Chapter

Using Information Technologies (ICTs) to Improve Theobroma Cocoa Extension Service: Lessons from the Case of Ghanaian Bean Farmers

Julia Bello-Bravo and Anne Namatsi Lutomia

Abstract

Ghana's modern cocoa production depends on farmers having access to innovations and updated best practices delivered through "new" information and communication technology (ICT) channels. However, extension services continue to face familiar delivery shortfalls affecting both the national-level extent of Ghana's cocoa production and the local livelihoods of its producers. This chapter draws on questionnaire data collected during a training workshop for postharvest loss prevention with mostly university-educated farmers to explore how they access innovation and best practices information through new and old technological channels. Key findings indicate that while farmers utilize both old and new ICTs, they still experience the familiar barriers of low agricultural extension agent-to-farmer ratios and shortages of resources. Recommendations include (1) ensuring that the affordances of "old" technologies are amplified rather than replaced by "new" ones, and (2) the use of highly scalable educational animations deployed individually for training or through virtual communities of practices to "bypass" the perennial issue of resource shortfalls in extension services.

Keywords: video animations, cocoa, farmers, lCTs, Ghana

1. Introduction

Theobroma cacao, commonly known as cocoa or cacao, is a tropical tree species belonging to the Malvaceae family. Native to the Amazon basin and other regions of South and Central America, the term "Theobroma" is derived from the Greek words "theo" ("deity") and "broma" ("food"), hence the notion that cocoa is the "food of gods." *Theobroma cacao* is cultivated primarily for its seeds, used to produce cocoa powder, cocoa butter, and chocolate products [1]. Presently, cocoa is widely cultivated in many parts of the world, including West Africa, where it is a significant source of income for many smallholder farmers.

Ghana is internationally known for its cocoa production and trade. As the second-leading world cocoa producer, it has registered an annual minimum cocoa bean output of 700,000 metric tons since 2012. For instance, the 2020/2021 crop season recorded an estimated 1.1 million metric tons in cocoa beans production. The Ghana Cocoa Board (COCOBOD), the government institution responsible for regulating cocoa buying prices, identified some threats to cocoa production in Ghana [2].

Research on smallholder farmers in Africa, including Ghana, has long indicated significant time and cost savings from using information and communication technology (ICT) for extension services [3]. Agriculture information benefits smallholder farmers by improving food production and increasing agriculture development and information on farming practices, market prices, and disease and pest control. The proliferation of mobile phones has been critical for smallholder farmers because they can increase agro-entrepreneurship by allowing efficiency in accessing markets, promoting investment, and empowering them [4]. However, Ghana's cocoa production faces challenges regarding extension service delivery to cocoa farmers. Inadequate extension services, limited access to information, poor infrastructure, language barriers, and limited funding are key challenges that cocoa farmers face [2]. Both old and new technologies are used to access this information. Old technologies include communication tools and modes of communication prior to the advent of computers and mobile phones, e.g., typewriters, landlines, VCRs. New technologies include smartphones, tablets, computers, artificial intelligence, and cloud computing that can center use experience.

The proliferation of affordable ICTs has paved the way for knowledge transfer in the agricultural community around the world using local languages and video-capable devices [5, 6]. Another benefit of mobile phones is speeding up access to, adapting, and sharing information [7]. Relatedly, Overå [8] found that farmers join social and business networks to seek useful and relevant information, which helps them to make better decisions for profitable, efficient, and productive agricultural production [9].

This chapter aims to identify how cocoa farmers in Ghana access information for better cocoa production using old and new technologies. It asks: (1) What kind of devices do farmers own? (2) What sources of information do farmers access for relevant information about beans? (3) What types of information do these sources provide? (4) How do farmers rate this information? and (5) How can the farmers learn to use their devices to access video animations? The chapter draws on the experiences of 15 male cocoa farmers' responses to a survey at a workshop for using a hermetic jerrycan storage technique to prevent postharvest bean loss [10]. Our findings generate recommendations for the use of old and new technology pathways in disseminating agricultural information to improve cocoa production.

