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Are farmers ready to use phone-based digital tools for agronomic advice? Ex-ante user readiness assessment using the case of Rwandan banana farmers

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ABSTRACT

Purpose: Digital extension is widely embraced in African agricultural development, promising unprecedented outcomes and impact. Especially phone-based services attract attention as tools for effective and efficient agricultural extension. To date, assessments of digital extension services are generally ex-post in nature, thus consideration of users and broader systems occurs once an intervention is broadly identified. However, early understanding of user needs, readiness, and relevant context is a prerequisite for successful adoption and sustainable use of digital extension services. We conducted an ex-ante assessment of user readiness (UR) for phone-based services.

Design/Methodology/Approach: We developed an ex-ante framework to assess UR, considering capabilities, opportunities, and motivations of targeted users. The case study of Rwandan banana farmers served to verify the UR framework, using survey data from 690 smallholder farmers.

Findings: Findings demonstrate limited capacity to access and use phone-based extension services, especially those requiring a smartphone, and a mismatch between expected UR and actual UR, current capabilities and opportunities. Findings provide entry points for designing suitable digital extension projects and interventions, suggesting a need for capacity building.

Practical implications: The UR-framework provided understanding about current limitations in farmer readiness for digital extension. This ex-ante approach to explore UR before designing digital interventions for African farmers is recommended. It points at the importance of embedding digital technologies into existing practices and creating blends of 'digital' and 'analogue' or 'high-tech' and 'low-tech'.

Theoretical implications: The UR-framework provides a structured approach to developing pre-intervention insights about users and use-context, supporting informed strategizing and decision-making about digital extension. It is a relevant addition to existing readiness frameworks, participatory design methods, and

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ex-post intervention performance assessments, as part of a balanced readiness level assessment.
Originality/Value: This is the first ex-ante assessment of UR for digital extension services in an African context, and the first attempt to analyse Rwandan farmers' readiness for digital extension services.

Introduction

Rapid technological advancements and increasing availability of all kinds of digital tools and technologies have led to widespread experimentation and implementation in Africa with digital agriculture (Daum et al. 2021), defined as the use of digital tools and technologies in the management of and decision-making about agricultural systems and value chains (Eastwood et al. 2019a; Klerkx, Jakku, and Labarthe 2019; Wolfert et al. 2017). Examples of digital agriculture include market and financial access tools, registration of farming activities, and agricultural advisory services. Many African governments have accordingly developed policies supporting digital agriculture (Malabo Montpellier Panel 2019) e.g. Rwanda's ICT for Rwandan Agriculture Policy (2017) – and the African Union recognized digitalization as a top priority for achieving the ambitious goals under its Agenda 2063 (African Union 2019). Digital agriculture additionally has an increasingly important share in donor portfolios visible also in rising investments (Tsan et al. 2019). The digital agriculture sector has expanded at an impressive rate over the past few years, with a reported 44% per annum increase in the number of registered farmers as users of digital tools (Tsan et al. 2019). The growing interest in the sector comes with high stakes and expectations for the outcomes and impact of interventions.

In this article, we focus on one dimension of digital agriculture, namely digital agricultural extension. In this context, we explore the current capacity of African farmer end-users to adopt and use digital extension technologies and tools, especially phone-based services. Digital agricultural extension tools deliver or are a component of agricultural extension services, and include pest and disease diagnostic tools, soil management decision support systems, and tools that support the exchange of agricultural knowledge. Digital extension can be standalone, replacing traditional 'analogue' extension, but mixed models where digital tools are combined with analogue, e.g. face-to-face extension, are possible too (Fabregas, Kremer, and Schilbach 2019; Klerkx, Jakku, and Labarthe 2019; Steinke et al. 2020). Digital extension services promise to contribute to e.g. increased crop production, reduced pest and disease pressure, better insight into soil health conditions and, ultimately, improved livelihoods through better and more inclusively accessible information (Agyekumhene et al. 2020). They are also seen as potentially disruptive (Eastwood et al. 2019b) as their potential to increase connectivity and transparency among those who have relevant applied knowledge (Fielke, Taylor, and Jakku 2020) may radically change the way in which agricultural extension is organised. Many of today's digital extension services, especially those that use (smart)phones to send and collect information, target actors operating at farm or village level (e.g. smallholder farmers, extension agents). This trend assumes that widespread access to and use of mobile phones has cleared the way for phone-based extension such as SMS and IVR advisory services or disease diagnostic apps.

Despite the enduring hype and promises around digital tools in agriculture, it has been argued that we lack understanding about actual use and that current use is overestimated (Baumuller 2016; Klerkx and Rose 2020; Steinke et al. 2020). For example, some interventions reportedly reached over 1 million farmers (e.g. E-Soko in Ghana, and Smart Nkunganire in Rwanda), yet of the farmers registered for those digital agriculture services, an estimated 42% actually used the service and only 15–30% were truly active users (Tsan et al. 2019). Similarly, several studies point to barriers to the adoption of phone-based services, including limited added value, poor technological infrastructure, inappropriate ICT policies, and low capacity levels of (farmer) users to use the technologies (Aker, Ghosh, and Burrell 2016; Ayim et al. 2020; Munthali et al. 2018). Hence, knowledge about the transformative capacity of digital extension is still limited (Ingram and Maye 2020) and research claiming evidence of the impact of digital interventions in agriculture in Africa is largely anecdotal (Tsan et al. 2019; Sulaiman et al. 2012).

Given the shortage of truly successful experiences, there is increasing recognition that the entry-point for studying and developing digital extension services should be the user and the specific use context in which digital technology is used (Steinke et al. 2020; Sulaiman et al. 2012). User-centred (or human, co-creation, or participatory) approaches are therefore increasingly used in the design and pilot phase of digital extension services and considered indispensable for sustainable development by some (Gonsalves et al. 2005; Ortiz-Crespo et al. 2020; Steinke et al. 2020). User-centred approaches can guide developers in designing and implementing interventions that fit with user needs and context (Steinke et al. 2020). The existing capacity of users and the digital and agricultural system can make good starting points for such a design approach. Using an ex-ante approach to assess e.g. existing agricultural information practices of intended users, communication customs, and the role of different (digital) media for sending and receiving information, can give insight into the complex environment in which a new digital extension service has to integrate and fit, and may inform about specific user features and requirements for a digital extension service before a design process starts. This is where this study aims to make a contribution, using a framework (User Readiness (UR) framework) that was developed with the purpose of conducting an ex-ante study into the readiness of targeted users of a digital extension service by looking at user capacity, behaviour, and context. It draws on insights from the public health field, and responds to a call for an interdisciplinary approach to digital extension design, combining insights from economic, agricultural, ICT, and behavioural sciences (Fabregas, Kremer, and Schilbach 2019). The used framework specifically aids assessment of the current capacity of target users of a digital extension service, in our case a (smart)phone-based service and helps to understand 'user readiness'. This adds the factor of human–technology interaction to digital extension. In a development context, this factor is often overlooked. However, elsewhere human–technology interaction has been identified as critical to demonstrate the value and meaning of technology to farmers and other actors (Fielke et al. 2021; Ingram and Maye 2020) and it has been suggested that more research in this area is needed in the field of study focused on extension and advisory services (Klerkx 2020; Klerkx 2021). To the best of our knowledge, a framework for in-depth, quantitative, assessment of UR does not exist yet, especially one that can be applied to a developing countries context. Our framework puts the ex-ante capacity of target users and their context at the centre of digital innovation. A study that used a qualitative analytical framework to assess Australian farmers' UR appeared helpful for determining the resources and actions required to reduce (social) risks of digital development (Fielke et al. 2021). Similarly, by developing and applying the user-readiness framework, it could become possible to adapt the full digital intervention design to the real-life situation, hence moving beyond fitting a specific digital extension tool or technology to its user (like user-centred design approaches do).

