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Good intentions in complex realities: Challenges for designing responsibly in digital agriculture in low-income countries

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Abstract

Human-centred design (HCD) approaches are adopted to develop digital agriculture interventions inclusively and responsibly. Whether these approaches indeed lead to responsible designs remains unclear, especially for low-income countries. Using a Rwandan case-study, we contribute to debates on inclusive, participatory and responsible design by developing a framework for operationalising HCD and responsible innovation in practice and studying the process of designing a digital agriculture intervention for banana disease management. The four dimensions (inclusion, anticipation, reflexivity, responsiveness) of responsible innovation and our own framework of digital rights served as analytical lenses. Findings show that power relations and digital capacity negatively affect user inclusivity in design. The context in which HCD is deployed hinders anticipation, reflexivity and responsiveness, resulting in design decisions that do not fully respect digital rights and thus in potentially irresponsible digital technologies. Broader, long-term

consequences of digital technologies should be a central consideration in design processes, while responsible innovation theory needs to become cognizant of the complex realities in which digital innovations emerge.

KEYWORDS
digital development, digital rights, HCD, ICT4Ag, participatory design, responsible innovation

INTRODUCTION

Today's omnipresence of digital technologies renders into a gold rush for a share in the global digital economy (MacFeely, 2019; Tabesh et al., 2019). Digital data-generating technologies are a pillar of the fourth agricultural revolution or Agriculture 4.0 (Klerkx & Rose, 2020; Rose & Chilvers, 2018) with expectations that these technologies may contribute to the transformation of agricultural systems in developing countries (Barrett, 2020; Reardon et al., 2019). Discourse about digital agriculture associates it with emergent and game-changing technologies, productivity and environmental benefits (Barrett & Rose, 2022). Low-income countries (LIC) and their agro-food systems present promising markets for the digital technology and agriculture industry (Lanchester, 2017; Trendov et al., 2019), and the number of active digital agriculture interventions in LIC and middle-income countries increased from 53 in 2009 to over 700 in 2020 (GSMA, 2020). Digital agriculture comprises a whole suite of on-farm and off-farm technologies, such as precision technology, drones and robotics. Examples include market and financial access tools, digital farmer profiles and agricultural advisory services. (Eastwood et al., 2019b; Klerkx et al., 2019; Wolfert et al., 2017).

Few critical studies on digital agriculture focus on LICs (Klerkx et al., 2019), and those assessing ethical and governance challenges and responsible innovation in smart farming concentrate mostly on Western countries (Bronson, 2018, 2019; Rose & Chilvers, 2018; van der Burg et al., 2019). The influence of digital interventions on knowledge, power dependencies and inequalities, or alterations to rural livelihoods in LICs has largely been ignored (Agyekumhene et al., 2020). This is problematic since farming communities in LICs are specifically vulnerable to potential negative consequences of digital technologies, with fewer resources to react to changing livelihood conditions (Dearden & Kleine, 2020) and because the design of digital agriculture technologies affects smallholder's digital rights as we elaborate later.

To counteract negative consequences and attend to aspects of power, ethics, and justice, the implications of digitalization should be considered early in technology development and together with stakeholders (Bronson, 2019; Eastwood et al., 2019a; Klerkx & Rose, 2020; Rose et al., 2021). This demands a process that pays attention to the structural conditions surrounding the development of digital technology, for example, sociocultural issues, infrastructural limitations and problems in agricultural production systems. Human-centred design (HCD) approaches like participatory design and co-design (Steen, 2011) respond to the desire to design digital agriculture technologies (in LICs) for the user (Krell et al., 2020) and together with stakeholders (Agyekumhene et al., 2020; Kenny & Regan, 2021; Steinke et al., 2020). Anticipated product users get the role of 'expert of his/her experience' and participate extensively in the design process (Sanders & Stappers, 2008). Participation of stakeholders in designing and implementing digital

technologies promises reduced 'design-reality gaps' and designs that are more inclusive and better fitting with user needs, demands and interests (Ortiz-Crespo et al., 2020; Steinke et al., 2020). Arguably, an HCD approach supports responsible innovation in digital agriculture although discourse about responsible innovation and HCD approaches have developed in isolation. Individual studies on responsible innovation or HCD are additionally either prescriptive rather than evaluative or without LIC focus (e.g., Eastwood et al., 2019b; Steinke et al., 2020). This article fills this gap, contributing to debates on inclusion, technology shaping and responsible design by answering the question 'How do HCD approaches deploy responsible innovation in digital agriculture in LICs and attend to smallholder farmers' digital rights?' We look at structural ethical issues such as the limited access and skills of farming communities (often referred to as the digital divide). We furthermore debate the data governance structures that are currently in place and how these could increasingly impact digital designs and the pursue of digital rights. For this, we build on a growing collection of voluntary guidelines for digital rights that pay specific attention to marginalised communities in the Global South and assess whether those guidelines are adopted in HCD processes and if the current regulatory spaces are adequate to govern digitalisation in agriculture.

Hereafter, we conceptualise HCD and responsible innovation and present a digital rights framework for analysing responsibility in design processes. Next, we apply the framework to a particular case and investigate if the design approach contributed to responsible design and attended to digital rights. Empirical data came from ICT4BXW, a project in Rwanda that developed a smartphone application for banana disease management.

