Research Report

ICT4Scale in Smallholder Agriculture: Contributions and Challenges

Helena Shilomboleni

CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS) East Africa, International Livestock Research Institute, Kenya

Bernard Pelletier

Farm Radio International, Canada

Berhane Gebru

FHI 360, USA

Abstract

This article presents the main findings from a meta-review study of 15 agricultural development projects that employed a diversity of information and communications technology (ICT) tools in combination with other interventions to scale up innovations in low-income smallholder agriculture, predominately in sub-Saharan Africa. Overall, the study finds that interactive ICT tools and platforms are valuable in their capacity to improve the quality of agricultural extension and climate information services and, as such, can help smallholder farmers better manage predicted risks on the farm and elsewhere in the agriculture sector. The scope of impact in most of these projects, however, was largely premised on the numbers of beneficiaries reached (e.g., with information pertaining to an innovation). The efficacy of scaled-up results to achieve positive, long-lasting livelihood impacts in smallholder agriculture is more complex, and often requires effecting systemwide change on multiple dimensions, e.g., in societal values, institutional arrangements, market relations, and policy decision making. The scaling process here requires long-term attention, even if the impacts are not immediately apparent.

Keywords: ICTs, scaling up, food security, agricultural development, gender, impact at scale

Introduction

There is growing recognition that information and communications technologies (ICTs) comprising traditional media and newer tools, such as mobile phones and web-enabled services, can contribute positively to household food security and rural income in developing countries' agriculture (Duncombe, 2018; Gray et al., 2018; Trendov, Varas, & Zeng, 2019). This view point is informed partly by the relatively slow progress made in addressing development outcomes as well as by a momentum surrounding scaling up agricultural innovations to achieve greater impact at scale for a large number of beneficiaries (see Sachs et al., 2017). Various scholars and development practitioners have illustrated the value of ICT-mediated tools to improve service delivery in smallholder agriculture, such as the provision of timely and accurate extension information, enhanced coordination of input and output supply chains, and greater access to financial services (Aker & Ksoll, 2016; Deichmann, Goyal, & Mishra, 2016; Duncombe, 2018).

Yet there remain important gaps in our understanding of the developmental impact of ICTs at scale (see

To cite this article: Shilomboleni, H., Pelletier, B., & Gebru, B. (2020). ICT4Scale in smallholder agriculture: Contributions and challenges. Information Technologies & International Development, 16, 47–65.

Brown & Skelly, 2019), particularly with regard to achieving long-lasting positive impact in agricultural development projects and programs. To address this gap, Farm Radio International (FRI), Canada and Farm Radio Trust (FRT), Malawi launched a 30-month research initiative, "Harnessing ICT to Scale-up Agricultural Solutions" (ICT4Scale) (running from May 2017–October 2019), to examine the roles and contributions of ICTs in scaling agricultural innovations for food, nutrition, and income security, with a focus on sub-Saharan Africa (FRI, 2017a). Several studies were undertaken to generate evidence on how different combinations of ICTs, institutional arrangements, and actors affect the implementation of agricultural innovations and to offer lessons to governments and development actors seeking to use ICTs in their agricultural development initiatives more effectively.

This article presents the main findings from one of the ICT4Scale studies, a meta-review of 15 agricultural development projects that employed a diversity of ICT tools in combination with other interventions to scale up innovations in low-income, smallholder agriculture, predominately in sub-Saharan Africa. The range of ICTs used by the projects comprised interactive radio broadcasts; mobile phones (for Short Message Services [SMSs], voice calls, unstructured supplementary service data [USSD], and interactive voice response [IVR]) and social media (WhatsApp and Facebook); and e-vouchers. Among these, radio proved to be the most widely used communication channel among rural populations. ICT-enabled interactive radio programs are particularly valuable to translate complex agricultural information (e.g., climate data and weather agro-advisories) into relevant and applicable content for farmers' unique circumstances.

While the utility of ICT tools to disseminate useful and timely agricultural information is clear, the efficacy of scaled-up results to achieve positive, long-lasting livelihood impacts for poor rural communities is more complex and often requires effecting systemwide change on multiple dimensions (e.g., in societal values, institutional arrangements, market-relations, and policy decision making). Most projects examined here made modest efforts to build up the capacity and skills of local stakeholders (e.g., radio stations, government agencies) to effectively deliver custom-tailored agricultural extension services to large numbers of smallholder farmers. These efforts are important because the sustainable spread of innovations is contingent on empowered local stakeholders and institutions that can drive the scaling process (Hartmann et al., 2013; Massler, 2012; Middleton, de la Fuente, & Ellis-Jones, 2005).

