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Fostering social inclusion in development-oriented digital food system interventions

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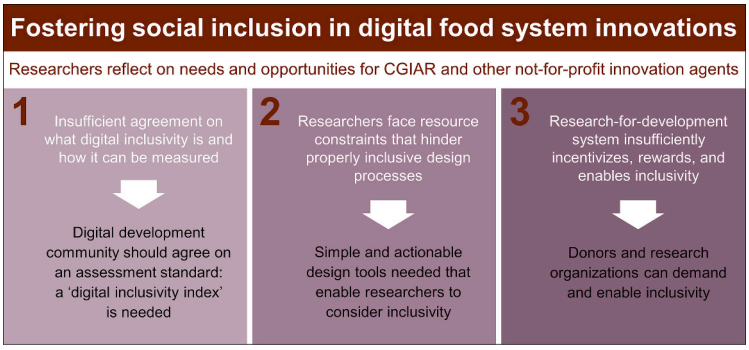
HIGHLIGHTS

- Inclusivity of digital interventions is challenged by digital divides, harmful side-effects, and conceptual unclarity
- The digital development community should agree on transparent, standardized procedures for assessing inclusivity
- Researchers need simple, hands-on methods to actively consider inclusivity during design of interventions
- Inclusivity-aware project design and internal inclusivity reviews at research organizations may improve digital inclusion

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Digital innovations can enhance the participation of often-marginalized social groups – including women and resource-poor farmers in low- and middle-income countries – in sustainable, profitable food systems. But digital interventions can also reinforce existing inequities by further increasing the competitive advantage of user groups privileged with literacy, access to smartphones, or high investment capacity. To ensure that the digital transformation in the Global South leaves no one behind, therefore, deliberate efforts are needed to promote the inclusivity of emerging digital innovations. To date, however, there is a lack of practical guidelines and tools to critically assess, demonstrate, and enhance the inclusivity of digital food systems interventions. Too often, inclusivity remains a blurry concept and distant objective. In result, digital development researchers and practitioners have limited incentives for investing time and effort into safeguarding inclusivity.
OBJECTIVE: With this short communication, we intend to contribute to future, practice-oriented discussions about social inclusivity in development-oriented digital interventions for sustainable food systems. We provide a critical reflection on the current discourse around digital inclusion in development context and outline

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challenges and opportunities for considering inclusivity in the design and deployment of digital food system innovations.

METHODS: Drawing on literature as well as the authors' own experiences with the design and implementation of digital innovations within research-for-development, we highlight 'blind spots' in the current discourse around digital inclusion in low- and middle-income country context. We then develop practical suggestions for overcoming these limitations.

RESULTS AND CONCLUSIONS: We propose a concrete agenda for enabling researchers and other innovation stakeholders, including donors, to contribute to more inclusive digital food system innovation in low- and middle-income countries. First, a standard concept and procedure is required for transparently assessing the inclusivity of digital services. Second, as many digital development stakeholders work under resource constraints, simple design tools can help them effectively consider social inclusion criteria during the design of digital solutions. Lastly, a stronger emphasis on inclusivity is required throughout the research-for-development system, ensuring that design processes themselves are inclusive, rather than considering only the final digital products.

SIGNIFICANCE: As the importance of digital innovation keeps growing within the wider agricultural development discourse, this article helps researchers and practitioners gain conceptual clarity on the goal of digital inclusion. Through concrete suggestions on how inclusivity could be considered in practice, the article promotes a more equitable, inclusive digital transformation of food systems.

1. Shortcomings in the digital inclusion discourse

Numerous digital technologies and data-driven services have emerged in support of most aspects of food systems in low- and middle-income countries (CTA, 2019; FAO and ICRISAT, 2022; Porciello et al., 2022). Digital services can, for example, improve farmers' access to agronomic and climate information, help coordinate agricultural in- and output markets, or ease smallholders' access to crop insurance and credit (Ochieng Ogutu et al., 2014; Fabregas et al., 2019; Ceballos et al., 2019). Reported outcomes of digitalization in agricultural value chains include higher yields, increased farmer incomes, and reduced environmental impacts, underscoring the potential of digital tools and services for supporting efforts towards the SDGs (Balafoutis et al., 2017; Fabregas et al., 2019; Porciello et al., 2022). In recent years, this potential has caused growing attention and investment by development donors, humanitarian organizations, and research-for-development organizations operating in low- and middle-income countries (World Bank, 2016; Heeks, 2018; USAID, 2020a; King et al., 2021). However, increasing digitalization also risks consolidating or widening already existing social disparities (van der Burg et al., 2019, Hackfort, 2021, McCampbell et al., 2021, Abdulai, 2022). For example, by relying on mobile internet connectivity via smartphones, some digital services potentially increase the competitive advantage of wealthier, less remote, and more educated farmers while offering little benefits to the most marginalized (Wyche and Steinfield, 2016; Bronson, 2019; Mehrabi et al., 2021; Coggins et al., 2022; GSMA, 2023).

