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Using radio and interactive ICTs to improve food security among smallholder farmers in Sub-Saharan Africa☆

Heather E. Hudson [a,b,*], Mark Leclair [b], Bernard Pelletier [b,c], Bartholomew Sullivan [b]

[a] University of Alaska Anchorage, USA
[b] Farm Radio International, Ottawa, Canada
[c] McGill University, Canada

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ABSTRACT

Radio is the most widely used medium for disseminating information to rural audiences across Africa. Even in very poor communities, radio penetration is vast; it is estimated there are over 800 million radios in Sub-Saharan Africa. The paper summarizes evidence on food insecurity in Sub-Saharan Africa and strategies to provide information on innovative agricultural practices to smallholder farmers. The research in this paper is then discussed within the context of research on information and communication technologies (ICTS) for development. Next, the paper presents the ICT-enhanced participatory radio campaign approach and ICT innovations introduced by Farm Radio International, a Canadian nongovernmental organization. The paper analyzes two participatory radio campaigns that use both listening groups and ICTs to engage African farmers. Research on these radio campaigns in six African countries is reported to examine how the participatory approach impacted listenership, knowledge and initial adoption of agricultural techniques and practices presented in the radio campaigns. The authors conclude that the findings of research on these projects could be highly relevant for increasing awareness and adoption of agricultural practices in Sub-Saharan Africa. They also appear promising for other development sectors and for other developing regions.

1. Introduction

Developing regions face many critical challenges, of which the most basic is producing sufficient food for their people. Some 220 million people in Sub-Saharan Africa (SSA) do not have enough to eat; three quarters of them live in rural areas. They depend on farming to feed themselves and to generate income for other needs on land that is often prone to natural disasters such as drought or floods. Development agencies such as the UN's Food and Agriculture Organization (FAO) state that Africa is in a food security crisis (FAO, IFAD, WFP, 2015).

Radio remains the most widely used medium in rural Africa and a key instrument of strategies attempting to reach people who may be illiterate and are often without electricity. In the communities participating in the projects described below, approximately 76 percent of households owned a radio (Farm Radio International, 2011b). Radio is therefore an instrument of choice for creating awareness of best practices to enhance food security among African farmers but it also has the potential to go beyond solely dissemination of information to help increase adoption of innovative agricultural practices.

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* Corresponding author. Institute of Social and Economic Research (ISER), University of Alaska Anchorage, USA.
E-mail address: hehudson@alaska.edu (H.E. Hudson).

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With the rapid development and penetration of information and communication technologies (ICTs) in rural Africa, there is now an increased interest from both the communication-for-development (C4D) and agricultural R&D communities in assessing the potential of ICTs to contribute to delivery of extension and advisory services and to rural development in Africa (Aker, 2011). In particular, given the widespread access to radio broadcasts, there is a strong interest in exploring ways in which ICTs can enhance traditional radio programming (Gilberds & Myers, 2012; Manyozo, 2009). Within that context, the purpose of this paper is to present an approach that integrates ICTs with radio programming to enhance interactivity and farmer participation, and thus increase the potential for adoption and scaling-up of agricultural innovations.

The paper is organized as follows. First, we summarize evidence on food insecurity in Sub-Saharan Africa (SSA) and strategies to provide information on innovative agricultural practices to smallholder farmers. We then we place the research in this paper within the context of research on ICTs for development (ICT4D). Next, we present the ICT-enhanced participatory radio campaign (PRC) approach and ICT innovations introduced by Farm Radio International (FRI), a Canadian nongovernmental organization (NGO) that supports radio broadcasting for rural development in Africa. Two major FRI projects involving six countries in East and West Africa are then presented and analyzed to examine how the participatory approach impacted listenership, knowledge and initial adoption of agricultural techniques and practices presented in the radio campaigns. Finally, we present conclusions and lessons for rural development and communications policies.

2. The challenge of food insecurity in Sub-Saharan Africa

With 13 percent of the world's population, SSA's population includes a disproportionate 27.7 percent of the world's undernourished (FAO et al., 2015). Although the prevalence of undernourishment in SSA is estimated to have declined from 33 percent to 23 percent between 1990–92 and 2014–16, with the growing population, the total number of undernourished people has continued to increase to approximately 220 million in 2014–16 compared to 175.7 million in 1990–92. Thus achieving food security in SSA remains one of the key challenges facing national governments and the international development community. The majority of people affected by poverty and food insecurity in SSA live in rural areas; their livelihoods consist primarily of family farms involved in agricultural, fisheries, pastoral, community forestry, or aquaculture activities (FAO, 2014). Their heavy reliance on natural resources and ecosystem services and the relative weakness of rural institutions contribute to increasing the vulnerability of these family farms to environmental and climatic shocks, market volatility, and political unrest - a vulnerability that was clearly demonstrated during the 2007–2008 food crisis (Headey & Fan, 2010; IFAD 2011; ILO 2012).

The relatively slow progress in reducing food insecurity in SSA thus raises crucial questions about how national governments and the international community approach food security research and development initiatives (Hickey, Pelletier, Brownhill, Kamau, & Maina, 2012). Despite the development and testing of agricultural innovations that have demonstrated a clear potential to enhance household food and nutrition security, a major challenge remains to increase the uptake of these practices by smallholder farmers and to scale-up these practices over larger populations and geographical areas.

3. Facilitating innovation among smallholder farmers

Many agricultural practices have been developed and proposed over the years to address the problem of food and nutrition insecurity in rural areas. Often presented as components of larger strategies such as climate-smart agriculture (Lipper et al., 2014), agro-ecology (Altieri, 1999), integrated landscape management (Bailey & Buck, 2016), or resilient agriculture (Bennett et al., 2014), examples of practices include the diversification of crops and animals within farming systems, the cultivation of more nutritious and drought tolerant crops, integrated soil fertility and water management practices - e.g., composting, green manure, fertilizer trees, minimum tillage, improved post-harvest storage and processing methods, integrated pest management, and improved livestock management practices. Furthermore, in addition to improving agricultural productivity, farmers need appropriate strategies to generate income from their crops and livestock and access viable input and output markets. Smallholder farmers' access to relevant and timely information regarding these practices is thus a necessary component to enhancing food security in rural areas. Yet awareness alone is not sufficient; there is also a need to address the social, institutional and policy processes that affect farmers' capacity or willingness to implement these new practices.

Agricultural extension and advisory services (EAS) have the potential to play a vital role in addressing some of these challenges (Davis, Babu, & Blom, 2014). In effect, in addition to their more traditional role of knowledge broker for the dissemination of agricultural technologies, EAS are playing an increasingly important role in supporting linkage building and facilitation activities that can contribute to enhancing the institutional and social processes underlying innovation among small-scale farmers (Kilelu, Klerkx, Leeuwis, & Hall, 2011; Klerkx, Schut, et al., 2012; Muhammad, Maina, Pelletier, & Hickey, 2016). The emphasis is then put on creating an enabling environment for innovation through the facilitation of social learning and collaboration among farmers and other stakeholders, and the building of farmers' capacity to operate within their existing institutional environment (Davis & Heemskerk, 2012; Klerkx, Van Mierlo, & Leeuwis, 2012; Sulaiman & Davis, 2012).

4. Radio for development and ICT4D

The theoretical foundations of the research presented below rest on lessons from three inter-related fields of research:

- The effects of mass media, particularly in rural and developing regions

- The diffusion of innovations
- The role of interactivity in learning and adoption.

Research on the role of broadcasting media in development has been carried out since the 1960s, in sectors including agriculture, education, health care and economic development (see Schramm, 1964). McAnany (2012) provides a comprehensive review of the field of communication and social change, focusing primarily on developing regions. Rogers (2003, first edition 1962) defined diffusion as the means by which an innovation is communicated through certain channels over time to members of a social system. He identified various steps in the process of adopting an innovation, the role of information at various steps in the process, and channels that included both mass media and interpersonal communication. Numerous communication researchers have applied diffusion theory in analysis of the adoption of innovations in developing regions (Zanello, Fu, Mohnen, & Ventresca, 2016).

