Original Manuscript

Digital inequalities among smallholder farmers in Benin: Determinants of attitude, material access, skills and usage

Information Development
1–14

DOI: 10.1177/02666669241280411
journals.sagepub.com/home/idv
Sage

Morrisson Gouthon
Laboratory of Research on Innovation for Agricultural Development (LRIDA), Faculty of Agronomy, University of Parakou, Benin

Mori W. Gouroubera
Laboratory of Research on Innovation for Agricultural Development (LRIDA), Faculty of Agronomy, University of Parakou, Benin

Clarisse Tama-Imorou
Faculty of Letters, Arts and Human Sciences (FLASH), Department of Sociology, University of Parakou, Benin

Ismail Moumouni-Moussa
Laboratory of Research on Innovation for Agricultural Development (LRIDA), Faculty of Agronomy, University of Parakou, Benin

Abstract
Digital inequalities in the agricultural sector have become a prominent concern since the advent of digital technologies. To address these inequalities among farmers, it is essential to gain a comprehensive understanding of their nature and underlying determinants. Drawing upon Van Dijk's theory of resources and appropriation, this study was conducted in Benin, a West African country, involving a sample of 307 smallholder farmers. Structural equation models are used to analyze the data. Firstly, the results reveal that the attitude of farmers is positively associated with their material access to digital technology, which, in turn, fosters the development of their digital skills encompassing both formal and strategic skills. These skills propel the integration of digital technology into agricultural practices. Farmers' attitudes not only influence their access to digital tools but also significantly shape the development of their skill sets and the effective use of digital technologies in agriculture. Consequently, attitude emerges as an important factor in appropriating digital technology. Furthermore, this study identifies personal characteristics of farmers, including gender, age, income, level of education, and the presence of school-going children in their households, as factors influencing digital inequalities. Policies should foster positive attitudes, enhance digital skills, ensure equitable access, and address gender-specific barriers to reduce digital inequalities among smallholder farmers in agriculture.

Keywords
digital inequalities, digital divide, agriculture, determinants, Benin

Submitted: 25 January 2024; accepted: 19 August 2024

Introduction

The term "digital inequality" originated in the United States during the 1990s, primarily focusing on disparities in physical access to digital technology with the rise of laptop computers and the Internet (Lupač, 2018). Over time, its scope has expanded to

Corresponding author:
Morrisson Gouthon, Laboratoire de Recherche sur l'Innovation pour le Développement Agricole (LRIDA), University of Parakou, Parakou, Benin.
Email: morrissongouthon@gmail.com

encompass differences in motivation toward digital technology, physical and material access, digital skills, and usage (Durand et al., 2022). Digital inequalities are closely linked to disparities in access to resources, services, information, and the resulting digital benefits (Golder et al., 2010). According to Ramalingam and Hernandez (2016), these inequalities have excluded approximately 4 billion people worldwide from accessing opportunities, goods, and services facilitated by Information and Communication Technologies (ICTs), potentially giving rise to further inequalities within communities (Ozsoy and Muschert, 2020). In Africa, digital inequalities, particularly in internet access, have imposed economic constraints and marginalized a significant portion of the population (Robinson et al., 2015). Consequently, digital inequality has emerged as a pervasive issue across various sectors, including transportation (Durand et al., 2022), healthcare (Bol et al., 2018), communication (Nguyen et al., 2021), education (Jantjies, 2020; Torres-Diaz and Duart, 2015), and increasingly in agriculture with the advent of digital agriculture.

Undoubtedly, the integration of digital technology into agriculture, often referred to as digital agriculture, has induced a profound transformation that is rightly hailed as the fourth agricultural revolution (Rose and Chilvers, 2018). This revolution has not only increased the profitability of agricultural endeavors (Saiz-Rubio and Rovira-Más, 2020) but has also brought precision and efficiency to the allocation of essential inputs (Lezoche et al., 2020). Extensive research has underscored the crucial role of digital agriculture in enhancing productivity and environmental sustainability (Barrett and Rose, 2022). Particularly, Information and Communication Technologies (ICTs) have emerged as valuable tools, facilitating the sharing of crucial information and knowledge among farmers in developing nations and catalyzing positive economic growth (Senapathy, 2021). While the significance of digital technology in agriculture is well-established and supported by a wealth of scientific literature (Barrett and Rose, 2022; Eastwood et al., 2019; Shepherd et al., 2018), it prompts us to delve deeper into the issue of digital inequalities within this transformative landscape of agriculture.

While digital technology has the potential to revolutionize agricultural practices and offers a plethora of benefits, inequalities in access to these technologies persist among individuals (Büchi et al., 2018) and notably among smallholder farmers in rural areas—often the heart of agriculture—paradoxically bearing the brunt of these disparities (Park, 2017). Consequently, digitally underserved farmers find themselves deprived of the advantages that digital technology can bring to agriculture. This untapped potential in agriculture due to digital inequalities becomes particularly relevant in the context of rural areas in developing countries such as Benin, where these inequalities hinder not only agricultural progress but also overall sustainable development. Before addressing these digital inequalities, it is crucial to identify the underlying factors that cause them. As a result, several studies have undertaken this endeavor (Blank and Reisdorf, 2023; Chaqfeh et al., 2023; Chen and Li, 2022; Lissitsa et al., 2022). Some have focused on explaining digital inequalities through the lens of individuals' characteristics (Bol et al., 2018; Islam and Inan, 2021; Nguyen et al., 2020). However, these previous studies were often limited in scope and depth, leaving room for further investigation.

Little research has addressed digital inequalities in the agricultural sector, focusing on sectors where the impact of digital technology is less revolutionary, such as communication, education, and transport. Furthermore, existing studies on determinants predominantly focus on European, North American, or Australian contexts (Durand et al., 2022) with significantly different levels of digital adoption compared to developing countries. These limitations are recognized in several studies that call for examining digital inequalities in contexts where such differences are more pronounced, such as those observed in developing countries with a more heterogeneous population—personal characteristics (Van Deursen et al., 2021). Benin, like many other developing countries, faces a digital divide despite the government's efforts through a digital agriculture strategy for the period 2020 to 2024.

In this paper, we investigate digital inequalities in Benin among smallholder farmers. First, we analyze digital inequalities through its four stages – attitudes, material access, skills, and usage according to the resources and appropriation theory (Van Dijk, 2005). Then, we determine how important smallholder farmers' socioeconomic conditions and personal characteristics are associated with the four digital inequalities stages.

