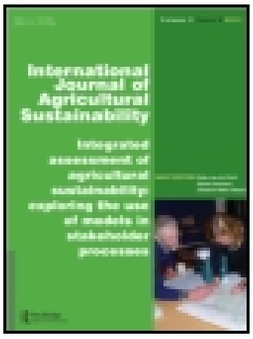

International Journal of Agricultural Sustainability

ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage: https://www.tandfonline.com/loi/tags20

Going digital in agriculture: how radio and SMS can scale-up smallholder participation in legume-based sustainable agricultural intensification practices and technologies in Tanzania

Silvia Silvestri, Musebe Richard, Baars Edward, Ganatra Dharmesh & Romney Dannie

To cite this article: Silvia Silvestri, Musebe Richard, Baars Edward, Ganatra Dharmesh & Romney Dannie (2020): Going digital in agriculture: how radio and SMS can scale-up smallholder participation in legume-based sustainable agricultural intensification practices and technologies in Tanzania, International Journal of Agricultural Sustainability, DOI: 10.1080/14735903.2020.1750796

To link to this article: https://doi.org/10.1080/14735903.2020.1750796

INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY
https://doi.org/10.1080/14735903.2020.1750796

Going digital in agriculture: how radio and SMS can scale-up smallholder participation in legume-based sustainable agricultural intensification practices and technologies in Tanzania

Silvia Silvestri [a], Musebe Richard[a], Baars Edward[b], Ganatra Dharmesh[c] and Romney Dannie [a]

[a]CAB International, Nairobi, Kenya; [b]International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria; [c]ILogix, Nairobi, Kenya

ABSTRACT

In 2016, a study was conducted in Tanzania to assess the impact of radio and SMS in scaling-up smallholder participation in legume-based sustainable agricultural intensification (SAI) practices and technologies. The study aimed to answer the following research questions: (i) does participation in the campaign enhance farmers' knowledge of legume-based sustainable agricultural intensification practices and technologies? (ii) what is the impact of the campaign on the adoption of legume-based sustainable agricultural intensification practices and technologies?; (iii) does exposure to multiple ICT-enabled channels result in larger gains (in terms of knowledge and adoption) than exposure to only one channel? (iv) is it more cost-effective to use radio or SMS alone or use them in combination? The results show that both awareness and adoption are boosted if SMS supports radio campaigns. However, radio alone is the most cost-effective approach. Each dollar spent on the radio campaign results in 2.1 farmers that have adopted at least one new practice, compared with 0.5 farmers for SMS and 0.4 farmers for radio and SMS combined. Other factors were also important in facilitating uptake of legume-based SAI practices, such as gender, age, education and land size, but were not statistically significant when rated against the communication channels used.

KEYWORDS
Radio; SMS; awareness; adoption; legume; Tanzania

Introduction

Improved agricultural legume practices and technologies exist, that provide the opportunity to small scale farmers to increase their crop production and household income (Livondo et al., 2015) and achieve sustainable agricultural intensification (SAI). Limited awareness and knowledge of farmers of improved legume technologies translates in low adoption rates (Letaa et al., 2015). One of the ways to improve farmers' awareness and knowledge is through promotion of agricultural technologies to farmers (Guerin & Guerin, 1994; Juma, 2009). The extent to which farmers succeed in agricultural endeavours relies largely on the availability and access to accurate, reliable and targeted information (Ali & Kumar, 2011; Khoshnodifar et al., 2016; Muriuki et al., 2016). Sustainable development in the agricultural sector is, therefore, strongly dependent on effective communication for dissemination of agricultural technologies to end-users. Extension workers are key providers of agricultural information and advisory services to farmers in Sub-Sahara Africa (SSA) (Davis, 2008). Their role is particularly crucial when it comes to promoting improved agricultural technologies. However, their capacity to provide timely and actionable information to a large number of farmers might be hampered by the low ratio extension worker to farmer, poor infrastructure, together with low motivation and accountability (Aker, 2011; Anderson & Feder, 2007; Bell, 2015). There is a growing body of literature on the strategic application of information and communication technology (ICT) to the agricultural

CONTACT Silvia Silvestri silsilvestri@gmail.com CAB International, Nairobi, P.O. Box 633-00621, Kenya

industry in Africa and the opportunity for economic growth and poverty alleviation that it offers (Aker, 2011; Aker & Mbiti, 2010; Chavula, 2012; Nakasone et al., 2006; Omri Van et al., 2014; Qureshi, 2015). Although fellow farmers, local agro-dealers, and local government agencies still play a key role in farmers' learning and technology adoption (Korsching & Hoban, 2008; Mtega & Ronald, 2013), ICT can supplement interpersonal communication and further validate and disseminate the information and support its adoption. Unlike conventional extension approaches, ICT-based extension advisory methods enable to reach more farmers, often in a timely and cost-effective way (Davis, 2008; Saravanan, 2015). ICTs have therefore the potential for scaling-up smallholder participation in SAI.

Radio is among the most widely used media for disseminating information to rural audience across Africa together with mobile phones, as a result of the increased ownership and widespread use among farmers (Hudson et al., 2017; Sousa et al., 2016; Sullivan, 2011). Hence, they offer the opportunity to reach often remote, dispersed and poorly serviced farmers, by overcoming barriers of distance and poor road infrastructure (Baumüller, 2018). At the same time, radio is one of the most well studied ICT-based extension advisory methods, allowing farmers to access information and service providers to provide information. Innovation has occurred where new ICT-based extension advisory methods are paired with radio. For example, combinations such as radio and mobile phones, often through the use of SMS, can become an important tool in information exchange and community networking.

