Journal of Agricultural Science; Vol. 14, No. 12; 2022
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Potential of Bluetooth Wireless Technology as a Tool for Agricultural Extension

Dieudonne Baributsa[1]

[1] Department of Entomology, Purdue University, W. Lafayette, IN, USA

Correspondence: Dieudonne Baributsa, Department of Entomology, Purdue University, W. Lafayette, IN 47907, USA. Tel: 1-765-494-8713. E-mail: dbaribut@purdue.edu

Received: October 3, 2022 Accepted: November 1, 2022 Online Published: November 15, 2022

doi:10.5539/jas.v14n12p28 URL: https://doi.org/10.5539/jas.v14n12p28

The research was financed by the Bill and Melinda Gates Foundation (BMGF).

Abstract

Information and Communication Technology (ICT) provides opportunities to improve farmers' livelihoods. Bluetooth wireless technology (BWT) is a simple cellphone-based innovation that can significantly reduce the cost of disseminating information to farmers. A two-stage survey was conducted in Ghana in 2011 and 2012 to: (i) appraise cellphone ownership, cost, and the existence of BWT, and (ii) assess the potential of using BWT to disseminate information to farmers on grain storage technology. The survey was conducted in four districts in the Northern and Ashanti regions of Ghana. Results of the appraisal study show that there were 27 cellphones for about 1,000 people, with 20% owned by women. The majority (78%) of phones were purchased new for $20 or less. About half (48%) of the cellphones had BWT. The follow-up study showed that most respondents learned (91.7%) and received (88.3%) the videos on grain storage (Purdue Improved Crop Storage-PICS) technology via BWT from extension agents. Three-fourths of the respondents watched the PICS videos on their cellphones six times or more. Among those who received the PICS videos, each viewed and shared it with nine and seven more people, respectively. The overall results support the effective use of BWT embedded in basic phones as a tool for conveying agricultural extension messages to farmers. Development partners and extension services should take advantage of BTW embedded in basic phones to improve access to agricultural and health information.

Keywords: digital solutions, ICT in agriculture, grain storage, PICS bags, Ghana

1. Introduction

The use of Information and Communication Technology (ICT) has significantly increased in the last few decades around the world. In Africa, cellphone use went from 17 to 620 million mobile connections from 2000 to 2011 (Phillips et al., 2011). During this same period, cellphone penetration increased from 2% to 62%, changing dramatically the lives of millions of people. A close look at the data suggests that basic phones remain the most predominant handset among users in Sub-Saharan Africa (SSA) varying from 40% in South Africa to 62% in Tanzania (Silver & Johnson, 2018). The rapid market penetration of mobile phones in developing countries is dramatically improving the lives of rural communities.

Advances in technology have provided opportunities to improve access to information and decision-making among smallholder farmers (Asenso-okyere & Mekonnen, 2012; Deichmann, Goyal, & Mishra, 2016). In agriculture, cellphones have helped smallholder farmers reduce costs associated with access to financial services such as banking and money transfers (Aker, Boumnijel, McClelland, & Tierney, 2011; Mbiti & Wei, 2011). In addition, cellphones have also improved smallholder farmers' access to market information including the price of crops and livestock (Aker, 2008; O'Donnell, 2013). Cellphones have played an important role in improving livelihood and decreasing poverty rates among rural communities (Sife, Kiondo, & Lyimo-Macha, 2010).

The development of several mobile-based information delivery systems such as voice messages, short message service (sms), internet, e-wallet, and videos have increased the use of ICT (Aker, 2011). Enhancing information delivery through ICT tools can help increase access to technologies and innovations/knowledge, hence making agricultural activities more efficient. This can result in increased agricultural yields and incomes on smallholder farms (Quandt et al., 2020). Though progress has been made, the use of ICT tools among rural farmers is limited

due to several constraints. These include the cost of access to technology and the delivery of services (*e.g.*, the price of cellphones, poor infrastructure, poor policies, and literacy) (Ayim, Kassahun, Tekinerdogan, & Addison, 2020).