Radio programs, often in conjunction with agricultural extension and other outreach activities, have been frequent components of agricultural campaigns. One of the earliest efforts to use radio for rural development was the Canadian Farm Radio Forum beginning in the 1940s. Interactivity in the form of listening groups where farmers met and discussed the content of the radio broadcasts was part of the radio farm forum model on the Canadian prairies. In developing regions, radio broadcasts have been included in development campaigns and as components of distance education curricula since the 1960s. Radio remains an effective means of reaching rural Africans, as more than 75 percent of households in SSA have radio sets. In the past decade, cellular network coverage has expanded to include rural areas, and mobile phones have also proliferated, even among low income rural populations. By mid-2014, there were 329 million unique subscribers in SSA, equivalent to a penetration rate of 38 percent (GSMA, 2015). Thus many households, even in rural regions, have access to a mobile phone.

Interactivity has been found to increase learning and adoption of new practices through such techniques as listening groups and classroom activities to accompany instructional programs, and more recently through interactive technologies such as mobile phones (Hudson, 2006, 2014). The value of interactivity also relates to the view that innovation processes, which underlie farmers' adaptation capacity and decisions to uptake new practices, could be considered an outcome of learning, reflective, and transformative processes involving interactions among multiple stakeholders and institutions (Hall, Janssen, Pehu, & Rajalahti, 2006). Development practitioners and researchers have thus sought to harness the potential of these new Information and Communication Technologies (ICTs) in development initiatives (e.g., Aker, 2011; Gilberds & Myers, 2012; Meera, Balaji, Muthuraman, Sailaja, & Dixit, 2012; Munyua, Adera, & Jensen, 2009). Development agencies such as the FAO have drawn attention to the potential of new applications such as radio streaming and websites and other materials available online (Girard, 2003). Funding agencies have begun to support projects exploring the potential of ICTs to achieve development goals. Numerous studies, mostly at the macro level, have provided evidence of the impact on socio-economic development of the rapid diffusion of mobile phones and increasing access to the Internet (see, for example, Katz, 2012; International Telecommunication; Union, 2015; Waverman, 2005; World Bank, 2016).

5. FRI's participatory radio approach

FRI's efforts to integrate interactive ICTs in the radio campaigns are based on lessons from this research on the role of communication in development: (1) that modern technology can be used for the production of more compelling and entertaining content that can build and hold an audience's attention over time, and (2) that modern technology can facilitate more substantive interaction from the listening audience. In turn, based on findings of the research cited above, engaging content and audience interactivity could result in increased knowledge acquisition and adoption of agricultural practices presented in the radio programs.

For more than 30 years, FRI has developed agricultural content for use by African radio stations, and in recent years, FRI has trained African broadcasters to produce and deliver development programs for farmers. Building on this experience, FRI has recently undertaken several initiatives to introduce participation and interactivity in rural radio campaigns as part of a strategy to increase knowledge and ultimately adoption of improved agricultural practices that could increase food security. The use of ICTs, particularly mobile phones, has become an important component of this strategy.

The rural radio forums in Canada operated on the principles of "Listen, discuss, act." Interaction among listeners is a crucial component in communication for development. The second step of "discussion" can potentially benefit greatly from the two-way nature of interactive radio programming incorporating mobile phone technology. The proliferation of mobile phones has made possible implementation of several innovative strategies to enhance FRI-supported programming in SSA. Technologies ranging from recordable wind-up radios distributed to community listening groups to interactive voice response (IVR) systems are components of FRI's modern interactive radio strategies. These innovations enable FRI programs to expand from a one-way information delivery medium to provide a platform for knowledge exchange and discussion among farmers.

The interactive strategy discussed in this paper is known as a Participatory Radio Campaign (PRC) (Farm Radio International, 2011a). The PRC is a planned series of radio programs broadcast to a targeted farming population over a specified period of time (usually about four months), and is intended to help farmers adopt a particular farming practice or improvement. PRCs are designed to engage farmers in the selection of topics and to engage farmers at every step. Farmers are involved in:

- selecting the improvement or innovation to be featured;
- discussing the pros and cons of adopting it;
- making an informed decision about whether or not to take up the improvement;
- providing practical advice during the adoption process (Farm Radio International, 2015a).

Table 1
Technological innovations used in FRI projects.

Problem addressed	Technology used	Details of intervention
Increasing listenership	SMS text message reminders	SMS reminders are sent out 30 minutes before the beginning of each weekly broadcast, reminding listeners to tune in and remind their neighbors.
Ensuring radio coverage in hard-to- reach locations	Wind-up radios with SD card slots	Community listener groups, especially in areas with spotty radio coverage, are given wind-up powered radios that are capable of recording broadcasts for later listening sessions. SD cards can be swapped by staff from radio stations who travel weekly to hard-to-reach locations, effectively providing radio programs beyond radio coverage.
Ensuring interaction by large numbers of audience members	Beep-2-vote missed call technology	FRI has developed a simple method of gathering votes from audiences using missed calls. Radio stations can solicit real-time feedback from their audience on "yes" or "no" (or any binary question) and aggregate votes using web-based software. This technology is both free for the user and easy for almost anyone with access to a mobile phone.
Building a local listener database	Voice-based registration trees	Radio stations in Tanzania and Uganda have used voice registration trees. Listeners call a number, hang-up and are called back by an interactive voice response (IVR) system to opt-in to receiving future communications. This technique engages radio audiences to enable more regular future interaction. Radio stations and development partners are also able to gather valuable demographic information from registrants.
Ensuring deeper interactions with targeted information	Interactive voice response (IVR) polls and quizzes	Like beep-2-vote, farmers can call a number and hang up to initiate a free callback. A voice-based menu provides a platform to deliver more intricate multiple choice polls and quizzes. The data gathered from these interactions can be used to provide content for future broadcasts as well as feedback for mid-course corrections for radio producers. This system does not require literacy and is free-of-charge for the caller.
Providing content for later programs	Interactive voice response (IVR) "leave a message" service	IVR systems include an option to "leave a message." This feature is often included as a way for farmers to leave open-ended comments or questions for use in future radio programs. It has also been employed as a means to gather monitoring and evaluation data for radio projects.
Linking listeners with valuable services	Beep-4-services	Using both SMS and voice-based systems, farmers can receive SMS messages or call backs after sending a missed call to obtain useful information. Weather information, planting material procurement locations and contact information for local input providers are delivered by voice or SMS. These links create a useful extension to radio programs to increase listener engagement as well as providing a valuable on-demand service.
Capturing voices of farmers	Low-cost MP3 recorders	Inexpensive MP3 recorders with good quality audio recording capabilities allow radio broadcasters to include more farmers' voices on the air, helping to add legitimacy to broadcasts. Previously, stations owned one or two expensive recorders used only by senior staff. This democratization of field recording has resulted in a major improvement in field recording for African broadcasts.

A key component is a Community Listening Group (CLG) which listens to the programs and discusses them, and provides regular feedback. The CLG provides interactivity through discussion along the lines of the original farm radio forum, but also uses ICTs to provide feedback and interact with the radio programmers and resource people interviewed, such as extension officers.

6. Enhancing participation through interactive ICTs

FRI has developed a suite of ICT tools to both simplify and increase interactions between audiences and broadcasters. Mobile phones are widely available in rural Africa, with subscribers typically using "pay as you go" pricing models to prepay for service in small increments. To save money, rather than paying for SMS or voice calls, users may call and let the phone ring once and hang up (known as beeping) to signal a message to someone they know. The message might be predetermined, such as "I have arrived," or a request for the recipient to return the call. FRI has adapted this technique as a means for farmers to provide feedback about radio programs. An example is Beep-2-vote, in which a broadcaster might ask listeners to vote on what topic they want to hear about the following week by beeping a different telephone number for each choice. The broadcaster can tally the votes and announce the winning selection on the air (Farm Radio International, 2015b).