2. Scientific animations without Borders and agriculture education

Founded in 2011, Scientific Animations Without Borders (SAWBO) creates educational animations in local languages shareable on ICTs (especially cell phones) for adult learners with little or no print-literacy [11]. These educational animations cover over 140 topic areas in more than 280 languages and dialects—especially around the topics of agriculture, health, women's empowerment, and peace-building—and have reached 50+ million people since the program's inception. These videos can be downloaded free of charge and shared within communities [11, 12]. SAWBO's primary goal has been a systems approach to knowledge chains that generate educational materials on best practices accessible to and adopted by the widest possible demographic [13, 14].

A knowledge chain consists of four process links and the transitions between them [15]: (1) to identify and scientifically frame a problem so that solutions to that framing of the problem are implied, (2) to embody that scientifically abstract solution to the problem in a concrete, animated video—overdubbed as needed into any locally accurate dialect—as a means of effecting knowledge transfer about the importance, context, and need to act on the solution offered for the problem in the video, (3) to disseminate and maintain an infrastructure that affords not only free and easy access to SAWBO videos for educators, learners, and researches but also a means for SAWBO to collect and incorporate feedback on any video or part of the knowledge chain itself, and (4) to look for ways to more widely scale the reach of any video and the processes that developed it. This chain includes loop-backs that support later modification of videos produced, above all translation into new languages and dialects that affords dramatically scaling-up the reach of any video at decreasing unit cost [14]. This approach has allowed individuals and organizations of any size, from small community-based organizations to large government and international organizations, to access, select, and adapt scientifically accurate educational content in local languages relevant to local problems in need of interventions [15].

3. Extension service and cocoa production

Sustaining the interest of cocoa farmers in the sector requires significant investment and research into the welfare and sustainability of their farming practices. The majority of cocoa production in Ghana is carried out by smallholders who cultivate on land plots <2 hectares using traditional production methods, resulting in low yields [16]. To enhance agricultural productivity and alleviate poverty in these areas, disseminating modern agricultural technologies to rural farmers is crucial [17].

Unfortunately, the growth of rural cocoa-growing communities and the agricultural sector is hindered by inadequate and ineffective delivery of extension services [18]. Given the high global demand for cocoa beans and the low productivity levels of approximately 90% of Ghanaian farms, extension services are essential for developing the human capacity of farmers and providing them with financial support [18].

In the twenty-first century, the role of extension services has in principle, expanded to encompass more than simply technology transfer and production improvement [19]. Agricultural extension programs aim more holistically to facilitate systematic development and improvement of the farming environment, reduce poverty, enhance agricultural production, promote processing capabilities, and teach large groups of farmers new knowledge and best practices, ultimately generating improved productivity and income [19].

3.1 Digital divide and cocoa production in Ghana

The gender gap and smallholder production are impacted by Ghana's digital divide in the cocoa industry. Digital literacy, internet connectivity, and access to digital technologies are significant drivers of the divide, which impacts many facets of cocoa production. Limited access to digital technologies and the Internet prevents smallholder farmers (male and female) from accessing vital information and knowledge resources [20]. These barriers and lack of access impede productivity and hinder farmers' capacity to adapt to climate change and other challenges. The digital divide also excludes women and smallholder farmers from accessing financial services, thus

increasing socio-economic gender disparities [21]. Another impact of the digital divide is the lack of access to markets and value chain integration. Digital platforms and e-commerce provide farmers access to markets, fair prices, and direct contact with buyers [22].

Importantly, while low or no print-literacy affects access to digital information [23], it does not necessarily impact the capacity to learn through digital means [13]. Equally, while higher levels of education often associate with increased use of digital information [22], this does not guarantee farmers' ability to access such information. Lack of access to the Internet and digital technologies means farmers cannot connect to markets and gain market insights. Consequently, their capacity to interact with customers, learn about the market, and engage in fair competition along the cocoa value chain is constrained. A lack of training and unfamiliarity with digital tools can further hinder the ability to navigate online platforms, access information, and leverage digital resources for improved farming practices [22]. Bridging the digital literacy gap through targeted training programs can empower smallholder farmers to make more informed decisions and enhance productivity. Addressing the digital divide in cocoa production is critical to giving smallholder farmers' voices more power; closing gaps will afford more power over farming operations and decision-making and access to financial services [20].