Efforts to disseminate postharvest storage technologies such as the Purdue Improved Crop Storage (PICS) bags in sub-Sahara Africa have focused mostly on the use of radio and limited use of television and ICT tools (Baributsa, Lowenberg-Deboer, & Kamarou, 2010; Baributsa, Lowenberg-DeBoer, Murdock, & Moussa, 2010; Moussa, Otoo, Fulton, & Lowenberg-DeBoer, 2009; Muriuki, Munyua, & Wanga, 2016). These traditional extension services are expensive (Deichmann et al., 2016). Thus, there is a need for new and innovative ICT approaches that use technology already embedded in basic phones owned by the majority of people in rural communities.

Bluetooth wireless technology (BWT) embedded in ubiquitous (basic) cellphones provides an opportunity to deliver extension content at a lower cost when compared to other ICT tools. The BWT has several advantages compared to other ICT approaches. It does not require internet connectivity to operate. The content is stored on the local device (remains local) and can be viewed anytime without internet connectivity. This is critical because most people in rural areas, particularly farmers, own basic phones which cannot connect to the internet (Krell et al., 2021; Silver & Johnson, 2018). Solutions such as BWT which rely on basic or feature phones would be well suited for use in rural areas where access to smartphones and internet connectivity are limited due to poor infrastructure and cost (Sen, Bank, & Choudhary, 2009).

Though BWT has been used in other fields to improve visually impaired drivers' safety and access to information (Bohonos, Lee, Malik, Thai, & Manduchi, 2008; Rudisill & Zhu, 2021), it has had minimal applications in agriculture. BWT has been used to transfer data on farmers' cellphones for record keeping when selling their products and for improving the performance of low-power embedded sensors (Balmos, Layton, Ault, Krogmeier, & Buckmaster, 2013; Sen et al., 2009). No efforts have looked at using BWT embedded in cellphones to build awareness or train farmers on new technologies. This study, the first of its kind, was conducted to assess whether phone-based BWT could be used for disseminating knowledge on PICS technology to reduce grain storage losses among rural communities. The objective of the study was to assess cellphone ownership, cost, and the existence and use of BWT to reach farmers with new information on improved grain storage technology.

2. Method

2.1 Study Area

To assess the potential use of cellphones with BWT to share training videos, a two-stage survey was conducted in 2011 and 2012 in the Ashanti and Northern regions of Ghana. Four districts were selected in both regions including, Ejura in the Ashanti region, and Yendi, Savelugu, and Saboba in the Northern region. These districts were selected due to their involvement in the PICS project demonstration activities on the use of hermetic bags.

2.2 Data Collection

Thirty-two communities/villages were randomly selected from the four districts (eight from each district) to collect data. The first phase of the study consisted of conducting an inventory of cellphones in the 32 communities in the four districts from July 1st to 30th 2011. The goal was to assess cellphone ownership in rural communities. Four enumerators collected data in two villages in each of the four districts. To identify people with cellphones, enumerators went from house to house in each of the communities. Data collected included cellphone ownership, its condition (new or used when purchased), year of purchase, cost, and the existence of BWT.

The second phase of the study consisted of developing, distributing via BWT, and assessing the dissemination of videos on the use of PICS bags for cowpea storage. The PICS videos were locally produced in three vernacular languages (Twi, Dagbani, and Gurune) and English. These videos were developed to help farmers, especially those who did not attend demonstration activities, learn how to use PICS bags. The PICS videos were culturally sensitive, used native speakers and local sceneries, had some drama, and were less than five minutes long.

To disseminate the PICS videos, one extension agent was recruited in each of the four districts where the first phase of the study was conducted. After the production, PICS videos in the four languages were transferred to the cellphones of each of the four extension agents (Figure 1). Extension agents were shown simple steps on how to share files (*e.g.*, videos via BWT) as described in this link: https://www.youtube.com/watch?v=dq4-DWdfuRA. Extension agents shared the PICS videos with potential users during field visits, while

implementing their regular duties. Names and contact information of people who received the PICS video were recorded on forms. A total of 145 people received the PICS videos.

Six months after disseminating the PICS videos, 60 randomly selected participants (representing 45% of those who received the PICS video) were interviewed. Sample selection was stratified based on the proportion of the number of participants from each district and community. A questionnaire was developed and had both open and close-ended questions. Data collected included socio-demographic characteristics of respondents, how they received the PICS video, how many times they had watched and shared it, and its usefulness. The evaluation included the usefulness of PICS videos among respondents, and other potential areas of application (health, crop production, etc.).

