they target with a technology or service. This is because people who are likely to access, benefit from and participate in digital innovation are those within marginalized

actors who have better education, higher incomes, higher social status and are male (Mendez Garcia, 2011; Tewathia et al., 2020). In addressing digital inclusivity, it is therefore imperative to assess, anticipate and mitigate these unintended consequences. Finally, digital inclusivity within this domain is indicated by the extent to which the targeted actors are included in the governance of digital innovation processes, such as in policy making processes and management of stakeholder networks (Munthali et al., 2018)

Towards a digital inclusivity index in food systems

There has been a global call for decentralization and localization of interventions, especially in agriculture and natural resources management (van Bruggen et al., Nikolic, and Kwakkel 2019).; Ustyuzhantseva 2021). Non-tangible elements of digital inclusion are therefore becoming increasingly important, even though they are difficult to quantify and measure. However, interventions on social inclusion within innovation processes, including digital innovation, are still based on a linear paradigm that emphasize access to and use of digital innovations (Lythreatis et al., 2022). Based on the findings in this analysis, we argue for a more holistic understanding of digital inclusivity, that considers both technical and social changes caused by digital innovation. While access and use to digital technologies and services remain a challenge, especially in less industrialized countries (Aissaoui, 2021; Zheng & Walsham, 2021), digital innovation is multi-faced, and fostering access in an environment where the other domains of inclusivity are lacking may multiply rather than reduce social inequalities. The fast rate of development of digital innovation means that most people who are considered marginalized by digital innovation are aware of the potential and impact of these technologies and services and demand involvement in the development and management of these processes. Participation of these actors is therefore important in making digital innovations

desirable and legitimate. These marginalized actors can also contribute their knowledge, skills, and labor into digital innovation processes.

A holistic understanding and approach to digital inclusivity is therefore not only ethical, but also imperative to the social acceptance and legitimacy of digital inclusivity interventions. The challenge for a such a holistic approach to digital inclusivity would be how to develop a measure for the non-tangible aspects of digital inclusion such as how marginalized actors are negatively impacted by digital innovation and how digital innovations change meanings and practices within the communities they are targeted at. We propose the indicators pointed out in this review as key elements of a digital inclusivity index that can act as a guideline with such tangible indicators for enabling digital inclusivity. However, we acknowledge that formal research and development is still skewed towards industrialized countries (Chataway et al., 2014). There is therefore a risk that the dimensions and indicators developed through this study may predominantly be based on research and projects conducted by industrialized countries in less industrialized countries. It is therefore necessary to make the index development process inclusive, by engaging with actors based in less industrialized countries such as government agencies, local communities, knowledge institutions, and civil society. These actors can provide necessary feedback that will be useful in the co-development and validation of the index.

An important question in the development of a digital inclusivity index is who is to be included in digital inclusivity. In this review, we have considered women in rural areas, indigenous people such as pastoral communities and smallholder farmers in rural communities as groups of people who are usually marginalized from the process and benefits of innovation in agriculture and land and water management. Our understanding of social inclusivity is therefore based on the most marginalized based on income, gender, and social status, which are the three most important categories of social inclusivity indicated in literature on the digital inclusivity (Aissaoui, 2021; Lythreatis et al., 2022; Van Dijk &and Hacker, 2003). Since inequalities intersect across these

19

categories of people (Hankivsky et al., 2014; Kwan, 2021; Zheng & Walsham, 2021), our focus was on the development of dimensions and indicators that can be applicable across different groups of marginalized or vulnerable people. While is it not possible for interventions to address all dimensions and parameters of digital inclusivity, a holistic understanding of how a digital innovation can be inclusive or exclusive can be a useful starting point do develop context specific interventions without compromising on the other dimensions.

Next steps in the index development process

The dimensions and indicators pointed out in this review can form the basis for a digital inclusivity index which can be a guide to fostering a socially inclusive digital transformation process. However, we acknowledge that formal research and development is still skewed towards industrialized countries as pointed out for instance by Chataway et al. (2014). Studies and reports included in this review may therefore have a bias towards research and projects carried out by industrialized countries in less industrialized countries. It is therefore necessary to make the index development process inclusive, by engaging with actors based in less industrialized countries such as government agencies, local communities, knowledge institutions, and civil society. These actors can provide necessary feedback that will be useful in the co-design and co-development of the index. Such a testing and validation exercise in order to develop a standardized digital inclusivity index is currently underway under the CGIAR initiative on digital innovation.