CONCEPTUAL FRAMEWORK

Linking responsible innovation and HCD

Designing digital technologies comes with social and ethical responsibilities (van der Burg et al., 2019). This notion of responsibilities receives more attention standing growing recognition of the complexity and interrelatedness of digital technologies and larger digital ecosystems. Technology and what it 'is' or 'does' starts with how it was designed (Roeser, 2012); hence, questions about conceptualisation, design and use of technologies and their positive or negative impact on societies arise (Jirotka & Stahl, 2020). Designs reflect wants, needs, desires, norms and values of its designers (Van den Hoven et al., 2012; von Schomberg, 2011). Concepts like responsible innovation (von Schomberg, 2011) help to think about and take responsible, value-based choices in design processes that anticipate possible consequences of innovations and build capacity to respond to those consequences. Von Schomberg (2011) defined responsible innovation as: '*A transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products*' (p. 9). Stilgoe et al. (2013) identified four dimensions to responsible innovation: anticipation, inclusion, reflexivity and responsiveness (AIRR). Responsible innovation has features in common with HCD approaches, like stakeholder participation, empathy for target users and context and reflexivity on design outputs (Steen, 2012; Table 1). While designing a new product, designers aim for a balance between user desirability, technological feasibility and economic viability (Lafond & Davis, 2016). Three broad phases form the iterative HCD approach: (1) inspiration (the problem or opportunity for which a solution will be designed is defined and the prospective users are studied); (2) ideation (ideas are generated, developed and tested in rapid,

TABLE 1 Synthesis of the four dimensions guiding responsible innovation (definitions based on Stilgoe et al. (2013) and Stilgoe et al., 2013 and Wittrock et al. (2021b) and their operationalisation for an human-centred design (HCD) approach

Dimension	Definition	Operationalisation for HCD
Inclusion	Inclusive innovation processes allow stakeholders with diverging concerns and perspectives to deliberate and dialogue	- Including future users in research, design, decision-making and evaluation - Addressing social inequalities among stakeholders to foster meaningful participation (e.g., access to and understanding of design process, project/intervention objectives) *HCD phase: inspiration, ideation, implementation*
Anticipation	Defining the possible scenarios for and consequences of innovations, and considering concerns regarding these consequences	- Defining who is responsible for anticipation, when and with whom present - Envisioning and understanding possible consequences of digital innovation with stakeholders and outlining affected moral values and rights - Actively anticipating possible effects beyond piloting *HCD phase: inspiration, ideation, implementation*
Reflexivity	Reflecting on activities, commitments and assumptions that shape science, innovation and governance. This includes the individual capacity to call into question processes and results of innovations	- Making reflexivity a planned activity in the timeline of the HCD process - Aiming at equal capacity and opportunity of all stakeholders (incl., e.g., vulnerable, illiterate) to reflect on assumptions and consequences of the design process *HCD phase: ideation, implementation*
Responsiveness	Continuously changing the shape or direction of digital design or intervention in response to demands or values of stakeholders, society or the enabling environment	- Ensuring the means for iteration and design/intervention adaptations pending new insights or changes in the environment (e.g., in flexible timelines and budgets) - Defining the scope of responsiveness–what can realistically be addressed given project limitations? (expectation management) *HCD phase: ideation, implementation*

iterative cycles); (3) implementation (further testing and refining of prototypes in a real-life context; Steinke et al., 2020).

Digital rights in agriculture in LICs

Arguably, responsible innovation and HCD are both efforts towards achieving (morally) responsible designs (Roeser, 2012) that protect or realise moral values. In the context of digital agriculture, these values are embedded in digital rights. Digital rights have received considerable attention

in Western settings (e.g., Australia and Europe; van der Burg et al., 2020; Wiseman et al., 2019b). Similar debates emerge for LICs, for example, in Africa (Ayamga et al., 2020). International actors increasingly formulate guidelines and policies for digital development at a global, international or organisational level, practically translating existing principles for protection and realisation of human rights to the digital sphere(UN Systems Organizations, 2018; WSIS, 2003). Historically, digital rights entailed mostly the right to access (the internet), denouncing what is often referred to as the digital divide (Hernández et al., 2020): the gaps between the Global North and Global South, urban and rural areas and in accessing infrastructure. Later, the digital divide concept became separated into first- and second-level digital divide, the former describing access to infrastructure and availability of hardware and (internet) connectivity, the latter referring to questions of digital literacy, that is, skills to operate hardware (e.g., smartphone) and software (e.g., browsing the Internet; van Deursen & Solis Andrade, 2018).

Digital rights mostly exist in guidelines, company policies or handbooks, while legal regulations are sparse (Wiseman et al., 2019a) and focus on protecting the right to privacy and data security of users regarding processing of personal data on national or transnational level (e.g., General Data Protection Regulation (GDPR) in the European Union, Kenyan Data Protection Act). Hence, the ethical landscape is fragmented, occupied by voluntary standards like the FAIR principles (Go FAIR Initiative, 2016; Wilkinson et al., 2016); Principles for Digital Development (Digital Impact Alliance, n.d.) and technical guidelines (e.g., Building for Billions (Google Developers, n.d.). A review of existing guidelines and policies resulted in a framework that informed our analysis (Table 2; see Appendix 1 for more details).

METHODS

We employed a single–case-study approach (Ridder, 2017). A research problem and relevant variables for investigation were identified; however, relationships between theory and variables were not formulated beforehand. The single-case design allowed us to test the developed framework and unravel the working of an HCD process in agricultural development through in-depth analysis of the phenomena of interest in the context in which they emerge.

Case-study description

ICT4BXW is a research for development project in Rwanda led by the International Institute of Tropical Agriculture, a Consortium of International Agricultural Research Centers (CGIAR) research centre. We studied the project's piloting phase (2018–2020). In phase 1, ICT4BXW covered 138 villages across eight districts, within four provinces. ICT4BXW piloted a digital extension intervention for the control and prevention of Banana *Xanthomonas* Wilt disease (BXW) in 69 intervention villages. The project aimed to develop a digital tool to support inclusive access to information, efficient and cost-effective control of BXW, targeted investments in BXW management by government agencies and, ultimately, reduce loss of banana productivity and livelihood due to BXW. HCD stood central in ICT4BXW to develop the digital tool. A Ugandan design company was hired to facilitate a participatory process, design the interface of BXW-App and a dashboard and manage technical development of both frontend and backend. For the latter, the design company collaborated with a Dutch startup that deploys young African software developers. Important events in the inspiration phase included a baseline survey with farmers ($n = 690$)

TABLE 2 Overview of commonly defined digital rights based on analysis of existing guidelines and policies