Figure 1. Representation of feature phones used to transfer and watch PICS videos via Bluetooth wireless technology (BWT)

2.3 Data Analysis

Data collected during both phases were entered into Excel and then transferred into SPSS 21.0 for Windows for coding and analysis. Descriptive statistics and correlations were generated during the analysis.

3. Results

3.1 Cellphone Ownership-Inventory

A total of 679 people were identified as owners of cellphone in 32 communities (Table 1). Based on census data available for 22 out of the 32 communities surveyed, there were 25 cellphones in a community of 935 people. About 80% and 20% of cellphone owners were 40 years old or less, and women, respectively. More than three-quarters (78%) of the cellphones were purchased new; mostly bought by men (80.5%). More than 91% of the phones were purchased in the last three years. About three-fourths (76.4%) of people purchased their cellphones for 30 Ghana cedis (GHS) ($20) or less. About half of the cellphone (48%) had BWT; mostly owned by men (84.3%). There were 10 different brands of cellphones, but one was the predominant (64.4%) among all users.

Table 1. Characteristics of respondents and cellphones they owned

Variables	Category	Percent of respondents				
		Northern			Ashanti	Total (n = 679)
		Saboba (n = 160)	Savelugu (n = 65)	Yendi (n = 265)	Ejura (n = 189)	
Gender	Male	95.6	87.7	78.5	67.7	80.4
	Female	4.4	12.3	21.5	32.3	19.6
Age	Less than 30	63.1	50.8	69.7	49.2	60.7
	Between 31-40	23.1	33.3	16.7	24.3	21.9
	Between 41-50	10.0	6.3	7.6	14.8	10.1
	Higher 51	3.8	9.5	6.1	11.6	7.4
Bluetooth capability	Yes	47.5	100	34	49.5	47.8
	No	52.5	0	66	50.5	52.2
Purchased condition	New	81.2	98.5	74	75.1	78.4
	Used	18.8	1.5	26	24.9	21.6
Age of cellphone	< 2 years	73.1	92.3	56.6	68.8	67.3
	2- 3 years	21.9	7.7	29.8	21.2	23.4
	4-5 years	3.1	0.0	7.2	9.0	6.0
	> 5years	1.9	0.0	6.4	1.1	3.2
Price of phone (GHS)	< 20	39.0	53.8	53.7	45.7	48.0
	21-30	35.8	36.9	18.1	33.3	28.4
	31-40	18.2	7.7	18.9	16.1	16.9
	> 40	6.9	1.5	9.3	4.8	6.7

Note. US $1 = 1.50 Ghana cedis (GHS) on July 10, 2011.

3.2 Dissemination of the PICS Videos and Follow-Up Survey

About 82% of the respondents were 40 years old or younger (Table 2). Among all the respondents, 70% were male and 68.3% were married. At least 66% of the respondents attended formal education (primary to university), while 20% did not attend school. Farming was the primary and secondary activity for 43.3% and 46.7% of respondents, respectively. Other primary activities included business, students, and teachers. The primary crops grown by the respondents were cowpea (53.3%), maize (78.3%), soybean (15.0%), and rice (26.7%).

Table 2. Demographic characteristics of the respondents to the survey conducted in the Ashanti and Northern regions of Ghana in 2012

Variables	Category	% respondents (n = 60)	Variables	Category	% respondents (n = 60)
Gender	Male	70.0	Age	Less than 30	60.7
	Female	30.0		Between 31-40	21.9
Marital status	Married	68.7		Between 41-50	10.1
	Unmarried	31.7		Higher 51	7.4
Level of education	None	20.1	Activity	Farming	43.3
	Koranic	8.3		Business	25.0
	Literacy	5..0		Students	13.3
	Primary	23.3		Teachers	15.0
	Secondary	23.3		Others	3.3
	Tertiary	20.0			

Extension agents were the most important source of information about the existence of the PICS videos (91.7%) and the major source for acquiring them (88.3%) (Table 3). Most respondents received information about the PICS video from one source (96.7%). Though friends played a minor role in disseminating the PICS videos, they were the major source of other videos received on the devices of respondents (70%). A little over half of the respondents (51.7%) receive the PICS videos in Twi, 45% in Dagbani, and 3.3% in English. No one received the PICS video in Gurune. About half of the respondents received the PICS videos in the first three months after the launch of the dissemination. Among respondents, 41.7% asked for help to receive or transfer the PICS videos to

others, while only 21.7% asked for help to watch them on their devices. Three-fourths of the respondents watched the PICS videos six times or more. All respondents found the PICS videos useful because they showed step-by-step how to use PICS bags in a simple way. The majority (94.9%) of the respondents were satisfied with the quality and content of the videos. The drama component of the PICS videos was the most liked part (80%) followed by the use of a local language (6.7%). Two respondents did not like the quality of the sound and the length of the videos.