Improving internet connectivity, developing rural infrastructures, providing inexpensive access to digital technologies, and providing focused digital literacy initiatives for smallholder farmers (including women) should be priorities. To guarantee that the advantages of the digital revolution in cocoa production are available to all stakeholders, public–private partnerships, legislative efforts, and interventions should promote inclusive and sustainable strategies.

4. Case study of Ghanaian cocoa farmers

4.1 Method

Data for this study is drawn from a training workshop in Ghana in 2017 that provided improved agricultural technological tools and skills to farmers using a 4.5-minute-long animated SAWBO video. While the immediate goal of the workshop focused on learning gains around the improved postharvest loss prevention technique using jerrycans and willingness to adopt it as a practice, data collected from 15 male farmers also included modes of access they utilized for obtaining agricultural information. A survey questionnaire was administered in Fante (the locally most comfortably spoken language among participants) to measure learning gains, willingness to adopt the loss prevention technique, qualitative reactions to the video itself, and pathways to obtaining agricultural information.

Participants were 15 male cocoa farmers by profession from the central region of Ghana, purposefully sampled from five villages for the postharvest loss prevention training. Quantitative responses were tabulated and analyzed in Excel (**Table 1**).

5. Findings

Device ownership affects extension service information access. Farmers in the study had both "old" (TV, radio) and "new" technologies (computers, tablets, and

Characteristic	Response Categories	Number	Frequency %
Gender	Male	15	100
Marital status	Divorced	1	7
	Single	1	7
	Married	13	87
Education status	Tertiary education (university degree	13	87
	High school and diploma)	2	13
Group of age in years	18–29	2	13
	30–50	9	60
	51–70	4	27

Table 1.
Demographic data of the responders.

mobile phones, with and without video capability). All participants possessed the "old" access modes, with the majority (86%) owning smartphones. Similarly, although the majority owned PC computers, the majority also did not own laptops. (See **Table 2**).

The participants reported their perceptions about the video animation. Most heard the training clearly, and ten reported the visual quality was mostly clear. Regarding the strengths of the video for understanding, 15 participants reported that

Device Ownership	Response	Number	Frequency %
Radio	No	0	0
	Yes	15	100
TV	No	0	0
	Yes	15	100
Desktop Computer	No	3	20
	Yes	12	80
Laptop	No	13	87
	Yes	2	13
Tablet	No	6	40
	Yes	9	60
Smartphone	No	1	6
	Yes	13	86
Video-capable cellphone	No	0	0
	Yes	1	6
Nonvideo-capable cellphone	No	0	0
	Yes	0	0

Table 2.
Device ownership.

the video's language was totally understandable. All reported the picture quality as good and demonstrated the technique. The participants found no weaknesses in the videos and provided no comments for improvement (see **Table 3**).

Regarding the usefulness of the video for training, learning, and technical accuracy, all participants indicated the videos were very useful as learning resources and offered completely technically correct information. They also indicated that they found the video animation presentation very interesting (see **Table 4**).

Farmers answered "yes" or "no" to the relevance of various sources of information for cocoa production. In general, all information pathways were noted as relevant. Two participants replied that politicians were not relevant sources of information (See **Table 5**).

How farmers rate the perceived or actual usefulness of information from various sources is important. All information pathways were noted as very useful, with the exception of two participants who identified government extension staff and politicians as somewhat useful (see **Table 6**).