For the purpose of our study, we focused on Rwandan banana farmers and Rwanda's (digital) agricultural system as a case study. We applied our UR framework to find out whether the UR and the context of use meet the conditions necessary for a (smart)-phone-based digital extension service to be adopted and have an impact.

Conceptual framework: an approach to study technology UR for using digital agriculture technologies

The UR framework follows in the footsteps of various technology assessment frameworks developed since the 1970s to assess and communicate the maturity of new technologies (Mankins 2009). Traditionally Technology Readiness Assessments were prospective studies that examined at the onset of a programme to what extent and in what context (e.g. laboratory setting or real-life setting) a technology had demonstrated its capacity to perform the functions for which it had been designed, often assigning a readiness level to the examined technology. Today we also see spin-offs of the original framework such as scaling readiness (Sartas et al. 2020) and innovation readiness (Benson 2019). However, in such assessments, it is typically the technology or innovation that is evaluated for its readiness, while the user remains largely invisible. This focus on the functionality of a technology in a specific context arguably reflects a technocentric emphasis in existing readiness assessments. Yet, based on the foregoing contexts, we can argue that the technological readiness of a digital extension service does not guarantee adoption or impact if the users of that service are not ready too. This is in line with recent work that argues for 'balanced readiness level assessment' contemplating several sorts of readiness beyond technology readiness (Vik et al. 2021).

Conceptually, the UR framework builds on general theories from the behavioural sciences that have been used to explain adoption and behaviour change in a wide range of settings, including also agriculture (see for overviews e.g. Engler, Poortvliet, and Klerkx 2019; Meijer et al. 2015; Mills et al. 2017). To operationalize the idea of UR we employ the COM-B model of behaviour (Michie, Atkins, and West 2014; Michie, van Stralen, and West 2011) that was originally developed in the context of public health interventions, and which synthesises insights from several prominent behaviour change models (Michie, van Stralen, and West 2011). The COM-B model proposes that for a person to engage in a specific behaviour (B) at a moment in time, that person needs to have the physical and psychological capability (C) and the social and physical opportunity (O) to perform that behaviour, as well as have the automatic and reflective motivation (M) to do so more than any other competing behaviour at that moment (Barker, Atkins, and de Lusignan 2016; Michie, van Stralen, and West 2011). For the UR-framework we took the COM components of the original model, but instead of focusing on actual behaviour (B) we consider that the COM components together shape UR which we define as the capacity of an individual or group of individuals to perform a behaviour (in this case using a digital extension service). Using the COM components, we conceptualize UR as a quantifiable parameter that may continuously vary in time and space, and that derives its value from a set of contextually relevant variables. We propose that optimal UR for a digital technology lies at the intersection of the component's capability, opportunity, and motivation (Figure 1).

Based on the original definitions of C, O, and M by Michie, van Stralen, and West (2011), we define capability as 'the individual's psychological and physical capacity to engage in using a digital technology or extension service'. This includes having the necessary knowledge, skills, and stamina. Opportunity is defined as 'all the factors that lie outside the individual that make the use of a digital technology or extension service possible or prompt it'. This includes contextual factors that shape accessibility, affordability, and social acceptance. Motivation is defined as 'all those brain processes that energize and direct the use of a digital technology or extension service, not limited to goals and conscious decision-making'. It includes (unconscious) habitual processes, emotional responses, as well as goals and analytically made decisions. We have translated these general definitions towards the context of digital agricultural extension (see Table 1) and used this to design a survey questionnaire with operational questions (see below and Annex 1).

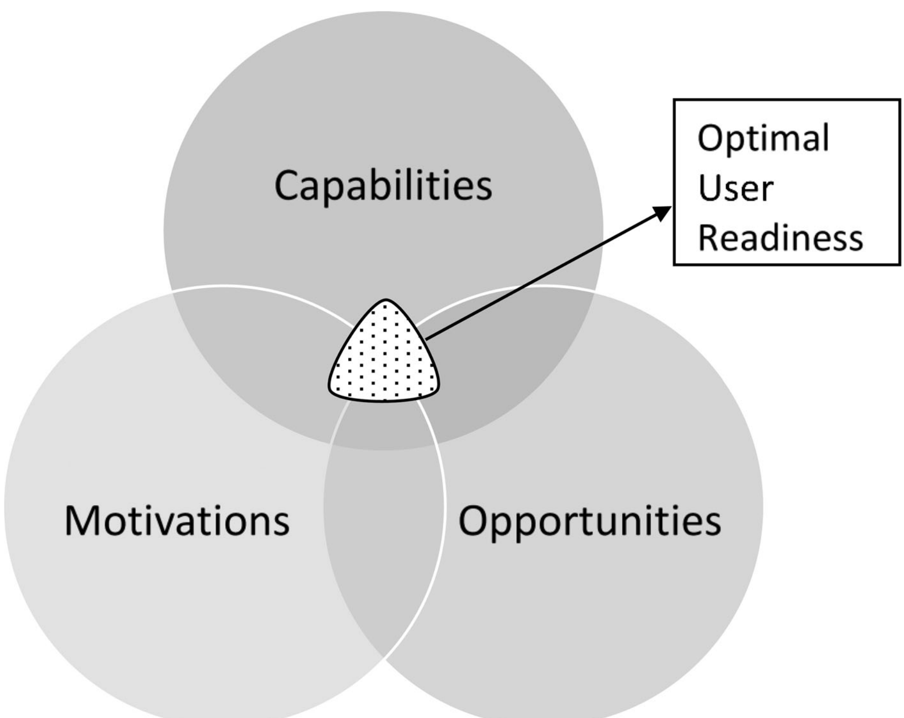


Figure 1. Schematic representation of the COM components and User Readiness (COM-UR, from here on UR framework).