A few studies are there that have assessed the impact of the use of radio and mobile phone in delivering agricultural information that triggers an increase in awareness and uptake (Aker, 2011; Baumüller, 2018; Hampson et al., 2016; Hudson et al., 2017; Kaskekacharo, 2016). Hudson et al. (2017) have shown that participatory radio campaigns increased knowledge and adoption of promoted agricultural practices in four African countries, including Tanzania. A review of the literature on the impact of mobile phone-based services for farmers in developing countries, conducted by Baumüller et al. (2018), presented contrasting and limited evidence. Fafchamps and Minten (2012) found that SMS did not impact the likelihood of Indian farmers to change crop varieties and agronomic practices. Similarly, Tambo et al. (2019) found that SMS leads to a weak or none impact on knowledge and adoption of pest management practices for fall armyworm. However, other studies have shown that mobile-based services are associated with improved knowledge and adoption of agricultural practices (Fu & Akter, 2016; Larochelle et al., 2019), production of diversified crops (Aker and Ksoll, 2016), gender equality and improved household welfare (Sebakira & Qaim, 2017). The majority of these studies mostly analyze the impact of one communication channel at the time or look at the 'cumulative' impact of the application of a series of communication approaches. Tambo et al. (2019) looked at the combined effects of radio and SMS and found no robust significant effects of exposure to both radio and SMS over radio alone.

In this paper, we assess the impact of an ICT-enabled extension campaign that was used to provide information to small-scale farmers on legume-based sustainable agricultural intensification practices and technologies. 'An extension campaign is a coordinated effort to inform many farmers in a relatively short period of time about an agricultural topic of widespread concern or interest' (Boa et al., 2016). The campaign took place within the framework of the UP-scaling Technology in Agriculture through Knowledge and Extension (UPTAKE) project (http://africasoilhealth.cabi.org/about-ashc/ashc/uptake/) and of the Gender and the Legume Alliance, Integrating Multimedia Communication Approaches and Input Brokerage (GALA) project (http://africasoilhealth.cabi.org/about-ashc/ashc/gender-and-the-legume-alliance/). The campaign used two different ICT applications: interactive radio, and mobile phone short message service (SMS), that were used alone and in combination. It was hoped that the farmer's knowledge and adoption of improved legume technologies would be enhanced by the use of complementary ICT-based extension channels.

Our study contributes to the literature on the effectiveness of ICTs as a means to scale-up smallholder participation by focusing on farmers' knowledge and management of legume technologies, whose adoption rates are still very low across SSA. Furthermore, we add to the literature by comparing the use of radio and SMS alone and in combination. Most previous studies on the impact of ICT-mediated interventions have analyzed these two ICT tools in isolation. In contrast, our study is based on an intervention that allows us to explore their unique and combined effects. The research questions addressed in this

study include: (i) does participation in the campaign enhance farmers' knowledge of legume-based sustainable agricultural intensification practices and technologies?; (ii) what is the impact of the campaign on the adoption of legume-based sustainable agricultural intensification practices and technologies?; (iii) does exposure to multiple ICT-enabled channels result in larger gains (in terms of knowledge and adoption) than exposure to only one channel? (iv) is it more cost-effective to use radio or SMS alone or use them in combination?

There is a growing demand for knowledge on how to use ICTs as a means to scale-up smallholder participation in SAI and consequently improve agricultural productivity and raise incomes. Therefore, the results of the study could better inform donors' investments and ICT projects about efficiency and effectiveness in the use of radio and SMS for communication and extension of legume-based sustainable agricultural intensification practices and technologies.

Study context

Back in 2006, Tanzania was the second-largest producer of dry beans in Sub-Saharan Africa. However, the average yields are still below the potential of 1500–3000 kg/ha given favourable rainfall patterns, and the availability of improved varieties and input such as fertilizer. There are several reasons for low yields by most smallholders, such as poor seed quality, susceptibility to pests and diseases, low soil fertility, and poor crop management (Hillocks et al., 2006). As mentioned, innovative agricultural technologies are available. However, the diffusion process of innovations through information is hindered by farmers' specific characteristics, together with institutional factors and environmental factors. Information on agriculture and natural resources management have been provided to farmers through government extension services, which are effective but reach a few farmers, given the high ration of farmers to extension workers (KIT, 2015). Other sources of information for beans include radio, NGOs, seeds shops, newspapers and fellow farmers. ICT interventions have been also used in the past, although principally through less 'fashion' forms such as village information centres and telecentres (Mtega & Msungu, 2013).

Materials and methods

Radio programme and SMS campaign

During the year 2016, a 16 weeks' radio programme on beans took place in Tanzania (Figure 1). The campaign ran during the cropping season and both radio programme and SMS content were aligned with the beans cropping cycle. The content of the campaign was developed on the basis of a technical brief, driving quality and consistency of messages, and compiled in a participatory manner with experts and stakeholders. The technical brief reflected

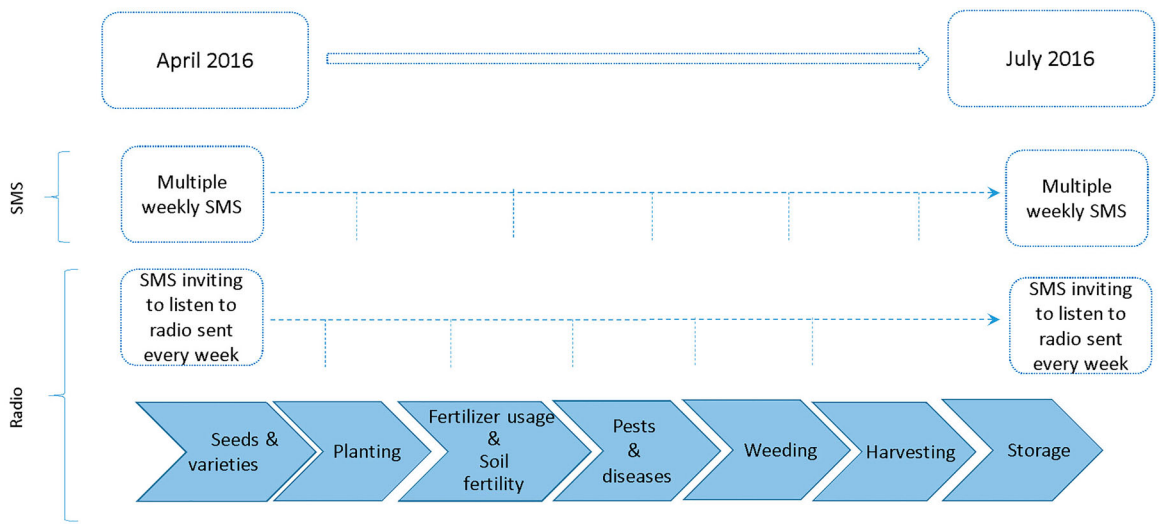

Figure 1. Scheme illustrating the deep dive study.