Most of these projects, however, largely premised their scope of impact—in terms of successful or scaled development efforts—on numbers of beneficiaries reached (e.g., with information pertaining to an innovation). The tendency to link information access to technology uptake can be problematic as it might overlook complex socioeconomic factors that influence farmers' decisions to adopt innovations and the differentiated ways in which other family members benefit (or not) from them. Considering these tendencies, this article seeks to explore the potential contributions of ICTs in scaling agricultural solutions in a way that brings sustainable and equitable benefits for smallholder farmers, especially women.

This article is organized as follows: First, a literature review discusses the contributions of ICTs to scaling and achieving long-lasting positive impact. Next, the article outlines the methods used to undertake this study. The following section presents the main findings and discusses the implications for ICT4Scale theory and practice. A short conclusion ends the article.

Literature Review

Whereas countless agricultural innovations have been successfully pilot tested, most rarely reach their intended impact of contributing significantly to food security targets or other UN Sustainable Development Goals (Woltering, Fehlenberg, Gerard, Ubels, & Cooley, 2019). This limited success is partly attributed to a narrow focus around scaling, often premised on conventional, linear trajectories from technology research and development to subsequent transfer to large numbers of end users. Indeed, widely used definitions of scaling emphasize reaching large numbers of people and greater geographic coverage (e.g., with new technologies, products, and models that can increase productivity and farm incomes). Yet agricultural innovations are often introduced in complex food system value chains, involving interlinkages among production, postharvest handling, transportation, and marketing—issues that need to be addressed jointly for scaling efforts to achieve some level of sustainable change.

The scaling of innovations is also influenced by contextual and relational factors such as economic incentives, political objectives, and social learning (Shilomboleni & De Plaen, 2019). These factors necessarily demand project actors to undertake efforts that can create functional organizational structures, garner institutional and policy support, and build the capacity of committed advocates who can drive the scaling process over time (Hartmann et al., 2013; Menter, Kaaria, Johnson, & Ashby, 2004). An approach to scaling that fosters systemwide change to achieve lasting impact at scale, in terms of sustained adoption and improvements in livelihoods, is driven by measures that engage key contextual considerations along the broader agricultural value chains (Wigboldus, 2018; Woltering et al., 2019).

ICTs can play an important role in enhancing the scaling-up process by facilitating interactions and linkages among relevant stakeholders and institutions while making information about agricultural innovations available, accessible, and affordable. As such, there is a need for greater scientific evidence to better understand how and where exactly in the scaling-up process ICTs can have a positive impact. ICTs are also potentially effective and efficient in helping low-income smallholder farmers build an awareness of agricultural improvements; increase productivity and incomes; and improve gender-related outcomes in the context of new interventions.

Several scholars have highlighted how ICTs can also be used to expand the social inclusion of marginalized individuals and groups in agricultural development efforts, including to advance gender equality and female empowerment (Chipidza & Leidner, 2017; Frieden, 2013). A gender lens in scaling innovations using ICTs is particularly important in Africa's smallholder agriculture where women account for a large share of agricultural output, but tend to have unequal access to and use of ICTs compared to men (World Bank, 2017). Further, cultural gender norms in many African smallholder agricultural societies traditionally give men greater control over the management of productive resources and assets (land, livestock, income, etc.) and more control over household spending decisions compared to women (Lambrecht, Vanlauwe, Merckx, & Maertens, 2014; Pircher, Almekinders, & Kamanga, 2013). Where these gender dimensions are ignored, the scaling process may inadvertently increase the exclusion and inequality of marginalized groups, including in the distribution of power, resources, and benefits at the household level (IFAD 2015; KIT, Agri-ProFocus, & IIRR, 2012; Quisumbing et al., 2014). Strengthening the effectiveness of agricultural interventions and the successful spread of innovations, therefore, requires, at minimum, gender-responsive approaches, which promote equal benefits for men and women from new opportunities and ensure that unanticipated negative results (e.g., the burden of extra labor on women and girls) are properly assessed.

Whereas multiple ICT-enabled agricultural interventions in Africa often aim to promote women's empowerment, the emphasis is often on financial returns (i.e., to increase crop yields and income) (World Bank, 2017). A broader view on empowerment moves beyond improving women's individual access to resources to building collective responsibility and agency around relational and institutional structures that shape women's lives (KIT et al., 2012). Such efforts aim to bring about transformative change by providing a platform where communities can better understand and challenge structural norms that undermine women's capacities to take advantage of opportunities in agricultural value chains and markets, as well as in policy spaces (Njuki, Parkins, Kaler, & Ahmed, 2016). Empowerment outcomes in such interventions are generally measured based on four domains of power: *power over*—control over income and labor, assets and resources; *power to*—capacities, skills, awareness; *power within*—internal and psychological resources; *power with*—collective agency and action (KIT et al., 2012).