Table 1. Overview of UR-framework components as adapted from Michie, Atkins, and West (2014) and a brief explanation with examples of their application in the context of digital extension services.

Component + general definition	What to consider in context of digital agricultural extension	Examples of operational categories
Physical capability Physical skills, strength or stamina	• The state of farmers' physical ability and skills to use a digital device	• Capability to use a touchscreen on a (smart)phone
Psychological capability Knowledge or psychological skills and stamina to engage in the mental process	• Education/literacy levels • Previous experience with using digital technology	• (e)-Literacy • Capability to use various functions in a phone • Capability to understand interrelations between different phone functions
Physical opportunity Environment affording opportunity by means of time, (economic) resources, locations, cues	• Organization of the (digital) extension system • (Economic) resources available • (Digital) infrastructure	• Time and (financial) resources to own and use a mobile phone • Network availability
Social opportunity How farmers 'think', farmer's mindset, affording opportunity by means of interpersonal influences, social cues, cultural norms and values	• Gender norms in farming communities • Mindsets about digital technology and agricultural extension • Social interaction in farmer communities	• Equal access of men, women and different age groups to own or use a mobile phone • Cultural norm that use of digital technologies by women may bring shame on the family
Reflective motivation Processes involving plans (self-conscious intentions) and evaluations (e.g. beliefs, norms, goals, values about good/bad)	• Perceived government enforcement mechanisms • Experienced norms and beliefs about agriculture and digital technology • Innovativeness of farmer • Future goals of farmer	• Belief that phone-based information is trustworthy • Intention to use an app to retrieve agronomic advice • Perceived barriers to adopt digital tech • Perceived pressure to use an app
Automatic motivation Processes involving emotional reactions, desires (wants/needs), impulses, reflexes	• Perceived needs and demands • Expressed interests	• Wanting to receive information about agriculture • Experiencing the need to become digitally connected

Materials and methods

Case study

In order to study UR, we selected a digital extension project (ICT4BXW) led by the International Institute of Tropical Agriculture that operates in Rwanda. Rwanda has a strong national vision for digital extension service delivery (MINAGRI 2016). The ICT4BXW project aims to use citizen science and ICT to develop (cost)effective and scalable tools for advancing the prevention and control of Banana *Xanthomonas* Wilt (BXW) disease in East and Central Africa (ICT4BXW, 2018). To meet its objectives the project developed and field-tested a smartphone application called 'BXW-App'.

Our study's main focus is smallholder banana farmers in Rwanda for whom banana is a major contributor to food security. Rwanda's banana production system is diverse but overall banana is grown by 90% of households (Nsabimana et al. 2008) occupying over one fifth of all cultivated land, being the main permanent crop, and contributing the largest share to the country's total crop production in metric tonnes (NISR 2020) and both subsistence and income to smallholder farmers. Banana mats, being perennial, are an important resource in Rwanda's agricultural system and produced across a broad range of agro-ecological zones either as mono- or as intercrop. It provides an array of ecosystem services e.g. supporting soil erosion protection, in addition to food, feed, and fibre (Ocimati et al. 2019; Uwamahoro et al. 2019). The crop additionally has cultural value in Rwandan society. Similar to other staple crops in East and Central Africa, banana production is challenged by issues such as diseases, limited or unequal access to knowledge and information services, limited agronomic knowledge of farmers, and poor market infrastructure (McCampbell et al. 2018; Uwamahoro et al. 2019). These issues threaten food security and provide a disincentive for continued investment in staple crops like banana. Issues like diseases, knowledge, and information access and needs are generally addressed through agricultural extension services. In this context, a variety of recent extension interventions included the introduction of digital extension technologies (e.g. research-led BXW-App, private sector-led Viamo 3-2-1 Service [operated as *845# in Rwanda], and government-led Smart Nkunganire). While using a single case study poses limitations in terms of the ability to generalize, we believe that the ICT4BXW project provides a good context to further explore the idea of UR in relation to digital extension, especially smartphone-based extension. Recognizing that the findings may not be extrapolated, the insights and lessons derived may offer food for thought beyond Rwanda and banana farming system contexts.

Study area and methods

We used a mixed-methods approach for our study, including qualitative and quantitative data collection. A detailed survey was conducted to collect relevant data from banana farmers ($n = 690$) in eight districts (Kayonza, Gatsibo, Rulindo, Burera, Rubavu, Karongi, Muhanga, Gisagara) in four provinces in Rwanda (Eastern, Northern, Western, Southern), covering all agro-ecological zones where banana is produced (Figure 2, Table 2, Annex 1). The survey instrument was developed for and deployed on a mobile-based digital platform (using Open Data Kit and conducted by enumerators in the local language (Kinyarwanda). The survey included a broad range of topics related to household characteristics, general farming activities, banana production, agronomic practices, and disease management, agricultural extension and communication, and use of ICT (including phones). More specifically, it operationalised the variables of the UR framework as described in Table 1 (see for details Annex 1). Field implementation of the survey was conducted in August 2018 as a part of baseline assessment for the ICT4BXW project. To enrich our understanding of existing information exchange practices, we conducted additional surveys with farmers ($n = 40$) and farmer promoters (FPs) ($n = 5$) in two sectors in four villages in Kayonza district. Farmer promoters are government-supported volunteers who act as extension agents at the village level. Moreover, data were collated from key informant interviews with banana agronomists, stakeholders within the banana extension delivery system, and subject-matter specialists on banana and BXW disease management in Rwanda ($n = 9$).