nationally agreed recommendations as well as farmers' information needs on legume management. The radio programme was broadcasted once per week between April and July 2016. The radio campaign used interactive radio programmes, where radio broadcasters visited farmers ahead of the radio programme to fine-tune the content of their radio show, and farmers could further engage with the radio programme through various mobile phone services (Hampson et al., 2014). Concurrently an average of five SMS per week, aligned with the radio program, was sent to 1000 farmers to test efficacy of SMS. A total of 80 structured SMs messages in Kiswahili language were sent. Each message was crafted with an equal length, and a maximum of 160 characters. The content of each single SMS was validated by a team of experts.

The radio campaign was led by FRI, while the production and diffusion of the SMS were led by CABI.

It was envisaged that the radio program and the SMS would enable local people to receive information about beans on a variety of topics which included planting (with land preparation – early planting, planting in well-drained and broken down soils, intercropping – with what crop and measurements to consider –, spacing – need of regular spacing between seeds and the use of knotted ropes to measure the spacing between seeds-), seed varieties and seed selection (names of resistant and certified varieties were shared, usage of clean seeds suggested, quantity of seeds per acre to use), organic and inorganic fertilizer usage (need for application of manure and inorganic fertilizer at planting, and how application should be done), soil fertility (need for soil testing, quantity and type of fertilizer to apply in relation to the type of soil), pests and diseases (included how to recognize symptoms of presence of pests and diseases such as bean anthracnose, angular leaf spots, common blight, etc., control methods for fungal diseases, bean flies, etc.), weeding (included timing and modality), harvesting (included timing and modality), and storage (included use of Purdue Improved Crop Storage (PICS)[1] bags, management of pests during storage, selection of saved seeds).

The radio campaign reached 243,000 farmers (UPTAKE, 2017), in Northern and Southern Highlands of Tanzania. These areas account for about 80% of legumes cropped land in Tanzania (Mitschke, 2017).

Leveraging on the radio campaign, we selected a group of 1500 farmers, through a multi-stage random sampling procedure from a dataset of 4000 farmers that grow beans, to be involved in a deep dive study to assess the impact of radio and SMS used alone and in combination. The dataset of farmers growing beans included contacts of farmers involved in the following projects: (i) an interactive radio program part of a 'research in development' project' led by Farm Radio International (FRI) and N2Africa (Gilberds, 2016); (ii) the 'Integrated project to increase agricultural productivity in the breadbasket area of Southern Tanzania', led by the African Conservation Tillage Network (ACT); (iii) and a series of demonstration plots organized by the Selian Agricultural Research Institute (SARI). Farmers were selected through a random procedure that considered: district, gender and headship.

Out of the 1500 farmers, 500, called from now onward 'radio', were invited through an SMS sent at the beginning of each week of the radio program, to listen to specific radio stations at a specific time of the day for gathering advice on beans cultivation. Another 500, from now onward called 'SMS' received on average 5 SMS per week covering the same topics of the radio program. A last group of 500, called 'radio and SMS', received 5 SMS per week covering the topic of the radio program, together with SMS inviting them to listen to the radio.

Household survey

Quantitative data on campaign outcomes were gathered through individual interviews among a representative sample of farmers from each group. The outcome evaluation survey was administered through Computer Assisted Telephone Interviews (CATI) and assessed the effectiveness of the campaign in increasing awareness and uptake of the promoted bean SAI practices and technologies. The farmers were interviewed at the end of the cropping season following the communication campaign. The evaluation focused on farmer's self-assessment with respect to new knowledge acquired through the campaign for each different topic of the campaign; relevance of the information received; and adoption of promoted practices after the campaign. A set of questions asking farmers why they haven't been implementing a specific practice was included in the survey. This part of the survey included both precoded and open answers. Out of the 1500 contacts made, the survey rendered a final number of 241 (16%) valid interviews – poor network connectivity and lack of constant supply of electricity played a

key role in reaching out farmers. Only those farmers that declared to have listened to the relevant radio campaign programs on agriculture that were target of the study and recalled listening to topics that coincided with those of the targeted radio programs were included as valid respondents. Similarly, only those farmers that declared to have received SMS messages on growing better beans and recalled reading about topics that coincided with the SMS content were included as valid respondents'. We, therefore, obtained the following valid interviews: 65 farmers for 'radio and SMS'; 59 farmers for 'radio'; 117 farmers for 'SMS'.

Empirical approach

The data obtained were analyzed using descriptive statistics, multiple linear regressions and principal component analysis.

Multiple linear regression was used to assess factors that influence awareness and adoption. The factors assumed to affect awareness and adoption were: age, area under beans, gender of the farmer, education status and communication channels used to deliver information during the campaign. Given that the farming practices were not mutually exclusive, principal component analysis was used to establish the effect of the communication channels on awareness and adoption of all practices combined. Variables for awareness and adoption of different farming practices were coded as either 0 (zero) if not aware or did not apply/adopt and 1 (one) to indicate awareness or adoption. The principal component analysis method was then used to derive scores for awareness and adoption of all the practices. A higher score was associated with high awareness or high adoption rates. Descriptive statistics which included means and percentages were complemented with Chi-Square tests to establish associations and the magnitudes of farmers benefiting from different communication channels.

Cost-effectiveness

The most effective approach is not always the most cost-effective (Levin & McEwan, 2001). Therefore, we measured the cost-effectiveness and the effectiveness per unit of cost of radio, SMS and radio and SMS combined, in order to compare the relative costs to the outcomes (benefits) of each approach used in the campaign.