Digital right	Definition	Guidelines and policies referring to it
General digital rights		
Access to information	The right of every human to have access to information and the services provided online in an accessible language	Global Open Data for Agriculture and Nutrition (GODAN) Best Practices; Internet Rights and Principles Coalition (IRPC) Internet Rights and principles; World Summit on the Information Society (WSIS) declaration
Free expression	Right to express oneself without censorship or fear of persecution based on the reported information or online activities	IRPC Internet Rights and Principles
Data security and privacy	Protection of personal (and non-personal or farm) data and information provided by individuals	All legal regulations + EU Code on Agricultural Data Sharing; United States Agency for International Development (USAID) Policy; Oxfam Policy; CGIAR Guidelines; UNDG Guidance Note; UN Personal Data Protection and Privacy Principles; World Food Programme (WFP) Guidelines
Transparent governance and accountability	Transparency about parties collecting, owning and using data, as well as those responsible for the data	IRPC Internet Rights and Principles; UN Personal Data Protection and Privacy Principles; EU GDPR; CGIAR Guidelines; UNDG Guidance Note
Rights recognized specifically for low-income countries and/or vulnerable people		
(Data) ownership and control	Right of data subjects to remain the owner and in charge of what data is collected, by whom and for what purpose, including the option to opt-out	USAID Policy; International Committee of the Red Cross (ICRC) Handbook; WFP Guidelines
Access to (personal) data	Right to access (and in case of personal data correct) data at any moment in time	GODAN Best Practices, EU GDPR, ICRC Handbook, WFP Guidelines
Data minimisation and purpose definition	Use of data must be specified upon collection and further processing be limited to the agreed use cases	EU GDPR, GODAN Best Practices, ICRC Handbook, UNDG Guidance Note, WFP Guidelines
Informed consent	Free choice to consent to data collection, including receiving information about the data that is collected, by whom and for what purpose	Oxfam Policy, WFP, UN Personal Data Protection and Privacy Principles, EU GDPR, USAID Policy, ICRC Handbook, Oxfam Policy, CGIAR Guideline, WFP Guidelines
Protection from direct or indirect harm	The act of collecting data should not negatively impact the data-originator directly or indirectly	Oxfam Policy, EU GDPR, USAID Policy, CGIAR Guidelines, UNDG Guidance Note

and farmer promoters (FPs; $n = 138$) plus a multistakeholder rapid appraisal workshop. An FP is a village-level extension agent who is a farmer him-/herself. Every village in Rwanda has an FP and he/she is the last-mile actor in the country's extension system (MINAGRI Rwanda & The Belgian Development Agency, 2016). For the ideation phase, four design workshops and one e-literacy training for FPs took place. The implementation phase included e-literacy and project-identity training for 69 FPs, user experience surveys and (remote) support.

The main output of the design process was 'BXW-App', a digital extension service that supports diagnosis and control of BXW, gives information about banana agronomic practices and registers the local presence of BXW. BXW-App is available for free on Google Play with English and Kinyarwanda (Rwanda's common language) language options. The app has four sections: 'What is BXW' (giving technical information about the disease), 'BXW management' (providing information about best practices for managing BXW), 'agronomy practices' (informing about agronomic best practices for banana production) and 'diagnostic procedure' (scouting BXW symptoms in a plot and diagnose the disease). All sections have a combination of text, illustration and voice-over to enhance content accessibility for a wide variety of farmers.

BXW-App has FPs as its primary users. Secondary users of the information provided, or data collected by BXW-App are farmers, researchers and government representatives (e.g., staff of the Rwanda Agriculture and Animal Resources Development Board).

Data collection

Empirical data was collected in the ICT4BXW project in Rwanda, mostly consisting of qualitative data. USE surveys (Lund, 2001) were conducted with 18 FPs in two project districts, Kayonza and Burera. Additionally, observational data were collected by following the same FPs in the field while they were using BXW-App and interacting with farmers. FPs were purposively sampled from ICT4BXW intervention villages. We conducted nine group interviews with banana farmers (Kayonza district, 18 farmers in four interviews) and (Burera district, 27 farmers in five interviews) with a focus on farmer experiences with BXW-App and perceptions about privacy, (data) security and sharing of data. Interviewees participated voluntarily, were informed about the interview's objective and gave their consent to (anonymised) use of the data for research purposes. Key interviews with project staff, partners and designers were conducted ($n = 17$) to learn about project organisation and management, use of and understanding about the HCD method and interactions and experiences within the project. Additionally, internal project documents were consulted to develop an understanding of events, activities and decisions made in ICT4BXW. Last, insights were gathered from observing the design process up-close, for example by attending three design workshops as an embedded researcher.

Analytical approach

To analyse the interview and USE-survey data, we used a combination of deductive and inductive coding in ATLAS.ti8. Broad themes were identified based on the conceptual framework, while specific codes were added deductively for relevant quotes. We used triangulation to verify findings from analysing interviews and survey data with observational data from the HCD process and BXW-App in use and project reports.

To create our analytical framework, we analysed the existing guidelines for digital rights (see Table 2 and Appendix 1) as well as operationalised the Responsible Research and Innovation (RRI) approach (Table 1) to create a foil for evaluation of the HCD process implemented in the case-study.

FINDINGS

In this section, we show how the design process was organised and how this structured interaction between stakeholders and design decisions. Findings are organised along the four AIRR dimensions and related themes: (1) inclusion: social roles, power relations and trust; (2) anticipation: impacts and consequences for digital rights; (3) reflexivity: steering capacity; (4) responsiveness: project limitations and mindset.

Inclusion: social roles, power relations and trust

How people are included in the design process affects their influence on the design of the technology and their ability to observe and control how designs respond to needs and values and, ultimately, digital rights. Beyond asking *who* was included in the design process, we used interview and observational data and project documentation to analyse *how* different stakeholders were included in the design process. Table 3 shows who occupied which role in the ICT4BXW project.

We identified five stakeholder roles: decision-makers, implementers, participants, users and silent observers. Beyond anticipated users of BXW-App (e.g., FP, sector agronomist (SA), various other stakeholders were involved in the HCD process, each with their interests and project tasks. The inclusion of more diverse stakeholders with diverging interests affected the priority that was given to the rights and needs of users.

Findings show that those in the role of implementer were rarely in the position to take decisions. Rather, implementers, such as technicians or assistants, followed orders or did what they were paid for (programmers) by decision-makers. Nevertheless, especially technicians and assistants played an indispensable role as intermediaries between users and other stakeholders. A result of implementers being lower in the hierarchy was that not all information was (correctly) shared, got lost in 'translation' or not acted upon, which affected the projects' ability to be reflexive and responsive.