Farmers reported that they received relevant information from varying sources of information. Radio, smartphones, video-capable phones, neighbors/friends, newspapers, and government extension services provided similar information about bean

Questions	Responses	Number	Frequency %
Could you hear the training clearly	Mostly clear	2	13
	Totally clear	13	86
Was the visual quality good?	Mostly clear	10	67
	Totally clear	5	23
Strengths of the video for understanding	Action and demonstration	15	100
	High-quality pictures	15	100
Strengths of the video for understanding	Language understandable	15	100
	High-quality pictures	15	100
Weakness of the video for understanding	The videos had low sound	0	0
	The video was too short	0	0
	Pictures were not clear	0	0
	The video was too fast	0	0
	The video was slow at times	0	0
What suggestions do you have for improving the video used in training?	The video should be slow	0	0
	The sound should be louder	0	0
	The container was not transparent	0	0
	The video should be low	0	0
	The picture should be clear	0	0
	The training should be done in communities and farms	15	100

Table 3.
Perception of video animations and suggestions for improvement.

Usefulness of videos	Usefulness of videos	Number	Frequency %
Usefulness in training	Very useful	15	100%
The usefulness of video in learning	Very useful	15	100%
Technical correctness	Very useful	15	100%

Table 4.
Usefulness of video in training, learning, and technical correctness.

Sources	Relevant to bean production			
	Yes	Frequency %	No	Frequency %
Radio	15	100	0	0
Television	15	100	0	0
Smartphone	15	100	0	0
Video-capable cellphone	1	6	0	0
Neighbors/Friends	15	100	0	0
Family members	15	100	0	0
Newspapers	15	100	3	20
NGO Extension staff	15	100	0	0
Government Extension staff	13	87	2	13
Politicians	13	87	2	13

Table 5.
Sources of information relevant to bean production.

Sources	Useful	Number	Frequency %
Radio	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	15	100
Television	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	15	100
Smartphone	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	15	100
Video-capable cellphone	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	1	6
Neighbors/Friends	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	15	100

Sources	Useful	Number	Frequency %
Family members	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	15	100
Newspapers	Not very useful	0	0
	Somewhat useful	0	0
	Very useful	15	100
	Not very useful	0	0
NGO Extension staff	Somewhat useful	0	0
	Very useful	15	100
Government Extension staff	Not very useful	0	0
	Somewhat useful	2	13
	Very useful	13	87
Politicians	Not very useful	0	0
	Somewhat useful	2	13
	Very useful	13	87

Table 6.
Usefulness of information relevant to bean production.

farming seeds, planting, growing and storage, and pricing beans. Television provided the most information and showed farming demonstrations. The NGO extension staff focuses on postharvest loss prevention. In contrast, government extension service staff and politicians uniquely focus on bean production and seed and bean prices for the market. Politicians provided information about producing beans, seeds, and pricing beans (**Table 7**).

Sources	Relevant information
Radio	Bean farming-seeds, planting, growing and storage, pricing beans
Smartphone	Bean farming-seeds, planting, growing and storage, pricing beans
Video-capable phone	Bean farming-seeds, planting, growing and storage, pricing beans
Television	Showing demonstrations and farmers' experience about bean production: seeds, planting, growing, postharvest loss prevention, and storage, pricing beans
Neighbors/Friends	Bean farming-seeds, planting, growing and storage, pricing beans
Family members	Bean farming-seeds, planting, growing and storage, pricing beans
Newspapers	Bean farming-seeds, planting, growing and storage, pricing beans
NGO Extension staff	Postharvest loss prevention
Government Extension staff	Bean farming-seeds, planting, growing and storage, pricing beans
Politicians	Producing beans, seeds, and pricing beans

Table 7.
Sources and categories of relevant information.

Farmers were asked to rate the quality of categories of information on an 8-point scale (from 0 to 7, low to high). All sources of information were rated 7, with the exception of government extension staff and politicians, which two participants rated as 6 (**Table 8**).

When asked if they intended to share the postharvest loss prevention video animation with others after the workshop, all the participants said they would certainly share it (**Table 9**).

The farmers were asked whether people could download and upload the animation on a desktop, laptop, smartphone, or video-capable phone. All of the participants indicated this was possible (see **Table 10**).

Sources	Ranking								Total responses
	0	1	2	3	4	5	6	7	
Radio								15	15
Smartphone								15	15
Video-capable phone								15	15
Television								15	15
Neighbors/Friends								15	15
Family members								15	15
Newspapers								15	15
NGO Extension staff								15	15
Government Extension staff							2	13	15
Politicians							2	13	15

Table 8.
Ranking of quality of information by sources.