Equation (1) represents the cost per unit of effectiveness, that is how many dollars are spent per farmer that has learned or adopted at least one of the promoted practices. The most cost-effective approach presents the lowest CE ratio.

$$\text{Cost-effectiveness (CE)} = \frac{\text{Net Cost}}{\text{Net Benefit}} \quad (1)$$

Equation (2) represents the effectiveness per unit of cost; the most cost-effective approach presents the highest EC ratio.

$$\text{Effectiveness per unit of cost (EC)} = \frac{\text{Net Benefit}}{\text{Net Cost}} \quad (2)$$

Costs were monetized and measured as actual expenditures.

Benefits were not monetized, but measured as (i) the percentage of the farmers reached that learned at least one new topic; (ii) the percentage of the farmers reached that adopted at least one of the practices promoted.

Results and discussion

Change in awareness and knowledge

Any adoption decision is preceded by a period of awareness and learning/acquisition of knowledge (Rogers, 1995). Initially, there might be a limited amount of information available or only a limited amount of available information might be digested (Jabbar et al., 2003). New knowledge and experience are gained also through observation of adopters, which might lead to increase/or modify the technology a farmer is adopting, or to discontinue the use of a technology. The so-called 'innovation assessment lag', which is the time between the initial awareness and the use of a technology varies from farmer to farmer (Fisher et al., 1996). The results here presented reflect changes in awareness and knowledge that were measured shortly after the campaign ended.

Table 1 summarizes per each topic of the campaign those that were sources of new knowledge for the farmers. Overall, across the three groups, farmers gained knowledge of legume-based sustainable agricultural intensification practices and technologies, demonstrating how ICT-based agricultural extension can be beneficial. 'Seed varieties and seed selection' was ranked first by about 60% of the farmers interviewed. Use of improved bean varieties is still very low in Tanzania (Letaa et al., 2015), this, together

Table 1. Farmers that learned something new as result of the campaign (%).

Topics of the campaign	Radio	SMS	Radio & SMS	Average across all channels
Planting	36	44	60	46
Seeds	49	56	69	58
Fertilizer and soil fertility	32	26	22	26
Pests and Diseases	36	37	51	40
Weeding	10	9	11	10
Harvesting	5	10	15	10
Storage	9	21	31	21

with the fact that farmer might not be familiar with the commercial names of some bean's varieties, would explain why there was a major contribution to increasing knowledge for this topic. In addition, farmers learned about the importance of using quality seeds of improved varieties that are more resistant to adverse conditions in order to ensure higher yields and better understood the link between the use of a more vigorous, fast-growing seed and higher tolerance to pests and diseases. The importance of seed selection was also mentioned, together with their storage and preservation.

'Planting' generated some new knowledge and adoption for about 46% of the farmers interviewed, especially with respect to the need for regular spacing between seeds and the use of knotted ropes to measure spacing between seeds. Proper spacing of bean plants is a method of precision agriculture important for maximum bean yields and ease of care and picking. However, famers in Tanzania lack information in particular on seed spacing and land preparation among other stages in the cropping cycle (Mitschke, 2017).

The topic of pests and diseases yielded also some new knowledge in particular with respect to the importance of timely pest control and spraying, and the use of recommended pesticide. 'Harvesting' and 'weeding' were the least mentioned by the farmers in terms of providing new learning.

With respect to the source of the information that generated new knowledge, the combination of radio and SMS provided most of the new learning to farmers across the different subject areas. Overall the respondents learned at least one new topic: 1.8 times through listening to 'radio', 2.0 times through receiving 'SMS' and 2.6 times through the combination of 'radio and SMS'. Therefore, a greater impact on knowledge was achieved through the combined use of different communication sources.

Adoption

In this paper, we refer to adoption in terms of integration of a new technology into existing practice. However, since this study took place shortly after the communication campaign, some of the farmers might be actually 'trying' out a technology (Loevinsohn et al., 2012). We are therefore not considering the timing factor and therefore neither rate of adoption nor intensification of adoption.

On average, about 80% of the farmers declared to have done something different after having participated in the campaign. The topics that scored a higher rate of adoption after the campaign was 'seeds' followed by 'planting' and pest and disease management (Table 2). Practices such as spacing, use of decomposed farmyard manure, and timely harvest were implemented by the majority of farmers, largely because the households can use own labour and sources meaning there are barely any cash needing costs associated with it.

Some of the promoted practices, such as the use of chemical fertilizer, and more tolerant (pest-disease, drought) seed varieties, besides the cost factor, were not implemented because of the lack of knowledge on where to find the available inputs. Lack of clarity about the steps to follow to apply the received information was also mentioned as a barrier. Indeed the level of literacy of farmers plays a key role in the understanding of the information received, however, there is another important factor to consider which is the relationship between the complexity of a message and the suitability of a channel used to deliver it, as explained in Kansiime et al. (2017), Figure 2. Indirect methods, such as mass media, might be useful to raise awareness of topics that require a basic level of understanding, such as information about a new seed variety or, but might be less suitable to deliver more complex messages, which might also present some technicalities, and

Table 2. Practices adopted by farmers as result of the campaign (%).

Topics of the campaign	Radio	SMS	Radio & SMS	Average across all channels
Planting	27	37	51	38
Seeds	34	41	45	40
Fertilizer & soil Fertility	25	18	19	20
Pests & diseases	34	31	40	34
Weeding	7	9	9	8
Harvesting	5	10	11	9
Storage	8	15	23	16

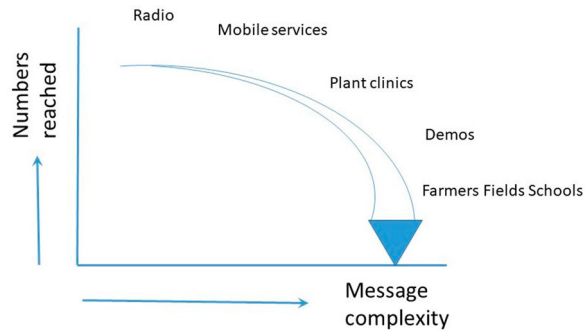

Figure 2. Relationship between communication channel, message complexity and reach (modified from Kansiime et al. 2017).

would be better delivered through alternative types of communication (for example through demonstration plots, videos, leaflets, etc.)