Like all development-oriented interventions targeting potentially vulnerable population, such as resource-poor farmers, digital innovation processes must 'do no harm'. Therefore, designers of digital food systems interventions should actively consider inclusivity concerns (Dette, 2018; Rothe et al., 2023). In practice, smallholder farmers and other stakeholders targeted by digital interventions often have little digital skills and experience, as well as limited access and exposure to mobile networks and data streams (Mehrabi et al., 2021; McCampbell et al., 2023). While there is evidence that many smallholders already integrate digital tools in farming, this often involves creative use of rather simple services – such as phone calls, SMS, or WhatsApp groups – rather than dedicated agri-apps (Coggins et al., 2022; Porciello et al., 2022; Abdulai et al., 2023). Relatively low 'digital readiness' of smallholder farmers in low- and middle-income countries, as well as highly heterogeneous information needs and preferences, imply that many nascent, sophisticated digital solutions may not be inclusive to large shares of their intended target group (McCampbell et al., 2021, 2022; Daum et al., 2022).

These observations suggest many digital innovation processes do not adequately implement the principles of responsible research and innovation (RRI, see Stilgoe et al., 2013, Jirotka et al., 2017, Regan, 2021). Digital innovation agents, such as researchers, social entrepreneurs, donors, or investors, could more consciously, and more effectively, ensure inclusivity towards marginalized social groups. As a guiding framework for the digital design process, RRI encourages four key principles: early *anticipation* of potential negative outcomes; *inclusion* of diverse voices and perspectives, including those typically marginalized; *reflexivity* around innovation agents' own assumptions and potential biases; and *responsivity* along the design process, to adapt to emerging insights and stakeholder feedback (Regan, 2021). Considering these principles during the design and implementation of digital interventions is expected to help achieve digital services that match the resources, needs, and preferences of smallholder farmers.

The RRI framework recommends attitudes and behaviors for facilitating an inclusive innovation process. There is no clear vision, however, regarding the goal of such processes: 'digital inclusion' remains a vaguely defined concept. To date, there is limited agreement among researchers and practitioners about what digital inclusion entails and how it can be assessed. For example, the *National Digital Inclusion Association*, a US-based NGO, provides a definition centered on first-level digital divides (quality infrastructure, accessible hardware), and second-level digital divides (user skills) (NDIA (National Digital Inclusion Association) (online), n.d.). First- and second-level divides between regions, genders, social strata, or education levels are widely documented (Mehrabi et al., 2021, Vimalkumar et al., 2021, Abdulai et al., 2023, GSMA, 2023). Many authors also consider third-level digital divides, related to *"uneven capacities to capitalize on the access and use of ICTs and transform it into tangible and concrete outcomes."* (Ragnedda and Gladkova, 2020:19f, see also Ng et al., 2021, Lythreatis et al., 2022). And McCampbell et al. (2021) point out that individuals can simultaneously be included and excluded, for different reasons and at varying degrees. This current lack of conceptual precision challenges the ability of designers and researchers to actively consider inclusivity concerns. Without a clear definition, it also remains difficult for donors and funding agencies to determine inclusivity-related targets and demand accountability from funding recipients.