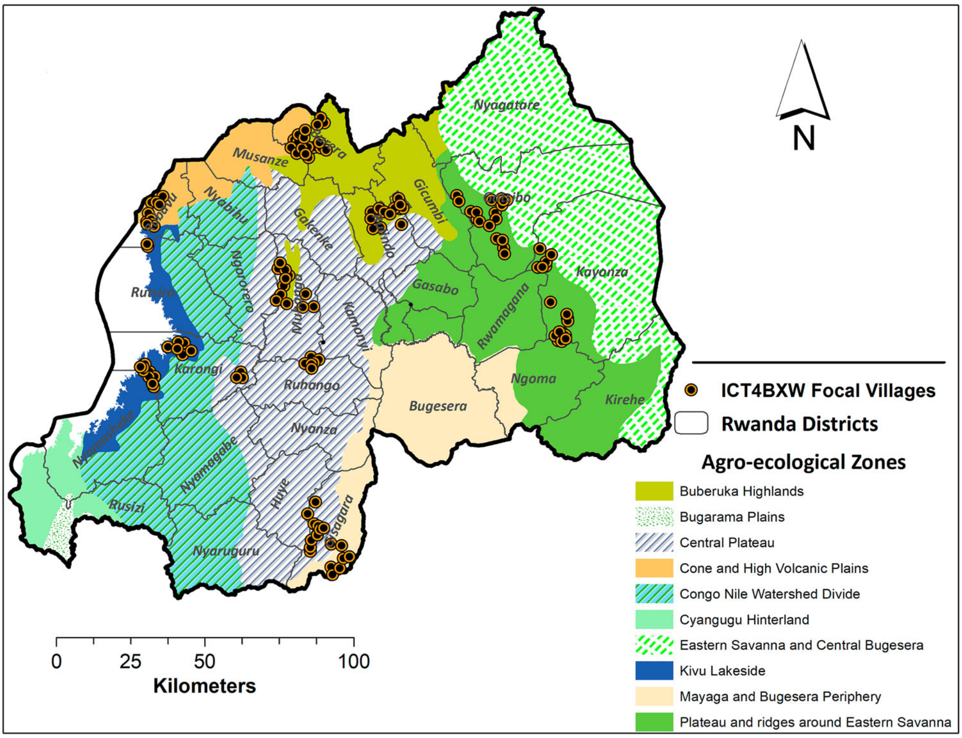


Figure 2. Overview of distribution of focal villages where farmers were surveyed.

Table 2. Overview of respondents in banana farmer survey.

Variable	Indicator	Frequency ($n = 690$)	Percentage (%)
Gender	Male	413	60
	Female	276	40
	Unknown	1	0.1
Age	16–30 years	60	9
	31–60 years	495	72
	60+ years	135	20
Head of household	Yes	132	19
	No	558	81
Education	No education	123	18
	Primary school	466	68
	Lower secondary school	71	10
	Upper secondary general	21	3
	Upper secondary technical	1	0.1
	Upper secondary teaching	3	0.4
	University Bachelor	3	0.4
	University Master	2	0.3
District	Kayonza	90	13
	Gatsibo	90	13
	Rulindo	90	13
	Burera	90	13
	Rubavu	60	9
	Karongi	90	13
	Muhanga	90	13
	Gisagara	90	13

Sampling strategy

Districts were selected in consultation with extension delivery officers from Rwanda's Agriculture and Animal Resources Board (RAB), and with reference to data from a countrywide BXW assessment which was conducted by RAB in 2017–2018. The two selection criteria include (1) diversity across Rwanda's agro-ecological zones to ensure representativeness of all major banana producing zones, and (2) different banana production typologies to ensure that the districts represented production diversity.

Purposive sampling was conducted from nine strata of villages that were grouped based on two criteria: (1) distance between village and district office based on a three-point scale (short, medium, large). Where distance was a weighted measurement based on true road distance and road pavement type; (2) BXW incidence severity (low, medium, high) which was determined based on reports from sector and cell agronomists together with real-time expert observations at the time of sampling. Two villages were selected from each stratum, thereby considering a third criterium: Distance between villages. There had to be either a minimum distance of 5 km between sampled villages or a non-sampled village in between two sampled villages. This resulted in 18 selected villages for every district, except for Rubavu ($n = 12$) where no villages were sampled in the large distance strata due to the absence of banana production in those areas. In each sampled village, 5 farmers from five different households were surveyed, 3 males, and 2 females. Men were always surveyed by male enumerators and women by female enumerators. Households were selected randomly, however respondents could not be neighbours.

Data analysis: assessment of ex-ante UR

Robust inference of UR was generated by sub-dividing the COM components in the UR framework and mapping relevant independent variables to each sub-component. The inherent value of this approach is that it offers the flexibility to incorporate as many pertinent variables as possible, to robustly and reliably quantify UR at individual levels, within groups, and across groups.

Mathematically this looks as follows:

$$UR = f\ (Capability\ (a|b)*Opportunity(a|b)*\ Motivation(a|b)) \tag{1a}$$

$$UR\ = f(\mathrm{Cphy}*\mathrm{Cpsy}*\mathrm{Mref}*\mathrm{Maut}*\mathrm{Ophy}*\mathrm{Osoc}) \tag{1b}$$

$$UR\ Index\ [Component] = \frac{\sum_{i=1}^{j} CFij_{Scored}}{\sum_{i=1}^{j} CFij_{Total}} \tag{2}$$

$$UR\ Index\ [Overall] = \sum_{n=1}^{n=j} \frac{(TUR\ Index\ [Component]\ _{ij})}{n} *100 \tag{3}$$

where, $a|b$ denotes the partitioning of each core UR sub-component, $CFij_{Scored}$ is the score for each component factor (CF) based on the respondent's answer. $CFij_{Total}$ is the total attainable score across the CFs within each component; *Cphy* is the physical capability, *Cpsy* is the psychological capability, *Mref* is the reflective motivation, *Maut* is automatic motivation, *Ophy* is a physical opportunity, and *Osoc* is social opportunity.

Binary scores (0 or 1) were assigned to each of the 690 respondents based on their response to the questions/variables in Annex 1.[1,2] To avoid bias in the UR-index as a result of differences in the number of variables (ranging from 8–30 variables per framework sub-component) included in the framework we applied stepwise rescaling of the individual scores (by assigning equalizing weights to components). This resulted in an aggregated score for each COM component for each respondent, which was then rescaled based on relative weight for each category. Subsequently, we added the overall rescaled value to derive a continuous value of 0–1, indicating the overall ex-ante UR score per respondent. To determine the relative UR score of the sampled population, the overall respondent scores (5 classes) were reclassified and calculated based on the number of respondents in each class. Figure 1 shows a schematic representation of the theoretical optimum, where scores are closer to 1 for each of the components and a balance exists between capability, motivation, and opportunity scores.

Results

Overall ex-ante UR

The rescaled scores for the various components of the UR framework (Figure 3) show that most of the banana farmers surveyed are limited in their physical capability, psychological capability, and physical opportunity, with average scores of 0.22, 0.21, and 0.32, respectively (with a value range between 0 and 1, 1 being optimum score). Approximately 85% of the respondents scored below 0.3 in their physical capability and psychological capability, while a similar number of farmers scored less than 0.4 in their physical opportunity. In contrast, the majority of the respondents had the high automatic motivation and social opportunity, with 85% and 70% respectively scoring greater than 0.7.