Further analysis was conducted using principal components to establish the effect of radio and SMS on awareness and adoption of all farming practices. This was necessary given that farming practices are not mutually exclusive. One practice contributes to the effectiveness of another practice and it is not possible to omit one practice after using another. Similarly, adoption of different practices contributes to overall output at the farm level. Effectiveness of the communication channel was measured by the extent to which it contributed to increased awareness and uptake of technology (Ssemakula & Mutimba, 2011). Efficiency of any agricultural technology generated and disseminated depends on effective communication which is crucial for the adoption process (Sobia et al., 2015). Table 3 presents a summary of scores for awareness and adoption of the farming practices disseminated to farmers using radio, SMS or both radio and SMS. A combination of radio and SMS had the highest score indicating higher influence on awareness and adoption.

Results from the test between-subject effects multiple linear regression analysis showed that the communication channels had a positive and significant effect ($p < 0.10$) on creation of awareness (Table 4). Other factors also contributed to awareness about farming practices, but their contribution was not statistically significant. Education generates the requisite exposure to seek for information. Farmers who were relatively advanced in age appeared to have acquired more awareness of the farming practices promoted through the campaign. This may be because they were less familiar than younger farmers with respect to the practices promoted.

Pairwise comparisons were conducted to establish the difference in effect on awareness by the three communication channels (Table 5). The results based on awareness scores as the dependent variablerevealed that a combination of radio and SMS is more effective in creating awareness. The differences between a combination of radio and SMS rated against SMS only and radio only are statistically significant ($p \leq 0.05$). This may be because the same information is provided in two different formats, thereby increasing farmer capacity to understand it. Furthermore, the use of different formats increases the probability of targeting farmers with their preferred format. The second most effective communication channel to create awareness are the SMS messages.

Table 3. Raw scores for different communication channels.

	Awareness scores		Adoption scores	
Communication channels	Mean	Standard Deviation	Mean	Standard Deviation
Radio and SMS	0.79	0.91	0.67	1.04
Radio	0.48	0.96	0.42	1.08
SMS	0.49	0.91	0.43	0.99

Table 4. Tests of between subject effects on awareness of different farming practices.

Factors affecting awareness	Type III sum of squares	Df	Mean Square	*F*	*p*-value
Corrected Model	19.01	22	0.86	1.02	0.44
Intercept	0.476	1	0.48	0.56	0.45
Age	1.64	1	1.64	1.95	0.17
Cultivated land	0.01	1	0.01	0.01	0.92
Communication channels	4.77	2	2.38	2.82	0.06
Gender	0.02	1	0.01	0.02	0.90
Education	1.06	3	0.35	0.42	0.74
Error	171.52	203	0.85		
Total	267.11	226			
Corrected Total	190.53	225			

Table 5. Pairwise comparisons of the effect of communication channels on awareness.

Communication channels (1)	Communication channels (2)	Mean Difference (1–2)	Std. Error	Sig.
Radio and SMS	Radio only	0.64	0.31	0.04
	SMS only	0.55	0.28	0.05
Radio only	Radio and SMS	−0.64	0.31	0.04
	SMS only	−0.09	0.27	0.73
SMS only	Radio and SMS	−0.55	0.28	0.05
	Radio only	0.09	0.27	0.73

Table 6. Tests of between subject effects on adoption of different farming practices.

Factors affecting awareness	Type III sum of squares	df	Mean Square	*F*	*p*-value
Corrected Model	26.45	22	1.20	1.153	0.30
Intercept	2.25	1	2.25	2.156	0.14
Age	0.37	1	0.37	0.354	0.55
Cultivated land	0.01	1	0.01	0.010	0.92
Communication channels	6.31	2	3.16	3.025	0.05
Gender	0.38	1	0.38	0.361	0.55
Education	2.64	3	0.88	0.845	0.47
Error	211.75	203	1.04		
Total	295.69	226			
Corrected Total	238.20	225			

The effect of communication channels on adoption of the practices learnt was positive and statistically significant ($p = 0.05$) as shown in Table 6. The communication channels build farmer capacity by providing the requisite advice in a form that was easy to understand and use. This was also confirmed through the answers to the open questions asked to farmers about the clarity of the messages delivered. Other factors were also important in facilitating the adoption of the practices, such as gender, age, education and land size, but were not statistically significant when rated against the communication channels used.

Table 7. Pairwise comparisons of the effect of communication channels on adoption.

Communication channels (1)	Communication channels (2)	Mean Difference (1–2)	Std. Error	Sig.
Radio and SMS	Radio only	0.78	0.34	0.02
	SMS only	0.67	0.31	0.03
Radio only	Radio and SMS	−0.78	0.34	0.02
	SMS only	−0.11	0.30	0.71
SMS only	Radio and SMS	−0.67	0.31	0.03
	Radio only	0.11	0.30	0.71

Pairwise comparisons of the different communication channels using adoption as the dependent variable revealed that a combination of radio and SMS was more effective in contributing to adoption of the different practices (Table 7). The difference in contribution by a combination of SMS and radio compared to SMS only and radio only is statistically significant ($p < 0.05$).

Cost-effectiveness

The results from the cost-effectiveness analysis are presented in Table 8. Since the cost-effectiveness for awareness and adoption for radio is the lowest (0.4 dollars are spent per farmer that has learned at least one new topic and 0.5 dollars are spent per farmer that has adopted at least one new practice or technology), it can be said that radio is more cost-effective than SMS alone and radio and SMS combined. Each dollar spent on radio campaigns results in 2.5 farmers that have learned at least one new practice, compared with 0.5 farmers for SMS and 0.4 farmers

Table 8. Cost-effectiveness and effectiveness of cost for 'SMS', 'radio' and 'radio and SMS'.