Concluding remarks

Digital innovation is a double aged sword. While it can offer solutions to problems such as collection and access to data to be used for processes such as monitoring quality of water and disease management in farms, it also presents potential negative outcomes such as misuse of data and multiplying pre-existing inequalities in communities where it is implemented. A digital inclusivity index, based on tangible and intangible dimensions and parameters, as identified in this review could be useful to enhance the social inclusivity of digital innovations. Such an index needs to be co-developed, validated, and operationalized with communities, government agencies, academic institutions and social enterprises that are based in less industrialized countries, to ensure that it is legitimate and useful.

References

- Abdulai, A. R. (2022a). A New Green Revolution (GR) or Neoliberal Entrenchment in Agri-food Systems? Exploring Narratives Around Digital Agriculture (DA), Food Systems, and Development in Sub-Sahara Africa. *Journal of Development Studies*, *58*(8), 1588–1604. https://doi.org/10.1080/00220388.2022.2032673
- Abdulai, A. R. (2022b). Toward digitalization futures in smallholder farming systems in Sub-Sahara Africa: A social practice proposal. *Frontiers in Sustainable Food Systems*, 6. https://doi.org/10.3389/fsufs.2022.866331
- Abdulai, A. R., KC, K. B., & Fraser, E. (2022). What factors influence the likelihood of rural farmer participation in digital agricultural services? experience from smallholder digitalization in Northern Ghana. *Outlook on Agriculture*. https://doi.org/10.1177/00307270221144641
- Acilar, A., & Sæbø, Ø. (2021). Towards understanding the gender digital divide: a systematic literature review. *Global Knowledge, Memory, and Communication*. https://doi.org/10.1108/GKMC-09-2021-0147/FULL/HTML
- Adenle, A. A., Wedig, K., & Azadi, H. (2019). Sustainable agriculture and food security in Africa: The role of innovative technologies and international organizations. *Technology in Society*, *58*. https://doi.org/10.1016/j.techsoc.2019.05.007

- Aissaoui, N. (2021). The digital divide: a literature review and some directions for future research in light of COVID-19. *Global Knowledge, Memory, and Communication*. https://doi.org/10.1108/GKMC-06-2020-0075/FULL/HTML
- Arnstein, S. R. (1969). A Ladder of Citizen Participation. *Journal of the American Planning Association*, 35(4), 216–224. https://doi.org/10.1080/01944366908977225
- Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., Talsma, E.
 F., & Khoury, C. K. (2019). When food systems meet sustainability Current narratives and implications for actions. In *World Development* (Vol. 113, pp. 116–130). Pergamon. https://doi.org/10.1016/j.worlddev.2018.08.011
- Benfica, R., Chambers, J., Koo, J., Nin-Pratt, A., Falck-Zepeda, J., Stads, G.-J., & Arndt, C. (2023). Food System Innovations and Digital Technologies to Foster Productivity Growth and Rural Transformation. *Science and Innovations for Food Systems Transformation*, 421–437. https://doi.org/10.1007/978-3-031-15703-5_22
- Benitez, G. B., Ayala, N. F., & Frank, A. G. (2020). Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. *International Journal of Production Economics*, 228, 107735. https://doi.org/10.1016/J.IJPE.2020.107735
- Bhawra, J. (2022). Decolonizing Digital Citizen Science: Applying the Bridge Framework for Climate Change Preparedness and Adaptation. *Societies*, *12*(2), 71. https://doi.org/https://doi.org/10.3390/soc12020071
- Boggia, A., Carolan, M. S., Ragetlie, R., Najjar, D., & Oueslati, D. (2022). "Dear brother farmer": Gender, agriculture, and digital extension in rural Tunisia during the COVID-19 pandemic. *Cgspace.Cgiar.Org.* https://doi.org/10.3390/su14074162
- Brunton, G., Oliver, S., & Thomas, J. (2020). Innovations in framework synthesis as a systematic review method. In *Research Synthesis Methods* (Vol. 11, Issue 3). https://doi.org/10.1002/jrsm.1399