In this article, a group of digital development researchers presents and reflects on three aspects of academic and institutional progress that could help achieve more inclusive digital innovation. Our perspective centers on public-good, research-for-development experiences within CGIAR. This is a global partnership of international non-profit research organizations for agri-food system transformation, where multiple centers and units work on digital innovation. In result, our analysis might not equally apply to the for-profit agritech sector, nor to the ongoing digital transformation of agriculture in high-income countries. Our analysis is based on recent literature and a reflection of our own experience with digital food system innovation processes within CGIAR, for

example, for food and nutrition security monitoring (Müller et al., 2019; Bonilla et al., 2023), agro-advisory services (Kropff et al., 2021, Ortiz-Crespo et al., 2021, Müller and Schumann, 2023), seed supply planning (Steinke et al., 2023), accelerated crop breeding (Ortiz-Crespo and Weinsheimer, 2023), and on-farm experimentation (Quirós et al., 2024).

The identified three opportunities are: First, the development of universal minimum standards and procedures for assessing the inclusivity of digital food system innovations. Second, the creation and diffusion of actionable design tools and ready-made methods that enable innovation agents to actively consider and enhance inclusivity in the process of creating digital solutions. And third, the provision of stronger incentives for researchers and other innovation stakeholders to actively cater for inclusivity in digital interventions. The article intends to spark wider academic thought and stakeholder discussions on how digital food system innovation processes can lead to more inclusive outcomes in a development context.

2. Three opportunities for more inclusive digital food system innovation

2.1. Agreed minimum standards for assessing digital inclusivity

Discussions around digital inclusion frequently focus on overcoming or mitigating existing digital divides (Ng et al., 2021; GSMA, 2023). Policy makers and researchers tend to emphasize inequalities regarding access to infrastructure and hardware (i.e., divides in *availability* and *affordability*; USAID, 2020b). Often, less attention is placed on socio-culturall dimensions of digital exclusion, such as unequal levels of digital skills or unequal willingness to engage with digital services, that is, the *ability* and *appetite* dimensions of digital inclusion (Digital Future Society, 2019). Whether individuals are inclined to use a digital innovation ('appetite') is influenced by an interplay of many factors that are highly context-specific, fluid, and generally harder to assess than availability and affordability. Such factors may include the specific contents of a digital intervention, but also previous digital experiences, online insecurity concerns, language and literacy barriers, or social norms that restrict certain individuals' use of digital media (Jakku et al., 2019; Rijswijk et al., 2021; Shang et al., 2021; Porciello et al., 2022).

Depending on the local context and type of digital solution, any of these factors may or may not mediate exclusion of individuals from digital interventions. Given this high context-specificity, it is no surprise there is a lack of transparent and holistic standard criteria for approaching the question: how inclusive is a digital innovation? Yet in current research-for-development practice, the lack of analytical instruments for assessing digital inclusion means that donors cannot easily demand inclusivity. Various flexible research and innovation frameworks, such as RRI or participatory design, exist to guide innovation stakeholders' actions. Without auditable criteria, donor-funded innovation processes risk ignoring locally relevant dimensions of exclusion. Many projects, for example, focus on metrics that are relatively easy to observe and report, such as gender-disaggregated innovation uptake, but provide little evidence on the distribution of benefits from a digital intervention. Moreover, potential harm caused by digital interventions to targeted individuals is rarely assessed (Stone, 2022). This means that donors and researchers often have insufficient knowledge about the state of inclusivity of their digital innovations, which limits their ability to improve it. Diligent implementation of RRI principles in the digital innovation process makes inclusive outcomes more likely, but this is not guaranteed. To date, there is no generalizable tool or procedure to scrutinize the inclusivity of digital innovations. To operationalize RRI for digital food system innovation processes, a transparent and holistic standard for assessing digital inclusivity may therefore be useful (Opola et al., 2023a).