Farmers were seen as users of the information provided by BXW-App but not as users of BXW-App itself (those were FPs) and therefore not invited to participate in the design process. As a result, farmers relied on other stakeholders (e.g., FPs) to represent their interests or defend their rights. Additionally, our interview data shows that there was only partial transparency towards farmers, for example, about project objectives, the data that was collected and shared and that farmers' understanding regarding this differed per village. For example, interviews revealed that farmers were not unequivocally informed that data about the presence or absence of BXW in their farms could be accessible to government officials.

Conflicting interests emerged when stakeholders debated the opportunity to use data about farmers and their farms, or FPs and their activities, for performance surveillance purposes. Both the government partner and SAs showed interest in such data, while the project managing organisation and design company rejected the idea: BXW-App was not meant as a

TABLE 3 Stakeholders in the ICT4BXW project

Stakeholder	Stakeholder interest	Project tasks	Role in HCD process
Donor	Visible positive impact on rural livelihoods and scaling	Provide project funding, Monitor project log-frame, grant or reject a second project phase	Silent observer
Scientific partner 1 (Project managing organisation)	Scientific outputs, research for development impact, strengthening partnership with government, showcasing organisational capacity in digital agriculture	General project management, implementation and control of field activities, monitoring and evaluation, reporting to donor, leading scientific activities, remuneration of participants, communicate project results	Decision-maker (project leader), implementer (research assistants)
Government partners	Improved, up-to-date insights about Banana *Xanthomonas* Wilt (BXW), reduced impact of BXW on production, income and food security, practical implementation of ICT for Rwandan Agriculture (ICT4RAg) policy, partnership with CGIAR centres	Future owner of BXW-App, secure access to field sites and actors in the extension system, contextualisation of disease information, support or coordinate field activities	Decision-maker (head of banana research programme) Implementer (research technicians)
Scientific partner 2	Integration with other BXW work, dissemination of disease management approach, collaboration on scientific outputs	Technical expertise and input to create content for BXW-App	Participant
Design company	Design as per client's demands, opportunity for future assignments with CGIAR centres	Lead HCD process, design interface of the project, engage with stakeholders and users	Decision-maker
Programmer	Technology design as per client's demands, opportunity for future assignments with CGIAR centres and design company	Translate interface design from designer to actual programmed design, develop platform backend and databases, adapt app and backend functionality to stakeholder needs	Implementer

(Continues)

TABLE 3 (Continued)

Stakeholder	Stakeholder interest	Project tasks	Role in HCD process
Sector agronomist	Increased insight into presence and management of disease, increased insight into the performance of farmer promoters (FPs)	Participate in design workshops, interact with and support FPs, coordinate with government partner	Participant, user
FP	Increased insight into presence and management of disease, improved interaction with farmers, improved status and trust in the community	Participate in design workshops (sample), attend capacity building activities, train other FPs about the project and on smartphone and app use, visit and register farmers, in the app, run diagnostic procedure on farm, visit SA to upload data	Participant (sample), user
Farmer	Improved disease knowledge, increased insight into presence and management of disease, improved interaction with FP	Interact with FP, visit farm with FP to run the diagnostic procedure, register and share farm and personal data in app	User

performance-monitoring tool. Moreover, concerns existed that FPs would distrust the application if they feared being surveilled by it. FPs were never involved in decision-making about this. Despite the initial reservations towards performance monitoring, a review of BXW-App's backend showed that monitoring of an individual's performance was possible for those with the access credentials (including some actors from the government partner). Considering that these partners would eventually gain ownership over the application, combined with Rwanda's top-down structure and the existence of performance contracts for government officials, this design decision could have real consequences for individual users of BXW-App.

Thus, FPs and farmers and their interests were less central than one might expect. Power relations furthermore influenced design decisions. Table 4 shows some design changes made in the ICT4BXW project and the roles influencing that change.

FPs mainly influenced the interface and content design, especially through incremental changes contributing to the usability, usefulness and usability of BXW-App. Big design changes that altered the application's nature, for example, about the role of the user, came from decision-makers. Farmers (as end-users and data providers today and future BXW-App users) had no direct influence on the design. Their interests should have been represented by the FPs since FPs are also (lead)farmers themselves. Tables 3 and 4 show that FPs and, especially, farmers were in a weak position to defend their rights, for example, to transparent governance; ownership, control and access to data; informed consent and protection from harm because of their role as participants or user rather than decision-maker.

TABLE 4 Examples of design changes resulting from stakeholder engagement

What changed	Original design	New design	Main decision influencer
Expected role of the user	Farmers collecting information about disease transmission for scientists (citizen science)	Information transfer to farmers by scientists via FPs, registering farmers and collecting data about disease presence in visited farms	Decision-makers (Scientific partner 1, government partner)
Users of the application	Farmers, extension agents, scientists	FPs, sector agronomists	(Scientific partner 1, government partner)
Actor responsible for submitting data	FPs (farmers)	Sector agronomists	(Scientific partner 1, government partner)
Available information in the app	Diagnosis, control and prevention	Diagnosis, control, prevention and general agronomic practices for banana crop	Participants (FP, SA)

Despite observed transparency and power issues, farmers in group interviews expressed high levels of trust in other, more powerful actors (e.g., researchers, government) when asked about their thoughts regarding sharing information about themselves, their families and their farms:

> 'The government always thinks about us [i.e. looks after us]. If it introduces or gives someone permission to introduce a project, it is for our good. Thus, we do not think that there are any negative impacts that can come from the fact that we have provided information to that app'. (Farmer, Kinunga2, Kayonza)

Asked if the provided data could be available to anyone:

> '[…] either way we are beneficiaries of the sharing of our information. It is for our development and that of the whole country in general'. (Farmer, Kinyababa, Burera).