Activity	Sharing certainty	Number	Frequency%
Sharing video	Certainly not share	0	0
	Not sure whether to share	0	0
	Probably share	0	0
	Certainly share	15	15

Table 9.
Intention to share the video with others after the training.

Ability to download and upload animation to devices	Number	Frequency %
Desktop computer	15	100
Laptop	15	100
Smartphone	15	100
Video-capable phone	15	100

Table 10.
Ability to download and upload animations on various devices after practice.

Confidence level in downloading and uploading videos to devices	Not confident at all	Not very confident	Somewhat confident	Very confident	Not sure
Desktop computer	0	0	0	15	0
Laptop	0	0	0	15	0
Smartphone	0	0	0	15	0
Video-capable phone	0	0	0	15	0

Table 11.
Confidence level in uploading and downloading video animations to devices.

The farmers were also asked to indicate whether people could confidently upload and download video animations on devices such as desktop computers, laptops, smartphones, and video-capable phones confidently. All participants indicated that they were very confident this could be done (**Table 11**).

6. Discussion

Across Africa, many smallholder farmers are accessing information, services, and products to boost crop yields and increase efficiency and incomes using digital technologies. Smallholder farmers currently benefit from various innovations in agriculture or agri-tech. These innovations include mobile apps for inputs such as seeds and weather alerts. There are also other farming precision solutions such as satellite, drone imagery, and sensors that provide real-time data about the health of crops.

The farmers reported using mobile phones to communicate with other farmers and extension service officers. They also added that they use mobile phones to access information more quickly. Consistent with other research [24–26], challenges these farmers face associated with using mobile phones include network failure, high cost of data bundles, and lack of reliable electricity for charging phones.

Although old forms of accessing information—including radio, word of mouth, home visits, and extension services—persist, these are not necessarily efficient, adaptive, or fast enough on their own and benefit from working hand-in-hand with new ICTs and mobile phones [27, 28].

Informal agricultural knowledge is passed down to family members, neighbors, or both. Farmers may easily exchange information with other farmers and between generations, which requires no considerable transaction costs [19]. Our research supports the notion that farmers still rely on word of mouth from their friends, neighbors, and families, but such access now also occurs via mobile phones.

In contrast, formal information channels offer (1) precise guidance on workable adaption strategies, (2) information in understandable terms that focus on cocoa smallholders, and (3) information responsive to pressing livelihood concerns. Our research demonstrates that farmers evaluate the information they receive as relevant or not; while this means that information must be tailored to meet the farmers' needs [29], it is unfortunate that politicians and government extension officers could be perceived as less relevant. Reasons for this were not given by the two participants who noted this; however, research also indicates that a combination of animated viewing and facilitated discussion afterward achieves higher learning gains than traditional

extension teaching in isolation [13]. This may be a way to overcome a perceived relevance shortfall in extension service providers.

Cocoa production in Ghana is not culturally neutral. Concerning the cocoa industry, politicians play a significant role in shaping and informing policies, programs, and resource allocation, which impact farmers and the cocoa sector [30]. Unlike other information pathways, which had a 100% consensus on the relevance and usefulness of the information, a majority of farmers indicated that information received from politicians was also useful and relevant, but two did not find it optimally so.

Lastly, all of the participants said they would "certainly share" the video animation with others and were confident of their ability to access and download the video for such use in the future. Participants appreciated the possibility of re-watching part or all of an animated video as a refresher and the ability to play, stop, fast-forward, and replay the videos, consistent with other research; for example, Van Mele [31] highlighted how this kind of flexibility in video media facilitates effective training and learning in developing countries.

7. Recommendations

Notwithstanding the enthusiasm for new technologies [32], existing infrastructures of "old" technologies still afford communicating important agricultural information to farmers. Specifically, they continue to be very well-suited for delivering educational and best-practices information, including educational materials on SAWBO's videos. The main inefficiencies of these channels, which should not be abandoned, include less ability to adaptably, flexibly, or in real-time deliver newly emerging information to farmers, especially about markets. The appeal, usability, and technological familiarity of mobile phones for providing such flexible, adaptive, and real-time information make them exceptionally promising [33], providing that they do not reproduce or worsen existing social inequalities, particularly around access by female farmers.