Table 3. Awareness and use of PICS videos disseminated in the Ashanti and Northern regions of Ghana in 2012

Category	% respondents (n = 60)			
	Learned about PICS videos from	Received PICS videos from	Received non-PICS videos from	
Extension agents	91.7	88.3	0	
Farmers	3.3	5.0	0	
Friends	8.3	5.0	70	
Cellphone vendors	0	0	1.7	
Others	3.3	1.7	3.3	
Category	Watched PICS videos (times)	Shared PICS videos (people)	Watch PICS videos with others (people)	# non-PICS videos on cellphone
0	5.0	31.7	16.7	28.3
1-5	33.3	38.3	30.0	26.7
6-10	21.7	16.7	33.3	28.3
More than 10	40.0	13.3	20.0	16.7

Among the respondents, 68.3% shared the PICS videos with 272 people via BWT, while 83.3% watched the PICS videos with 425 people on their cellphones (Table 3). Women were only 17.1% of those who shared the PICS videos with others via BWT and with only 40 people. About 72% of the participants noted that they have other types of videos on their cellphones; with 55% having 1-10 videos. Only one respondent paid about 5 GHS (USD $3.33) to receive a video.

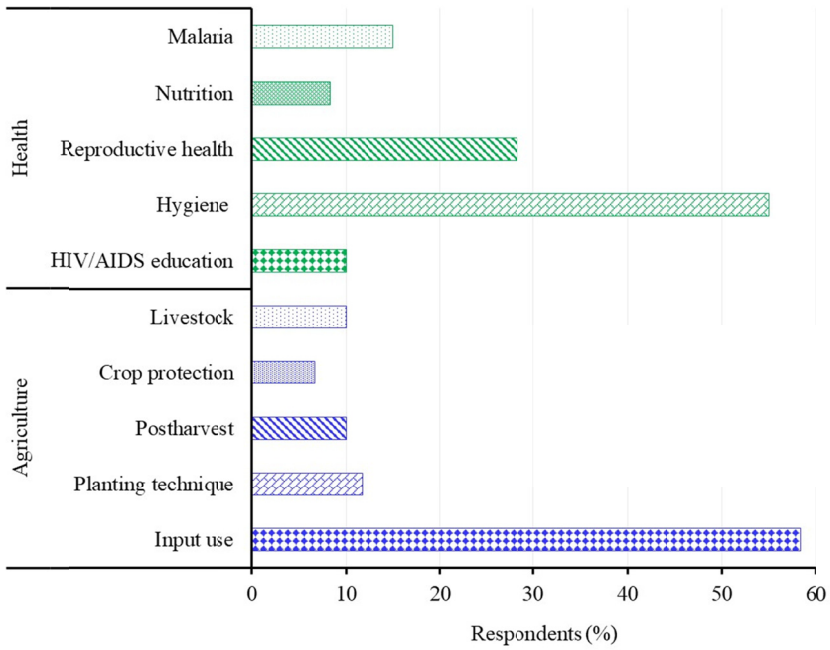

Figure 2. Respondents' feedback (n = 60) on potential areas where other videos (transferred via BWT) could help improve access to knowledge and practices in agriculture and health

Other than calling, respondents used their cellphone to watch videos (80%), send sms (40%), listen to the radio (48.3%), browse the internet (31.7%), take photos (40%), and send/receive money (1.7%). When asked what other subjects the dissemination of videos via BWT may be useful for, respondents noted agriculture (100%) and health (93.3%) (Figure 2). The development of other videos to improve the use of inputs-fertilizer and seed-(58.3%) and hygiene (55%) were the most important areas of interest for agriculture and health, respectively.