Thus, an apparent trust in data collection existed based on the perception that those accessing the data would do something beneficial with it. With few exceptions, farmers did not demand transparency about what the data would be used for and by whom, neither clarification about their rights

In summary, ICT4BXW attempted to be inclusive, involving a variety of stakeholders in the HCD process. However, users of BXW-App were outnumbered by other more powerful stakeholders, and their influence on the most impactful design decisions was limited. That said, interviewed farmers seemed to trust powerful stakeholders and allow them to take decisions on their behalf. Knowing the context of Rwanda and farmers' position on the receiving end in the project, some restraint regarding the latter finding is appropriate since interviewees may have been cautious about expressing their true thoughts about these sensitive topics. Regardless, the findings suggest

a large responsibility of powerful actors with decisions about adherence to digital rights (like the rights to access information, transparent governance and accountability and informed consent) being in their hands.

Anticipation: considering consequences and impact on digital rights

Anticipation is about defining possible scenarios for and consequences of a design. Within an HCD process, anticipation is mostly visible in the inspiration and ideation phases, for example, when designers and other stakeholders aim to discover about users and use context and suitable designs. For our case-study, we find that anticipation of contextual limitations (e.g., the low network coverage and high data cost in rural Rwanda) led to technical design solutions. For example, BXW-App was made accessible offline, with local storage of data and a minimised download size, for example, through compressing movies and illustrations. However, we find that while project leaders dealt with tangible (short-term) challenges, the responsibility for anticipating longer-term ethical issues or challenges appearing at scale was mostly passed on to the design company. When asking an interviewee from the design company if the project considered potential security issues, the response suggested that, for now, there were no such issues because of the small scale and low granularity of the data:

> 'The way it is put in there now, it doesn't matter so much because it is all enough guesswork'.

However, the same interviewee recognised that by adding information and increasing granularity this could change, for example, the collected data could be misused to monitor data originators:

> 'What would really be an easy step is to see if, but also for the FP, if he [i.e. the farmer] does his job'. and 'if the government wants more detailed information [. . .]. Yes, there's a danger there. For both the FP and the farmer'.

Nevertheless, the anticipation of possibly emerging digital rights violations was not prioritised. Since the application initially targeted a rather small number of people, the perception existed that risks were limited. However, scaling of project outputs to a larger user base was desired (e.g., ICT4BXW worked with 69 FPs but planned to scale countrywide (approx. 15,000 FPs) and potentially regionally in Phase 2). In absence of clear guidelines or regulations to adopt digital rights, ethical considerations became driven by personal values as the following quote from a design company interviewee illustrates:

> 'The government would actually be perfectly fine with knowing what a farmer does with the feedback and also attach punishments to that. And that is, of course, the last thing that you want. So, in the end, there was some kind of a dilemma. Because it is of course all possible. But we didn't do it, because it wasn't the intention. So, you have to continue to talk. Back to the basics of "no we want to discover patterns in the disease transmission and for that, you don't have to know at an individual level what happens exactly per farm. It is about patterns at a larger scale. But well the next. . . I already know, the next step from the government would be to indeed individualise it".'

Anticipation of the consequences of design decisions was not a participatory exercise but rather a task of the design company. They in turn had to negotiate with stakeholders about including or omitting design features that could violate the digital rights of some users. Especially the rights to transparent governance and accountability were hereby violated, subsequently increasing the risk of data security breaches and violation of rights to data privacy or access to personal data. Additionally, informed consent from data originators is impossible without prior anticipation of potential consequences, neither can protection from direct or indirect harm be ensured.

Reflexivity: steering capacity in digital design

The ability to reflect on the impact and consequences in the HCD design process depends on two crucial factors: enabling people to participate in reflection and creating space for reflection. Digital literacy (i.e. second-level digital divide) is a known limiting or enabling factor for participation. ICT4BXW responded to this by coupling capacity-building activities with the design workshops, for example, training participants to operate a smartphone and BXW-App. Although user training was planned for in the project proposal, the real need for capacity building had been underestimated. Most FPs had never used a smartphone or any type of computing device before, and procedures like typing or taking a picture were alien to them.

By transferring skills on how to use digital technologies, ICT4BXW addressed the second-level digital divide. However, truly meaningful participation of FPs in the design and data collection process would have required the capacity of FPs to also (partially) understand the functions and processes behind the working of digital technologies and data processing practices. Such requires a level of digital literacy beyond second-level literacy, allowing a user to actively and critically reflect on the digital technology in use and would be paramount to realise rights like ownership, control and access to data and the right to informed consent. ICT4BXW did not invest in building this digital literacy.

Another finding relates to space for reflexivity. By nature, an HCD process is iterative, and design iterations happen based on design evaluations. A review of project documents tells that indeed some necessary or desired design adaptations were noted by designers and project leaders or asked for by users. In practice, however, adaptations were mostly limited to technical ones (e.g., bugs). More far-reaching design updates were postponed because of time, budget and manpower limitations, expiring contracts with the design company and additionally used as a rationale for a second project phase.

Responsiveness: project limitations and positivist mindset

For an HCD process to lead to responsible, value-based digital agriculture technology, flexibility (e.g., in timelines and objectives) and awareness of the product's scope and limitations are necessary. In ICT4BXW budgets, timelines and deliverables were all pre-set and determined in consultation with a few stakeholders (i.e. project leader, Scientific partner 2, government partner). Regarding decisions about the project scope for ICT4BXW, an interviewee from the managing organisation said:

> '[…] when we were setting up the project, we […] have thought out and written down many things […]. So, I think that we then already figured out a lot conceptually and

> thought about "well, how can we align this with a big problem in Rwanda? Some theme that is a hot topic and, well, that resonates well at various levels".'

This illustrates how, right from the start, much was already established, for example, developing a digital solution for a particular banana disease, partnership with the government, using mobile phone technology. This implies that technologies (e.g., mobile application) and problem definitions were fixed with limited space to alter this during the HCD process, meaning that the existence of, for example, rigid funding lines and transversal topics (e.g., digital by default) directly influence the HCD process.