Low-cost software can also be used to build a database of mobile phone numbers. This technique has been used in PRCs to build a contact list of members of the community listening groups so that they can be reminded to listen to the program. While the station must pay for the SMS messages, they can be a cost-effective means of encouraging listening and participation. FRI developed an application using Telerivet, software that can be loaded on an Android phone, to help radio stations track SMS and beeped or missed calls. The smartphone must be connected to the Internet, for example through a mobile data (3G) connection or Wi-Fi. The station can organize its contact list using a web browser on a computer, and can set up call outs, such as reminders 30 minutes before a program. The software can also aggregate responses to Beep-2-vote questions and display them for the broadcaster in real-time (see Farm Radio International, 2015b and Telerivet).

Since some farmers may be illiterate and unable to type an SMS, another feature that can be added to Beep-2-vote is voice messaging. Farmers' opinions can be recorded and then played on the radio using the "Beep2LeaveVoice" message service. This service has also been used for buyers and sellers, who leave their contact details, which are then aired during the radio broadcast. The platform for this application was developed by a Ghana-based start-up (see Votomobile).

Interactive Voice Response (IVR) systems can be used to provide several forms of interactivity with listeners. Listeners can call a number, hang up, and be called back by the system so that they do not have to pay to opt-in for future information. IVR systems can also

be designed with menus for polls or quizzes. The listener can call the IVR number, hang up, and receive a return call offering prompts to select choices from menus. These IVR call-back systems are free for callers and do not require literacy.

The community listening groups in the projects described below shared a wind-up, solar-powered, radio set with MP3 recording and playback built in to facilitate group listening. They could also record the programs for later listening and record their discussion or comments. The radios also have SD card slots so that the cards may be swapped out by radio staff. They can thus provide access to programs recorded on the cards in areas where reception is poor.

Low-cost MP3 recorders allow broadcasters to collect interviews and wild-sound audio of high quality on field visits. Along with digital editing technology, this inexpensive but valuable equipment has added a level of professionalism to radio broadcasts.

These technological innovations and applications are summarized in Table 1.

7. Mapping audience coverage and reach

To estimate the impact of rural radio campaigns, it is important to know the reach or population covered by rural radio broadcasts. This information is generally not available for African radio stations covering rural areas; any available estimates are generally inaccurate or out-of-date. In order to create reliable estimates of potential listeners, actual listeners, and a radio station's "broadcast zone," FRI has developed a process for creating maps that show broadcast coverage zones for its radio station partners.

FRI collected the following information from each station:

- the location of the radio station transmitter (using GPS)
- the transmitter height above average terrain (HAAT)
- the effective radiated power (ERP) of the transmitter (in watts)
- the gain of the transmitter (dBi)

These four variables are fed into open-source GIS mapping software that adheres to Federal Communications Commission standards for determining FM radio contours based on the principles of FM radio signal propagation shown in the Irregular Terrain Model (ITM) (Longley & Rice, 1968). A detailed description of the mapping methodology can be found in FRI 2015a.

Population maps are overlaid with the radio contour maps produced by this method, and two calculations were made in each broadcast zone:

- total potential population – the population in the station's broadcast coverage zone, and
- total potential rural population – the rural population in the station's broadcast zone ("rural" is defined as less than 400 people/km^2). Total adult population is calculated using estimates of adult population percentages in each country from UN data.

8. Interactive farm radio services project in East Africa

8.1. Project overview

African farmers need better access to agricultural information to provide sufficient nutritious food for their families and communities and to help them plan for and cope with climate change. An interactive radio project was designed to help small-scale farmers to increase production of nutritious food in the context of a changing climate. Though not exclusively directed to women, the project actively engaged women farmers, invited them to express their information needs regarding farming for nutrition and climate smart agriculture, and linked them through interactive and participatory radio with the relevant researchers, results, inputs, services and markets.

The fifteen-month project was carried out in Ethiopia, Malawi, Tanzania, and Uganda. A radio station partner in each country was trained in the PRC approach. A participatory model including listening groups and interactives ICTs was implemented to provide an opportunity for men and women farmers and researchers to interact to discuss and address agricultural challenges together. In each country, consultations were thus conducted in the communities to identify the agricultural innovation to be promoted in the PRC. Key criteria used for the selection of these innovations included: climate-smart, nutrition sensitive, potential to benefit women, linkage to existing input and output markets. The following practices were selected:

- Ethiopia: Improving the production of the staple crop enset (*Ensete ventricosum*);
- Malawi: The use of marker ridges in conservation agriculture;
- Tanzania: Improving the production of sorghum (*Sorghum bicolor*);
- Uganda: Introduction of the cassava (*Manihot esculenta*) NASE 14 variety.

In each case, the PRC included the promotion of a basket of practices associated with the selected agricultural innovation.

A total of 151 hours of participatory radio programs was broadcast in the four campaigns. Using the mapping methodology outlined above, FRI estimated a potential listening audience of more than five million adults in the broadcast zone of the four radio stations, and approximately 2.2 million farmers listened to at least one PRC episode.

Listening groups were organized in each country, with a total of 82 listening groups consisting of 2313 members, of which 51.5 percent were women. Several of the ICT strategies described above were used in the campaigns. ICTs were employed for a number of purposes, including:

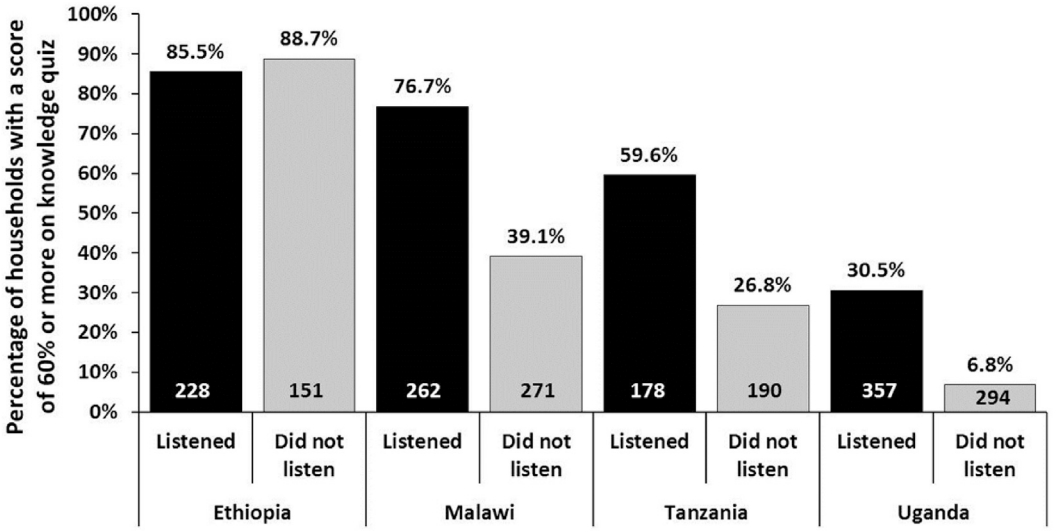

Fig. 1. Percentage of listening and non-listening households with a score of 60 percent or more on the knowledge quiz for the *Interactive Farm Radio Services* project. Total sample size for each category appears at the bottom of the bar for a grand total of 1931 households.

- monitoring (for example, to understand what farmers were learning);
- promoting listener participation;
- enabling farmers to ask questions;
- sending out information on request (concerning weather or markets);
- gathering listener and CLG feedback on the quality of the shows.

For example, in Tanzania, SMS alerts were sent out before the programs, and weekly Beep-2-vote questions were included with follow-up SMS to mobile phones. Also, every week, the radio station received feedback from Community Listening Groups (CLGs) via a tool called *Sauti ya Mkulima Wiki Hii* – "Voice of the Farmer This Week." After discussion, each group's nominated contact person left a missed call at the call-in telephone number, and received a call back. The contact person sent the feedback by pressing numbers on the phone. The CLGs were also able to leave comments by recording their voices on the IVR service.