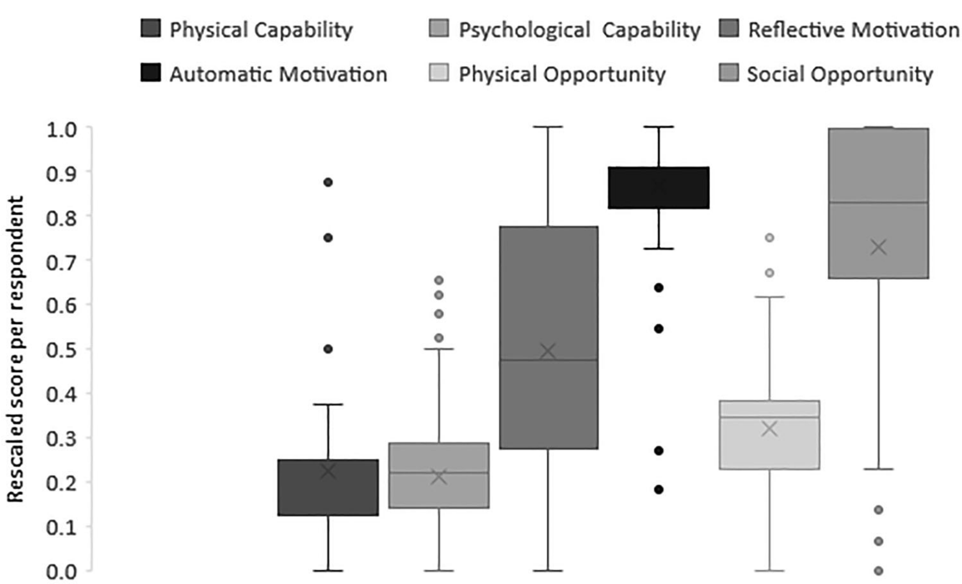


Figure 3. Calculated scores for framework sub-components among farmers based on responses to multivariate survey. The 'x' symbol shows the mean score.

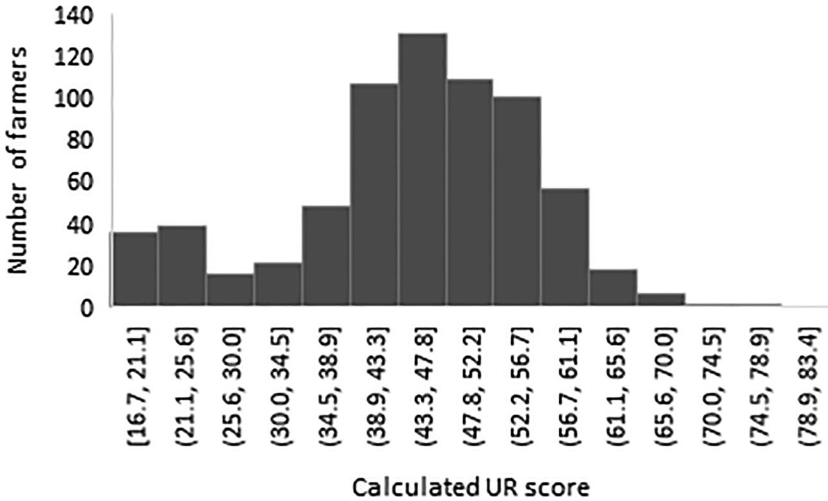


Figure 4. Distribution of ex-ante User Readiness (UR) scores of banana farmers in Rwanda.

The aggregated and standardized UR score across the sub-components show that the majority of the respondents (82%) scored between 30% and 60% (Figure 4), and there was a gradual decline of the scores with the age of the respondents. Both male and female respondents are comparable in their overall UR scores, and we found no significant difference when disaggregating different age categories. Generally, the average UR score (44.6%) was close to the median (46.1%), with a tendency for respondents to attain lower score ranges (skewness = −0.58).

Further comparison of the sub-components based on selected demographic factors indicates that similar limitations characterize the respondents, notwithstanding gender, location, education, and age group (Figure 5(a–d)). Although there is no gender-related disparity in the average scores of respondents across the sub-components (Figure 5(a)), there are differences between studied districts, especially based on the social opportunity and reflective motivation (Figure 5(b)). Further, the disparity gap is wider in the social opportunity and psychological capability relative to the educational level of the respondents, with farmers who had university education scoring over 10 times higher in both sub-components when compared to those who did not attend school (Figure 5(c)). The disaggregation by age (Figure 5(d)) showed that respondents all have high automatic motivation, but major differences are observable in their reflective motivation and social opportunity where the younger age ranges (e.g. 20–30-year olds) scored significantly higher (> 50%) than the older age ranges (e.g. > 70-year olds).

Zooming in on UR variables related to digital technology access, ownership, and digital competency

The use of ICT devices among surveyed farmers is prevalent, with approximately 80% of the respondents indicating that they have used at least one of the common devices (basic-, smartphones, radio, TV, laptop, tablet, or personal computer). Among the respondents, four out of every five farmers have used or owned basic phones and radios (67% and 71%

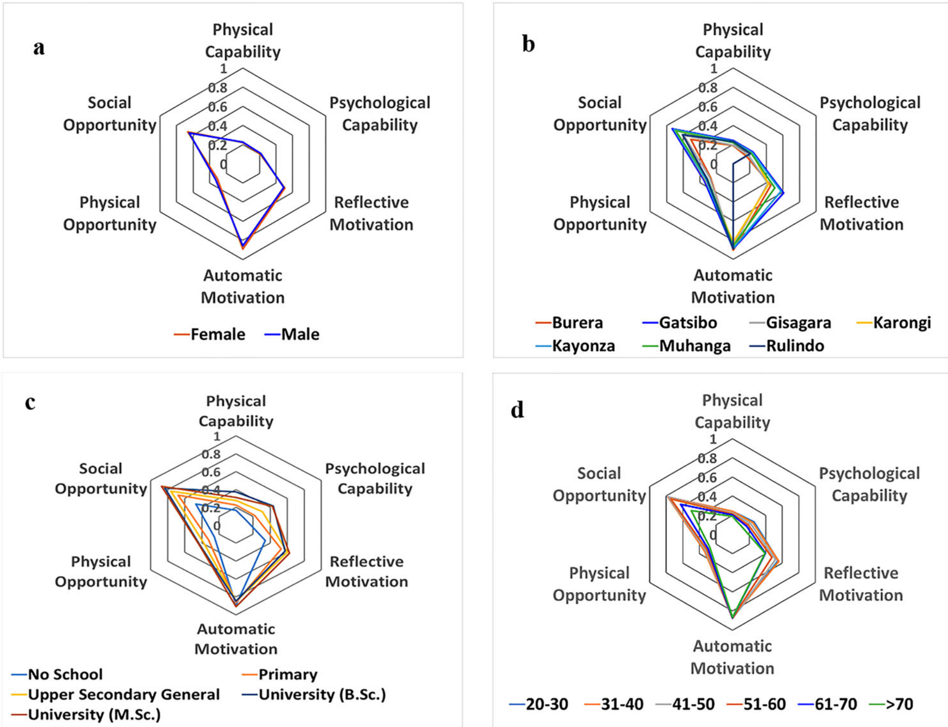
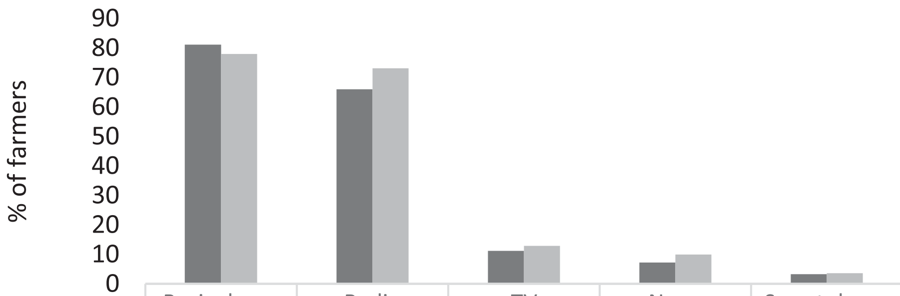