Responsiveness demands outlining the scope of sociocultural issues, infrastructural limitations and problems in agricultural production systems that a digital agriculture technology may address or cause. Rather than such critical realism, we observed much optimism about the transformative capacity of digital technology in ICT4BXW:

> 'My expectation of this project [...] is that this becomes [...] that true demonstration of what a [...] development process for digital tools should look like and what an early warning system in the future should look like'. (Project leader)

FPs similarly expressed technological optimism in interviews, for example, when talking about how BXW-App and the smartphone impacted their status in communities:

> '[...] now that farmers see me with the smartphone, they are more interested in listening to what I tell them. Before, they used to ignore the advice [...]'. (FP, Nyagafunzo, Burera) and

> '[...] when I am explaining to them [i.e. farmers] while having pictures, I can speak with confidence because what I am telling is supported by the visuals in the app'. (FP, Rusera, Kayonza)

These quotes suggest that the mere existence of the smartphone and BXW-App was perceived as a major benefit by FPs, creating conditions in which users are unlikely to ask critical questions about a technological design. Within this context, it became possible that the project's data management plans concerned project (research) data but did not outline policies regarding, for example, privacy, access rights or opting out, for users of and data collected by BXW-App. Hence, in line with findings presented in the anticipation section, we observe a lack of concern about the impact of BXW-App and the data collected and an unproductive sphere for reflexivity and responsiveness.

DISCUSSION

We analysed the enactment of HCD in one case-study from Rwanda to study responsible innovation in digital agriculture in LICs and attendance to smallholder farmers' digital rights. To derive our findings, we used a framework that operationalises HCD, RRI and digital rights. Although the precise context and observations are case-study–specific, the overall findings provide relevant insights about and lessons for digital agriculture in LICs and contribute to larger scientific debates about digital divides and inclusion, participatory and responsible innovation and

technology shaping (e.g., Barrett & Rose, 2022; Higgins & Bryant, 2020; Rotz et al., 2019). Overall, findings indicate that user-centeredness and inclusiveness, promises inseparable from HCD approaches, only partially materialised. At the surface level, it appeared that the AIRR dimensions were integrated into the HCD process. Closer analysis revealed that all that glitters is not gold: Various stakeholders were included and consulted about their needs and desires for interface design and application functions, but power structures within and beyond the project context affected higher-level decision-making, in turn influencing safeguarding of digital rights. Moreover, enactment of the design approach lacked attention for potential broader and more long-term (negative) consequences. For example, the possibility to use BXW-App as a performance-monitoring tool was welcomed by several stakeholders without questions. It appears that our case lacked the RRI framework's anticipation and reflexivity dimensions. Arguably, this is a missed opportunity: These dimensions may have facilitated the critical thinking and deliberation with stakeholders about digital rights, aspects of power, ethics and justice and inequality while designing the digital agriculture intervention that others recommend (Bronson, 2019; Eastwood et al., 2017; Klerkx & Rose, 2020; Rose, Wheeler, Winter, Lobley & Chivers, 2021). Hereafter, we further reflect on participation capacity, the role of power imbalances and neglect of digital rights. We tease out broader theoretical and practical implications for responsible design in digital agriculture.

The missing link–people's capacity to participate in RRI and HCD practice

Scholarship on designing responsibly in digital agriculture has argued that HCD and RRI approaches can empower stakeholders to reflect on how to better design technologies for their particular contexts and mitigate undesirable consequences (Bronson, 2019; Ortiz-Crespo et al., 2020). Our study nuances that. Current approaches, in our case enacted through an HCD approach, will not always suffice to achieve this, echoing ideas on the need to have sufficient 'RRI readiness' (Eastwood et al., 2019a). Findings showed that participation empowered stakeholders to influence the design of a digital agriculture innovation and bridge tangible design-reality gaps. But stakeholders could not always execute this power due to capacity limitations, affecting, for example, ability to anticipate or reflect on the consequences of design decisions; demand for adherence to digital rights (e.g., privacy, data ownership and control or informed consent). Given digital capacity limitations, one may question the overall capacity of project stakeholders to anticipate, be reflexive or responsive to the possible consequences of BXW-App on a higher level or at scale. Without impeaching the project and stakeholders' intentions, we think that these capacity issues may cause the observed apparent naivety and inability to fully contemplate the consequences of digital technologies. This hinders effective participation. More than a shortcoming of the HCD approach, or incompetency of project implementers, we argue that these capacity issues are a side-effect of the inherently complex character of digital technologies. By nature, tools like BXW-App come with many 'unknowns' and 'unseens' (Klerkx et al., 2019), effectively making them technological black boxes (Ajunwa, 2020). For stakeholders, it is then innately difficult to perceive the ensuing emergent effects of the technology or intervention they are designing, including potential harms. It appears that within this intransparent context, participants merely lack the comprehension to perceive and protect moral values and digital rights that are at stake. This notion expands understanding about third-level digital divides (Scheerder et al., 2017), which entails capacities needed to critically assess digital technologies and their potential impact within a broader system and their effect on responsible design and design outputs. Neither HCD nor RRI currently

provide clear guidance for coping with these intangible (future) design-reality gaps in digital agriculture and thus insufficiently build readiness to effectively enact responsible design in digital agriculture.

Implications of power relations: good intentions versus on-the-ground realities

We already know that relations between actors in digital agriculture are not neutral (Rotz et al., 2019) and that power can affect decision-making in design processes (Hyysalo & Johnson, 2016; Sanders & Stappers, 2008). For ICT4BXW, it meant that representatives of farming communities (e.g., FPs) were less powerful and thus in a weaker position as decision-makers. The different stakeholders participating in the design process were nevertheless often treated as homogenous. In doing so, the social context in which the inclusion of stakeholders in decision-making takes place was ignored. Power imbalances in digital agriculture make that the powerful (e.g., donor, project managing organisation) face smaller risks and bigger benefits (Cinnamon, 2020), providing little incentive to be responsible and adhere to digital rights. Simultaneously, the less powerful (e.g., farmers, FPs) are poorly protected from direct or indirect harm caused by digital technologies (Mann, 2018) and lack the digital capacity and agency to demand, for example, to be informed about present-day and future use of collected data. This makes the space for participation in designing a digital technology restricted and controlled by a few powerful actors. It appears that both in profit and not-for-profit contexts in LICs, including diverse stakeholders in a design process, does not solve inequality, power dependencies or accountability issues. This contradicts the idea that responsible design approaches give participants an equal voice. In practice, there may be explicit or implicit choices in responsible design processes, which render them less inclusive (Klerkx & Leeuwis, 2008), and creating responsible designs that fit with different users' needs or giving users an expert role in design is easier said than done. This has implications for the meaning of inclusivity in (debates about) RRI and HCD. We would argue that inclusivity becomes less meaningful when diverging interests and power relationships between stakeholders are not actively addressed. Hence, explicit attention for shaping inclusiveness while dealing with issues such as conflicting interests is required (following Skrimizea et al., 2020; Turner et al., 2020; van Mierlo et al., 2020).