Sustaining women's empowerment in the long run, much like attaining meaningful scaling results, requires fostering some level of systems change on these four domains of power, both at the interpersonal (social) and political (policy) levels. In the scaling-up literature, an important dimension of empowerment involves strengthening people's (leadership) capabilities to participate in, negotiate with, influence, control, and hold accountable institutions that affect their lives (Massler, 2012). At the interpersonal level, this demands inclusive and iterative participatory learning processes that establish a shared vision around equitable intrahousehold relations and decision making to benefit everyone (Njuki et al., 2016). The process also requires analyzing more closely what happens within a household once an innovation is adopted, including the expected benefits and costs to different family members (Theis, Lefore, Meinzein-Dick, & Bryan, 2018). At a political level, empowering local stakeholders to engage meaningfully with policy processes (e.g., through advocacy and collaboration)

is vital to help open institutional structures more conducive to power sharing and allocating resources more fairly (see Westermann et al., 2018).

This meta-review sought to explore the potential contributions of ICT4Scale agricultural interventions to scaling long-lasting livelihood impacts, in ways that improve the delivery of agricultural extension services. Such effective scaling also foster systems change to improve the functionality of agricultural value chains and to bring about more equitable and sustainable benefits, particularly for female farmers. The following questions guided this study and the broader IC4Scale research initiative:

- What combinations of ICT tools, actors, and institutional arrangements are most effective and efficient in scaling agricultural solutions?
- What strategies for the use of ICTs are successful in facilitating the scaling of agricultural solutions (e.g., interaction with audiences, type and quality assurance of information and content)?
- What are the gender equality considerations of ICT-enabled scaling of agricultural solutions?
- What barriers may limit the reach and/or effectiveness of ICTs in scaling initiatives?

The methods used to conduct the meta-review are elaborated in the next section.

Methodology

Selection of Projects

A first set of 196 projects was identified following an online search of agricultural development projects undertaken in the Global South that used ICT tools for scaling innovations for food and nutrition security. The study focused on projects implemented in sub-Saharan Africa, but also included initiatives in Asia and Latin America considered of interest (i.e., on scaling, using ICTs). This initial search was primarily performed using the Google search engine and targeted agricultural development initiatives and programs undertaken by international nongovernmental organizations, UN agencies, the World Bank, CGIAR centers and research programs, the International Development Research Centre (IDRC), multilateral funding and development agencies, and leading private foundations. As the research was being led by FRI and FRT, initiatives from these two organizations were also included as a subset of this original dataset. The inclusion of FRI and FRT projects in the meta-review provided an opportunity for these NGOs to critically examine their approach to using ICT4Scale in relation to other development initiatives. At the initial stage, the search was kept broad to include initiatives in agriculture and in food and nutrition security that either ended recently or were near completion. In addition, key journals that feature the use of ICTs for agriculture were searched for relevant journal articles. Grey literature was identified by the study team via manual searches of websites using Google Scholar and other search engines, and from contacts with expertise in ICT4Agriculture. The websites of the following organizations involved in the development and deployment of ICT solutions for agriculture were searched: International Institute of Communication and Development (IICD), ICT4D Collective, IDRC, the World Bank, United Nations Development Programme, FAO, and UNESCO.

From that list of 196 projects, a subset of 71 was selected using the following criteria:

- Explicit aim at scaling an agricultural innovation;
- Distinct use of ICTs as an integral component of the scaling strategy. This research initiative considered ICT tools in the Internet mobile domains, landline and cellular telephones, and radio and television broadcasts;
- Some explicit consideration of gender-related issues in the project design and implementation;
- Projects that have ended within the last two years or are relatively close to ending.

Of these 71 projects, 23 were implemented by FRI or FRT, while 48 were implemented by other organizations (15 of which had components implemented in Asia or Latin America).

The next step was to identify a subset of 15–25 projects that could be included in the review. The 71 projects were scored on the basis of scaling objectives in place (e.g., expected outcomes, number of people to be reached, etc.), the number of ICT approaches used, and the availability of adequate project information

(e.g., initial proposal, project documents and reports, M&E strategy). Among projects with a higher score, the final selection of 15 projects used in this review was made based on the availability of project contact information and willingness to participate in the study. Seven of these projects were implemented by FRI and FRT, and the remainder were conducted by other development organizations. These projects aimed to bring to scale a diversity of agricultural innovations such as agro-advisories, weather and climate services, agricultural decision-support tools and services, agricultural inputs and commodities market information, mobile-based financial services, and nutrition interventions that promote the availability of nutritious food at the household level.

Interviews

The first author conducted 17 semistructured interviews with project coordinators and staff from the 15 selected projects. These interviews sought to provide further insights into the scaling approaches and measures taken (e.g., to transfer a technology or to build capacity) and the scope of the projects' gender equality considerations. In addition to project documents and reports, the interviews offered a means of triangulation and verification in answering the research questions of the study.

Content Analysis

An inductive content analysis was used to identify and organize key themes and concepts from both the interview transcripts and about 45 project documents. The organization of these themes and concepts was also informed by the literature review of peer-reviewed journal articles and grey literature materials presented above.