With 85% of respondents involved in farming as their primary or secondary activity, 98.3% were aware of hermetic bags (95% of PICS and 3.3% of GrainPro). Respondents heard of hermetic bags from one (80%) or two sources (16.7%) including extension agents (81.7%), PICS videos (25.0%), radio (5.0%), farmers (3.3%) and television (1.7%). Though half of the respondents (53.3%) attended PICS training activities, 91.7% claimed that they knew how to use the PICS bags. They learned to use the bag from village demonstrations (55.0%), PICS videos (60%), and market demonstrations (8.3%).

4. Discussion

4.1 Cellphone Ownership-Inventory

Ownership of mobile phones (average of 25 per community) was low compared to other countries (Baributsa et al., 2010; Quandt et al., 2020). This low estimate was due in part to a low presence of household members during the visits of the extension agents. Based on the most recent data, it is clear that cellphone ownership has significantly increased in the last decade with more than 50% of households in a community having a mobile phone (Krell et al., 2021; Quandt et al., 2020). This rapid increase in mobile phone ownership in rural communities can be attributed to the lower cost of the devices, improved network connectivity, access to electricity, and power-efficient devices (Ayim et al., 2020; Houngbonon, Le Quentrec, & Rubrichi, 2021; Phillips et al., 2011; Wyche & Olson, 2018). In addition, improved access to energy sources (solar, generator, etc.) and services (cellphone battery charging outlets- Figure 3) have helped increase cellphone ownership and use in rural communities. Increased cellphone ownership should make it easier for farmers and others to access information on their devices.

Figure 3. A cellphone charging station in rural Zinder, Niger (2015)

There were several brands of cellphones, but one dominated the market (67%) because its devices were sturdy and could withstand handling conditions in rural communities. Most devices were predominantly basic cellphones; half of them embedded with BWT. Various studies have indicated that most people in SSA own basic phones (Krell et al., 2021; Silver & Johnson, 2018). The ownership of smartphones is low in most sub-Saharan African (SSA) countries, particularly among the less educated people (Silver & Johnson, 2018) and women (Wyche & Olson, 2018). Significant disparities were observed in the ownership (purchased new phones and those with BWT) and usage (sharing and watching PICS videos) of mobile phones between male and female. Such gaps reported in previous studies can be explained by socioeconomic and cultural barriers, and limited financial capacity among women compared to men (Krell et al., 2021; Santosham & Lindsey, 2015; Wyche & Olson, 2018).

4.2 Dissemination of the PICS Videos and Follow-Up Survey

The follow-up survey showed that most respondents were involved in agriculture; as is always the case in rural communities in SSA (Njoroge, Baoua, & Baributsa, 2019). Though contacts between farmers and extension services continue to decrease over time due to limited resources (*e.g.*, cuts in funding and personnel), the role of extension agents remains crucial in introducing innovations in rural communities. Extension agents were key in disseminating the PICS videos, while other videos were shared by friends. This finding suggests that multi-prong approaches are needed to introduce videos via BWT in rural communities. Using multiple channels to disseminate innovation/knowledge will ensure that farmers get the required information to effectively make decisions (Muriuki et al., 2016). Most respondents used their cellphones to watch videos despite that some of them requested help in transferring or receiving videos.

People who received the PICS videos proactively shared and viewed them with others. Among those who received the PICS videos, each shared with seven people. Given that most farmers own basic cellphones without internet connectivity, tapping into BWT would reduce the time and cost required to build awareness and provide training on new agricultural technologies. The transfer of a video in itself was not a new concept; however, using BWT to disseminate agricultural knowledge was the novelty of this research. There was a negative correlation (-55.5%) between the level of education for those who did not attend school and the ability to share the PICS videos. There would be a need to provide training among farmers on basic knowledge of the use of BWT to share videos to increase dissemination.

Though cellphone ownership is often low among farmers, video sharing via BWT is a cost-effective way to disseminate information in rural communities. Among those who received the PICS videos, each viewed it with nine more people. There was an interest to receive videos that addressed other urgent issues in agriculture (use of fertilizer) and health (hygiene). This interest can be explained by the fact that these are rural communities heavily involved in agriculture who also have limited access to health care services. The fact that the videos were able to help the respondents learn how to use PICS bags may explain their interest in receiving training material on other subjects.