Although a recommendation to strengthen extension service delivery by increasing national investment in it faces the perennial shortfalls of agent and budgetary allocations, the recommendation must still be made. Here again, the use of animated video helps increase extension's capacity by reducing its budgetary overhead [14]; these can be (and are being) delivered via "old" technologies. Extension effects can also be amplified and supported by using social media (WhatsApp) groups to form virtual communities of practice for supporting agricultural innovations and the adoption of best practices [15]. Such communities of practice (both virtual and offline) can generate context-specific solutions to local problems, the testing, development, or adaptation of technologies [34], and thus the dissemination of formal and citizen-generated research to farmers. For food security, as perhaps the most important backbone of the Sustainable Development Goals, extension services can link up with grassroots, citizen-led, or community-of-practice activities to train farmers on postharvest loss prevention, increased quality standards to enhance crop yields, and other value-addition techniques. These increase the profitability of cocoa farming and improve the livelihoods, well-being, and quality of life for farmers. Lastly, further work must be done to identify more channels for reaching the widest demographic. In the face of the changing climate and the future of the globe generally, we can no longer afford to miss people with life-critical information and skills.

8. Limitations and future research

The major limitation on the generalizability of this study is its small sample size of male, predominantly university-level educated participants. However, SAWBO has designed and tested its video media for effectiveness with the widest demographic possible, regardless of age, gender, educational and technological literacy, or geographic (rural/urban) isolation [13, 35]. The findings of this study for appeal, willingness to share, and video knowledge transfer for this particular demographic agree with previous research [10]. The limited sample also reflects the technological familiarity of more highly educated groups; that is, while mobile phones are globally the most common digital access device, laptops, and tablets are much less common for people in Africa [5]. The high prevalence of PC computers is consistent with exposure to computers among university-educated groups [36]. This highlights that future research to investigate modes of old and new information access by women is necessary, especially as women typically experience more limited access to education and digital technologies often associated with them [36–38].

9. Conclusions

The diffusion of "new" technologies always occurs through the infrastructures and channels of existing technologies, now becoming "old." In this study, while the predominantly university-educated participants had the new digital access technologies of PC computers and mobile phones, they also all had televisions and radios. When focusing on the promising affordances of new technologies, we should not overlook or even seek to supplant the old technologies. For example, these days books are in many ways obsolete, and yet they still have certain affordances, advantages, pleasures, and cultural habits that would disappear if completely replaced by digital "texts."

This point has direct bearing on attempts to innovate within a still-predominantly agricultural society like Ghana's cocoa production. We are currently in the International Decade of Indigenous Languages, as part of a global effort to preserve and honor indigenous knowledge, thinking, and practices. This is not solely to "archive" such knowledge, thinking, and practices like fossils or museum pieces in the event of their extinction but also to draw upon the various wisdoms contained within them for the benefit of humanity general as it faces the prospect of its extinction outright. The recommendation to not supplant or entirely replace Ghana's "old" technologies for agricultural support for cocoa with "new" technologies is not merely strategic (because the transition would then be smoother). It is also because traditional agricultural settings are themselves rooted in wisdom of adapting, amplifying, and modifying old practices, usually in sustainably "slower" ways.

Ghanaian farmers rely on old and new ICTs to access information, whether radios, television, smartphones, or word of mouth. Information access barriers include a lack of appropriate extension service, low agricultural extension agent-to-farmer ratios, and a digital divide in accessing ICTs, especially by women. As always, smallholder farmers need (1) access to relevant information to improve cocoa productivity, (2) in relatable and usable language and forms, and (3) both formal and informal access to ICT-amplified extension services [39]. Maintaining a continuity between the "old" and the "new," and ensuring the fewest disruptions without reproducing or worsening existing social inequalities, is essential to this.