In Malawi, SMS and voice platforms were selected to increase interactivity, share information and gather feedback from farmers throughout the campaign. In Uganda, farmers own mobile phones, but many are not able to write an SMS. With the use of IVR, farmers' opinions could be heard using the "Beep2LeaveVoice" message application. This service was also used for buyers and sellers, who left their contact details, which were then aired during the radio program. In total in the four campaigns, nearly 20,000 SMS alerts were sent in advance of the programs. There were approximately 25,000 interactions via the "Beep-2-vote" system.

8.2. Research methodology.

Between March and May 2015, an outcome evaluation survey was conducted to assess the effectiveness of the PRCs across the four project countries. The survey was administered to communities purposefully selected within the area covered by each participating radio station. In addition, a number of communities were initially selected to act as control communities that did not receive the radio signal. However, high levels of listening in the regions thought to be outside of the range of the broadcast made it difficult to identify true controls. Therefore, the assessment of the effect of the PRC was done instead by comparing listening vs. non-listening households across all communities. In total, the project included 26 communities across the four countries.

In each community, a systematic random sampling of every nth household was performed. The survey concentrated on changes in knowledge, uptake or trial of the promoted practice, and quality of the radio programs. A total of 1931 respondents were interviewed with a structured survey instrument. Interviewers entered responses on mobile phones equipped with software that recorded the responses and sent data to a central site. A one-tailed z-test was used to assess whether a significantly greater percentage of listening households than of non-listening households scored above 60 percent on the knowledge quiz, and similarly, whether a significantly greater percentage of listening households than non-listening households implemented at least one of the promoted practices.

8.3. Research findings

Fig. 1 shows the percentage of listeners vs. non-listeners who obtained a score of at least 60 percent on the knowledge quizzes administered in each country. In Malawi, Tanzania and Uganda, a significantly higher percentage of households listening to the PRC program obtained a score equal or greater than 60 percent than did non-listening households ($p < 0.001$). Performance on the

knowledge quiz was better for Malawi with 76.7 percent of listeners scoring at least 60 percent on the quiz, followed by Tanzania with 59.6 percent of listeners achieving that score. While the difference was also significant in Uganda, less than 30 percent of listeners achieved that score. In Malawi and Tanzania, non-listeners may have had greater prior knowledge of marker ridges and sorghum, respectively, compared to the prior knowledge of the cassava variety NASE 14 in Uganda.

Ethiopia displays a pattern different from the other three countries. The level of knowledge is higher than for the other countries with no apparent effect of the PRC program. With about 87 percent of the households in Ethiopia obtaining a score of 60 percent or higher, results suggest that the farmers in the project area may have already been quite familiar with enset, a traditional and important staple crop in the south and southwestern parts of the country (Brandt et al., 1997; Tsegaye & Struik, 2002).

As might be expected, listening to more programs was associated with higher scores on the knowledge quizzes. Those who listened to half of the programs scored more than 45 percent higher than those who did not listen to any programs, while those who listened to all the programs scored 68 percent higher on the knowledge quizzes (Fig. 2).

Fig. 3 shows that being a member of a community listening group (CLG) boosted knowledge levels even more, with members of CLGs scoring slightly higher than all listeners shown in Fig. 1. With the exception of Ethiopia (see discussion above), the difference is significant at $p < 0.001$.

Listening to the PRC also had a significant impact on the number of households implementing at least one of the promoted practices in Malawi, Tanzania, and Uganda (Fig. 4). In Uganda the percentage of listeners implementing at least one practice was 2.7 times the percentage of non-listeners, while in Tanzania it was 2.9 times the percentage of non-listeners. In Malawi, 1.9 times the percentage of listeners compared to non-listeners implemented at least one promoted practice, with significance for all three countries at $p < 0.001$. Again, Ethiopia was an outlier, with a much smaller increase among listeners ($p = 0.057$), and more than 50 percent of both listeners and non-listeners implementing a promoted practice (see discussion above).

Recognizing women's essential role in farming in SSA, as well as their primary responsibility for feeding their families (World Bank, FAO, & IFAD, 2009), the project adopted a gender-sensitive approach that facilitated both women and men's participation in project activities and the selection of agricultural practices that could address their needs and priorities. Responses from the outcome evaluation survey were therefore disaggregated by gender and analyzed to compare female and male listeners and non-listeners. For female respondents, 48.4 percent listened to a radio program, compared with 57.9 percent of male respondents ($p < 0.001$; two-tailed test). In all cases except Ethiopia, both female and male listeners were significantly more likely to implement at least one of the promoted practices than non-listeners (all at $p < 0.001$ except male respondents in Malawi at $p = 0.003$). No statistically significant differences were found in the proportion of households implementing at least one practice between female and male listeners (Fig. 5).

More than 80 percent of members of listening groups in Malawi and Tanzania implemented at least one of the practices discussed in the radio campaigns. While the percentage was much lower in Uganda, almost twice the percentage of group members implemented the improvement as nonmembers (Fig. 6). The greater proportion of households adopting at least one practice in CLG members compared to non CLG members was significant at $p < 0.001$ for Malawi, Tanzania, and Uganda, and at $p = 0.013$ for Ethiopia.

When disaggregating the results for the listening groups by gender and using a two-tailed z-test, among CLG members, the percentage of respondents implementing at least one of the practices was higher for men (73.9%) than for women (50.9%) in Ethiopia ($p = 0.005$) and higher for women (86.6%) than for men (66.7%) in Malawi ($p = 0.021$). The difference was not statistically significant in Tanzania and Uganda ($p = 0.889$ and $p = 0.952$, respectively).

It is not possible to disaggregate from the available data whether any specific interactive ICT strategy made a difference to adoption. However, all listeners were exposed to the participatory model of the radio campaigns. In addition, the members of the listening groups

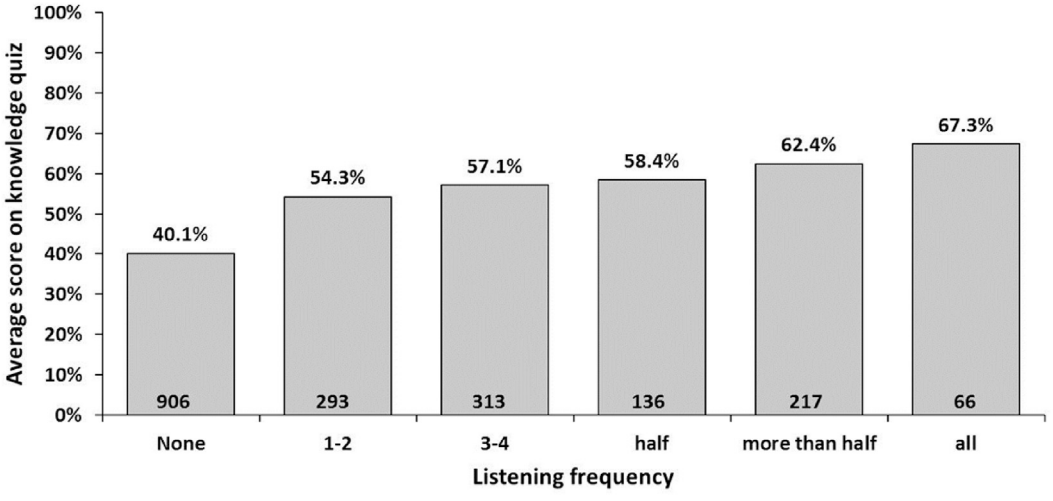

Fig. 2. Relationship between average score on knowledge quiz and listening frequency of PRC episodes for the *Interactive Farm Radio Services* project. Total sample size = 1931.