Figure 5. Average disaggregated scores for sub-components of Ex-ante User Readiness among banana farmers in Rwanda, based on gender (a), location (b), education level (c), and age group (d).

ownership for women and men respectively), very few (1 out of 10 farmers) have either used or owned a computer, smartphone, or feature phones. One out of 10 farmers also indicated that they neither own nor use any device: 12% of women and 13% of women do not own any ICT device (see also Figure 6). Further disaggregation of device ownership and use by gender and age indicated similarity between both male and female farmers for most devices, while younger farmers (< 45 years old) own and use ICT devices more than older (> 45years old) farmers. Thus, generally, the access and use of digital devices are limited to radio and basic phones, while about one out of five farmers indicated that they neither own nor use mobile phones. Although basic phone ownership and use among men is higher (78%) than among women (62%), both genders report similar (negligible) ownership of smartphones (3%). Similarly, 37% of the female respondents noted that they do not have access to any type of phone, in contrast to 21% among men. These results especially affect the opportunity and capability scores. The low uptake of smartphones obviously impacts UR score for smartphone-based extension.

Internet access and cellular services

Our survey data showed that the use of the internet and internet-based services among banana farmers is very low, with less than 10% of respondents indicating that they have ever accessed the internet (on their phones). This affects readiness for digital services requiring a data connection. Like phone ownership, a gender disparity exists with at



	Basicphone	Radio	TV	None	Smartphone
% Female	81	66	11	7	3
% Male	78	73	13	10	4

Device used

Figure 6. Digital devices that are regularly (at least once per 30 days) used by respondents. Total *n* of sample = 690.

least 8 out of every 10 internet users being men. Younger farmers have accessed the internet more than older ones, with 78% of respondents who have accessed internet on their phones being 50 years or younger. Almost 50% of the surveyed farmers who can access a mobile phone use it to call or use SMS at least once a day, however this is more common among the younger farmers with a steady decline of usage among farmers who are older than 40 years (Figure 7). A substantial number of, especially older, farmers rarely or never make calls.

Based on the above results it appears that various demographic characteristics are linked to UR, suggesting that beyond addressing male-female gaps focus should be on

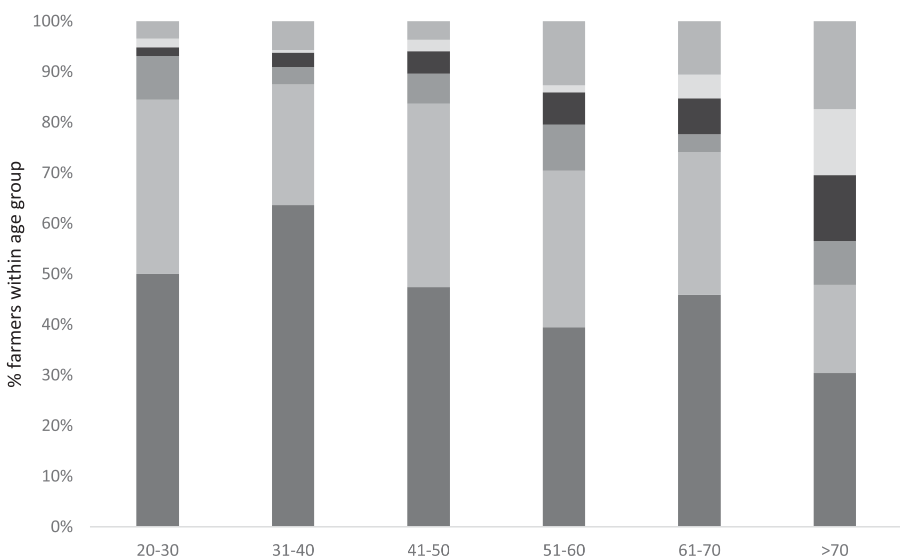


Figure 7. Phone usage for calls among surveyed banana farmers in Rwanda with access to a phone (*n* = 619).

developing farmer-focused interventions that facilitate equitable access to (basic) digital tools and extension services for diverse farmers. For example, the most observable gender-related difference in UR-index (34% in females and 39% in males) is associated with respondents aged 70 years and above. This finding can also be linked to the overall decline in UR with age. Results suggest that without additional capacity development equitable use and scaling of digital extension services, like the app developed by the ICT4BXW project, may only be achieved for a sub-group of farmers (in this case younger (male) users, mainly in the age range of 20–40 years).

Discussion

The aim of this study was to explore how ex-ante assessment of UR and use context can contribute useful insights that provide input for the development of digital extension services. We presented the UR framework as an approach to assess the current capacity of African farmers to adopt and use digital extension technologies and tools. Applying the framework for the case of smallholder banana farmers in Rwanda, we looked at the current capabilities, opportunities, and motivations of farmers. This study unravels important elements that impact readiness to adopt and use phone-based extension services, as more and more digital agricultural services are being developed and offered to African smallholder farmers.