Acknowledgements

This research comprises a QED Group LLC and USAID-funded project. The funding aimed to generate 'how-to' videos for agricultural techniques or technologies. Dr. Samuel Amoa-Mensa, director of the Center for Learning and Community Engagement (CLCD) in Cape Coast, Ghana, facilitated the data collection during the study. Many thanks to our funders and Dr. Amoa-Mensa for being the host institution during our fieldwork.

Conflict of interest

The authors declare no conflict of interest.

Author details

Julia Bello-Bravo and Anne Namatsi Lutomia*
Purdue University, West Lafayette, USA

*Address all correspondence to: alutomia@purdue.edu

References

[1] Verna R. The history and science of chocolate. The Malaysian Journal of Pathology. 2013;**35**(2):111-121

[2] Ghana Cocoa Board. Ghana Cocoa Board. 2023. Available from: https://cocobod.gh/

[3] Aker JC. Dial "a" for Agriculture: Using Information and Communication Technologies for Agricultural Extension in Developing Countries (Working Paper 269). Washington, DC: Center for Global Development; 2010

[4] Folitse BY et al. The determinants of mobile-phone usage among small-scale poultry farmers in Ghana. Information Development. 2019;**35**(4):564-574

[5] Bello-Bravo J et al. Breaking out: The turning point in learning using mobile technology. Heliyon. 2021;**7**(3):e06595

[6] FAO. Food and Agriculture: Driving Action across the 2030 Agenda for Sustainable Development. Rome, IT: FAO; 2017

[7] Nyamba SY, Mlozi MR. Factors influencing the use of mobile phones in communicating agricultural information: A case of Kilolo District, Iringa, Tanzania. International Journal of Information and Communication Technology Research. 2012;**2**(7):558-563

[8] Overå R. Networks, distance, and trust: Telecommunications development and changing trading practices in Ghana. World Development. 2006;**34**(7):1301-1315

[9] Lwoga ET. Bridging the agricultural knowledge and information divide: The case of selected telecenters and rural radio in Tanzania. The Electronic Journal of Information Systems in Developing Countries. 2010;**43**(1):1-14

[10] Bello-Bravo J et al. An 89% solution adoption rate at a two-year follow-up: Evaluating the effectiveness of an animated agricultural video approach. Information Technology for Development. 2020;**26**(3):577-590

[11] Rodríguez-Domenech MÁ, Bello-Bravo J, Pittendrigh BR. Scientific animations without Borders (SAWBO): An innovative strategy for promoting education for sustainable development. Sustainability Science. 2019;**14**(4):1105-1116

[12] Maredia MK et al. Can mobile phone-based animated videos induce learning and technology adoption among lowliterate farmers? A field experiment in Burkina Faso. Information Technology for Development. 2018;**24**(3):1-32

[13] Bello-Bravo J et al. Facilitated discussions increase learning gains from dialectically localized animated educational videos in Niger. Information Technology for Development. 2018;**24**(2):1-25

[14] Bello-Bravo J et al. Dramatically increased accessibility and decreased cost-per-person impacts are needed for scaling IPM in Africa. Current Opinion in Insect Science. 2022;**54**:100971

[15] Bello-Bravo J et al. Gender, Digitalization, and Resilience: Failing Forward. New York City, NY: Routledge; 2023

[16] Danso-Abbeam G et al. Technical efficiency in Ghana's cocoa industry: Evidence from Bibiani-Anhwiaso-Bekwai District. Journal of Development

and Agricultural Economics. 2012;**4**(10):287-294

[17] Asfaw S et al. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. Food Policy. 2012;**37**(3):283-295

[18] Binam JN et al. Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. Food Policy. 2004;**29**(5):531-545

[19] Feder G, Savastano S. Modern agricultural technology adoption in sub-Saharan Africa: A four-country analysis. In: Pingali P, Feder G, editors. Agriculture and Rural Development in a Globalizing World: Challenges and Opportunities. New York City, NY: Routledge; 2017. pp. 11-25

[20] Ohemeng FLK, Ofosu-Adarkwa K. Overcoming the digital divide in developing countries: An examination of Ghana's strategies to promote universal access to information communication technologies (ICTs). Journal of Developing Societies. 2014;**30**(3):297-322