The development of such a universal standard faces at least three challenges. First, digital inclusion is highly context-specific. Individuals may face different kinds of exclusion from different digital services for different reasons. This raises the question of 'who' is being considered by a standard, and who may be overlooked. That is, what social determinants should be taken into account to make the assessment holistic and generalizable, and yet applicable in practice. Gender, ethnicity, education, wealth, digital literacy, rurality, disability, and many more variables could be considered (Lythreatis et al. 2022). McCampbell et al. (2021:207) argue that such decisions require some subjective judgments, since *"(…) trade-offs make exclusion almost inevitable as design-for-all or one-size-fits-all solutions are highly complex and oftentimes simply impossible"*. This complexity is exacerbated by the fact that different stakeholders involved in digital food system innovation pursue different goals, currently leading to different priorities regarding inclusion (Opola et al., 2021; McGrath et al., 2023). Second, it is difficult to observe and measure inclusivity at levels beyond individual users, such as the design process or the institutional context (Heeks et al., 2013). There is general agreement that active, ongoing involvement of diverse members of the target group along the design process can help mitigate risks of exclusion (Waller et al., 2015, Jakku et al., 2022, Patrick and Hollenbeck, 2021). However, the intensity of user engagement in the design and governance of digital innovations is hard to measure and monitor. This said: third, there is no 'ideal' level of user participation in digital design processes. Co-designing digital solutions with target users, such as smallholder farmers or agricultural advisors, is often beneficial for inclusivity. In some contexts, however, participatory design can be particularly challenging, misleading, or even unfeasible. If implemented with insufficient time, skill, or institutional support, for example, participatory design processes may create an illusion of inclusivity, leading to unsatisfactory outcomes (Norman, 2005; Mani-Kandt and Robinson, 2021; McCampbell et al., 2022; Steinke et al., 2022). These challenges contribute to fuzziness and potential disagreement in trying to assess digital inclusivity.

In light of this complexity, researchers, funding agencies, and other innovation agents would benefit from clear and unambiguous guidelines for envisioning desired inclusivity-related outcomes. We suggest that the digital-for-development research community should collaborate to agree on a common minimum standard for assessing digital inclusivity. The challenges mentioned above require careful attention. Nonetheless, it is possible to define universal, normative standards that are applicable across highly heterogeneous contexts. Prominent examples include assessment standards for organic agriculture, the UNDP's *Human Development Index*, or the *Women's Empowerment in Agriculture Index* (WEAI; Alkire et al., 2013). Each of these examples allows assessing an abstract principle (e.g., environmental sustainability, human development) by a transparent set of verifiable metrics and criteria.

Such an index would fulfill several functions. First, by providing clearly formulated, verifiable criteria and corresponding assessment methods, an index for digital inclusivity would provide researchers and digital designers with concrete guidance for enhancing the inclusivity of the innovations they develop. This concrete guidance would distinguish the index from more universal frameworks, such as RRI. Second, by fostering greater agreement on targets, a standardized inclusivity index might support more effective collaboration between different digital innovation stakeholders. It would also enable donors and investors to set realistic targets and include clear inclusivity-related requirements already in the call for proposal. In result, otherwise marginalized communities and individuals are likely to participate more meaningfully in digital innovation processes, leading to more inclusive and beneficial digital solutions. Third, in light of limited resources available for digital design processes, the index could help innovation stakeholders prioritize which aspects of inclusivity to emphasize most strongly. In the future, a digital inclusivity index should also allow for context-specific adaptations that might ease its usability. It may also be valuable to develop abbreviated or extended versions, for different types of use cases or user groups. For example, there are multiple versions of the WEAI, for use in different contexts (e.g., intervention projects or baseline research).

2.2. Greater capability for considering inclusivity in the design process

Inclusive design processes acknowledge diversity within the target group, allowing innovation agents to recognize potential exclusion at early stages. Therefore, inclusive design processes are likely to generate more inclusive digital solutions. By applying participatory design methodologies, such as human-centered design, innovation agents can promote inclusion. Because different members of the target group are likely to face different forms of exclusion, an inclusive design process typically implies intense and continued participation of a diverse sample of the target group (Waller et al., 2015). Engaging diverse perspectives can help challenge researchers' potentially biased assumptions, thus enabling reflexivity and early anticipation of positive and negative outcomes (Jakku et al., 2022). But many international agriculture-for-development projects face challenges that hinder the implementation of thorough user research and socially inclusive design processes. Challenges include, for example, tight deadlines, limited budgets, pressure to demonstrate pre-determined impacts, and limited human-centered design skills and awareness among researchers (Leeuwis et al., 2018; Mani-Kandt and Robinson, 2021; McCampbell et al., 2022; Steinke et al., 2022). These pressures – which all boil down to the scarcity of time, budget, and staff – often confront digital development projects with trade-offs.