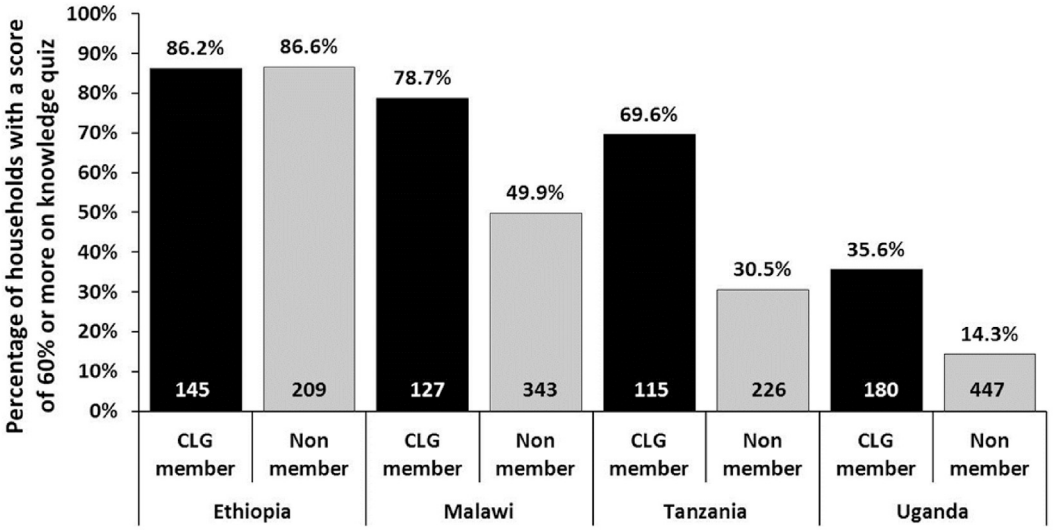

Fig. 3. Percentage of households with a score of 60 percent or more on the knowledge quiz for members and non-members of Community Listening Groups in the *Interactive Farm Radio Services* project. Total sample size for each category appears at the bottom of the bar for a grand total of 1792 households.

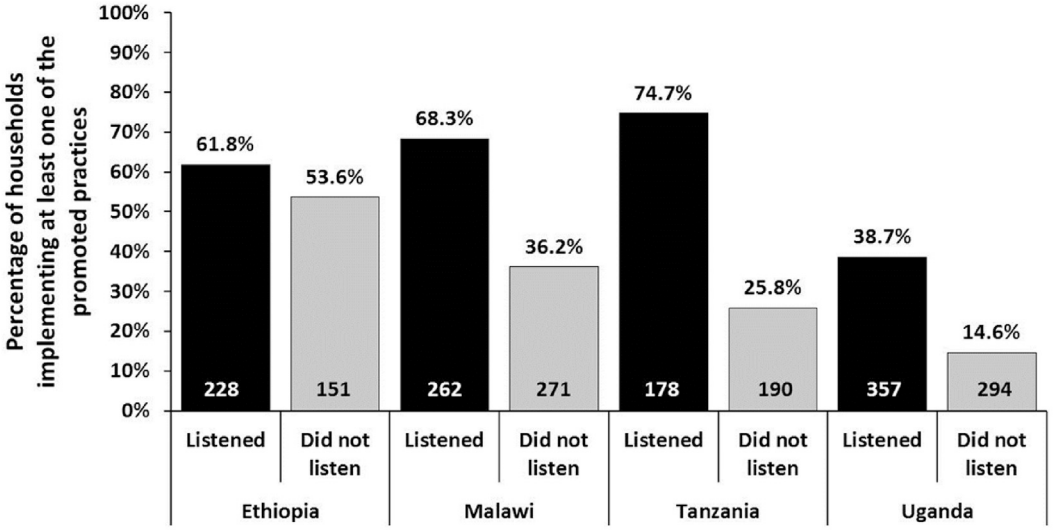

Fig. 4. Percentage of listening and non-listening households that have implemented at least one of the promoted practices in the *Interactive Farm Radio Services* project. Total sample size for each category appears at the bottom of the bar for a grand total of 1931.

were able to interact with each other to discuss the programs and to provide feedback via the IVR systems.

The value of the participatory model is illustrated by some of the comments from those interviewed during the evaluation. An extension officer in Tanzania said the radio programs had been helpful in sharing knowledge and informing farmers: "The usual way of extension services would require me to visit farmers at their fields and it would take me forever to reach all farmers, but with radio and ICT, now I can reach so many farmers in a very short time." In Uganda, farmers said that radio staff visited them and recorded their voices. Many farmers heard their voices on the radio, which they liked and helped them to feel empowered. In Ethiopia, although may knew about enset as a traditional crop, they were not aware of some new farming practices. An extension worker noted: "Enset is in danger of extinction in Kembata area due to severe diseases. Farmers have not got any training [or] information on enset as on other crops. With the coming of the radio program, I heard them say 'the forgotten crop is reviving.' They are motivated by the program" (Farm Radio International, 2015a). In some regions, women who did not have a radio at home listened to the program in their neighbors' houses during coffee ceremonies. An extension worker explained that, "Women take care of all the processes after planting enset. The program enables women to better take care of their enset farm."

In summary, results from the outcome evaluation survey and farmers' individual and group interviews indicate that the ICT-

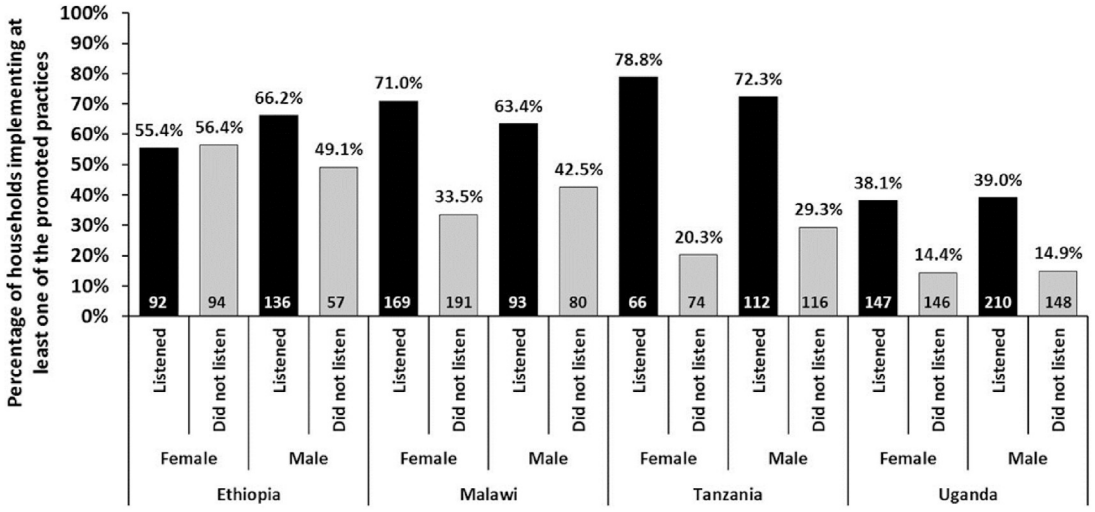

Fig. 5. Percentage of listening and non-listening female and male respondents who implemented at least one of the promoted practices in the *Interactive Farm Radio Services* project. Total sample size for each category appears at the bottom of the bar for a grand total of 1931.

enhanced PRC was effective at increasing awareness and at facilitating farmers' decisions to uptake the promoted practices. The effect of the PRC on farmers' uptake of the promoted practices was similar among women and men even though men had slightly more access to the radio programs. Results from the listening groups, however, in particular in Malawi, highlighted the potential of this approach to enhance women's participation and access to information. Differences in the results obtained in the four countries appear to reflect the particular social, institutional, cultural and technological context within which the selected practices were promoted, highlighting the need to acknowledge these local specificities in developing and assessing the PRC.

9. Reducing vitamin A deficiency with orange fleshed sweet potato

Vitamin A deficiency is a widespread health challenge in SSA (WHO, 2009), which can lead to anemia, decreased growth rate and xerophthalmia; increase the vulnerability to infections, in particular measles, diarrhea, and respiratory diseases; and reduce childhood survival (Sommer & West, 1996). As many as 43 million children under age 5 in SSA are considered at risk for vitamin A deficiency (Aguayo & Baker, 2005). Furthermore, vitamin A deficiency is also known to contribute to maternal mortality and poor health outcomes during pregnancy and breastfeeding (Sommer & West, 1996; Thorne-Lyman & Fawzi, 2012).