User readiness in view of the digital extension services that are developed: matches and mismatches

The overall UR-index calculation provides a basis to understand and compare the readiness of each farmer as a potential user of digital tools/technologies for farm-level decision support. Most of the surveyed farmers scored low on the UR-index (modal score = 40 −58%), indicating moderate levels of readiness of the target farmers as users of digital extension services like the one developed by the ICT4BXW project for diagnostics and surveillance of BXW disease and advisory about control measures. The exploration of sub-components associated with capacity, opportunity, and motivation of the farmers provides an enriching understanding of nuanced aspects of UR and adoption. For instance, at least four out of every five respondents scored > 80% in their 'automatic motivation', yet, less than two out of every five scored above 50% in their individual readiness score. It was noteworthy that other sub-components (mainly those associated with opportunity and capability) had a draw-down effect on the overall readiness scores, notwithstanding the demographic of the users. The limited readiness of farmers suggests that large-scale adoption of digital extension services may not be easily achieved, particularly services that utilize advanced technologies such as smartphones. Assessing the UR offers valuable information that can guide realistic expectations regarding the likelihood of adoption and ease of scaling among target users of a phone-based extension service.

Considering the results from this study and the type of digital extension services that are currently being developed, there is a strong basis to conclude that there is a major mismatch between the readiness of technology and the readiness of the users. Early-stage service providers often adopt low-tech tools that require functionalities on basic mobile phones, such as Short Message Service (SMS) and Unstructured Supplementary

Service Data (USSD) e.g. ESOKO, M-Farm (Baumüller 2018). Our study supports the notion that these services match the current reality and readiness of farmers in Rwanda. However, advanced digital technologies like smartphones or internet, which are considered relatively mainstream in high-income countries and by African urban elite, remain out of reach of the majority living in rural areas in Rwanda and other developing countries (Deichmann, Goyal, and Mishra 2016; Mehrabi et al. 2021; Munthali 2021). Yet, digital extension services are becoming increasingly sophisticated, including BXW-App and PlantVillage NURU (Mrisho et al. 2020), requiring phone functionalities and processing power that are only available and accessible on 'smart' devices. Our findings suggest that this outpaces the current readiness of the users, especially relative to the opportunity and capability sub-components, and points to a growing mismatch between the emerging digital technologies/services and the field level reality of the target users. The type of mismatch observed in Rwanda may be the result of ambitious expectations of designers, technology developers, and (project) implementing parties, combined with initial terseness of data regarding the contextual realities of the farmers. However, it appears that users who are young and educated are more promising as potential early adopters of digital tools, based on their high scores on sub-components such as social opportunity and reflective motivation. Therefore, this cluster of users can be targeted as an entry point for introducing new/advanced digital tools for adoption to accelerate development and improve livelihoods.

Further, donors continue to pursue the aspiration to introduce ever more sophisticated technologies to smallholder farming systems, e.g. Unmanned Aerial Vehicles, Artificial Intelligence (AI) and blockchain. Arguably, the introduction of digital technologies that are too complex and too difficult to access, given the capacity of targeted users, is reflective of the hyped and competitive digital agriculture field and the continuing technocentric focus in digital agriculture, and this may lead to 'misconfigured innovations' (Bronson 2019; Klerkx and Rose 2020; Fraser 2021). This is problematic because the acceptance of new technologies is generally tied to both people's willingness and capacity to adopt (Baumüller 2018; Minh et al. 2014; Swanson 2008). In the context of agricultural interventions in developing countries, the failure of an introduced technology due to non- or de-adoption is regularly blamed on the mindset of farmers (Murray 2000). However, our research indicates that besides mindset, or willingness (which relate to automatic and reflexive motivations), there is a range of other dimensions that may erode people's capacity to accept a new digital technology. The method we applied brings those dimensions to light and allows for a more holistic and systematic reflection on the process of technology acceptance (or rejection). Our findings align with previous research, which argues that human development (i.e. enhancing people's economic, informational, or social capabilities) rather than the ICT technology itself should be the central focus when designing and evaluating digital programmes (Gigler 2011).

The mixed bag reality of digital device ownership and use

Generally, digital device ownership or access is considered indispensable for delivery of digital content and advisory services to farmers, and this is often used as the sole benchmark for assessing digital connectivity (and divides) along rural–urban gradients, age classes, gender-classification, or socio-economic status (Trendov, Varas, and Zeng

2019; Agyekumhene et al. 2020). Our case study results, however, show a strong contrast between near-universal access of farmers to some digital devices (radio and basic phone) on the one hand, and very poor access to other devices (such as laptops, smartphones, tablets, etc.) on the other hand. For example, 75% of our respondents reported possession of a mobile phone, but only 3% own a smartphone. This not only indicates sub-optimal physical opportunities for users but also that sheer penetration of mobile phones may not simply be construed as a sign of readiness for adoption of all phone-based extension services among farmers. This finding is important given that phone-based extension services targeting African farmers are increasingly deployed on smartphones (Tsan et al. 2019), with the nascent expectation of existing or rapidly emerging universal access and capability to use them. Even though farmers' possession of smartphones will almost inevitably increase, this does not guarantee the overall improvement of UR towards optimal readiness. A relatively equitable possession of some digital devices (e.g. radio and basic or smart phones) could deceivably suggest that farmers are also well-positioned to adopt digital extension services. Although ownership of a device increases physical opportunity and psychological capability, it may not enhance the other opportunity, capability, and motivation factors. These together determine a user's overall capacity, and capacity, in turn, has been shown to affect adoption (Ayim et al. 2020; Kyobe 2011). Thus, capacity is the sum of many factors. Some (powerful) actors in the agricultural value chain may want to protect or increase their own informational or (economic) advantages (Ayre et al. 2019; Jakku et al. 2019), possibly by obstructing the opportunities, capabilities, and motivations of others. Additional concerns for the adoption of existing or emerging digital extension services arise from the gender digital divide that we found for phone ownership and the inequal UR for different user groups. This shows similarity to other studies which identified farmers' education to be influential for adoption and use of digital technologies (Salemink, Strijker, and Bosworth 2017), age and education as determinants of smartphone adoption among German farmers (Michels et al. 2020) and age and smartphone experience as moderating factors of the performance expectancy by potential users of digital health applications (Nunes, Limpo, and Castro 2019). Based on these findings, we argue that developers of digital interventions and services aiming to be inclusive should be especially considerate of user groups with the lowest UR. Within the scope of this article, we explored variations in UR of four only four variables representing different user groups (education level, age group, gender, and geographic location), there are numerous other variables that could be considered in follow-up research (e.g. income group, type of crop production system, farm size). Similarly, a closer analysis of sub-component scores could be relevant to identify which (combinations of) sub-components drive the readiness index score.