One trade-off relates to the allocation of project resources: researchers may consider inclusivity by facilitating a participatory design process that involves diverse target users from the very beginning, including the stage of problem definition (Stitzlein et al., 2020; Eastwood et al., 2022). But this initially costs time, requires skilled staff, and can delay project delivery due to unforeseen iterations. Moreover, participatory problem definition can highlight needs that lie outside the project scope, which can be restricted by donor priorities. In these cases, it may make little meaningful impacts on further design process (see Section 2.3 below). As a consequence, inclusivity often becomes a conscious concern only at later stages, for example, when collecting feedback from diverse test users (McGrath et al., 2023). Delaying inclusivity efforts in design processes saves resources during the project period. But it hinders responsivity by limiting opportunities for addressing the needs, challenges, or fears of excluded social groups. This, however, can turn out more costly in the longer run: retroactively improving the inclusivity of digital innovations that have already been designed and deployed may be near impossible if the digital service was not designed to address their needs and technology preferences in the first place.

Another trade-off relates to the concept of inclusivity itself: in many cases, actively catering for inclusivity requires conscious and transparent decisions on 'who' is meant to be included. For example, efforts to enhance the inclusion of women may have little or no effect on the exclusion of people with disabilities (such as impaired vision or hearing) or those living in extreme poverty (McCampbell et al., 2021). Much like one-fits-all solutions, there are no one-fits-all design challenges. So, on the basis of available resources for user research and prototyping, digital design teams may need to prioritize the forms of potential exclusion that shall be mitigated. To avoid disappointing design participants (and donors), transparent communication is crucial about who is being targeted and actively included, and who is not (Opola et al., 2021, 2023b). Other excluded social groups can be addressed in future iterations – but this may be hard to do successfully (see previous paragraph).

Given persistence of these pressures, gold-standard inclusive design processes are likely to be the exception in research-for-development. Therefore, we believe there is a need for simple, rapid, and heuristic design tools that enable motivated researchers to actively pursue inclusivity despite the described pressures. Agricultural and social scientists willing to follow the principles or RRI may need concrete, actionable guidance on the "how to" of inclusive design. User-friendly methods and procedures for research and decision-making could help them ask the right questions and draw useful conclusions. To be effective in supporting the development of inclusive innovation, such design tools should fulfill four criteria. First, they should be easy to learn and apply by researchers with limited experience in design methods. Second, they should require limited time commitment, for example, for data collection and analysis. Third, they should go beyond raising new questions and should generate concrete, actionable insights for mitigating exclusion. Fourth, they should be globally applicable while delivering context- or project-specific insights. One example of such heuristic design tools is the 'Rapid Inclusivity Assessment for Digital Agriculture' (RIA; Steinke and Schumann, 2022). RIA is a guided step-by-step analysis procedure that supports designers of farmer-facing digital solutions in enhancing the inclusivity of their designs. The tool relies on *user journey mapping*, a common design method for analyzing user satisfaction in commercial settings (Howard, 2014). A user journey map outlines the sequence of motivations, actions, and challenges a user may experience while interacting with a product. The RIA tool provides a simple template for user journey mapping, adapted to typical user experiences in digital agriculture services.

A detailed user guide and materials are provided by Steinke and Schumann (2022). In a RIA workshop, design teams (1) uncover potential risks of exclusion in the current concept or existing digital service, and (2) generate improved design ideas that may mitigate these risks of exclusion. They then develop a research plan to quantify with data to what extent the identified risks (see point 1 above) would actually lead to exclusion. This exercise of concrete anticipation helps to prioritize the inclusivity-oriented design adjustments (see point 2 above). As an output, RIA provides design teams with clear follow-up activities for enhancing inclusivity. For agricultural or social scientists motivated to contribute to inclusive digital innovation, a larger suite of such ready-to-use tools would be useful. For example, Ali et al. (2023) provide a validated, simple questionnaire for estimating digital skill levels in low-income populations. Such analyses can be a valuable input to empathizing with the target group and generating early ideas.

2.3. More inclusivity-oriented management of the research-for-development system

Current management of the wider research-for-development system insufficiently caters for inclusivity in digital innovation processes. We identify at least three reasons: first, competitive grant allocation often prioritizes the development and introduction of novel digital technologies over using existing ones. But novel technologies typically emerge in privileged parts of society. Using established technologies in creative ways may allow for more inclusive innovation. Second, an overly linear and predetermined design of project logframes leaves little scope for Involving marginalized voices in defining problems and solutions. And third, there are insufficient safeguards against potential negative impacts of digital interventions beyond the immediate target group. The three following paragraphs elaborate on these aspects.