Results and Discussion

The results from the research questions showed that combining the use of ICT tools with building institutional capacity (e.g., working collaboratively with local partners to facilitate the scaling process) helps to more effectively deliver agricultural extension information to smallholder farmers. These efforts are important as they can harness additional institutional support and resources to facilitate the sustainable spread of innovations, and in some cases improve the functionality of agricultural extension services, as evident in the Rwanda Climate Services for Agriculture project. The project team worked closely with district agricultural departments' training extension officers to integrate ICT-based climate information services and agro-advisories into their ongoing work of assisting farming communities across Rwanda's 30 districts.[1] Among the project's reported impact at scale was that climate information services have been incorporated into the national agricultural extension system, with ICT tools and platforms becoming vital components that provide farmers with timely access to location-specific data and related information.

On the question of which strategies are successful in scaling agricultural solutions, the results found that interactivity in the use of ICT tools and platforms between project teams and beneficiaries are particularly helpful for improving the quality of agricultural extension services and for teaching farmers to better manage predicted agricultural risks. FRI has made interactivity a key part of its approach into rural development, incorporating the use of low-cost ICTs in radio programs to foster knowledge sharing and learning among and between famers, agricultural extension officers, researchers, input suppliers, and others. Most of the FRI projects examined in this study built the capacity of local radio stations to operate an online web platform, known as *Uliza,*[2] that manages and logs all interactions with farmers. Using IVR, Uliza enables listeners to vote on poll questions (called "beep-2-vote"), request calls to receive specific agricultural information (called "beep-2-call") and participate in on-air interviews. ICT-enabled interactive radio programs were particularly valuable to interpret and translate complex information (e.g., climate and weather data) into relevant and applicable agro-advisory content for farmers' unique circumstances.

In Malawi, the Interactive Weather and Climate Adaptation Radio Programming (IWCARP) project broadcast agro-climatic content twice a week in 30-minute episodes on local radio stations. For each broadcast the

1. Interview with project officer, March 22, 2019.

2. Uliza ("to ask" in Swahili) uses IVR that allow farmers to access messages and alerts, vote on poll questions, leave messages, and request specific information.

Table 1. List of ICT-enabled Agricultural Development Projects.

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
Up-scaling Technology in Agriculture through Knowledge and Extension (UPTAKE) Tanzania	FRI; Centre for Agriculture & Bioscience International (CABI)	To disseminate and increase the uptake of improved and certified seed varieties (maize, potatoes, cassava, beans) and improved agricultural practices (e.g., postharvest handling), promoted under the Scaling Seeds and Technologies Partnerships among small scale farmers.	Mobile technology via Esoko platform (SMS alerts on buy and sell offers, SMS polling and surveys) and interactive radio that uses Uliza (FRI's interactive voice response [IVR]) system and dashboard) to communicate with farmers.	Collaborate with local stakeholders (extension officers, farmers, input suppliers) to develop and disseminate SMS content extension information on farm inputs, good agricultural practices, and market prices. Target female farmers (aim for 40% of project beneficiaries to be female) with information to adopt improved inputs. Ensure women are represented in key areas—extension officers, radio hosts, experts on the radio, and in write-shops for content development.	Reached 1,947,000 smallholder farmers with information on the use of improved agricultural technologies by radio programs. 39% of those reached were female. 141,000 farmers applied one of the promoted technologies.	June 2016 to Dec 2018
Achieving Impact at Scale and Economic Viability of Extension Services in Ghana (AIS) Ghana	FRI; Grameen Foundation	To scale up enhanced ICT-enabled extension services to smallholder households, resulting in adoption of productivity-enhancing technologies, specifically targeting women.	AgroTech ICT platform, which combines interactive radio broadcast and customized agent-mediated services.	Strengthen the capacity of local radio stations to broadcast interactive agricultural extension content related to farm inputs, production practices, and market buyers. Train agro-tech field agents to provide agro-advisory services and to sell improved farm inputs.	Reached 486,578 farmers with extension services, of which 174,821 have used or adopted a promoted input or practice; average yields for maize and rice increased over 30% among beneficiaries; increased access to information helped female farmers participate effectively in markets.	Aug 2015 to Feb 2018