Orange foods are rich in beta-carotene, necessary for vitamin A production. In many parts of SSA, sweet potatoes are a staple crop for farming families, but the traditional African sweet potato is pale yellow with a low content in beta-carotene compared to the bright orange varieties consumed in North America (Hagenimana, Carey, Gichuki, Oynuga, & Imungi, 1999). New varieties of African sweet potato have thus been bred that contain much more beta-carotene while also addressing consumers' preference for flavor and texture (Hagenimana & Low, 2000; Low et al., 1997). This "Orange Fleshed Sweet Potato" (OFSP) is a highly nutritious crop with demonstrated health benefits for pregnant women, new mothers and young children (Hotz et al., 2012; van Jaarsveld et al., 2005).

To scale-up the production and consumption of OFSP, FRI launched a three-year initiative using participatory radio and ICT strategies. The project was implemented in Burkina Faso, Ghana, Tanzania, and Uganda, working with 15 radio stations and with national OFSP champions. The OFSP project used similar approaches to the project discussed above, namely the PRC model, including involving target audience members in project design, establishing listening groups, and using a variety of interactive ICTs to enhance program quality and encourage listening and ultimately adoption of various techniques to improve cultivation, marketing, preparation, nutrition and consumption.

9.1. Research methodology

Participating communities were divided into Active Listening Communities (ALCs) and Passive Listening Communities (PLCs). ALCs were defined as communities that received the radio signal and in which there was significant interaction with the OFSP program, either through listening clubs, regular visits from radio station or project staff, or other types of interaction. PLCs were communities that could receive the radio signal, but had no other interaction with the project. Within a radio station's coverage area, ALCs and PLCs were selected purposefully by 1) targeting sweet potato-growing areas, and 2) choosing communities which allowed for travel that fitted within the project budget and timeline. Between April and July 2013, a baseline survey was administered to a random sample of 2219 households located in ALCs and PLCs using a systematic random sampling of every nth household in each community.

Similar to the Interactive Farm Radio Services project in East Africa described above, an outcome evaluation survey (endline survey) was conducted between June and August 2016 to assess the effectiveness of the PRCs across the four project countries. The endline

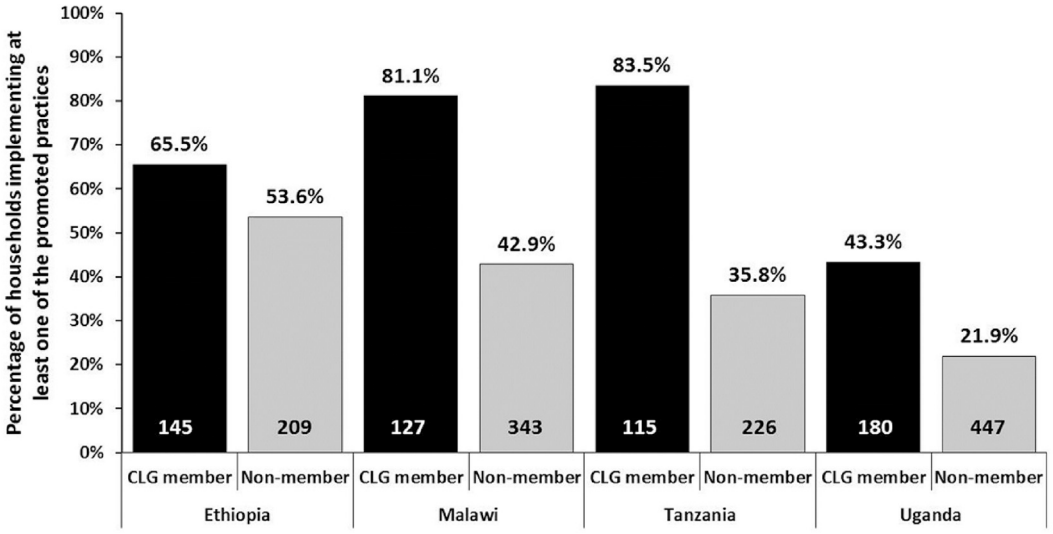

Fig. 6. Percentage of households implementing at least one of the promoted practices for members and non-members of Community Listening Groups (CLG) in the *Interactive Farm Radio Services* project. Total sample size for each category appears at the bottom of the bar for a grand total of 1792 households.

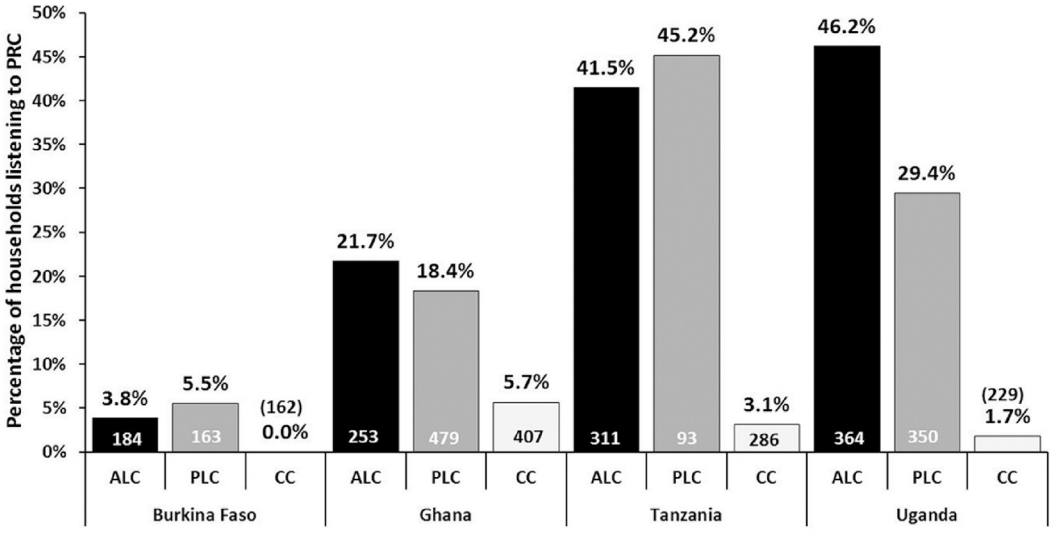

Fig. 7. Percentage of households reporting that they had listened to at least one PRC episode per community type and country for the *Scaling-up Orange Flesh Sweet Potato* project. Total sample size for each category appears at the bottom of the bar.

survey was administered to a new random sample of 3281 households from ALCs and PLCs but also from a number of Control Communities (CCs) that were similar to ALCs and PLCs in terms of agricultural practices and demographics but where it appeared that the communities could not receive the radio signal, again using a systematic random sampling of every nth household in each community. In total, the survey was administered to 58 communities across the four countries. However, the results of the survey in the control communities showed that numerous residents actually did listen to the radio programs. Therefore, the data were re-analyzed to compare all listeners with all non-listeners. We used a one-tailed z-test to assess whether listening households had a greater percentage of households than non-listening households for scores on knowledge quizzes, growing OFSP, or consuming OFSP.

9.2. Research findings

In Uganda, the percentage of households in the ALCs that had listened to at least one PRC episode was significantly higher than the percentage in the PLCs ($p < 0.001$) (Fig. 7). In Ghana, the percentage of the listeners in the ALCs was also higher, but the difference was

not significant. In Tanzania and Burkina Faso, the percentage of listeners was actually slightly higher in the PLCs, but the difference was not significant.

In Ghana and Tanzania, scores on knowledge quizzes were more than twice as high for listeners as for non-listeners. Scores were more than three times as high in Burkina Faso among listeners, although their overall scores were much lower. Those who did not listen to at least one program scored significantly lower in each country ($p < 0.001$) (Fig. 8).