Theoretical background and hypotheses

To highlight digital inequalities between farmers, we draw upon Van Dijk's (2005) theory of resources and appropriation, which not only elucidates the individual process of digital appropriation but also explains how one's profile contributes to digital inequalities. This theory posits that the personal and positional characteristics of individuals lead to disparities in resource allocation, thereby creating digital inequalities (Figure 1). The theory of resources and appropriation defines digital appropriation as a sequential process involving four primary constructs: attitude (motivation), material access, digital skills, and digital use. This process begins with an individual's attitude, specifically, their digital motivation, which reflects the attitude and reasons underlying their use or non-use of the Internet (Van Deursen et al., 2017). Digital motivation catalyzes this process. Consequently, even if digital technologies are readily accessible, individuals will not adopt them without demonstrating digital motivation. In this context, Van Dijk (2013) posits that most of those lacking digital tools lack motivation. Conversely, individuals who possess digital tools have typically cultivated a motivation for digital technology. Soomro et al. (2020) differentiate between two types of motivation: endogenous motivation, reflecting an individual's intrinsic desire to use ICTs, and exogenous motivation, in which ICT adoption is influenced by external factors. In either case, an individual's motivation plays a pivotal role in determining their material access to digital technology

Material access is the second level of the digital appropriation process. Material access implies physical access (if necessary) or ownership of a digital tool/service (Van Deursen et al., 2021). An individual can therefore materially access a digital tool without owning it. In developed countries, material access inequalities to digital technology have often decreased, whereas the opposite trend is observed in developing countries. Income, along with other personal characteristics, remains a significant factor influencing material access to digital technology. Once individuals have material access to digital technology, the next essential step is acquiring digital skills for effective utilization of the tool, often referred to as "internet skills," "e-skills," or "digital literacy" (Scheerder et al., 2017). These digital skills encompass various categories. Van Deursen and Van Dijk (2014) differentiate between operational, formal, informational, and strategic skills. Operational skills are foundational, serving basic digital functions, while formal skills enable individuals to explore the Internet more comprehensively. Informational skills empower individuals to search, select, and evaluate information effectively, and strategic skills facilitate the use of the Internet for significant goals and strategic decision-making. Additionally, communication skills are essential for individual engagement and interaction on the Internet. According to this theory, digital skills are directly associated with material access; however, we believe that individual attitude is also a determining factor.

Finally, digital technology usage represents the culminating stage in Van Dijk's appropriation process. In this context, usage denotes the effective and proficient application of digital technology (Habibi et al., 2020). Van Dijk (2017) suggests that the extent of this digital technology use can be quantified by usage duration, frequency, and the diversity of applications engaged. According to Van Deursen et al. (2021), increased usage of digital tools corresponds to amplified benefits, underscoring the significance of this final phase. However, it is crucial to emphasize that digital usage is intricately linked to an individual's attitudes, material access, and digital skills. In this regard, Zhang et al. (2020), in their examination of mobile applications, found that individuals with limited material access and digital skills, tend to use these applications less frequently. In this paper, digital inequalities are analyzed through the lens of these four levels of digital appropriation (attitude, material access, skills, and usage). Similarly, Van Deursen et al. (2021) analyzed digital inequalities focusing on these elements as digital inequalities indicators between individuals. Their work effectively confirms Van Dijk's theory of resources and appropriation. In other words, motivation determines material access to digital technologies which in turn influences the individual's digital skills. Inequalities in access therefore logically lead to inequalities in digital skills (Chen and Li, 2022). Likewise, the use of digital technology is determined by these skills. There are therefore inequalities between individuals in motivation, access, skills, and use of digital technology (Helsper, 2020). Many factors are associated with these inequalities.

Generally, the personal, economic, and social resources of individuals are associated with digital inequalities between them. Those with fewer resources have a poor perception of the benefits of digital technology lowering their motivation, access, and digital skills (Heponiemi et al., 2023). These personal factors include race, gender, and class (Robinson et al., 2015). Age, income, and education are also determining factors (Reisdorf and Groselj, 2017). Furthermore, we consider the presence of children in the household as a plausible determinant regarding the context. Indeed,

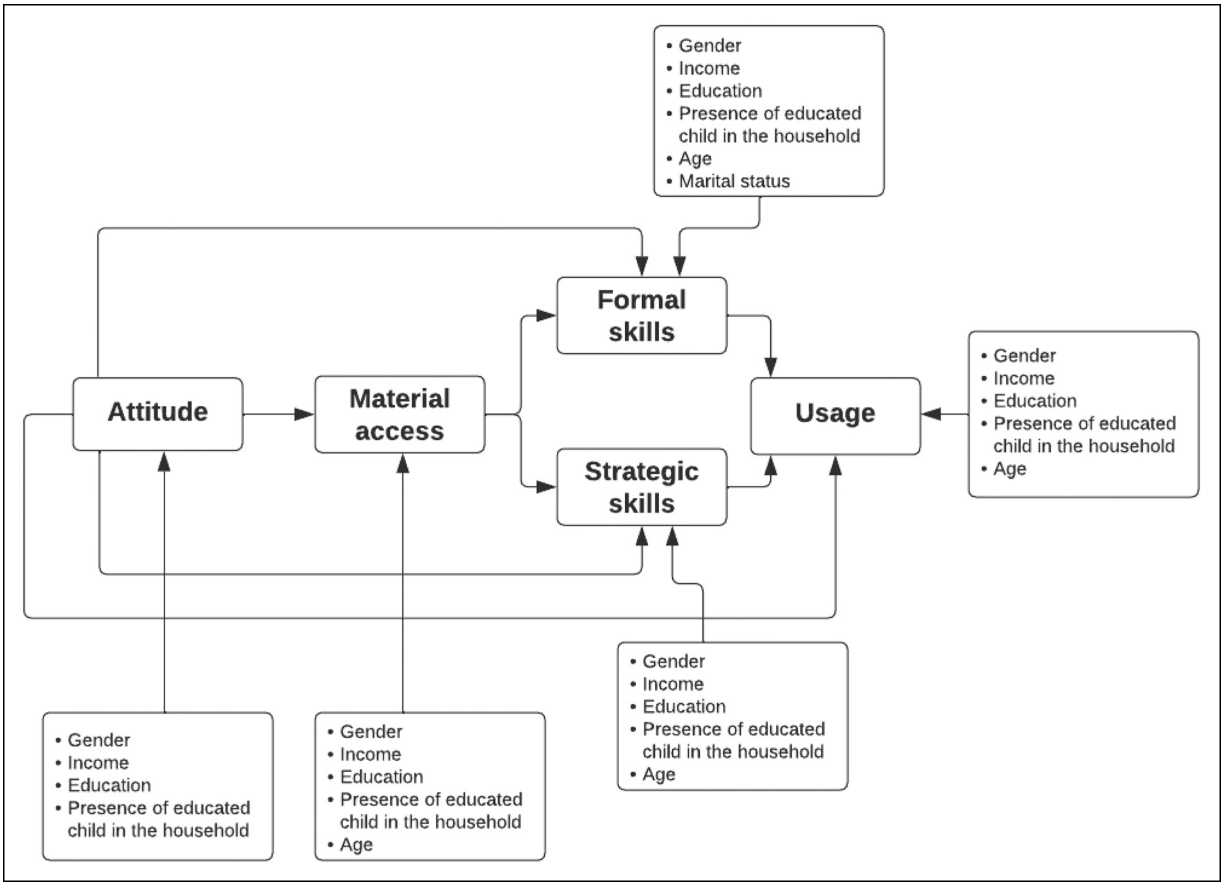

Figure 1. Analytical framework and hypothesis.