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
Her Farm Radio Ethiopia, Tanzania, Malawi, Uganda	FRI; FRT	To increase the extent to which farm radio programs feature female farmers' voices, perspectives, and concerns, and to provide them with increased access to information critical to improving their livelihood outcomes.	Interactive radio ("Her Voice on Air" campaign); women trained to form community listening groups, which were furnished with smartphones and wind-up radios to allow group members to communicate with broadcasters on Uliza platform.	Strengthen the capacity of local radio stations to broadcast interactive agricultural extension content designed to address the informational needs of women related to production practices and gender roles. Empower women to discuss their views on air on the above topics.	Reached over 8.1 million listeners; facilitated the production and broadcast of 262 episodes of farm radio programs containing content directly generated by women in 134 community listening groups. Project fostered a sense of empowerment and self-confidence in the women involved, who noticed an increased respect for their ability to educate others on farming practices.	Jan 2015 to June 2017
Scaling Up Improved Legume Technologies in Tanzania Tanzania	FRI; CABI; Africa Fertilizer & Agribusiness Partnership (AFAP)	To test how a multimedia campaign approach to scaling by targeting different members of a typical small-scale farming family (e.g., young/old, male/female) could best reach audience and influence their knowledge, decisions in adopting integrated legume technology packages.	A multimedia campaign comprising interactive radio, print and social media, comics, and mobile phones, together with demonstration plots and training to support traditional extension approaches.	Collaborate with various organizations to design and deliver agricultural extension content using complementary ICT approaches and traditional extension services related to bean and soybean technologies and market information.	Reached 655,662 members of farming households with information about integrated legume technologies; 128,589 farming households took up at least one of the promoted improved legume technology practices.	Nov 2015 to Feb 2018

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
Radio for Conservation Agriculture (R4CA) Tanzania, Ethiopia	FRI; Canadian Food Grains Bank's local partners	To scale up the reach and impact of conservation agriculture (CA) among smallholder farmers (promoting farmer-led experimentation and farmer-to-farmer support; training local NGO staff and extension officers; and creating an enabling environment with extension services, market linkages, and input supply programs).	Interactive radio capacity building for broadcasters through in-station training; continuous engagement with audiences through Uliza platform.	Strengthen the capacity of local radio stations to broadcast interactive extension content related to CA. Support local partners to liaise, collaborate, and strengthen the capacity of local government to promote conservation agriculture, as well as to lobby the national government to incorporate CA into the public agricultural extension system. Promote gender work that engages with the family unit to ensure that workloads are distributed fairly among all members.	180–200 hours of participatory radio programs delivered to a half-million farming families (potential listeners) with the expectation that at least 250,000 farmers will learn about CA, and at least half of them will demonstrate improved knowledge on CA and 30% (75,000) will apply at least three CA practices.	Mar 2015 to June 2020
Scaling-up Pulse Innovations for Nutrition Security in Southern Ethiopia Ethiopia	University of Saskatchewan; Hawassa University; FRI	To bring about wider-scale impact on the food and nutrition security status of smallholder farmers through scaling up of pulse innovations, comprising selected common bean and chickpea varieties using improved packages of practices (e.g., land preparation, optimum tillage practices, sowing time, seeding rate, etc.).	Participatory interactive radio: Farmers responded to poll questions during the radio programs with their phones to beep-to-vote system hosted on Uliza platform; community listening groups were formed, furnished with wind-up radios and USBs that can record radio program for members to listen to at times that better suited them.	Strengthen the capacity of local radio stations to broadcast interactive agricultural extension content related to chickpea and common bean farm inputs and production practices. Collaborate with Bureau of Agriculture to train government extension agents on pulse crop-based farming and assist farmers on the ground. Collaborate with health extension workers at Bureau of Health to conduct nutrition education for rural households, particularly women, involving complementary food processing and cooking.	51,068 households benefited from improved pulse varieties and site-specific agronomic and soil management packages; an additional 23,059 female households benefited from the nutritional activities (nutrition education, cooking, skill training programs for mothers); 9 seed-producing cooperatives were established.	Mar 2015 to Mar 2018

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
Interactive Weather and Climate Adaptation Radio Programming (IWCARP), Phase 2 Malawi	FRT; World Food Program; CGIAR Research Program on Climate Change, Agriculture, & Food Security (CCAFS)	To develop and disseminate agro-climatic content for farming communities, applying the Participatory Integrated Climate Services for Agriculture (PICSA) model to enable farmers to make weather- and climate-informed agricultural decisions for improved food security and disaster risk reduction.	Interactive radio to disseminate agro-climatic content (seasonal forecasts, disaster preparedness, diversification, pest and disease control); continuous interaction with and feedback from beneficiaries on Uliza platform via SMS (request on-demand weather extension services on "beep-4-weather").	Collaborate with the National Agriculture Content Development Committee to produce and disseminate ICT-based climate information services and agricultural extension. Strengthen the capacity of local radio stations to broadcast interactive climate and agro-advisory information.	Reached 1,328,908 farm households with interactive climate information services combined with seasonal agricultural advice through radio programming.	June 2018 to Dec 2019
Enhancing Resilience to Water-Related Impacts of Climate Change in Uganda's Cattle Corridor (CHAI) Uganda	FHI 360; Uganda Chartered Healthnet	To develop a sustainable and scalable ICT-based climate change adaptation information generation and dissemination model to support the actions of the Ministry of Water & Environment to enhance the adaptive capacity of smallholder farmers exposed to climatic hazards in Uganda.	Interactive FM radio broadcasts (talk shows and spot messages), SMS broadcasts, community loudspeakers, and face-to-face meetings.	Collaborate with the Uganda National Meteorological Authority, the Ministry of Agriculture in three districts, and other public stakeholders to generate subcounty-level weather information and to disseminate it to farmers alongside context-tailored agro-advisories translated into local languages. Strengthen the capacity of local radio stations to broadcast interactive climate and agro-advisory information.	Reached 250,000 farmers with climate and agricultural information, including seasonal and 10-day forecasts specific to subcounties, agricultural advisories to help farmers plan their crop/livestock farming in response to forecasted climate/weather conditions, weekly market information reports, and low-cost water harvesting techniques.	Oct 2015 to Feb 2018