Focus on novel technology rather than social innovation. Agricultural research-for-development is funded, for the most part, by donors from the humanitarian or public sector, including Global North governments, charitable foundations, and international organizations, such as the World Bank (Beintema and Echeverría, 2020). Funds for research staff and operations are often allocated based on competitive grants. This system aims to ensure that research generates cutting-edge outcomes at reasonable costs. However, it may also incentivize researchers to focus on more privileged social groups.

Competitive grants usually demand that researchers push the boundaries of science by delivering an entirely novel (digital) solution and demonstrating its potential impacts. But donors, as well as researchers, often assume the groundbreaking nature of digital innovation to come from harnessing a new technological opportunity, rather than from creative use of established technologies. By default, new technological opportunities tend to first appear in less marginalized parts of society. Targeting new technologies at users endowed with social,

intellectual, and financial capital increases the probability of technology firms' return on investment (Bronson, 2019; Rotz et al., 2019). Think of smartphone apps, or even SMS services that require literacy or numeracy. Thus, for researchers, designing and testing a novel digital innovation is often more easily achieved through working with wealthier, more educated, less remote, and more digital-ready farmers. From an RRI perspective, current grant allocation systems showcase insufficient reflexivity, as funding requirements may reflect techno-optimistic assumptions made by donor organizations, rather than strict problem-orientation (Steinke et al., 2021, McCampbell et al., 2023). But open-ended, problem-focused participatory design can lead to identifying viable solutions that do not involve digital elements at all – depending on local context and stakeholder preferences. Research projects that suggest innovation can emerge from designing open-endedly in resource-poor and vulnerable contexts, using what is already in place – established digital technologies and non-digital processes – are less likely to get funded (Bronson, 2019).

Overly linear and pre-determined project execution. Donors and policy makers provide funding for innovative research ideas that promise to promote expected development outcomes (Leeuwis et al., 2018). While grant managers tend to care for delivery of outputs and adherence to project timelines, researchers usually enjoy autonomy in designing the process for ending up with said outputs on time. This incentivizes researchers to present linear project logframes with predetermined outcomes. But an overly linear project design also risks focusing on the more obvious needs of more outspoken, opinion-leading, and socially privileged groups, contradicting the RRI principle of inclusion. The often-heterogeneous needs and aspirations of marginalized groups are harder to anticipate during desk-based proposal development (Cornwall, 2003; Hussain, 2010; Rose and Chilvers, 2018; Bronson, 2019; Klerkx and Rose, 2020). Thus, by putting little emphasis on iteration and context exploration, projects reduce the 'risk' of questioning original hypotheses and diverting substantially from the proposed digital innovation. After all, many researchers also tend to consider such adjustments as failure, rather than as outcomes of the necessary, unfolding dialogues with the project target group. In effect, incentivizing researchers to plan and execute linear project logframes can impede responsivity – hindering projects to act upon emerging, unanticipated insights about local stakeholders and context.

Weak safeguards against negative side effects. For reasons of accountability, researchers, donors, development agencies, and policy makers all need to assess the quality and impact of digital interventions. To measure and demonstrate the success of their work, they typically use performance metrics that are easy to quantify and report. Examples include adoption rates, user satisfaction rates, changes in on-farm practices, or effects on users' yields and incomes (Ortiz-Crespo et al., 2021; Porciello et al., 2022). Sometimes, outcomes are disaggregated by gender or social strata to monitor the social equity of direct impacts. But digital interventions can cause unintended social repercussions, also beyond the immediate target group. Uptake of digital agri-services may, for example, influence gender roles and contribute to women's disempowerment (Adeyeye, 2021), undermine farmers' skills and experiential knowledge (Ingram and Maye, 2020), or expose farmers to risks of surveillance and behavioral manipulation (Stone, 2022). Currently, research-for-development stakeholders working on digital food system interventions have little incentive to assess and mitigate potentially negative effects. Reflecting insufficient anticipation and responsivity in the digital innovation process.

To enable more inclusive digital innovation processes, the agricultural research-for-development system needs to be more strongly geared towards inclusivity. Donors and research organizations can play an active role in this transition:

Donors should explicitly demand social inclusivity being considered in digital design processes. A shift is needed towards funding more open-ended innovation processes that do not presume (digital) solutions at the proposal stage. Rather than pre-determining performance indicator levels that shall be achieved, these indicators, as well as the targeted levels, could be defined together with the project target group at the project outset. And beyond individual projects, donors could define funding priorities through more direct interactions with on-the-ground organizations, including civil society or public authorities. This may help move the funding focus away from an emphasis on cutting-edge technology, and towards solving actual challenges.