digital inequalities are more pronounced among adults (Francis et al., 2019). The youngest therefore use digital technology, as do the most educated (Bol et al., 2018). Also, persons with low income are more reluctant (Barzilai-Nahon, 2006) and those with higher income are more likely to use the Internet (Van Der Zeeuw et al., 2019). Similarly, less educated people have less Internet access (Van Dijk, 2005), less digitally competent (Scheerder et al., 2017) and less use (Blank and Groselj, 2014). Also, several studies have shown a positive relationship between social status commitment, and motivation to go digital. In other words, the less social status individuals have the less interest they find in engaging with digital technology (Büchi et al., 2018). In this study, we build up the analytical framework (Figure 1) and hypotheses based on the literature above. The hypotheses formulated are as follows:

Digital attitude

- $H_{1\text{-}1}$: (a) Gender, (b) income, (c) level of education, (d) presence/absence of an educated child in the farmers' household determine their attitude towards digital technologies.

Material access

- $H_{2\text{-}1}$: Farmers' attitude towards digital technology is positively correlated with their material access to digital tools
- $H_{2\text{-}2}$: (a) Gender, (b) income, (c) level of education, (d) presence/absence of an educated child in the household, and (e) age determine the farmers' physical access to digital services.

Digital skills

- $H_{3\text{-}1}$: Attitude is positively associated with farmers' digital skills (Formal and strategic)
- $H_{3\text{-}2}$: Material access is positively associated with farmers' digital skills (Formal and strategic)
- $H_{3\text{-}3}$: (a) Gender, (b) income, (c) level of education, (d) presence/absence of an educated child in

the household, and (e) age determine the formal digital skills of farmers.

- $H_{3\text{-}4}$: (a) Gender, (b) income, (c) level of education, (d) presence/absence of an educated child in the household, (e) age and (f) marital status determine farmers' strategic digital skills.

Digital usage

- $H_{4\text{-}1}$: Attitude is positively associated with digital use
- $H_{4\text{-}2}$: Digital skills are positively associated with the use of digital technology
- $H_{4\text{-}3}$: (a) Gender, (b) income, (c) level of education, (d) presence/absence of an educated child in the household, and (e) age determine the digital use by farmers.

Materials and methods

Sample

The study was carried out in Benin, a West African country, where agricultural production is greater in the northern zone. The country is subdivided into seven development poles. Poles 3 and 4 are those of crop diversification in North Benin. Thus, to guarantee the heterogeneity of the sample, farmers belonging to these development centers were the targets of our study. The communes of Natitingou and N'Dali belong to poles 3 and 4 respectively. They are therefore considered areas of agricultural diversification, thus justifying the choice made on them. In collaboration with state agricultural agents who have been working in these districts for several years, five (05) villages per district were identified as those representing the agricultural realities of each development pole considered. From a list of farmers, 307 were randomly selected in the ten (10) villages covered by the study, including the villages of Wèrèkè, Kakara, Gomez-kparou, Bouyérou and Yèroumarou in N'Dali district, as well as Bongou, Doyakou, Kotopounga, Pouya and Tigninti in the municipality of Natitingou. Approximately thirty farmers were selected from each village. Of the total number of farmers selected, 21.50% (n = 66) are women, and 78.50% (n = 241) are men. Also, among farmers selected for this sample, 51.14% (n = 157) belong to pole 4 and 48.86% (n = 150) are in pole 3. Table 1 specifies the sample for this research.

Data collection

In this study, we collected two distinct sets of data: one focused on the personal characteristics of farmers and the other centered on various dimensions of digital inequalities. The acquisition of information regarding personal characteristics was facilitated through a structured questionnaire administered via face-to-face interviews. The questionnaire delved into several crucial aspects, including gender (categorized as "male" or "female"), age, education (classified into four: "None" for illiterate, "primary," "secondary," and "university"), marital status (categorized as "Single," "married," "divorced," or "widowed"), annual income class divided into "low income" (<336 dollars), "medium income" (336–672 dollars), and "high income" (>672 dollars). The integration of these aspects into the questionnaire, is inspired by the work of Van Deursen et al. (2021) and has been adapted to the context of this study. The questionnaire also includes a section on whether there is an an educated child in the household which is answered with a simple "yes" or "no". These comprehensive personal characteristics data were systematically collected to enable a nuanced analysis of the determinants of digital inequalities among smallholder farmers.

The second category of data pertains to the assessment of various dimensions of digital inequality among farmers, involving their attitudes toward digital technology, material access, digital skills, and the utilization of digital technology in agriculture. Data concerning attitude and digital skills (both formal and strategic) were collected quantitatively using 7-level Likert scales, ranging from 1 (indicating the lowest level) to 7 (indicating the highest level). Table 2 provides an overview of the scales employed to measure attitude (mean = 5.12; standard deviation = 1.43; Cronbach's alpha = 0.91), formal skills (mean = 2.36; standard deviation = 1.44; Cronbach's alpha = 0.82), and strategic skills (mean = 2.37; standard deviation = 1.41; Cronbach's alpha = 0.85). We adapted the attitude Likert scale from the works of Durndell and Haag (2002) and Van Deursen et al. (2021), and the digital skills from Van Deursen and Van Dijk (2014), de Boer et al. (2019), and Van Deursen et al. (2021). We have distinguished digital skills to provide more precision to our analyses and results. Formal skills are linked to the use of the Internet, which is the very essence of digital technology. In some literature, authors relate to the "Internet of Things" to allude to digital technology (Li et al., 2015; Rose et al., 2015). Strategic skills are closely tied to the benefits of digital tools, as they enable individuals to maximize these advantages. Therefore, both formal and strategic

Table 1. Study sample.

Agricultural development pole	Districts	Villages	Number		Total
			Women	Men	
Borgou Sud- Donga- Collines (pole 4)	N'Dali	Wèrèkè	07	26	33
		Kakara	09	21	30
		Gomez-kparou	10	20	30
		Bouyérou	09	25	34
		Yèroumarou	07	23	30
Atacora Ouest (pole 3)	Natitingou	Bongou	00	30	30
		Doyakou	02	28	30
		Kotopounga	05	25	30
		Pouya	13	17	30
		Tigninti	04	26	30
Total		10	66	241	307

Table 2. Items measuring attitude and digital skills.