Media	Cost per farmer reached (USD)	% of farmers learning at least one practise	% of farmers adopting at least one practise	CE awareness ($ spent per farmer that has learned at least one new topic)	EC awareness (n. of farmers that learned at least one practise per $ spent)	CE adoption ($ spent per farmer that has adopted at least one practice)	EC adoption (n. of farmers that adopted at least one practise per $ spent)
SMS	1.85[a]	90.4	84.3	2.0	0.49	2.2	0.46
Radio	0.36[b]	89.8	74.6	0.4	2.50	0.5	2.07
Radio & SMS	2.21[c]	96.9	86.2	2.3	0.44	2.6	0.39

Assumptions: [a]As a benchmark for the cost related to the SMS, we considered the costs that were associated with the SMS campaign on maize for the UPTAKE project, where a total of 17 SMS were sent to 46,564 farmers. The average cost was derived by dividing the cost of the project (costs included cost to send the SMS and cost to produce the content) by the number of farmers reached.

[b]The average cost per farmer reached through radio was derived by dividing the total cost of the radio campaign (salaries, project set up costs, training of broadcasters, direct costs around equipment, and payment for radio airtime) by the number of farmers reached (Mitschke, 2017).

[c]The cost per farmer reached by radio and SMS is assumed to be given by the sum of the average cost per farmer reached by radio and the average cost per farmer reached by SMS.

for radio and SMS combined. Similar results are found for adoption.

Radio and SMS combined are the least cost-effective.

Comparison with conventional extension approaches such as extension visits, FFS (Farmers Fields Schools), farmer fields days (demonstration plots), indicates that radio and SMS either alone or in combination may be a cost-effective addition to conventional extension approaches (Harris et al., 2013; Mitschke, 2017; Ricker-Gilbert et al., 2008). However, one shall not assume that a specific ICT approach will always be cost-effective and lead to a better outcome. Before implementation, it would be important to understand the underlying institutional environment and the constraints (World Bank, 2016).

Conclusions

The present study examines the impact that radio, SMS and radio and SMS combined have on increasing awareness and uptake of legume-based sustainable agricultural intensification practices and technologies. It fills a gap in literature as most studies do not look into the cumulative impact of different ICT-based interventions.

The study is based on a communication campaign in Tanzania that used two complementary ICT-based channels (i.e. radio and mobile SMS messages). The results indicate that ICT-based extension campaigns-based approach have great potential to increase farmer's awareness and adoption of improved legume technologies, hence to scale-up smallholder participation in SAI. Sending identical messages, whereas delivery is tailored to various members of small-scale farming households through different but linked communication media is impactful. Both awareness and adoption are boosted if SMS supports radio campaigns. When a single communication media is used, SMS alone is the most effective.

Radio and SMS alone or in combination worked well to increase awareness of new seeds varieties and planting (this last one in terms of land preparation and spacing). There are two concurrent factors that possibly led to this: seed spacing and land preparation seem to be the topics for which farmers are lacking knowledge the most; secondly, indirect methods such as mass media, are useful to raise awareness for practices that require a basic level of understanding. When looking at cost-effectiveness, radio alone was the most cost-effective.

The use of ICTs adds a new dimension in delivering advanced and real-time information to the farmers. Digital approaches, such as radio and SMS are in rapid growth globally, thanks also to their scalability. The present study shows that on average, about 80% of sampled farmers have learned something new following the mass media communication campaign.

The choice of what methods to use should be informed by the knowledge of the underlying institutional environment and constraints, together with the level of complexity of the practice or technology to be transferred, the desired reach, and the characteristics of the intended target audience, with the latter including also cultural and gender norms. Available resources for the implementation of a communication campaign will also drive the choice of the media.

Furthermore, in this study, we focused on the role of complementary ICT-enabled extension services. It would also be interesting to study the complementarities between ICT-based and conventional extension approaches such as farmers training and demonstrations, to better understand trade-offs between the use of different extension approaches.

Note

1. The Purdue Improved Crop Storage (PICS) is a storage system developed by Purdue University that consists of two layers of polyethylene bags, surrounded by a third layer of woven polypropylene, thereby creating a hermetically sealed environment in which harvested crops are stored.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by UK aid; Netherland – Directorate-General for International Cooperation; Canada – Agriculture and Agri-Food Canada; China – Chinese Ministry of Agriculture; Australia – Australian Centre for International Agricultural Research; Switzerland – Swiss Agency for Development and Cooperation.

Notes on contributors

Silvia Silvestri holds a PhD in Agricultural Economics and Policy, a master in Agri-food business and a MSc in Biology. She is an international development and socio-economic expert with 15

+ years of experience in major international development initiatives with a focus on poverty alleviation. She is currently an independent consultant based in France. In her previous roles, she worked as Senior Socio-Economist at CABI, as senior scientist, Environment and Livelihoods, for the International Livestock Research Institute (ILRI), and as programme officer for the United Nation Environment Program-World Conservation Monitoring Center (UNEP-WCMC). Her areas of expertise include rural development, climate change, food security, bridging science and policy and equity. More recently, her work focused on the interaction between communication, extension and the use of ICT in agriculture.

Richard Musebe holds a PhD and MSc in Agricultural Economics with vast experience of over 20 years in international development, agricultural marketing and research. Richard has conducted extensive socio-economic studies on situation analysis, uptake of improved crop technologies, impact assessment; monitoring and evaluation; crop pest control and crop husbandry practices, value chain analysis, cost-benefit analysis, stakeholder analysis, marketing, outcome mapping and agricultural development communication. Research and development endeavours span several African counties, Jamaica and India with individual responsibilities for many development organizations and universities.

Edward Baars holds a post-graduate degree in Agriculture, Strategic Marketing and Marketing Research. He has gained professional experience of over 25 years in Africa, Europe and South-America covering the cross sectoral domains of International agricultural development and business, agri-food and investment finance, value chain development, financial Inclusion, extension, technology adoption, engineering, digitalization for agriculture (D4Ag) Solutions, performance monitoring and knowledge management, while designing, implementing integrated programs and strategies within these domains. Within several development programs, he was instrumental in designing and implementing inclusive Public Private Partnerships (PPPs) and developed and applied his skills in analytical approaches that provided understanding of differentiated impacts of development outcomes including gender equality and social inclusion considerations.