Getting videos to rural communities through BWT would accelerate the diffusion of information, innovations, and technologies. Some participants received and viewed other videos which were predominantly movie or music clips. Given that most rural households have limited access to television, most owners of basic cellphones with BWT watched the PICS and other videos for entertainment during free time (often in the evening). The drama component of the PICS videos made them attractive to the audience/respondents. The use of videos would be crucial to help farmers (mostly illiterate), who are not able to attend trainings, learn how to use new technologies or concepts that are difficult to describe in words but easy to understand when seen.

5. Conclusion

This study demonstrated that BWT embedded in basic cellphones can be effectively used as an extension tool for sharing agricultural information among people in rural communities. The exponential growth in sharing and viewing of the PICS videos is an indication that new knowledge and innovations can be disseminated among farmers using digital solutions such as BWT. This can increase the efficiencies of extension outreach by accelerating the exchange of knowledge among rural communities and lowering the cost of acquiring information. In addition, the BWT in basic cellphones can be effectively used during health crises such as Ebola or COVID-19 as it allows social distancing. Based on the findings of this research, we recommend that governments and development partners invest in promoting knowledge and innovations via basic digital solutions (*e.g.*, BWT) available on the cellphones of most rural people to improve agriculture and health.

Conflicts of Interest

Dieudonne Baributsa is a co-founder of PICS Global Inc., a social enterprise that commercializes postharvest technologies (including PICS bags) to smallholder farmers around the world and hence declares a conflict of interest. The funder (Bill and Melinda Gates Foundation) had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Acknowledgements

The author is grateful to the enumerators for collecting the data and the respondents for participating in the survey. Thanks to the Bill and Melinda Gates Foundation (BMGF) for supporting this study through the PICS1 Project (grant# INV-006972) to Purdue University.

References

Aker, J. C. (2008). Does Digital Divide or Provide? The Impact of Cell Phones on Grain Markets in Niger. *Center for Global Development Working Paper No. 154*. https://doi.org/10.2139/ssrn.1093374

Aker, J. C. (2011). Dial "A" for Agriculture: A Review of Information and Communication Technologies for Agricultural Extension in Developing Countries. *CGD Working Paper* (Vol. 269). Washington, D.C.: Center for Global Development. Retrieved from http://www.cgdev.org/content/publications/detail/1425497

Aker, J. C., Boumnijel, R., McClelland, A., & Tierney, N. (2011). Zap It to Me: The Short-Term Impacts of a Mobile Cash Transfer Program. *Center for Global Development Working Paper No. 268*. https://doi.org/10.2139/ssrn.1931641

Asenso-okyere, K., & Mekonnen, D. A. (2012). *The Importance of ICTs in the Provision of Information for Improving Agricultural Productivity and Rural Incomes in Africa*. *UNDP Working Paper 2012-2015*.

Ayim, C., Kassahun, A., Tekinerdogan, B., & Addison, C. (2020). *Adoption of ICT innovations in the agriculture sector in Africa: A Systematic Literature Review*. Wageningen University, Information Technology, Wageningen, The Netherlands.

Balmos, A. D., Layton, A. W., Ault, A., Krogmeier, J. V., & Buckmaster, D. R. (2013). *Investigation of bluetooth communications for low-power embedded sensor networks in agriculture* (Vol. 6). American Society of Agricultural and Biological Engineers Annual International Meeting 2013. https://doi.org/10.13031/aim.20131620559

Baributsa, D., Lowenberg-Deboer, J., & Kamarou, A. D. (2010). *Cell Phone Video for Communicating Hermetic Cowpea Storage Skills*. Retrieved from https://www.researchgate.net/publication/351083201_Cell_Phone_Video_for_Communicating_Hermetic_Cowpea_Storage_Skills

Baributsa, D., Lowenberg-DeBoer, J., Murdock, L., & Moussa, B. (2010). *Profitable chemical-free cowpea storage technology for smallholder farmers in Africa: Opportunities and challenges* (Vol. 0, p. 1046). 10th International Working Conference on Stored Product Protection, June 27 to July 2, 2010, Estoril, Portugal. https://doi.org/10.5073/JKA.2010.425.340

Bohonos, S., Lee, A., Malik, A., Thai, C., & Manduchi, R. (2008). Cellphone Accessible Information Via Bluetooth Beaconing for the Visually Impaired. In K. Miesenberger, J. Klaus, W. Zagler, & A. Karshmer (Eds.), *Computers Helping People with Special Needs* (pp. 1117-1121). *Lecture Notes in Computer Science* (Vol. 5105). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-70540-6_167