	Items	M	SD
Attitude	*Using digital devices/services …*		
	makes life less social (R)	5.35	2.00
	makes people servants of technology (R)	4.61	2.24
	will control our lives (R)	4.52	2.25
	dehumanizes society (R)	5.26	2.05
	makes me uncomfortable because I don't understand it (R)	5.32	1.97
	makes it difficult to protect my privacy (R)	4.81	2.14
	makes life easier and faster	6.02	1.11
	is the source of many good things that we benefit	6.15	1.06
	intimidates me (R)	5.66	1.70
	is the origin of the loss of our traditional values (R)	4.35	2.31
	is a new form of domination (R)	4.26	2.20
Formal skills	I know browsing websites	1.71	1.62
	I can search websites	1.66	1.56
	I have trouble finding browsing websites (R)	4.81	2.58
	I feel confident handling my device	3.71	1.89
	I can create chat groups with my device	1.76	1.63
Strategic skills	I can make decisions based on the information I find on the net	1.90	1.60
	I make money from the information found on my device	2.47	1.85
	The information found on my device allows me to achieve my professional goals	2.45	1.75
	My income will drop if I no longer use my device	2.68	1.94

R = Reversed.

skills are crucial in the digital realm. This strong connection highlights the importance of focusing on these skills to enhance the effective use of digital technologies. Material access, particularly to smart digital tools, was evaluated by presenting farmers with a checklist of common digital devices and inquiring about their ownership or their ability to utilize these tools when needed. For each digital tool listed, the farmer indicated whether they had physical access to it or not. Additionally, the agricultural utilization of digital technology was assessed by presenting farmers with a range of potential uses. In Benin, digital technology in agriculture is essentially devoted to e-extension (ACED, 2023; Tossou et al., 2020), the usage options presented to the farmer are linked to the search for information and agricultural knowledge on (i) parasitic attacks, (ii) production best prices, (iii) fertilization, (iv) conservation, and (v) other agricultural information. A farmer was deemed to employ digital technology for agricultural purposes if they indicated at least one of the presented digital uses as part of their practices.

Data analysis

To test the hypotheses, we conducted a comprehensive evaluation by employing a structural equation model using R software version 4.4.1. This analysis generated several indices to assess the model's robustness, including $\chi 2$, the $\chi 2$/df ratio (with df representing degrees of freedom), the Tucker-Lewis Index (TLI) ((>0.90), the Comparative Fit Index (CFI) (≥ 0.95), the Goodness-of-Fit Index (GFI) (>0.90), the Standardized Root Mean Residual (SRMR) (less than or equal to 0.08), and the Root Mean Square Error of Approximation (RMSEA) (≤ 0.08). Furthermore, the p-values associated with the standardized β coefficients for each explanatory variable were analyzed to determine their significance levels, considering thresholds of 1%, 5%, and 10%. Before conducting these analyses, we evaluated the reliability of the items used to measure attitude and digital skills among farmers, ensuring a Cronbach's alpha coefficient α of at least 0.70. Additionally, descriptive statistics, including frequencies and means, were employed to characterize the interviewed farmers and provide insights into the proportions of farmers with access to specific digital tools and engaged in various agricultural uses.

Table 3. Profile of farmers.

Variables	Frequency (%)
Gender	
Male	78.50 (241)
Female	21.50 (66)
Age	
17–35	45.28 (139)
36–50	35.83 (110)
51–70	18.89 (58)
Education	
None	50.80 (156)
Primary	24.40 (75)
Secondary	20.50 (63)
University	04.20 (13)
Marital status	
Single	10.40 (32)
Married	87.60 (269)
Divorced	00.70 (02)
Widow	01.30 (04)
Income	
Low (<336 dollars)	43.00 (132)
Middle (336–672 dollars)	27.70 (85)
High (>672 dollars)	29.30 (90)
Group membership	
Yes	34.20 (105)
No	65.80 (202)
Presence of a schoolchild in the household	
Yes	68.10 (209)
No	31.90 (98)

Results

Personal characteristics of farmers

Table 3 reveals that most farmers (78.50%) in the study area are men, aligning with the predominant role of men in agriculture in Benin, while women are more involved in processing and marketing agricultural products. Notably, a significant proportion of these farmers (50.80%) lack formal education. Indeed, in rural areas in developing countries like Benin, formal education is still a concern. Among those educated, however, 24.40% have completed primary education, 20.50% have finished secondary education, and 4.20% have a university-level education. The majority of these farmers (87.60%) are married. In these areas, marriage is of great socio-cultural importance, explaining this high rate of married farmers. Income levels vary among these farmers, with 43% earning a low annual income, 27.70% falling into the average income, and 29.30% having higher incomes. In other words, few farmers have high incomes. In this country, family farming and smallholder farmers are dominant, explaining the low proportion of farmers with high incomes. Furthermore, a notable minority (34.20%) belong to farmer groups, while the majority (65.80%) do not. Lastly, 68.10% of the interviewed farmers have school-going children in their households, indicating a growing awareness and increasing desire among rural communities to provide education for their children. National education policy initiatives, programs, and projects financed by foreign Technical and Financial Partners partly explain this awareness.

Measurement model

The α coefficients, which assess the reliability of the items, all exceed the 0.7 thresholds, indicating satisfactory reliability for attitude ($M = 5.12$; $SD = 1.43$; $\alpha = 0.91$), formal skills ($M = 2.36$; $SD = 1.44$; $\alpha = 0.82$), and strategic skills ($M = 2.37$; $SD = 1.41$; $\alpha = 0.85$). Also, the indices associated with the structural equation model demonstrate robustness: $\chi2 = 28.10$; $\chi2/df = 1.87$; $SRMR = 0.017$; $RMSEA = 0.053$; $CFI = 0.98$; $GFI = 0.99$; $TLI = 0.91$.

These findings indicate that farmers are quite motivated to use digital technologies but have weak formal and strategic skills. The findings also revealed that 32.20% of farmers had material access to smart digital tools while 67.80% did not have such access. The mobile phone is the digital tool to which these farmers have more access. Regarding usage, 24.80% of farmers use digital technology for agricultural purposes compared to 75.20%. This essentially involves the use of mobile phones to obtain agricultural information and knowledge. Of the farmers who engage in this e-agriculture, 16.90% use digital technology to obtain information/knowledge on parasitic attacks, 20.50% on production best practices; 16.60% on fertilization, 12.40% for conservation, and 11.10% for other agricultural information.

Structural model

The structural equation model illustrates the relationships between the different levels of digital appropriation (attitude, material access, skills, and usage) among farmers. This model also identified farmers' personal characteristics (gender, income, education, the presence of school-going children in the household, age, and marital status) directly associated with digital inequalities between them. Figure 2 summarizes these results.