Dharmesh Ganatra, founder and CEO of iLogix, has developed an innovative interactive platform, IOSIS, Input Output Supply Information System, for improved co-ordination, co-operation, capacity building and efficiencies within agricultural and commodity supply chains. He brings a wealth of experience and knowledge from the private sector having worked and lived on 3 continents: Europe, Asia and Africa. Business strategy, linkages to markets, market research, behaviour analytics and fintech are just some of the key areas of expertise he brings to the table as a serial entrepreneur.

Dannie Romney is currently Global Director for Development, Communications and Extension, one of CABI's four themes that support activities designed to get research into use in Africa, South and South East Asia as well as in Latin America. She also has strategic oversight of Monitoring and Evaluation and social science in CABI. Dannie has lived in Africa for 19 years and worked with smallholder farming systems in Africa, Asia and Latin America for 30 years. Before joining CABI in 2007 she worked for seven years at the International Livestock Research Institute (ILRI), including as Acting Director for the ILRI Innovation Systems theme for 1.5 years.

ORCID

Silvia Silvestri http://orcid.org/0000-0001-7427-0351
Romney Dannie http://orcid.org/0000-0002-5453-3932

References

Aker, J. C. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Aker, J. C., & Ksoll, C. (2016). Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. *Food Policy*, *60*, 44–51.

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. *Journal of Economic Perspectives*, *24* (3), 207–232. https://doi.org/10.1257/jep.24.3.207

Ali, J., & Kumar, S. (2011). Information and communication technologies (ICTs) and farmers' decision-making across the agricultural supply chain. *International Journal of Information Management*, *31*(2), 149–159. https://doi.org/10.1016/j.ijinfomgt.2010.07.008

Anderson, J. R., & Feder, G. (2007). Agricultural extension. In R. Evenson & P. Pingali (Eds.), *Handbook of agricultural Economics* (Vol. 3, pp. 2343–2378). Elsevier.

Baumüller, H. (2018). The little we know: An exploratory literature review on the utility of mobile phone-enabled services for smallholder farmers. *Journal of International Development*, *30* (1), 134–154.

Bell, M. (2015). *ICT-Powering behavioral change for a brighter agricultural future*. USAID/modernizing extension and advisory services (MEAS).

Boa, E., Javier, F., Chaudhury, M., Simbalaya, P., & Van der Linde, E. (2016). Plant health clinics: Note 23 GFRAS global good practices. https://www.g-fras.org/en/good-practice-notes/23-plant-health-clinics.html?showall=1

Chavula, H. K. (2012). Telecommunications development and economic growth in Africa. *Information Technology for Development*, *19*(1), 5–23. https://doi.org/10.1080/02681102.2012.694794

Davis, K. (2008). Extension in sub-Saharan Africa: Overview and assessment of past and current models and future prospects. *Journal of International Agricultural and Extension Education*, *15*(3), 15–28. https://doi.org/10.5191/jiaee.2008.15302

Fafchamps, M., & Minten, B. (2012). Impact od SMS-based agricultural information on Indian farmers. *The World Bank Economic Review*, *26*(3), 383–414. https://doi.org/10.1093/wber/lhr056

Fisher, A. J., Arnold, A. J., & Gibbs, M. (1996). Information and the speed of innovation adoption. *American Journal of Agricultural Economics*, *78*(4), 1073–1081. https://doi.org/10.2307/1243863

Fu, X., & Akter, S. (2016). The impact of mobile phone technology on agricultural extension services delivery: Evidence from India. *The Journal of Development Studies*, *52*(11), 1561–1576. https://doi.org/10.1080/00220388.2016.1146700

Gilberds, H. (2016). *Exploring the potential for interactive radio to improve accountability and responsiveness to*

small-scale farmers in Tanzania. Farm Radio International (FRI), 36 pp.

Guerin, L. J., & Guerin, T. F. (1994). Constraints to the adoption of innovations in agricultural research and environmental management: A review. *Australian Journal of Experimental Agriculture*, *34*(4), 549–571. https://doi.org/10.1071/EA9940549

Hampson, K. J., Chapota, R., Emmanuel, J., Tall, A., Huggins-Rao, S., Leclair, M., Perkins, K., Kaur, H., & Hansen, J. (2014). *Delivering climate services for farmers and pastoralists through interactive radio: scoping report for the GFCS Adaptation Programme in Africa*. CCAFS Working Paper no. 111. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

Hampson, K., Leclair, M., Gebru, A., Nakabugo, L., & Huggins, C. (2016). "There is No program without farmers": interactive radio for Forest Landscape Restoration in Mount Elgon Region, Uganda. *Society and Natural Resources*. doi:10.1080/08941920.2016.1239148

Harris, L., Norton, G., Karim, A., Alwang, J., & Taylor, D. (2013). Bridging the information Gap with cost-effective dissemination Strategies: The Case of Integrated pest management in Bangladesh. *Journal of Agricultural and Applied Economics*, *45*(4), 639–654. https://doi.org/10.1017/S1074070800005174

Hillocks, R. J., Madata, C. S., Chirwa, R., Minja, E. M., & Msolla, S. (2006). Phaseolus bean improvement in Tanzania, 1959-2005. *Euphytica*, *150*(1–2), 215–231. https://doi.org/10.1007/s10681-006-9112-9

Hudson, H. E., Leclair, M., Pelletier, B., & Sullivan, B. (2017). Using radio and interactive ICTs to improve food security among smallholder farmers in Sub-Saharan Africa. *Telecommunications Policy*, *41*(7-8), 670–684. https://doi.org/10.1016/j.telpol.2017.05.010

Jabbar, M. A., Saleem, M. A. M., & Gebreselassie, S. (2003). Role of knowledge in the adoption of new agricultural technologies: An approach and an application. *International Journal of Agricultural Resources, Governance and Ecology*, 2, 3/4 https://doi.org/10.1504/IJARGE.2003.003974

Juma, C. (2009). Science Meets farming in Africa. *Science*, *334* (6061), 1323. https://doi.org/10.1126/science.1217148

Kansiime, M., Mulema, J., Karanja, D., Romney, D., & Day, R. (2017). *Crop pests and disease management in Uganda: status andinvestment needs*. Rome: PARM/IFAD.