Deichmann, U., Goyal, A., & Mishra, D. (2016). Will digital technologies transform agriculture in developing countries? *Agricultural Economics (United Kingdom), 47*(May), 21-33. https://doi.org/10.1111/agec.12300

Houngbonon, G. V., Le Quentrec, E., & Rubrichi, S. (2021). Access to electricity and digital inclusion: Evidence from mobile call detail records. *Humanities and Social Sciences Communications, 8*(1), 170. https://doi.org/10.1057/s41599-021-00848-0

Krell, N. T., Giroux, S. A., Guido, Z., Hannah, C., Lopus, S. E., Caylor, K. K., & Evans, T. P. (2021). Smallholder farmers' use of mobile phone services in central Kenya. *Climate and Development, 13*(3), 215-227. https://doi.org/10.1080/17565529.2020.1748847

Mbiti, I., & Wei, D. N. (2011). Mobile banking: The impact of M-Pesa in Kenya. *Working paper 17129*. National Bureau of Economic Research, Cambridge. https://doi.org/10.3386/w17129

Moussa, B., Otoo, M., Fulton, J., & Lowenberg-DeBoer, J. (2009). *Evaluating the Effectiveness of Alternative Extension Methods: Triple-Bag Storage of Cowpeas by Small-Scale Farmers in West Africa*. Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2009, AAEA & ACCI Joint Annual Meeting, July 26-29, 2009, Milwaukee, Wisconsin.

Muriuki, N., Munyua, C., & Wanga, D. (2016). Communication Channels in Adoption of Technology with a Focus on the Use of Purdue Improved Crop Storage (PICS) among Small Scale Maize Farmers in Kenya. *Journal of Biology, Agriculture and Healthcare, 6*(18). Retrieved July 30, 2022, from http://www.iiste.org

Njoroge, A. W., Baoua, I., & Baributsa, D. (2019). Postharvest Management Practices of Grains in the Eastern Region of Kenya. *Journal of Agricultural Science, 11*(3), 33. https://doi.org/10.5539/jas.v11n3p33

O'Donnell, M. (2013). *Using ICT to Enhance Marketing for Small Agricultural Producers*. USAID Briefing Paper.

Phillips, T., Lyons, P., Page, M., Viviez, L., Molina, M., & Ensor, T. (2011). *African Mobile Observatory 2011: Driving Economic and Social Development through Mobile Services*.

Quandt, A., Salerno, J. D., Neff, J. C., Baird, T. D., Herrick, J. E., McCabe, J. T., … Hartter, J. (2020). Mobile phone use is associated with higher smallholder agricultural productivity in Tanzania, East Africa. *PLOS ONE*, 15(8), e0237337. https://doi.org/10.1371/journal.pone.0237337

Rudisill, T. M., & Zhu, M. (2021). Challenges of enforcing cellphone use while driving laws among police in the USA: A cross-sectional analysis. *BMJ Open, 11*(6), e049053. https://doi.org/10.1136/bmjopen-2021-049053

Santosham, S., & Lindsey, D. (2015). *Bridging the gender gap: Mobile access and usage in lowand middle-income countries*. GSMA Connected Women Global Development Alliance.

Sen, S., Bank, W., & Choudhary, V. (2009). *ICT Applications for Smallholder Inclusion in Agribusiness Supply Chains* (pp. 239-258). Washington DC: World Bank.

Sife, A. S., Kiondo, E., & Lyimo-Macha, J. G. (2010). Contribution of Mobile Phones to Rural Livelihoods and Poverty Reduction in Morogoro Region, Tanzania. *The Electronic Journal of Information Systems in Developing Countries, 42*(1), 1-15. https://doi.org/10.1002/j.1681-4835.2010.tb00299.x

Silver, L., & Johnson, C. (2018). *Internet Connectivity Seen as Having Positive Impact on Life in Sub-Saharan Africa*. Retrieved from Pew Research Center.

Wyche, S., & Olson, J. (2018). Kenyan Women's Rural Realities, Mobile Internet Access, and "Africa Rising". *Information Technologies & International Development, 14*, 33-47.

Copyrights