The results (Figure 2) indicate that farmers' attitudes toward digital technology, positively influence their access to smart digital tools. Farmers who are more motivated to use digital technologies tend to have greater material access. These motivated farmers perceive digital tools as more useful. To leverage the perceived usefulness of these technologies, motivated farmers exert more effort to access them, explaining the positive association between their attitudes and material access. Additionally, the results indicate that farmers' material access to digital technologies positively influences their digital skills, both formal and strategic. Farmers with greater access tend to develop stronger digital skills, as this access fosters a motivation to utilize digital technologies, leading them to engage in self-learning or seek assistance from others. Consequently, increased access enables these farmers to enhance their proficiency in using these technologies, resulting in superior digital skills compared to those with limited material access. In this relationship, the stronger digital skills of motivated farmers reflect their higher levels of material access, which in turn provides them with the psychological and technical conditions necessary to effectively utilize digital technologies. This dynamic logically establishes a positive relationship between farmers' digital skills and their usage of these technologies, suggesting that enhancing access to digital resources can significantly improve both the motivation and capabilities of farmers in leveraging digital tools for agricultural innovation. In essence, greater motivation among farmers to embrace digital technology leads to improved access to such technology, subsequently enhancing their digital skills (formal and strategic) and increasing their usage of digital tools in agriculture. Notably, this study further unveils a direct and positive association between farmers' attitudes and both their digital skills and usage of digital tools in agriculture. The more motivated farmers are, the more competent they become, which directly correlates with their increased use of digital technology. This motivation, even before they gain material access to the desired digital tools, drives some farmers to learn by observing others who are already using these technologies. For instance, one young farmer shared that he learned to navigate the internet simply by watching his friend do it before he owned his smartphone. Additionally, as farmers recognize the recent benefits of digital technology, their motivation to engage with these tools increases. However, this heightened motivation does not necessarily translate into improved access to other technologies or skills; instead, it diversifies how they utilize the digital technologies they already have. Thus, in the process of appropriating digital technology, or in instances of sporadic engagement, the attitude of farmers emerges as a crucial factor influencing their learning and adaptation. This underscores the importance of fostering a positive attitude toward digital tools, as it can lead to increased competence and usage, even in the absence of comprehensive material access.

Figure 2, in addition to illustrating the relationships between attitude, material access, skills, and usage, also highlights the characteristics of farmers—such as gender, income, education, presence of schoolchildren in the household, age, and marital status—that directly influence these constructs. These characteristics play a critical role in shaping farmers' attitudes toward technology adoption, their access to resources, and their overall skill development. It reveals that gender significantly influences material access to

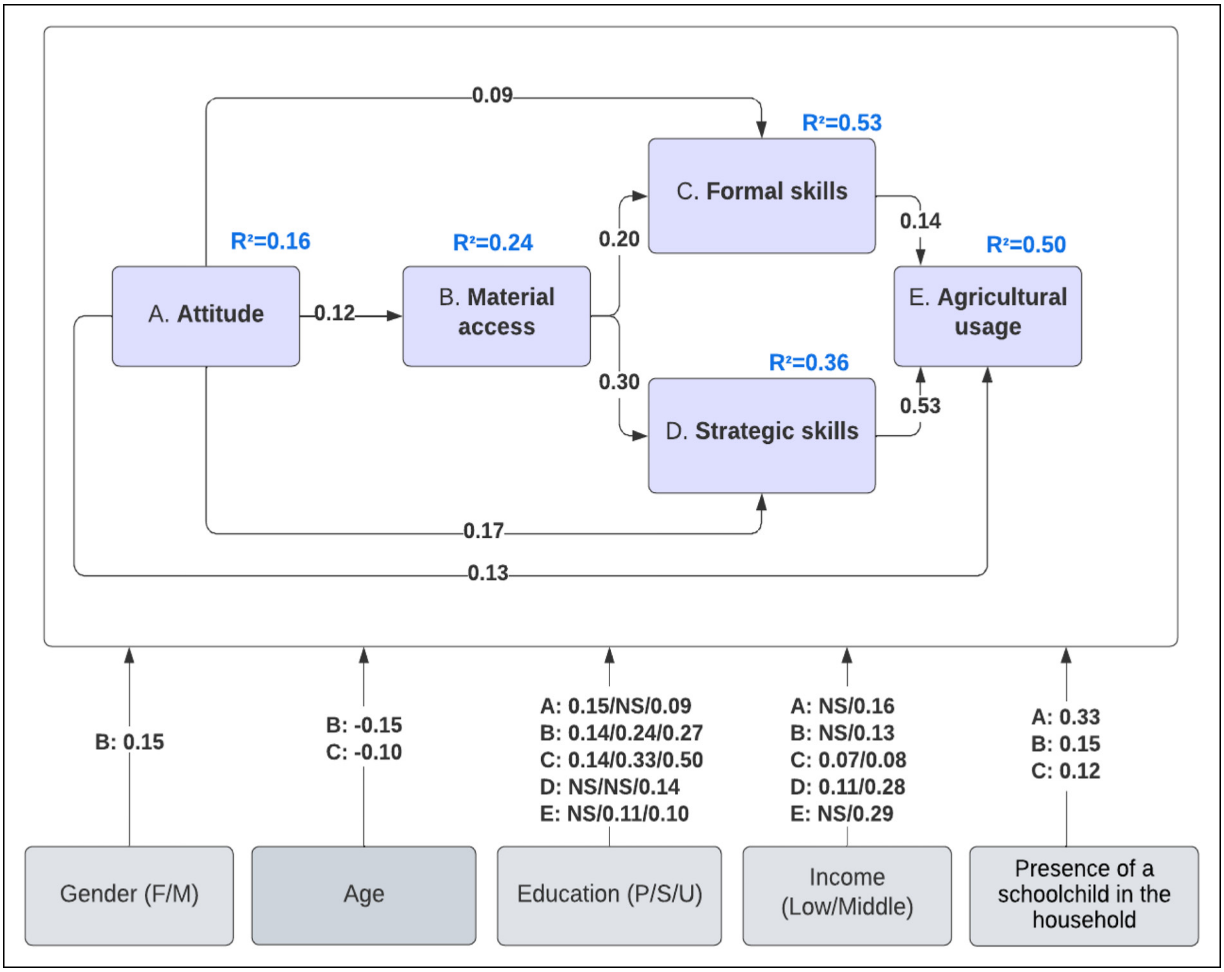

Figure 2. Structural equation model of the determinants of digital inequalities. F: Female; M: Male; NS: Not Significative; P: Primary; S: Secondary; U: University.