In all four countries, the percentage of listeners who cultivated OFSP was significantly greater than the percentage of non-listeners ($p < 0.001$), although again, Burkina Faso's percentages were much lower. The increase in Ghana was greatest, with 8.9 times the percentage of adopters in listening vs. non-listening communities, followed by 2.3 times the percentage in Tanzania. Overall adoption was highest in Uganda and lowest in Burkina Faso (Fig. 9).

Women play a major role in growing food for their families, and some studies have highlighted how the introduction of OFSP in rural communities may have an important gender dimension such as potential economic and health impact on women compared to men (Mudege, Mayanja, & Muzhingi, 2017; Quisumbing et al., 2015). Data were therefore disaggregated to compare results for female and male listeners and non-listeners. For females, 43.7 percent of respondents listened to a PRC program, compared with 51.0 percent of male respondents ($p < 0.001$; two-tailed test). In all cases, a higher percentage of women who listened to a PRC program tried growing OFSP compared to non-listeners, with the difference particularly striking in Ghana and Tanzania (both at $p < 0.001$). In Tanzania and Uganda, a higher percentage of women listeners planted OFSP than male listeners ($p = 0.006$ and $p = 0.001$, respectively). A similar trend was observed for Burkina Faso but was not found to be statistically significant ($p = 0.153$) (Fig. 10).

The percentage of listeners who consumed OFSP in their household within the past week was significantly greater than the percentage of non-listeners, with consumption highest in Tanzania and Uganda ($p < 0.001$ and $p = 0.004$, respectively) (Fig. 11). There may be several explanations for the relatively low consumption of OFSP compared to the percentage of farmers cultivating them. Many farmers may decide to grow OFSP primarily to sell, so that the crop is being consumed, but primarily by the people who purchase it in the marketplace, rather than by the farmers. Families may also need time to become accustomed to the new food (Low et al., 2015; Yanggen & Nagujja, 2006).

Data were pooled from all four countries to compare the percentages of households that (1) had a score of 70 percent or higher in the knowledge quiz; (2) were growing OFSP; and (3) fed OFSP to their family in the last seven days before the surveys between the baseline and endline surveys (Fig. 12). For each of these three variables, the listening households in the endline survey had higher percentages than households in the baseline survey and non-listening households in the endline survey ($p < 0.001$), suggesting that the interactive PRC initiative may have had a positive impact on knowledge and adoption of the practices of both growing and consuming OFSP.

The Scaling-up OFSP Project provided evidence that the ICT-enhanced PRC model contributed to increasing knowledge about, planting, and consumption of OFSP. Important differences among the four countries, however, highlighted the importance of appropriately considering the context-specific factors influencing farmers' decisions to grow and consume OFSP – such as food preferences, market access, post-harvest storage, and previous extension messages (Low et al., 2015; Mudege et al., 2017; Yanggen & Nagujja, 2006).

10. Conclusions

The results obtained from the projects described in this paper demonstrate the potential of the ICT-enhanced participatory radio approach to enhance food security of smallholder farmers in SSA. Broadcast radio remains an important means of reaching rural

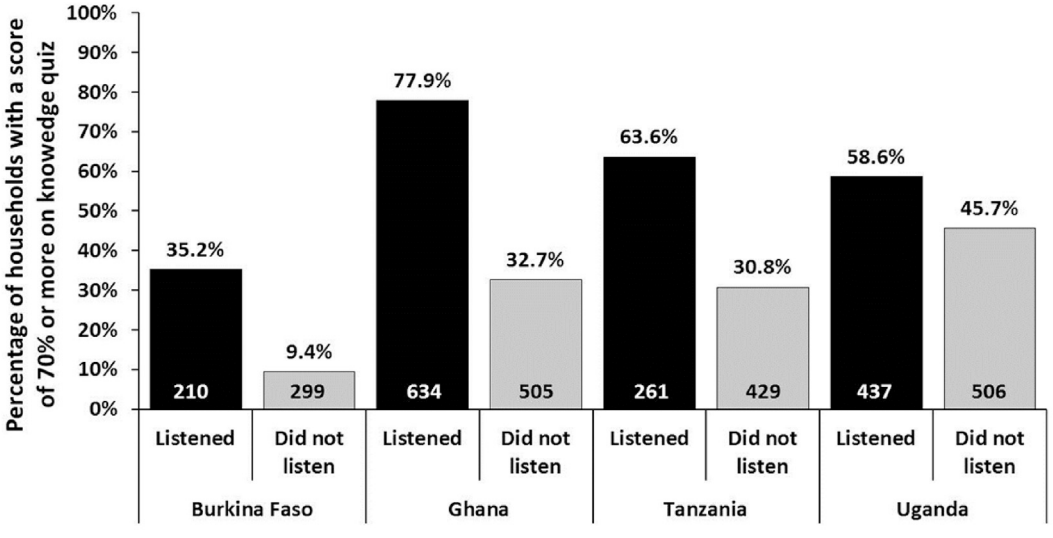

Fig. 8. Percentage of listening and non-listening households with a score of 70% or more on the knowledge quiz for the *Scaling-up OFSP* project. Total sample size for each category appears at the bottom of the bar for a grand total of 3281.

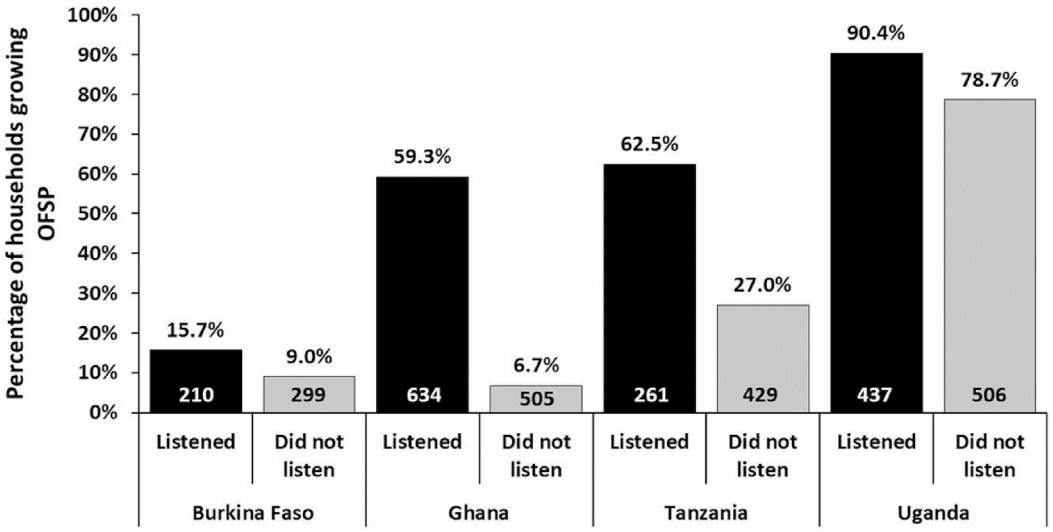

Fig. 9. Percentage of listening and non-listening households growing OFSP for the *Scaling-up OFSP* project. Total sample size for each category appears at the bottom of the bar for a grand total of 3281.