- Carter, M. R. (2022). Can digitally enabled financial instruments secure an inclusive agricultural transformation? *Agricultural Economics (United Kingdom)*, *53*(6), 953–967. https://doi.org/10.1111/agec.12743
- Chataway, J., Hanlin, R., & Kaplinsky, R. (2014). Inclusive innovation: an architecture for policy development. *Innovation and Development*, *4*(1), 33–54. https://doi.org/10.1080/2157930X.2013.876800
- Cozzens, S., & Sutz, J. (2014). Innovation in informal settings: reflections and proposals for a research agenda. *Innovation and Development*, *4*(1), 5–31. https://doi.org/10.1080/2157930X.2013.876803
- Daum, T., Ravichandran, T., Kariuki, J., Chagunda, M., & Birner, R. (2022). Connected cows and cyber chickens? Stocktaking and case studies of digital livestock tools in Kenya and India. *Agricultural Systems*, *196*.
 https://doi.org/10.1016/j.agsy.2021.103353
- Deichmann, U., Goyal, A., & Mishra, D. (2016). Will digital technologies transform agriculture in developing countries? *Agricultural Economics*, *47*(S1), 21–33. https://doi.org/10.1111/AGEC.12300
- Dey, B., & Ali, F. (2016). A critical review of the ICT for development research. In ICTs in Developing Countries: Research, Practices and Policy Implications. https://doi.org/10.1057/9781137469502_1
- Dixon-Woods, M. (2011). Using framework-based synthesis for conducting reviews of qualitative studies. *BMC Medicine*, *9*. https://doi.org/10.1186/1741-7015-9-39
- Dixon-Woods, M., Cavers, D., Agarwal, S., Annandale, E., Arthur, A., Harvey, J., Hsu, R., Katbamna, S., Olsen, R., Smith, L., Riley, R., & Sutton, A. J. (2006). Conducting a critical interpretive synthesis of the literature on access to healthcare by vulnerable groups. *BMC Medical Research Methodology*, *6*(1), 1–13. https://doi.org/10.1186/1471-2288-6-35/TABLES/2

- Fahmi, F. Z., & Savira, M. (2021). Digitalization and rural entrepreneurial attitude in Indonesia: a capability approach. *Journal of Enterprising Communities*. https://doi.org/10.1108/JEC-06-2021-0082
- Gurung, L. (2018). The Digital Divide: An Inquiry from Feminist Perspectives. *Dhaulagiri Journal of Sociology and Anthropology*, *12*. https://doi.org/10.3126/dsaj.v12i0.22179
- Hankivsky, O., Grace, D., Hunting, G., Giesbrecht, M., Fridkin, A., Rudrum, S., Ferlatte, O., & Clark, N. (2014). An intersectionality-based policy analysis framework: Critical reflections on a methodology for advancing equity. *International Journal for Equity in Health*, *13*(1), 1–16. https://doi.org/10.1186/s12939-014-0119-x
- Heeks, R., Foster, C., & Nugroho, Y. (2014). New models of inclusive innovation for development. *Innovation and Development*, *4*(2), 175–185.
 https://doi.org/10.1080/2157930X.2014.928982
- Hilbert, M. (2011). Digital gender divide or technologically empowered women in developing countries? A typical case of lies, damned lies, and statistics. *Women's Studies International Forum*, *34*(6). https://doi.org/10.1016/j.wsif.2011.07.001
- Holmström, J. (2022). From AI to digital transformation: The AI readiness framework. *Business Horizons*, *65*(3). https://doi.org/10.1016/j.bushor.2021.03.006
- Khoza, S., de Beer, L. T., van Niekerk, D., & Nemakonde, L. (2021). A genderdifferentiated analysis of climate-smart agriculture adoption by smallholder farmers: application of the extended technology acceptance model. *Gender, Technology and Development, 25*(1). https://doi.org/10.1080/09718524.2020.1830338
- Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming, and agriculture 4.0: New contributions and a future research agenda. In NJAS - Wageningen Journal of Life Sciences (Vols. 90–91). https://doi.org/10.1016/j.njas.2019.100315