[21] Abdulai A-R. The Digitalization of Agriculture and the (Un) Changing Dynamics of Rural Smallholder Farming Systems in Ghana, Sub-Sahara Africa. Guelph, Ontario, CN: University of Guelph; 2022

[22] Abdulai A-R, Bahadur K, Fraser E. What factors influence the likelihood of rural farmer participation in digital agricultural services? Experience from smallholder digitalization in northern Ghana. Outlook on Agriculture. 2023;**52**(1):57-66

[23] Brown A. Participatory Digital Extension in Agriculture: A Study from Ghana. Guelph, Ontario, CN: University of Guelph; 2023

[24] Bello-Bravo J et al. Making agricultural learning accessible: Examining gender in the use of animations via mobile phones. In: Mills M, Wake D, editors. Empowering Learners with Mobile Open-Access Learning Initiatives. Hershey, PA: IGI Global; 2017. pp. 74-100

[25] Gupta A, Ponticelli J, Tesei A. Information, Technology Adoption and Productivity: The Role of Mobile Phones in Agriculture. New York City, NY: National Bureau of Economic Research; 2020

[26] Porter G et al. Mobile phones, gender, and female empowerment in sub-Saharan Africa: Studies with African youth. Information Technology for Development. 2020;**26**(1):180-193

[27] Gupta A, Ponticelli J, Tesei A. Information, Technology Adoption and Productivity: The Role of Mobile Phones in Agriculture. Vol. No. w27192. Cambridge, MA: National Bureau of Economic Research; 2022

[28] Bello-Bravo J et al. Making agricultural learning accessible: Examining gender in the use of animations via mobile phones. In: Khosrow-Pour M et al., editors. Environmental and Agricultural Informatics: Concepts, Methodologies, Tools, and Applications. Hersey, PA: IGI; 2020. pp. 716-736

[29] Knowles MS, Holton EF, Swanson RA, editors. The Adult Learner. 7th ed. New York City, NY: Routledge; 2012

[30] Attipoe SG et al. Assessing the impact of non-governmental organization's extension programs on sustainable cocoa production and household income in Ghana. Journal of Integrative Agriculture. 2021;**20**(10):2820-2836

[31] Van Mele P. Video-Mediated Farmer-to-Farmer Learning for Sustainable Agriculture. A Scoping Study for SDC, SAI Platform and GFRAS. Ghent, Belgium: Agro-Insight; 2011

[32] Bello-Bravo J. "New wine in old bottles": Structures of feeling for a new way to see new wood products. Forests. 2023;**14**(3):524

[33] Aker JC, Mbiti IM. Mobile phones and economic development in Africa. The Journal of Economic Perspectives. 2010;**24**(3):207-232

[34] Bello-Bravo J et al. Identifying and evaluating farmer deviations from steps recommended for hermetic postharvest storage of beans in northern Mozambique. Journal of Stored Products Research. 2020;**87**:101628

[35] Bello-Bravo J, Rodríguez- Domenech MÁ, Pittendrigh BR. SDG1 in Europe: Micro-Grants, Poverty, and the Big-Picture Future of Sustainable Development in a Post-Pandemic World, in Sustainable Development Goals in Europe: A Geographical Approach, M.L. De Lázaro Torres and R. De Miguel González, Editors. Cham. CH: Springer; 2023. p. 3-20

[36] Williams CD, Pitchforth EL, O'Callaghan C. Computers, the internet and medical education in Africa. Medical Education. 2010;**44**(5):485-488

[37] Mariscal J et al. Bridging the gender digital gap. Economics. 2019;**13**(1):20190009

[38] Mossberger K, Tolbert CJ, McNeal RS. Digital Citizenship: The Internet, Society, and Participation. Cambridge, MA: MIT Press; 2008. p. 248

[39] Ilboudo J-P, del Castello R. Linking rural radio to new ICTs in Africa: Bridging the rural digital divide. In: Girard B, editor. The One to Watch Radio, New ICTs and Interactivity. Rome, IT: FAO; 2003. pp. 45-61