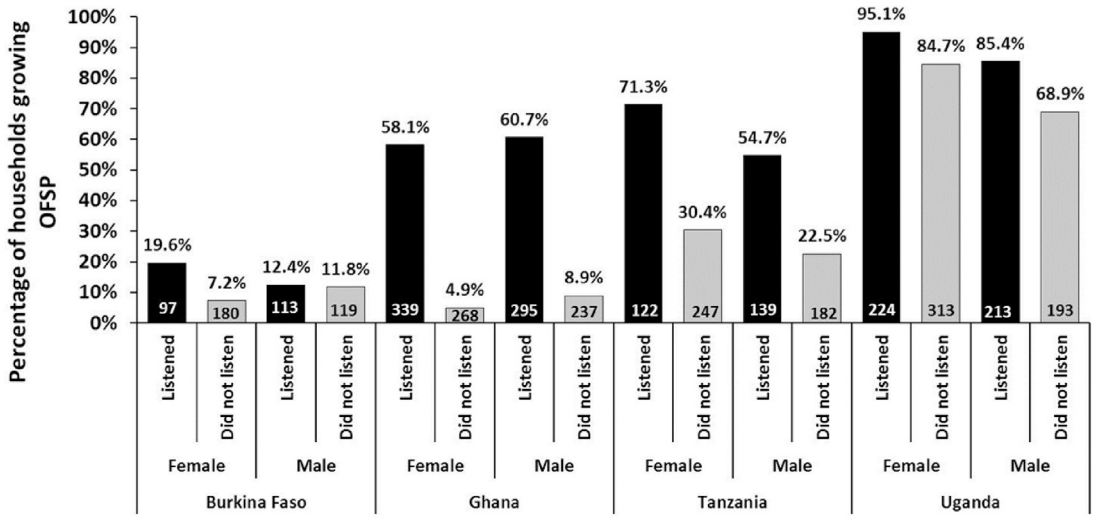

Fig. 10. Percentage of listening and non-listening female and male respondents growing OFSP for the *Scaling-up OFSP* project. Total sample size for each category appears at the bottom of the bar for a grand total of 3281.

Africans. Community listening groups, similar to those pioneered in early farm radio forums, can help engage listeners and increase knowledge. The research indicated that participatory strategies including the use of interactive ICTs can help to engage audiences, increase knowledge of agricultural improvements and innovations, and contribute to higher levels of adoption than result from listening alone. The focus on interactivity also has the potential to contribute to women's empowerment by giving them a voice, facilitating their involvement in decision-making, and strengthening their social capital (Farnworth & Colverson, 2015). These strategies build on earlier field research that showed that interactivity in the form of discussion groups, feedback to extension agents, and other activities could increase knowledge and adoption of practices and skills promoted in mass media broadcasts. In most cases, significantly more listeners adopted the agricultural practice that was the focus of the participatory radio campaign than non-listeners, with this result holding for both female and male listeners. Although some caution should be taken in attributing the observed behavior changes solely to the interactive radio programs, the results obtained in these two projects do suggest the potential of the PRC approach to enhance knowledge and facilitate the uptake of improved technologies by smallholder farmers (see also Hampson, Leclair, Gebru, Nakabugo, & Huggins, 2016; Oyaro & Farm Radio International, 2013).

In order to gain a better understanding of the diffusion, sharing, and utilization of information, future field research could be designed to ask respondents how they gained information about the new practice (which might include learning from others who had

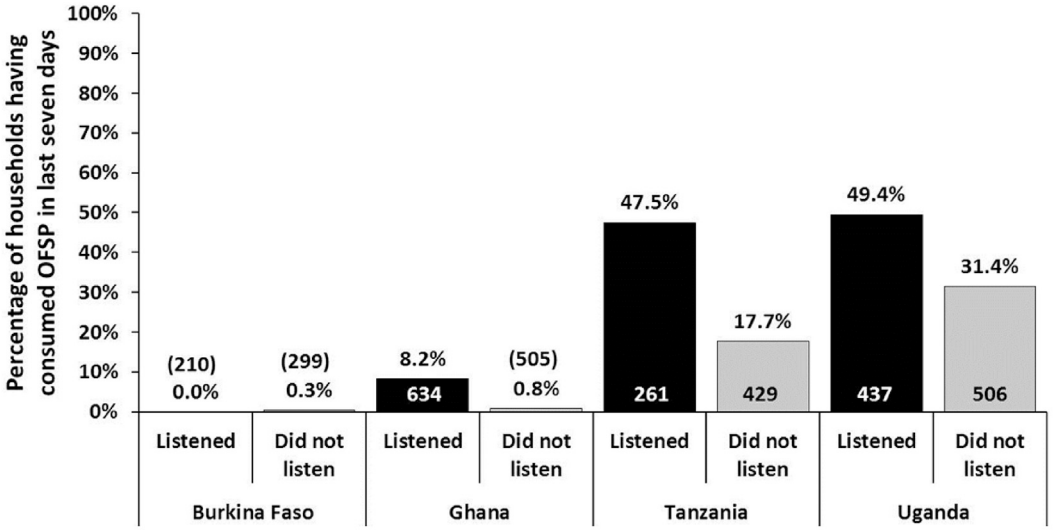

Fig. 11. Comparison of the percentage of households having consumed OFSP in the last seven days between listening and non-listening households for the *Scaling-up OFSP* project. Total sample size for each category appears at the bottom of the bar for a grand total of 3281.

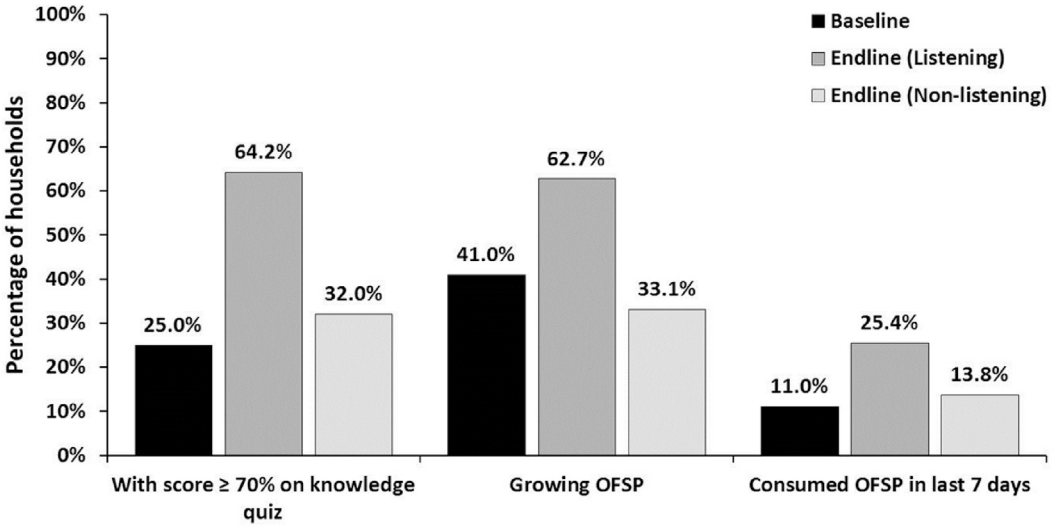

Fig. 12. Percentage of households from baseline and endline – listening and non-listening, surveys that had a score of 70 percent or more on the knowledge quiz; are growing OFSP; and consumed OFSP in the last 7 days. Sample size is 2219 for baseline; 1542 for endline (listening) and 1739 for endline (non-listening).

listened to the program as well as from other sources). Further research is also needed to determine what other factors influence adoption, particularly where overall levels remained low. For example, respondents should be asked to identify barriers to adoption (such as cost, availability of inputs, weather, etc.). Finally, there is also a need for future research to address the methodological challenges associated with assessing the impact of extension services and social learning initiatives, which are implemented in very complex social and institutional environments (Aker, 2011; Davis, 2008; Kristjanson, Harvey, Van Epp, & Thornton, 2014).

Considering the widespread coverage of radio broadcasting and availability of mobile phones in Africa, the approach analyzed here shows great potential to contribute to scaling-up initiatives. In general, the findings of FRI's participatory media projects, showing the effectiveness of mobile phones and software that can be used for feedback, comments, dissemination of additional information on demand, and aggregation and analysis of user data, could be highly relevant for increasing awareness and adoption of agricultural practices in SSA. They also appear promising for other development sectors such as health and community development, and for other developing regions.

There are also implications for telecommunications policy makers. First, radio, including local or community radio, remains an effective means of increasing knowledge in rural areas. Second, widespread rural mobile coverage and affordable mobile services can

facilitate development of participatory strategies that can help to improve food security in SSA. Therefore, policy makers should recognize the ongoing importance of broadcast radio and should adopt policies to extend mobile telephony coverage in rural areas.

Acknowledgments

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