Theoretically, digital rights frameworks could guide responsible design. But as indicated before, rights are in practice fragmented (van der Burg et al., 2020; Wiseman et al., 2019a) and less established than general human rights. Digital rights are furthermore mostly formulated as voluntary guidelines (Sanderson et al., 2018), with no unified framework to adhere to, formal obligation to adopt or institution to appeal to. This legal fragmentation provides opportunities for cherry-picking of digital rights and 'window dressing' (von Schomberg & Blok, 2019) or 'ethics washing' (Bietti, 2020; Hao, 2019): Powerful actors presenting their project and its outcomes and impact as responsible and ethical without necessarily being responsible or ethical under the hood. Thus far, the disjunction between high-level governance frameworks and actual design practices received only limited attention in academic work on RRI and digital agriculture (Eastwood et al., 2019a; Fielke et al., 2021; Rose & Chilvers, 2018). This article contributes an additional understanding of the context of LICs. In ICT4BXW, more complex rights, which are specifically important for LICs and vulnerable groups (e.g., protection from indirect harm, data purpose definitions, truly informed consent), were under-represented. This is not to say that ICT4BXW should be considered a case of window dressing. Project managers probably had the right intentions, but their

implementation fell short. Nevertheless, a danger of 'false' attempts of responsible design could be that, unintendedly, the opposite is achieved: irresponsible designs. For digital agriculture, in LICs, this could make already vulnerable groups of people (smallholder farmers) more vulnerable or result in undesired alterations to rural societies and livelihoods.

Implications for conceptualising responsible design

Finally, we look at the implications of our findings for conceptualising responsible design in digital agriculture. Responsible design in digital agriculture demands asking critical questions and deliberation about the potential consequences of technology. Such sensitivity to the pros and cons of technological innovation conflicts with the old belief that technology can fix all problems (Hartley et al., 2019). Ubiquitous critique on and concerns about this 'technological fix thinking' in the context of digital agriculture and development exists (e.g., Birhane, 2020; Mann, 2018; Rikap & Lundvall, 2020). Our findings confirm that this discourse still occurs in practice (Lajoie-O'Malley et al., 2020). We found technological optimism among diverse stakeholders, for example, visible in the unquestioned faith of users that BXW-App would yield a positive impact. The digital (agriculture) development sector embraces responsible design approaches to deliver designs that respond to user needs and can 'do good' for people in LICs. Our concern is that practitioners may (unknowingly) use these approaches as a quick fix to structural inequality in development projects without addressing the problems underlying that inequality.

The conceptualisation of responsible design approaches like HCD and RRI originates from the Global North. HCD emerged in the design sciences, aiming to develop innovations that 'work' today from a productionist and economic perspective and optimise their adoption and scale. This focus on technological feasibility and economic viability make HCD in itself rather technocratic. Similarly, responsible innovation has been critiqued for adopting the narrow economic and technological foci of innovation (Blok & Lemmens, 2015). In our view, the current approaches are ineffectual for developing responsible, rights-based designs in the context of digital agriculture in LICs. We follow Clapp and Ruder (2020), saying that to become truly inclusive, focused on user needs and responsibility, attention to the agricultural system and political economy in which digital technology becomes embedded is needed. Beyond this care for user needs, an understanding of the structural conditions that surround a digital design process is critical. Different from other technological innovations, digital data-generating innovations are more malleable (Moor, 1985) and less time- and place-restricted, hence reducing or removing existing boundaries and hierarchies (Heeks, 2018; McCampbell et al., 2021). The ICT4BXW case-study demonstrated the HCD approach's strength in developing a specific digital technology and planning the implementation and impact for a specific (local) context. This strong focus on local context, capacity and impact is often seen as an advantage of HCD (Ayre et al., 2019; Ortiz-Crespo et al., 2020; Steinke et al., 2020). Decisions by designers can nevertheless have a systemic impact (Bronson, 2019) and transformative technologies require local solutions that can contribute at a larger scale (Berthet et al., 2018; Emeana et al., 2020). In our view, HCD gives insufficient space to anticipate unintended consequences of digital technologies at scale or a system level, despite this being critical for responsible innovation and scaling (Wigboldus et al., 2016). The RRI framework does consider systemic impact yet lacks contextualisation to local realities and thus cannot guide the actual design of digital agriculture technology. This limited practical applicability and the challenge to deploy it in specific organisational and national contexts has been criticised before (de Hoop et al., 2016; Wittrock et al., 2021a). We observe a gap in the current framing of responsible design: Practical, short-term,

tangible matters such as privacy or inclusion in designing a digital interface are addressed, while higher-level issues such as data security or power dependencies are not. This has implications for anticipating the broader impacts of digitalisation, like redistribution of roles and responsibilities in smallholder agriculture systems or access to resources and markets (Mann, 2018, and capability to counteract those. Without attention to those broader impacts, issues (e.g., regarding digital rights, (future) design-reality gaps or inclusivity) build into locally developed technologies today will scale and solidify, affecting large numbers of people in the future (Bronson, 2018). Strong integration of the anticipation and reflexivity dimensions in design approaches, with explicit attention for systemic impact, would support better informed, more responsible design decisions that are the outcome of a consultative process rather than one (powerful) individual's choices. Joining Eastwood et al. (2019a), we recommend clear hands-on translations of the AIRR dimensions, contextualised for LICs and digital development, that guide analysis and evaluation of the local- and system-level responsibility of a design, and consider Tables 1 and 2 in this article as an initial contribution to this.