Lastly, the use of radio as a means of receiving one-way communication from trusted media outlets is common among farmers still to date. Previous studies similarly found radios to be important for information provision in rural communities (Sulaiman et al. 2012; Zanello 2012), suggesting that radio should not yet be disregarded for rapid information dissemination about agricultural challenges like BXW disease. Embedding digital technologies into existing practices and creating blends of 'digital' and 'analogue' (Burton and Riley 2018; Munthali et al. 2021) or 'high-tech' and 'low-tech' (Klerkx and Rose 2020) may be recommended especially when digital divides are a reality. A mix of new and existing practices and skills would currently respond better to the needs and capacity of a larger group of users, thus improving the potential scale and impact of agricultural extension. This way, farmers who cannot (yet) access mobile phones or have low UR are given an opportunity to catch up and potentially leapfrog to a more technologically advanced level (Alzouma 2005). This would reduce the chance that digitalization exacerbates rather than reduces inequality in agricultural development, as a risk noted by Cibangu (2019) and Trendov, Varas, and Zeng (2019).

Benefits and methodological reflections arising from the UR framework

The UR framework helped to understand the major perceptions and realities of targeted users in the case study geography and highlight relevant differences related to gender and age gradients among the respondents. Beyond providing an understanding of UR, the UR-index and individual (sub)-components provide diagnostic insights about an individual or collective readiness and can support the identification of appropriate interventions to improve UR. In alignment with Benson (2019), this UR framework presents an ex-ante analytical approach to assess UR based on existing practices. Therefore, the framework may assist developers of digital extension services at the early stages of identifying the targeted users that are ready to adopt and use an envisioned digital innovation, and those who require some form of help or alternative technology. Beyond helping with designing best-fit digital extension services, the framework supports apriori knowledge about potential adoption and outlook for scaling impacts. In this article, we applied the framework with interest in assessing UR for services that require smartphone functionalities, but we are confident that the framework is equally applicable in cases of digital technologies that are more or less advanced. The UR framework contributes an ex-ante, quantitative method to assess UR, makes a contribution to understanding the user side of digital development, and adds to an emerging body of literature that unravels what drives successful digital innovation in the agricultural sector from different angles (Birner, Daum, and Pray 2021; Fielke et al. 2021; Parra-López et al. 2021).

We recognize three methodological limitations or concerns related to the UR framework. Firstly, underlying deficiencies of one or more sub-component(s) may be masked once outcomes for sub-components are aggregated. For instance, a low(er) score on motivation may be compensated by a high(er) score on capability. Yet, the technology users (farmers) cannot attain optimal readiness to use the digital tool/technology without meeting the thresholds within each sub-component. This became evident in our case study results: Although the majority ($> 75\%$) of the respondents had a high social opportunity and automatic motivation score (> 0.75) the maximum total UR score attained did not exceed 60%. A high intrinsic motivation score may be a good indicator for acceptance of a digital technology but, in practice, the high score may be irrelevant if the same individual has a low psychological capability to use the technology. Motivation alone is not enough for successful adoption and use yet could stimulate users to increase their capabilities. Here we follow the logic proposed by Sartas et al. (2020), who argued that specific bottlenecks (i.e. lowest-scoring components) must be addressed before a user can be considered as ready to adopt a target innovation. Additionally, the lowest scoring components should inform necessary interventions to increase the likelihood of sustainable technology adoption.

A second methodological limitation relates to possible biases and interviewer effects. People may tend to overemphasize their needs, demands, and willingness to accept technologies when asked about this in a survey. This may relate to respondent's general curiosity about new objects and technologies (Ainembabazi and Mugisha 2014), and/or the expectation that giving a positive response will satisfy the interviewer or may lead to a higher likelihood of some in-kind or financial benefit for the interviewee. The latter is a known phenomenon in the context of rural interviewees who have a vested interest to gain from participating in a study (Triomphe et al. 2013). Inflated survey results for one or more (sub)-components may result in an inflated UR-index score, or vice versa if results are deflated, negatively affecting reliability. Also, the selection of variables was guided by the extant needs within the ICT4BXW project and those regularly highlighted as important drivers of adoption and capacity (Ali 2012; Michels, Bonke, and Musshoff 2019; Salemink, Strijker, and Bosworth 2017), so alternative information sources or variables (which could influence farmers' motivation) were not explored or included in the framework.

Lastly, although we looked at contextual realities and how they influence individual UR, a limitation of our study and the UR framework in its current form may be the dominant focus on individual or household level UR. This ignores that social interdependencies, social capital, and trust often play a critical role in a user's decision to accept a technology (Joffre et al. 2020; King et al. 2019), rendering adoption as a collective rather than an individual process (Leeuwis and Aarts 2020). Follow-up studies could explore how the influence of interaction and interdependencies between individuals and groups of individuals affects UR and interplays with technology and system readiness, to arrive at a balanced readiness level assessment (Vik et al. 2021).

Conclusion and recommendations

This study aimed to explore current UR of African farmers to adopt and use digital extension services, specifically the increasingly popular services that require smartphone functionalities. We presented the UR framework as an ex-ante method to early-on assess UR based on capabilities, opportunities, and motivations of targeted users. The UR framework was tested with a case study using data from 690 Rwandan banana farmers. Our case study findings demonstrate a mismatch between expected and realistic UR, especially regarding the current capabilities and opportunities of Rwandan farmers. Case study results confirm previous research that observed a need for both institutional innovation and building of local digital capacity. Findings show that ex-ante assessment of UR yields relevant entry-points for designing suitable digital extension projects and interventions, which may need to be less advanced than what is technologically possible.

We conclude that the UR framework can provide insights regarding the capacity and needs of technology users and the context in which a digital extension service will be used. The framework complements existing readiness frameworks and ex-post methods to analyse intervention success. In contrast with technology or scaling readiness, it takes the user and his or her context rather than the technology as a starting point. We believe that looking at technology, system, and UR and finding a sustainable balance between them is critical for digital agriculture to have a positive impact in the Global South. Insights from UR assessments can be translated to design requirements and be used as an input for user-centred design processes. Thus, the UR framework can support informed strategizing and decision-making about digital extension services as part of a balanced readiness level assessment. We recommend that developers adopt our ex-ante approach to explore UR before developing a new digital extension intervention for African smallholder farmers. Although this study only looked at current readiness, using data at one particular point in time, we recommend further research into the application of the UR-framework as a longitudinal assessment method that scientists and development practitioners can use to monitor the readiness of target users in relation to specific digital technologies over time.

Notes

1. We assume that missing/incomplete responses (i.e. n/a) imply the worst/negative value.
2. Note that Automatic Motivation has an inverted value of ‘0’ for True and ‘1’ for False because all of the variables are assessing ICT barrier.

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This paper is intended to disseminate research and practices about production and utilization of roots, tubers, and bananas and to encourage debate and exchange of ideas. The views expressed in the papers are those of the author(s) and do not necessarily reflect the official position of RTB, CGIAR, or the publishing institution.

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