digital tools, with male farmers having greater access than female farmers. Women have less material access than men. In rural areas of Benin, women's decision-making power, purchasing power, and autonomy are relatively limited. Female farmers often live under the supervision of men, who typically precede them in taking initiative. Consequently, accessing digital tools may require the approval or intervention of men. This, combined with women's lower purchasing power, likely explains their relatively low material access to digital technology compared to men. The findings also reveal that farmers' education levels and income directly influence their attitudes toward digital technology, their access to intelligent digital tools, their digital skills and their usage of digital technology for agricultural purposes. Indeed, higher levels of education and income are positively associated with farmers' motivation to utilize digital technology, access to digital tools, digital skills, and usage of digital tools in agriculture. The better-educated farmers are, the more motivated they become, and the greater their access to, skills in, and usage of digital technologies. The same applies to farmers with higher incomes. Education empowers farmers with more knowledge about digital technology and its advantages. So, the more farmers are educated, the more they know these advantages. This leads them to be less reluctant and therefore more motivated to use it, access it, develop the required skills, and use digital tools and services. Furthermore, the presence of school-going children in the household positively influences farmers' attitudes, access, and formal digital skills, indicating that farmers with educated children are more inclined to adopt digital technology and possess better access to digital tools and formal skills. Indeed, awareness of digital incapacity is an inhibiting factor in digital appropriation. Thus, these farmers are aware of this limitation, and they perceive their school children as possibilities of assistance, which breaks the demotivation factor with the consequences, a positive attitude, and material access. These children help them to explore the internet, which improves their formal skills. Additionally, age negatively impacts material access to smart digital tools and formal digital skills, suggesting that older farmers tend to have limited access to smart tools and formal digital skills. Digital technology has become increasingly prevalent, especially in recent years. Consequently, recent generations have intrinsically experienced this digital revolution more. As a result, younger farmers are more familiar with the internet, granting them greater material access to smart devices and more developed formal skills compared to older farmers.

In addition to these direct relationships, farmers' characteristics also exert indirect influences on digital inequalities (Table 4). Gender indirectly influences formal, strategic digital skills, and agricultural uses of digital technology among farmers. Women with less material access to digital technology also possess fewer strategic skills and use these technologies less frequently. Furthermore, aside from their direct effects, income levels, farmers' education levels, and the presence of educated children in the households also indirectly but positively impact attitudes, access, digital skills, and agricultural utilization of digital tools. Conversely, the direct and negative effects of age lead to negative but indirect effects on material access and the agricultural usage of digital technology. Marital status does not exert any direct or indirect influence on farmers' strategic digital skills. So, digital appropriation by farmers doesn't depend on this personal characteristic.

Discussion

The question of digital inequalities is still of great importance for better digital inclusion. Initially limited to its physical dimension, it has evolved significantly with the introduction of Van Dijk's theory of resources and appropriation (2005). This theory elucidates the process of digital technology appropriation through four interconnected levels: Attitude, material access, digital skills, and usage. In this study, our objective was to examine the interrelationships between these levels and identify the personal characteristics of smallholder farmers that influence them.

The findings of this study provide insights into Van Dijk's (2005) theory of resources and appropriation, within the agricultural context. Our research reinforces the linear relationship often established between the four levels of digital appropriation outlined in Van Dijk's theory. Farmers' attitudes positively influence their material access to digital tools, which subsequently enhances their digital skills, resulting in better usage of digital technology in agricultural purposes. Moreover, our study goes beyond this traditional linearity by unveiling a direct link between farmers' attitudes and both their digital skills and digital usage. This nuanced perspective contrasts with the research by van Deursen et al. (2021), which primarily focused on urban settings in the Netherlands and only established a direct influence of attitude on digital usage. These findings underscore that farmers' motivation to embrace digital technology not only facilitates their material access but also drives the development of their digital skills, ultimately shaping their active engagement in agricultural digitalization. This highlights the multifaceted nature of attitude and its importance in understanding digital inequalities. As emphasized by Reisdorf and Groselj (2017), motivation emerges as a crucial predictor of digital usage compared to individuals' sociodemographic characteristics, highlighting its pivotal role not only in digital usage but also in material access and digital skills acquisition.

In terms of digital skills, our study unveils the presence of two distinct skill sets that significantly influence the agricultural use of digital technology among farmers: formal skills and strategic skills. Formal skills encompass the ability to navigate the Internet, while strategic skills pertain to the capacity to leverage digital technology for decision-making and the accomplishment of substantial objectives. This differentiation in skill types represents a notable difference from previous research, which frequently treated digital skills as a singular construct. Our findings align with recommendations made by researchers, such as Van Deursen et al. (2021), who acknowledged the limitations of aggregating digital skills into one construct. Instead, they proposed a more nuanced approach, emphasizing the examination of distinct skill categories. Consequently, our results offer a refined understanding of the determinants of digital inequalities by delineating the specific types of skills that exert the most influence. Consequently, our findings shed light on a crucial aspect of digital inequalities among farmers. Specifically, our study reveals that farmers who possess proficient Internet navigation skills (formal skills) and those who can effectively leverage digital technology for decision-making are more inclined to embrace its use in their agricultural practices.

Table 4. Significant direct, indirect, and total effects of the determinants of digital inequalities between farmers.

		Direct	Indirect	Total effect	Hypotheses
H_{2-1}	Attitude→Material access	0.12	x	0.12	A
H_{3-1}	Attitude→Formal skills	0.09	x	0.09	A
	Attitude→Strategic skills	0.17	x	0.17	
H_{4-1}	Attitude→Usage	0.13	x	0.13	A
H_{3-2}	Material access→Formal skills	0.20	x	0.20	A
	Material access→Strategic skills	0.30	x	0.30	
H_{4-2}	Formal skills→Usage	0.14	x	0.14	A
	Strategic skills→Usage	0.53	x	0.53	
H_{1-1a}	Gender→Attitude	x	x	x	R
H_{2-2a}	Gender→Material access	0.15	x	0.15	A
H_{3-3a}	Gender→Formal skills	x	−0.005	−0.005	PA
H_{3-4a}	Gender→Strategic skills	x	0.02	0.02	PA
H_{4-3a}	Gender→Agricultural usage	x	0.01	0.01	PA
H_{1-1b}	Income→Attitude	x/0.16	x/0.04	x/0.20	A
H_{2-2b}	Income→Material access	x/0.13	x/0.02	x/0.15	A
H_{3-3b}	Income→Formal skills	0.07/0.08	x/−0.004	x/0.07	A
H_{3-4b}	Income→Stratégic skills	0.11/0.28	0.06/0.19	0.17/0.47	A
H_{4-3b}	Income→Agricultural usage	x/0.29	0.06/0.21	0.06/0.50	A
H_{1-1c}	Education→Attitude	0.15/x/0.09	0.04/x/x	0.19/x/0.09	A
H_{2-2c}	Education→Material access	0.14/0.24/0.27	0.02/0.03/0.03	0.16/0.27/0.30	A
H_{3-3c}	Education→Formal skills	0.14/0.33/0.50	−0.02/−0.01/−0.08	0.12/0.32/0.42	A
H_{3-4c}	Education→Strategic skills	x/x/0.14	0.04/0.04/0.12	0.04/0.04/0.26	A
H_{4-3c}	Education→Agricultural	x/0.11/0.10	0.04/−0.01/0.04	0.04/0.10/0.14	A
H_{1-1d}	Presence of a schoolchild in the household→Attitude	0.33	0.08	0.41	A
H_{2-2d}	Presence of a schoolchild in the household→Material access	0.15	0.02	0.17	A
H_{3-3d}	Prsence of a schoolchild in the household→Formal skills	0.12	−0.005	0.11	A
H_{3-4d}	Presence of a schoolchild in the household→Stratégic skills	x	0.13	0.13	PA
H_{4-3d}	Presence of a schoolchild in the household→Agricultural usage	x	0.17	0.17	PA
H_{2-2e}	Age→Material access	−0.15	−0.03	−0.18	A
H_{3-3e}	Age→Formal skills	−0.10	x	−0.10	A
H_{3-4e}	Age→Strategic skills	x	x	x	R
H_{4-3e}	Age→Agricultural usage	x	−0.03	−0.03	PA
H_{3-4f}	Marital status→Strategic skills	x	x	x	R

x: Not Significative; A: Accepted; PA: Partially accepted ; R: Rejected.