Kaskekacharo, D. 2016. *The use of mobile phones in agricultural extension in Southern Ethiopia* [Doctoral dissertation]. Sokoine University of Agriculture. http://www.suaire.sua.ac.tz:8080/xmlui/bitstream/handle/123456789/1487/DERIBE%20KASKEKACHARO.pdf?sequence=1&isAllowed=y

Khoshnodifar, Z., Ghonji, M., Mazloumzadeh, S. M., & Abdollahi, V. (2016). Effect of communication channels on success rate of entrepreneurial SMEs in the agricultural sector: A case study. *Journal of the Saudi Society of Agricultural Sciences*, *15*(1), 83–90. https://doi.org/10.1016/j.jssas.2014.04.001

Korsching, P. F., & Hoban, T. (2008). Relationships between information sources and farmers' conservation perceptions and behaviour. *Society and Natural Resources*, *3*(1), 1–10. https://doi.org/10.1080/08941929009380700

Larochelle, C., Alwang, J., Travis, E., Barrera, V., & Dominiguez Andrade, J. M. (2019). Did you really get the message? Using text reminders to stimulate adoption of agricultural technologies. *The Journal of Development Studies*, *55*(4), 548–564. https://doi.org/10.1080/00220388.2017.1393522

Letaa E., Kabungo C., Katungi E., Ojara M.M., Ddunduru A. 2015. Farm level adoption and a spatial diffusion of improved common bean varities in southern highlands in Tanzania. Africa Crop Science Journal, 23 (3): 261-277.

Levin, H. M., & McEwan, P. J. (2001). *Cost-effectiveness analysis: Methods and application* (2nd ed). Sage.

Livondo, L. J., Anderson, K., Macharia, E. W., & Oduor, P. O. (2015). Factors affecting communication channels preference by farmers in access of information on adoption of agricultural technology for striga control: A case of Bungoma County, Kenya. *International Journal of Current Research*, *7*(11), 23057–23062.

Loevinsohn, M., Sumberg, J., & Diagne, A. (2012). *Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? Protocol*. EPPI Centre, Social Science Research Unit, Institute of Education, University of London.

Mitschke V. 2017. *Inducing the adoption of good agricultural practices by educating Tanzanian smallholder farmers – what works best and at what costs?* [Master's thesis]. Wageningen University.

Mtega, E. P., & Msungu, A. C. (2013). Using information and communication technologies for enhancing the accessibility of agricultural information for improved agricultural production in Tanzania. *The Electronic Journal of Information Systems in Developing Countries*, *56*(1), 1–14. https://doi.org/10.1002/j.1681-4835.2013.tb00395.x

Mtega, W. P., & Ronald, B. (2013). The state of rural information and communication services in Tanzania: A meta-analysis. *International Journal of Information and Communication Technology Research*, *3*(2), 64–73.

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), 8–12. https://doi.org/10.7176/JBAH

Nakasone, E., Torero, M., & Mintem, B. (2006). The power of information: The ICT revoluation in agricultural development. *Annual Review of Resource Economics*, *6*(1), 533–550. https://doi.org/10.1146/annurev-resource-100913-012714

Omri Van, Z., Trish, A., Liezl De, G., & Kamal, M. (2014). *ICTs for agriculture in Africa*. World Bank.

Qureshi, S. (2015). Are we making a better World with information and communication technology for development (ICT4D) research? Findings from the Field and Theory Building. *Information Technology for Development*, *21*(4), 511–522. https://doi.org/10.1080/02681102.2015.1080428

Ricker-Gilbert, J., Norton, G. W., Alwang, J., Miah, M., & Feder, G. (2008). Cost-effectiveness of alternative integrated pest management extension methods: An example from Bangladesh. *Applied Economic Perspectives and Policy*, *30*(2), 252–269. https://doi.org/10.1111/j.1467-9353.2008.00403.x

Rogers, E. M. (1995). *Diffusion of innovations*. Free Press.

Royal Tropical Institute (KIT). (2015). Information needs assessments Tanzania. http://africasoilhealth.cabi.org/material_partner/kit-royal-tropical-institute/

Saravanan, R., Sulaiman, R. V., Davis, K., & Suchiradipta, B. (2015). *Navigating ICTs for extension and advisory services*. Note 11. GFRAS Good Practice Notes for Extension and Advisory Services. Lindau: GFRAS.

Sebakira, H., & Qaim, M. (2017). Can mobile phones improve gender equality and nutrition? Panel data evidence from farm households in Uganda. *Food Policy*, *73*, 95–103. https://doi.org/10.1016/j.foodpol.2017.10.004

Sobia, M., Shahrina, M. N., & Shameem, R. G. (2015). Influence of innovation attributes and communication channels on new fertilizer technology adoption by paddy farmers. *Australian Journal of Basic and Applied Sciences*, *9*(19), 109–117.

Sousa, F., Nicolay, G., & Home, R. (2016). Information technologies as a tool for agricultural extension to farmer-to-farmer exchange: Mobile-phone video use in Mali and Burkina Faso. *International Journal of Education and Development Using Information and Communication Technology*, *12*(3), 19–36.

Ssemakula, E., & Mutimba, J. K. (2011). Effectiveness of the farmer-to-farmer extension model in increasing technology uptake in Masaka and Tororo Districts of Uganda. *South African Journal of Agricultural Extension*, *39*(2), 30–46.

Sullivan, B. (2011). *The new age of radio: How ICTs are changing rural radio in Africa*. Farm Radio International.

Tambo, J. A., Aliamo, C., Davis, T., Mugambi, I., Romney, D., Onyango, D. O., Kansiime, M., Alokit, C., & Byantwale, S. T. (2019). The impact of ICT-enabled extension campaign on farmers' knowledge and management of fall armyworm in Uganda. *PLoS ONE*, *14*(8), e0220844. https://doi.org/10.1371/journal.pone.0220844

UPTAKE. (2017). *New Alliance ICT extension challenge fund: Up-scaling of interactive information and communication technologies to increase uptake of agricultural innovations in Tanzania*. Annual report, 36 pp.

World Bank. (2016). *World development Report 2016: Digital Dividends*.