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
MASAVA: Promoting fortified sunflower oil through eVouchers Tanzania	Sokoine University of Agriculture; Mennonite Economic Development Associates of Canada; University of Waterloo, Canada	To test whether SMEs can sustainably fortify crude sunflower oil with vitamin A for local consumption; to test whether using electronic vouchers can succeed in promoting consumption of fortified oil; and to test whether the fortified product can reduce micronutrient deficiencies in vulnerable groups, specifically lactating mothers and infants.	eVoucher (consumer-oriented discounts), which was later switched to an e-Wallet (retailer-oriented discount) sent to beneficiaries' mobile phones; Behavior Change Communications (BCC) campaign to publicize fortified oil through clinic demonstrations, cooking demonstrations, road shows, and cultural shows.	Strengthen the business capacity of several SMEs to undertake large-scale fortification of sunflower oil. Hire a local partner, the Tanzania Communications & Development Centre, to publicize fortified oil through a BCC campaign involving clinic demonstrations, cooking demonstrations, road shows, and cultural shows.	Three SMEs succeeded in fortifying and selling the oil through a network of 319 retailers—more than 142,000 L of oil—enough for almost a half-million people to consume it for a week; 100,000 people reached by the BCC campaign; blood and oil samples from participating households proved that fortified oil reduces micronutrient deficiencies.	Aug 2014 to Feb 2017
Ethiopian ATA-ICT for Agricultural Services Program Ethiopia	Ethiopian ATA funding agency	To streamline smallholders' and extension workers' access to information for sustainable agricultural growth and tailor extension services to different types of situations and communities to make the extension service more market oriented and context specific.	8028 Farmers Hotline, an IVRSMS mobile phone platform that provides smallholder farmers with free access to information on cereal, horticulture, and pulse/oil seed crops; and a push-based voice and SMS alert system that notifies extension workers and farmers of pertinent agriculture issues.	Collaborate with the Ministry of Agriculture & Livestock Resources, the Ethiopian Institute of Agricultural Research (EIAR), and Ethio Telecom to establish the 8028 Farmer Hotline to provide smallholder farmers with extension information on all major cereal, pulses, and high-value crops grown in Ethiopia.	Operationalized 90 service lines that connect smallholder farmers to automated and voice-recorded information on pre-planting, planting, crop protection, fertilizer application, post-harvest handling, processing, irrigation, and weather content; register at least 6 million callers; expand IVR helpdesk services to at least 120 ACC woredas or districts.	2011–ongoing

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
The Rwanda Climate Services for Agriculture Rwanda	CCAFS	Build on and scale up PICSA approach to extend the use of climate information (e.g., drought early warning, planting date decision support) to smallholder.	Interactive radio: radio listener clubs in which members participate in radio programs through call-ins and give feedback about the usefulness of the information using their mobile phones (SMSs, IRV; USSD, social media WhatsApp; Facebook, Twitter).	Collaborated with Rwanda's National Meteorological Agency to enhance the accuracy and use of climate information for national and local decision making. Strengthen the capacity of agricultural extension workers to integrate ICT-based climate information services into their work. Collaborate with a local community radio, Radio Huguka, to broadcast interactive climate- and agriculture-related information. Target female farmers (aim for a minimum of 30% of project participants in PISCA training to be female).	Integrated climate information services into Rwanda's national agricultural extension system through PICSA; trained over 1,000 government extension officers and volunteer farmers in the PICSA process; in turn, they have trained over 100,000 farmers.	Jun 2015 to Dec 2019
Smart Water for Agriculture Kenya	Netherlands Development Organization	To increase water productivity for 20,000 SME Kenyan farmers through a multipronged approach: irrigation acceleration platforms, improved access to/use of smart water technologies, and access to finance, and other services to increase their income and food security and to make them resilient to climate change.	Mobile technology: Push SMS to registered farmers with information about new products, extension advice, field days, etc.	Bring together multiple stakeholders through Irrigation Acceleration Platforms in five counties to foster interaction and collaboration among farmers/farmer groups, smart water solutions (technology) providers, financial institutions, and market buyers. Work with Shamba Shape Up, a weekly radio/TV program, to disseminate information related to smart water agriculture technologies, including link to financial services and companies investing in smart water agriculture products.	Facilitated the establishment of Irrigation Acceleration Platforms to increase water productivity by 20% for 20,000 SME farmers (at least 50% are women; 80% are vegetable producers). Reached over 8 million viewers through Shamba Shape Up.	Apr 2016 to Mar 2020