Until a universal digital inclusion standard emerges (see Section 2.1), and in absence of strong demand by donors, research organizations could go forward and establish internal monitoring and support structures. Mandatory ethics reviews for human-subject research are already widespread. For digital development projects, these could be expanded to include explicit social inclusivity considerations, providing researchers with advice on how to mitigate identified risks. In some private companies, including pharmaceutics giant *Merck* and communications start-up *Witty*, 'digital ethics boards' regularly review emerging digital innovations.[1,2]

Beyond individual projects, research organizations should ensure there is adequately skilled staff to lead inclusive digital innovation processes. Digital development projects relying on a team of pure agronomists and IT developers should be a thing of the past. To ensure that design ideas in digital development processes rely on context-based, emerging insights, research organizations need to foster interdisciplinary teams. Such digital design teams unite agronomic knowledge and tech know-how, but also capability in behavioral science and participatory design methods. Currently, user research is sometimes outsourced to external providers of design expertise.[3] This can be a viable approach, too. But in all cases, research-for-development organizations must ensure that researchers have the awareness and capacity to appreciate, and to act upon, processes of user research and iterative, user-centered development of design ideas.

3. Outlook

The global research-for-development system generates digital food system innovations that are, on the whole, insufficiently inclusive. Marginalized social groups, including poor farmers and rural women, do not adequately benefit from many donor investments into research. By analyzing the reasons that contribute to this unsatisfactory situation, this article shows how individual researchers, research organizations, donors, and policy makers can take action to embrace social inclusivity in digital innovation processes. A key next step for the digital development community is to operationalize the vague concept of digital inclusivity: innovation stakeholders in the public sector require agreed-upon standards for setting goals, a wider range of actionable tools to work towards these goals, and the right incentives to put these tools into action.

In the medium run, there is a need for growing the human capacity of research-for-development organizations for facilitating inclusive design processes. This could be achieved by increasing the awareness and fostering the skills of existing agricultural, social, or economic researchers. Hiring inclusive design experts, for example, from the tech industry, at research organizations could also help promote inclusive digital innovation processes (Jakku et al., 2022). Ultimately, an innovation environment is needed where all key research-for-development stakeholders – researchers, donors, partner organizations – embrace inclusivity. With inclusivity considerations engrained in, for example, funding allocation, recruitment policies, and M&E systems, novel responses to emerging food system challenges would be as inclusive as

[1] https://www.merckgroup.com/en/sustainability/business-ethics/advisors-for-bio-and-digital-ethical-issues.html

[2] https://www.witty.works/ethics-board

[3] Examples include Rare (https://rare.org) or Busara Lab (https://busaracenter.org)

possible by default.

And beyond research organizations? To some extent, research-for-development innovation can mitigate systemic digital exclusion of marginalized social groups. But inclusive digital innovation processes can only be part of the overall digital transformation of food systems, driven by policy makers, local communities, and the private sector. This involves ensuring that digital infrastructure and hardware are universally accessible and affordable. Policy makers can regulate the ongoing digital transformation with a stronger emphasis on inclusivity. For example, lower costs of mobile data and devices may be achieved by fueling competition, or by providing fiscal incentives for companies that fulfill inclusivity-related targets. Mobile phone companies can emphasize features that matter in under-resourced environments, such as physical robustness, strong loudspeakers, or user-friendly text-to-speech functionalities (see Wyche and Steinfield, 2016). In the future, a more inclusive digital transformation should rely on national and regional partnerships between policy makers, civil society organizations, the private sector, and research organizations, aligning their efforts towards agreed digital inclusion goals.

CRediT authorship contribution statement

J. Steinke: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **C. Schumann:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **S. Langan:** Conceptualization, Writing – review & editing. **A. Müller:** Conceptualization, Writing - review & editing. **F.O. Opola:** Conceptualization, Writing – review & editing. **B. Ortiz-Crespo:** Conceptualization, Writing – review & editing. **J. van Etten:** Conceptualization, Writing – review & editing.

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.

Data availability

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