This nuanced insight enhances the precision of our understanding of the factors contributing to digital inequalities within this context. That finding enriches the existing body of knowledge by providing a more detailed perspective on the determinants of digital disparities in the agricultural sector.

Furthermore, our study highlighted the significance of certain personal characteristics in shaping digital inequalities among farmers, including gender, age, education level, and income. These findings align with a wealth of existing research in various domains. For instance, Durand et al. (2022) identified these same characteristics as determinants of digital inequalities in transport services, while in the education sector, Oyedemi (2012) also indicated education level and income as influential factors. Moreover, the study revealed the presence of a school-going child in the farmer's household influences digital inequalities. This factor serves as a potential local source of technical assistance for farmers in utilizing digital technology. It exerts a positive influence on farmers' attitudes toward digital technology, their material access, and their schools. Essentially, the availability of local technical support motivates farmers to embrace digital solutions. The assurance of having assistance readily available also encourages them to secure physical access to digital tools. Furthermore, these school-age children play a pivotal role in addressing the issue of digital illiteracy among farmers, bolstering their digital skills. Importantly, our study introduces the notion of inverse relationships within the traditional framework of digital appropriation proposed by Van Dijk (2005). If the proximity of technical assistance in digital technology usage is indeed a determinant, then the inability to effectively utilize digital technology can demotivate farmers, leading to decreased material access, and a decline in their digital skills.

Conclusion and future research

This research focused on digital inequalities among smallholder farmers. It underlined the differences in attitudes, material access, digital skills, and digital usage among smallholder farmers. First and foremost, our study contributes to understanding digital appropriation within smallholder farmers context. Specifically, the study demonstrates that farmers with a positive attitude towards digital technology are more likely to access digital tools, subsequently enhancing their digital skills. This digital proficiency, in turn, facilitates a greater utilization of digital technology for agricultural purposes. Beyond this well-established linearity, our research unveils a more nuanced reality where farmers' attitudes directly influence not only their material access but also their usage of digital technology. This emphasizes the role of farmers' attitudes in digital inequalities, positioning them as a central element in the process of digital appropriation. On the other hand, our study reveals that several personal characteristics, including gender, age, education level, income, and the presence of school-age children in the household, play significant roles in shaping digital inequalities. Men, those with higher levels of education, high income, or households with school-going children have greater access to digital technology. These findings underscore the influence of personal characteristics on digital inequalities among smallholder farmers. Based on the results of this research, we recommend that policymakers encourage inclusive approaches to innovation, to involve digitally marginalized farmers in digital innovation processes in agriculture. This approach will help diagnose and address conflicts related to digital inequalities, ultimately leading to the development of effective and efficient digital innovations for farmers. In the context of Benin, digital technology is primarily used for sharing information and agricultural knowledge with farmers. Consequently, our study did not explore a wide range of agricultural uses of digital technology to determine which personal characteristics influence specific types of use. Future studies could address this.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The authors received financial support for the research from "DigiCLA project/AGriDI/ICIPE/European Union".

ORCID iD

Morrisson Gouthon https://orcid.org/0009-0009-0400-8986

References

ACED (2023) Écosystème de l'agriculture numérique au Bénin: Une analyse de l'environnement institutionnel, des solutions numériques et des acteurs. Rapport de recherche. Abomey-Calavi, Bénin, p.46.

Barrett H and Rose DC (2022) Perceptions of the fourth agricultural revolution: what's in, what's out, and what consequences are anticipated? *Sociologia Ruralis* 62: 162–189.

Barzilai-Nahon K (2006) Gaps and bits: conceptualizing measurements for digital divide/s. *The Information Society* 22(5): 269–278.

Blank G and Groselj D (2014) Dimensions of Internet use: amount, variety, and types. *Information, Communication & Society* 17(4): 417–435.

Blank G and Reisdorf B (2023) Digital inequalities and public health during COVID-19: media dependency and vaccination. *Information, Communication & Society* 26(5): 1045–1065.

Boer PS, Van Deursen AJ and Van Rompay TJ (2019) Accepting the Internet-of-Things in our homes: the role of user skills. *Telematics and Informatics* 36: 147–156.

Bol N, Helberger N and Weert JC (2018) Differences in mobile health app use: a source of new digital inequalities? *The Information Society* 34(3): 183–193.

Büchi M, Festic N and Latzer M (2018) How social well-being is affected by digital inequalities. *International Journal of Communication* 12: 3686–3706. https://ssrn.com/abstract=3871751.

Chaqfeh M, Asim R, AlShebli B, et al. (2023) Towards a World Wide Web without digital inequality. *Proceedings of the National Academy of Sciences* 120(3): e2212649120.

Chen W and Li X (2022) Digital inequalities in American disadvantaged urban communities: access, skills, and expectations for digital inclusion programs. *Information, Communication & Society* 25(13): 1916–1933.

Durand A, Zijlstra T, van Oort N, et al. (2022) Access denied? Digital inequality in transport services. *Transport Reviews* 42(1): 32–57.

Durndell A and Haag Z (2002) Computer self efficacy, computer anxiety, attitudes towards the Internet and reported experience with the Internet, by gender, in an East European sample. *Computers in Human Behavior* 18(5): 521–535.

Eastwood C, Klerkx L, Ayre M, et al. (2019) Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. *Journal of Agricultural and Environmental Ethics* 32: 741–768.

Francis J, Ball C, Kadylak T, et al. (2019) Aging in the digital age: conceptualizing technology adoption and digital inequalities. In: *Ageing and Digital Technology: Designing and Evaluating Emerging Technologies for Older Adults*. Singapore: Springer, pp.35–49. DOI: 10.1007/978-981-13-3693-5_3

Golder W, Newman L, Biedrzycki K, et al. (2010). Digital technology access and use as 21st century determinants of health: impact of social and economic disadvantage. In: *Implementing Health in All Policies: Adelaide*. Department of Health, South Australia, pp.133–143.

Habibi A, Yusop FD and Razak RA (2020) The role of TPACK in affecting pre-service language teachers' ICT integration during teaching practices: Indonesian context. *Education and Information Technologies* 25: 1929–1949.