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
Scaling out useful climate services for increased resilience and productivity in Senegal (CINSERE) Senegal	CCAFS; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	To develop and scale out useful climate services (i.e., on seasonal forecasts, 10-day forecasts, daily forecasts) to improve the livelihood, resilience, and productivity of smallholder farmers, pastorals, and fishermen.	A combination of interactive rural radio, SMSs and USSD, and other e-platforms (WhatsApp, Facebook) was used to deliver climate information.	Build the capacity of the National Meteorological Agency to develop and disseminate climate information and agro-advisories written for an audience of farmers. Strengthen the capacity of community rural radio stations to broadcast climate information and agro-advisories. Collaborate with mobile phone operators to disseminate climate information through SMS to farmers. Initiate advocacy efforts through science–policy dialogue to put in place legislation that supports climate information and other climate adaptation measures, including recognizing climate information as an important farm input in agriculture.	Reached over 7 million rural dwellers (not all farmers) via 82 rural community radios and SMS. Contributed to building the capacity of government agencies and fostering an enabling policy environment for climate services and related agro-advisories.	Mar 2016 to Dec 2019
GSMA mNutrition Initiative Nigeria, Ghana, Malawi, Mozambique, Tanzania, Kenya, Uganda, Zambia, Sri Lanka, Myanmar, Bangladesh, Pakistan	CABI; Global Alliance for Improved Nutrition; GSMA Mobile for Development Foundation; British Medical Journal; Oxfam GB; International Livestock Research Institute	To develop and scale up the delivery of nutrition messages and agriculture-related services for over 3 million people in Africa and South Asia through two existing GSMA mobile for development (M4D) platforms: mHealth platforms (targeted primarily at women and children), and mAgri platforms (targeted primarily at small-scale farmers).	Mobile network operator (MNO), using SMS and/or IVR push content tailored to beneficiaries' location, language, nutrition, or agricultural needs. Content could also be accessed using USSD menus where users register and choose what they wish to access (e.g., on a preferred crop).	Collaborate with local content partners (health clinics, agricultural extension agencies) to create localized, user-centric mobile message content on nutrition (e.g., feeding, dietary practices) and agriculture (planting, land management, harvest, storage practices). Collaborate with mobile network operators to disseminate nutrition and agro-advisory content through mobile phones apps (SMSs, IVR, USSD) to target beneficiaries.	Localized content produced in 12 countries and 24 local languages and delivered to over 5 million registered users; local partners trained in quality content development; over 12,000 messages and over 1,500 factsheets under mAgri and mHealth.	Jun 2014 to May 2017

Table 1. (Continued)

Project name & location	Implementing agencies	Project goals	ICT4Scale intervention	Scaling approaches & measures	Reported outcomes & impact at scale	Duration
Developing Climate Smart Villages in Latin America Colombia, Nicaragua, Guatemala	CCAFS; International Center for Tropical Agriculture	To support the scaling up and -out of climate-smart agriculture technologies and practices through national and local stakeholders.	GIS mapping, crop modeling, seasonal climate forecasting, and on-farm data visualization. Information as published on monthly seasonal agro-climatic forecast platforms that farmers and their organizations accessed on their mobile phones (e.g., via the Plan Your Crops software application).	Bring together 10 national partners (ministries of agriculture, meteorological agencies, grower associations) to develop and disseminate context-specific climate information and agro-advisories to scale up climate smart agriculture practices in climate smart village sites. Push climate information content to farmers through various ICT tools and platforms. Undertake gender work that targets different household members to co-produce knowledge on climate smart agriculture and to deliver climate services through various ICT tools and platforms.	Reached 300,000 farmers with context-specific agro-climatic advisories and services. In Colombia the success of the initiative has prompted the government to establish 15 local technical agro-climatic committees as a measure to promote food security, enhance adaptation, and reduce greenhouse gas emissions.	2015–ongoing

project team would invite a subject-matter expert to discuss a preselected theme (e.g., the onset of a dry spell within a season). The individual would interpret the climate information for specific districts and analyze the implications for agricultural production, including the types of pests and diseases that farmers could expect for crops and livestock, and what steps they could take to manage such climate and weather risks.[3] Thus, the purpose of the radio programs was not merely to provide climate information "because by their own do not mean much to farmers" (see footnote 3), but to help them plan for the types of crops, livestock, and livelihood options that would best suit their circumstances and local climate (see also Caine, Clarke, Clarkson, & Dorward, 2018). The radio programs also aired farmers' voices through the Uliza platform, which again was appreciated by communities. A project officer explains that farmers like to hear what climate risks their peers face and how they manage such challenges rather than hearing only from experts (see footnote 3).