- Koo, J., Kramer, B., Langan, S., Ghosh, A., Monsalue, A. G., & Luni, T. (2022). Digital innovations: Using data and technology for sustainable food systems. https://doi.org/10.2499/9780896294257_12
- Kudama, G., Dangia, M., Wana, H., & Tadese, B. (2021). Will digital solution transform Sub-Sahara African agriculture? In *Artificial Intelligence in Agriculture* (Vol. 5). https://doi.org/10.1016/j.aiia.2021.12.001
- Kwan, C. (2021). Toward an inclusive digital economy for all: Perspectives from an intersectional feminist social work lens. *International Social Work*. https://doi.org/10.1177/00208728211009579
- Lajoie-O'Malley, A., Bronson, K., van der Burg, S., & Klerkx, L. (2020). The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. *Ecosystem Services*, *45*. https://doi.org/10.1016/j.ecoser.2020.101183
- Lioutas, E. D., Charatsari, C., & De Rosa, M. (2021). c. *Technology in Society*, 67. https://doi.org/10.1016/j.techsoc.2021.101744
- Lythreatis, S., Singh, S. K., & El-Kassar, A. N. (2022). The digital divide: A review and future research agenda. *Technological Forecasting and Social Change*, *175*. https://doi.org/10.1016/j.techfore.2021.121359
- Mabaya, E., & Porciello, J. (2022). Can digital solutions transform agri-food systems in Africa? *Agrekon*, *61*(1). https://doi.org/10.1080/03031853.2022.2032223
- Maru, A., Berne, D., Beer, J. De, Ballantyne, P., Pesce, V., Kalyesubula, S., Fourie, N.,
 Addison, C., Collett, A., Chaves, J., Maru, A., Berne, D., De Beer, J., Ballantyne, P.,
 Pesce, V., Kalyesubula, S., Fourie, N., Addison, C., Collett, A., & Chaves, J. (2018).
 Digital and Data-Driven Agriculture: Harnessing the Power of Data for
 Smallholders. *F1000Research 2018 7:525*, *7*.
- McCampbell, M., Rijswijk, K., Wilson, H., & Klerkx, L. (2021). A problematization of inclusion and exclusion. *The Politics of Knowledge in Inclusive Development and*

Innovation, 199–213. https://doi.org/10.4324/9781003112525-18/PROBLEMATISATION-INCLUSION-EXCLUSION-MARIETTE-MCCAMPBELL-KELLY-RIJSWIJK-HANNAH-WILSON-LAURENS-KLERKX

- Mehta, V. K., Aslam, O., Dale, L., Miller, N., & Purkey, D. R. (2013). Scenario-based water resources planning for utilities in the Lake Victoria region. *Physics and Chemistry of the Earth, Parts A/B/C*, *61*, 22–31. https://doi.org/10.1016/j.pce.2013.02.007
- Mendez Garcia, O. P. (2011). Gender Digital Divide the Role of Mobile Phones among Latina Farm Workers in Southeast Ohio. *Gender, Technology and Development, 15*(1), 53–74. https://doi.org/https://doi.org/10.1177/097185241101500103
- Molina-Maturano, J., Verhulst, N., Tur-Cardona, J., Güerena, D. T., Gardeazábal-Monsalve, A., Govaerts, B., De Steur, H., & Speelman, S. (2022). How to Make a Smartphone-Based App for Agricultural Advice Attractive: Insights from a Choice Experiment in Mexico. *Agronomy*, *12*(3). https://doi.org/10.3390/agronomy12030691
- Müller, A., Ortiz-Crespo, B., & Steinke, J. (2022). Designing gender-inclusive digital solutions for agricultural development: An introductory guide and toolkit.
 https://cgspace.cgiar.org/handle/10568/118141
- Munthali, N., Leeuwis, C., van Paassen, A., Lie, R., Asare, R., van Lammeren, R., & Schut,
 M. (2018). Innovation intermediation in a digital age: Comparing public and private
 new-ICT platforms for agricultural extension in Ghana. *NJAS Wageningen Journal of Life Sciences*, 86–87, 64–76. https://doi.org/10.1016/j.njas.2018.05.001
- Ng, M., Haan, N. C. de, King, B., & Langan, S. J. (2021). *Promoting inclusivity and equity in information and communications technology for food, land, and water systems*. https://cgspace.cgiar.org/handle/10568/115154
- Noblit, G. W., & Hare, R. D. (1999). Meta-Ethnography: Synthesizing Qualitative Studies on JSTOR. *Counterpoints*, *44*.

- Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1). https://doi.org/10.1177/1609406917733847
- Nyadzi, E., Werners, S. E., Biesbroek, R., & Ludwig, F. (2020). Techniques and skills of indigenous weather and seasonal climate forecast in Northern Ghana. *Https://Doi.Org/10.1080/17565529.2020.1831429*, *13*(6), 551–562. https://doi.org/10.1080/17565529.2020.1831429
- Onsongo, E. K., & Schot, J. (2017). Inclusive Innovation and Rapid Sociotechnical Transitions: The Case of Mobile Money in Kenya. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2940184
- Ragetlie, R., Najjar, D., & Oueslati, D. (2022). "Dear Brother Farmer": Gender-Responsive Digital Extension in Tunisia during the COVID-19 Pandemic. *Sustainability (Switzerland)*, *14*(7). https://doi.org/10.3390/su14074162
- Stone, D. (2017). Understanding the transfer of policy failure: Bricolage, experimentalism, and translation. *Policy and Politics*, *45*(1), 55–70. https://doi.org/10.1332/030557316X14748914098041
- Stone, G. D. (2022). Surveillance agriculture and peasant autonomy. *Journal of Agrarian Change*, *22*(3). https://doi.org/10.1111/joac.12470
- Strauss, A., & Corbin, J. (1990). *Basics of qualitative research*. https://genderopendevelop.cms.hu-berlin.de/bitstream/handle/25595/12/whatsnew7.pdf?sequence=1
- Tewathia, N., Kamath, A., & Ilavarasan, P. V. (2020). Social inequalities, fundamental inequities, and recurring of the digital divide: Insights from India. *Technology in Society*, *61*. https://doi.org/10.1016/j.techsoc.2020.101251
- Timmermann, C. (2020). Procedural Justice and the Realization of Just Outcomes in Agricultural Innovation. *International Library of Environmental, Agricultural and Food Ethics*, *31*, 171–195. https://doi.org/10.1007/978-3-030-56193-2_8

- Tsan Michael, B. K., Totapally Swetha, Hailu Michael, & Addom. (2019). The Digitalisation of African Agriculture Report 2018–2019. Wageningen, The Netherlands: CTA/Dalberg Advisers. In *African Affairs* (Vol. 53, Issue 210).
- Utami, H. N., Alamanos, E., & Kuznesof, S. (2021). 'A social justice logic': how digital commerce enables value co-creation at the bottom of the pyramid. *Journal of Marketing Management*, *37*(9–10), 816–855.

https://doi.org/10.1080/0267257X.2021.1908399

- van Bruggen, A., Nikolic, I., & Kwakkel, J. (2019). Modeling with stakeholders for transformative change. *Sustainability (Switzerland)*, *11*(3). https://doi.org/10.3390/su11030825
- van der Burg, S., Bogaardt, M. J., & Wolfert, S. (2019). Ethics of smart farming: Current questions and directions for responsible innovation towards the future. In *NJAS* -*Wageningen Journal of Life Sciences* (Vols. 90–91). https://doi.org/10.1016/j.njas.2019.01.001
- Van Dijk, J., & Hacker, K. (2003). The Digital Divide as a Complex and Dynamic Phenomenon. In *Information Society* (Vol. 19, Issue 4, pp. 315–326). https://doi.org/10.1080/01972240309487
- Vassilakopoulou, P., & Hustad, E. (2021). Bridging Digital Divides: A Literature Review and Research Agenda for Information Systems Research. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-020-10096-3
- Zheng, Y., & Walsham, G. (2021). Inequality of what? An intersectional approach to digital inequality under Covid-19. *Information and Organization*, *31*(1), 100341. https://doi.org/10.1016/J.INFOANDORG.2021.100341