Helsper EJ (2020) Digital inequalities amongst digital natives. In: *The Routledge Companion to Digital Media and Children*. Australia: Routledge, pp.435–448.

Heponiemi T, Gluschkoff K, Leemann L, et al. (2023) Digital inequality in Finland: access, skills and attitudes as social impact mediators. *New Media & Society* 25(9): 2475–2491.

Islam MN and Inan TT (2021) Exploring the fundamental factors of digital inequality in Bangladesh. *SAGE Open* 11(2): 21582440211021407.

Jantjies M (2020) How South Africa can address digital inequalities in e-learning. *The Conversation* 29: 3.

Lezoche M, Hernandez JE, Díaz MDMEA, et al. (2020) Agri-food 4.0: a survey of the supply chains and technologies for the future agriculture. *Computers in Industry* 117: 103187.

Li S, Xu LD and Zhao S (2015) The internet of things: a survey. *Information Systems Frontiers* 17: 243–259.

Lissitsa S, Zychlinski E and Kagan M (2022) The silent generation vs baby boomers: socio-demographic and psychological predictors of the "gray" digital inequalities. *Computers in Human Behavior* 128: 107098.

Lupač P (2018) *Beyond the Digital Divide: Contextualizing the Information Society*. Emerald Publishing Limited. DOI: 10.1108/978-1-78756-547-020181008.

Nguyen MH, Gruber J, Fuchs J, et al. (2020) Changes in digital communication during the COVID-19 global pandemic: implications for digital inequality and future research. *Social Media+ Society* 6(3): 2056305120948255.

Nguyen MH, Hargittai E and Marler W (2021) Digital inequality in communication during a time of physical distancing: the case of COVID-19. *Computers in Human Behavior* 120: 106717.

Oyedemi TD (2012) Digital inequalities and implications for social inequalities: a study of Internet penetration amongst university students in South Africa. *Telematics and Informatics* 29(3): 302–313.

Özsoy D and Muschert G (2020) A comparison of high-skill and low-skill internet users in Northeast Anatolia, Turkey. In: *Digital Inequalities in the Global South*, pp.177–195. DOI: 10.1007/978-3-030-32706-4_9.

Park S (2017) Digital inequalities in rural Australia: a double jeopardy of remoteness and social exclusion. *Journal of Rural Studies* 54: 399–407.

Ramalingam B and Hernandez K (2016) 11. The multiple forms of digital inequality. In: *World Social Science Report, 2016: Challenging Inequalities; Pathways to a Just World*. France: UNESCO Publishing, p.68.

Reisdorf BC and Groselj D (2017) Internet (non-) use types and motivational access: implications for digital inequalities research. *New Media & Society* 19(8): 1157–1176.

Robinson L, Cotten SR, Ono H, et al. (2015) Digital inequalities and why they matter. *Information, Communication & Society* 18(5): 569–582.

Rose DC and Chilvers J (2018) Agriculture 4.0: Broadening responsible innovation in an era of smart farming. *Frontiers in Sustainable Food Systems* 2: 87.

Rose K, Eldridge S and Chapin L (2015) The internet of things: an overview. *The Internet Society (ISOC)* 80(15): 1–53.

Saiz-Rubio V and Rovira-Más F (2020) From smart farming towards agriculture 5.0: a review on crop data management. *Agronomy* 10(2): 07.

Scheerder A, Van Deursen A and Van Dijk J (2017) Determinants of Internet skills, uses and outcomes. A systematic review of the second-and third-level digital divide. *Telematics and Informatics* 34(8): 1607–1624.

Senapathy M (2021) Digital divide on agriculture using ICT devices among the farmers in Wolaita Zone, Southern Ethiopia. *Transformacje* 4(111): 3.

Shepherd M, Turner JA, Small B, et al. (2018) Priorities for science to overcome hurdles thwarting the full promise of the "digital agriculture" revolution. *Journal of the Science of Food and Agriculture* 100(14): 5083–5092.

Soomro KA, Kale U, Curtis R, et al. (2020) Digital divide among higher education faculty. *International Journal of Educational Technology in Higher Education* 17: 1–16.

Torres-Diaz J and Duart J (2015) Determinants of digital inequality in universities: the case of Ecuador. *Journal of E-Learning and Knowledge Society* 11(3): 150–161.
Tossou SH, Okou FA and Kpanou SBVK (2020) A systematic review of policy enforcement as a catalyst for digitalizing agriculture in West and East Africa. *Journal of African Development* 21(1): 68–95.
van der Zeeuw A, Van Deursen AJ and Jansen G (2019) Inequalities in the social use of the Internet of Things: a capital and skills perspective. *New Media & Society* 21(6): 1344–1361.
Van Deursen AJ, Helsper E, Eynon R, et al. (2017) The compoundness and sequentiality of digital inequality. *International Journal of Communication* 11: 452–473.
Van Deursen AJ, van der Zeeuw A, de Boer P, et al. (2021) Digital inequalities in the Internet of Things: differences in attitudes, material access, skills, and usage. *Information, Communication & Society* 24(2): 258–276.
Van Deursen AJ and Van Dijk JA (2014) *Digital Skills: Unlocking the Information Society*. Singapore: Springer.
Van Dijk JA (2005) *The Deepening Divide: Inequality in the Information Society*. USA: Sage publications.
Van Dijk JA (2013) A theory of the digital divide. In: *The Digital Divide*. London: Routledge, pp.49–72.
Van Dijk J (2017) Digital divide: impact of access. *The International Encyclopedia of Media Effects* 1: 1–11. DOI: 10.1002/9781118783764.wbieme0043.
Zhang M, Zhao P and Qiao S (2020) Smartness-induced transport inequality: privacy concern,lacking knowledge of smartphone use and unequal access to transport information. *Transport Policy* 99: 175–185.

About the authors

Morrisson Gouthon is a PhD student at the Doctoral School of Agronomic and Water Sciences (EDSAE) and a member of the Laboratory of Research on Innovation for Agricultural Development (LRIDA), University of Parakou, Benin. His current research focuses on digital co-innovation in agriculture. E-mail: morrissongouthon@gmail.com

Mori W. Gouroubera holds a PhD in Communication and Agricultural Extension from the University of Parakou, Benin. His research interests include digital usage in organizations and their institutionalization, climate change and adaptation strategies, agricultural digitalization and innovation systems. E-mail: gourouwm@gmail.com

Clarisse Tama-Imorou is Lecturer in Sociology at the Faculty of Letters, Arts and Human Sciences (FLASH) of University of Parakou, Benin. E-mail: clartama@yahoo.fr

Ismail Moumouni-Moussa is a Full Professor in Agricultural Sociology at the Faculty of Agronomy and Director of the Laboratory of Research on Innovation for Agricultural Development (LRIDA). He received his PhD from the Humboldt University in Berlin, Germany. His primary research interests include knowledge management and process facilitation. E-mail: ismailmm@gmail.com