CONCLUSION AND RECOMMENDATIONS

This evaluative study combined RRI and digital rights lenses to study the enactment of an HCD approach while developing digital agriculture technologies in LICs and contributes a framework to practically operationalise those concepts. Using empirical evidence from a Rwandan case-study, we analysed if and how the design approach contributed to developing responsible digital agriculture innovations. The normative sociological perspective of the responsible design was substantiated by adding digital rights as valuable input for responsible digital technologies. Evaluating a real-world design process, we identified four explanations why using HCD in LICs cannot guarantee the development of responsible, rights-based designs. First, capacity limitations of participants in design processes and users of design outputs affect the ability to critically assess design decisions. This influence has been under-addressed in the literature on design approaches in digital agriculture. Second, findings suggest that unequal power distribution affects different stakeholder roles' authority over design decisions, which is in line with previous research in the USA and UK (Carolan, 2018). This demands us to question if farmers (representatives) can truly be co-designers, and if inclusivity in design is achievable when deploying HCD, especially in LICs? False inclusion looms if digital incapability and power relations are ignored. Outputs of design processes may then, unintendedly, exacerbate old or create new divides and inequalities. Third, stakeholders on all levels showed a broad technological optimism about digital technologies. Alongside the aforementioned capacity limitations and power dimensions, this optimism hinders anticipation and reflexivity of consequences of digital agriculture. Voluntary and fragmented guidelines for responsible, rights-based digital innovation fail to provide the necessary impulse for change and instead promotes cherry-picking and 'window dressing'. We assert that anticipation and reflexivity to broader implications of using digital technologies in LIC contexts should become mandatory elements of design processes. Thus, recognition, protection and governance of farmer's digital rights should start when designing a digital technology. Else, the 'good for all' and 'good for everything' narratives surrounding digital agriculture in LICs will continue to hinder critical thinking and challenge the adoption of guidelines for responsible and rights-based design. Fourth, the local level at which the design process and decisions transpire mismatches with the system level at which unintended consequences of digital technologies emerge. Hence, there is too little attention for and oversight of consequences emerging at scale. Here, too, we

believe that critical discussion about system-level outputs, pointing out stakeholders' interests as well as the impact of different methodological approaches, is highly needed. Future studies could assess the validity of our findings for other digital agriculture projects in LICs, building a more robust understanding of the real-world working of design processes. We also recommend further research on hands-on and conceptual integration of RRI and digital rights in design methods to identify relations between local level design decisions and meta-level consequences early.

Practitioners aspiring responsible design are recommended to: (1) Actively mediate between different stakeholders to address diverging interests and power inequalities and invest in the digital capacity of stakeholders to make inclusion and participation meaningful. This includes investing in the capacity of project staff, especially regarding third-level digital divides and critical thinking about technologies. (2) Make anticipation, reflexivity and responsiveness integral elements of digital agriculture projects and design processes to foster responsible design. Scenario building exercises may help with this and support bridging third-level digital divides. (3) Public authorities are recommended to develop unified ethical and rights standards for digital agriculture that (4) recognise that local digital agriculture interventions may have systemic impacts, affecting social norms and values. Technological optimism cannot be an excuse to ignore or violate digital rights. This implies that practitioners, donors and legislators in LICs should take responsibility for securing the digital rights of all actors, especially vulnerable ones like farmers.

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CONFLICT OF INTEREST

This article is intended to disseminate research and practices about design approaches in digital agriculture and to encourage debate and exchange of ideas. The views expressed in the article are those of the author(s) and do not necessarily reflect the official position of RTB, CGIAR or the publishing institution.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author, M. McCampbell, in some cases with permission of the third party: The International Institute of Tropical Agriculture. The data are not publicly available due to their containing information that could compromise the privacy of research participants and interviewees.

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APPENDICES

TABLE A1 International sector policies and guidelines available for regulating the design of digital agriculture tools and systems

Organisation	Type	Policy/guideline	Summary/aim
Global			
Digital Impact Alliance	Principles design guidelines	Principles for Digital Development	Nine principles to help organisations design impactful and sustainable digital programmes and initiatives
Google	Technical design guidelines	Building for Billions	Technical documentation to improve connectivity, device capability, data cost, battery consumption and content
GOFair Initiative	Principles design guidelines	FAIR principles	Guidelines to improve the findability, accessibility, interoperability and reuse of digital assets
Internet Rights and Principles Coalition (IRPC)	Principles	Internet Rights and Principles	Definition of 10 rights and principles within the Internet Government Forum
Global Open Data for Agriculture and Nutrition (GODAN)	Best practices	Responsible Data in Agriculture	Best practices for managing agricultural data responsibly
WSIS	Principles/charta	Declaration of Principles	Vision for key principles of the information society
Regional			
EU	Legal framework	General Data Protection Regulation	European legal framework to regulate the storage and processing of personal identifiable information
EU	Principles/charta	Code of Conduct on agricultural data sharing	General principles for sharing agricultural data within the agro-food chain providing a non-binding code
Organisational			
USAID	Organisational policy	Considerations for Using Data Responsibly	Organisational framework for identifying and understanding risks associated with development data

(Continues)

TABLE A1 (Continued)

Organisation	Type	Policy/guideline	Summary/aim
ICRC	Organisational policy	Handbook on Data Protection in Humanitarian Action	Organisational handbook on the management of personal data in humanitarian situations
OXFAM	Organisational policy	Responsible Data Policy	Policy to define rights of data subjects and responsibilities of Oxfam as data controller
CGIAR Platform for Big Data in Agriculture	Organisational policy	Responsible Data Guidelines	Guideline for member organisations of the CGIAR system to manage privacy and personally identifiable information in the research project data lifecycle
UN System	Organisational policy/principles	Personal Data Protection and Privacy Principles	Principles for the processing of personal data across the UN System Organisations.
UNDG	Organisational policy	Guidance note on Big Data for achievement of the 2030 Agenda	Guidelines on data privacy, ethics and protection concerning the use of Big Data collected and shared by private entities with United Nations Development Group members
WFP	Organisational policy	Guide to Personal Data Protection and Privacy	Guidelines for WFP personnel regarding the processing of data concerning program beneficiaries