Interactive ICT tools and platforms also enabled project teams to receive timely feedback from end users and to monitor end users' uptake of innovations, which in some cases led to improvements in the design or delivery of new products. For example, the "*MASAVA:* Promoting Fortified Sunflower Oil Through eVouchers" project in Tanzania offered more than 500,000 e-vouchers to low-income households to purchase the oil (sold in one-liter bottles only) at a discounted price. By tracking the e-voucher data, the project team observed low levels of uptake from early on. These trends were confirmed in a midterm project assessment study (April 2016), which revealed that target households generally bought oil in smaller quantities or scoops[4] (~250 ml–500 ml) rather than one-liter bottles, and that oil was purchased by different household members, including children, who did not always have access to a mobile phone (Horton, Saleh, & Mosha, 2017). As a result, the project switched the discount from a consumer-based to a retailer-based voucher (e-Wallet), and changed the packaging to 5-, 10-, and 20-liters bottles that could be sold in scoops, indirectly passing the discount to consumers. These changes helped improve the demand of fortified sunflower oil. In the end, this product reportedly reached over a half-million consumers suffering from Vitamin A deficiency.

The evidence outlined above demonstrates the utility of interactive ICT tools and platforms to effectively deliver agricultural innovations and extension services to large numbers of smallholder farmers in a timely manner. Although most projects collaborated with local stakeholders and other partners to design and disseminate their innovations, their approach to scaling largely focused on optimizing the efficiency of innovations (e.g., information content or product) to increase the number of adopters. As such, projects took the numbers of beneficiaries reached with information pertaining to an innovation (e.g., access to improved seeds, productivity attributes) as a key metric for impact at scale or successful development results. This tendency to link information access to technology uptake speaks to the question about the potential limitations and/or effectiveness of ICTs in accounting for myriad socioeconomic factors that influence the adoption and impact of new innovations in agriculture.

For example, the GSMA's mNutrition Initiative's approach to scaling and its scope of impact largely focused on farmers' mobile phone data usage of agricultural value-added services disseminated through SMSs (IVR and USSD menus) (GSMA, 2017). This was evident in the project's monitoring and evaluation of the overall impact of the contents, messages, and behavior changes among end users, a task that was outsourced to an independent consulting firm.[5] Through "rapid feedback" phone surveys,[6] GSMA concluded that those farmers who actively used Agri-VAS repetitively (known as "power users") made significant on-farm changes (in planting, land management, and harvesting) and increased their production and income (GSMA, 2017). Increased levels of food production and income were used as proxies for food and nutrition security (see also Huggins & Valverde, 2018).

On the question of gender equality, the results found that although several projects had gender strategies to scale up female empowerment, most projects largely focused their attention on knowledge sharing and use of that knowledge as a measure of their interventions' effectiveness. This was evident in FRI's "Her Farm

3. Interview with project officer, April 11, 2019.

4. These are measuring cups, which are often used to sell smaller quantities of food items in poor environments.

5. Interview with project officer, March 21, 2019.

6. This is a method used to support rapid data collection via cell phones from project beneficiaries and can help to guide decision-makers with timely, actionable evidence.

Radio" project, where impact at scale was largely premised on changes in beneficiaries' knowledge, attitudes, and practices around specific innovations.[7] Despite the project's objectives around gender equality and efforts to empower women by building their capacity to gain better access to new technologies, aired radio content primarily addressed women's informational needs about crops and farming practices that were of interest to them (FRI, 2017b). Of course, the project sought to ensure that its activities promoted equitable benefits for both sexes and took inclusive measures to do so. Community radio listening groups brought men and women together to discuss gender-based violence and family planning. In some cases, such engagements enabled men to take more responsibility for helping women on the farm (FRI, 2017b). Yet, empowerment was chiefly viewed as the ability of women to discuss their perspectives and experiences, including farming practices on and off air, which were associated with an increased sense of self-confidence and respect from peers (FRI, 2017b).

Without minimizing the important role that information access plays in inducing positive behavior change around new technologies, smallholder farming systems are characterized by complex socioeconomic dynamics; scaling up even the best of agricultural innovations is often challenging. Counting the numbers of people reached with an innovation at the end of a project grant is therefore a poor metric for measuring impact as it can overlook important contextual and relational factors that influence farmers' decision making or indicate whether adoption will actually contribute to improved livelihood outcomes (see Woltering et al., 2019). Achieving meaningful scaled-up results in smallholder agriculture more often requires affecting the systems around an intervention—across the agricultural value chain—to work better (e.g., societal values, institutional arrangements, market relations, and policy decision making).

The "Developing Climate Smart Villages in Latin America" project[8] (2013–ongoing), for instance, engages with communities in inclusive and iterative ways to further its gender work (see also Howland, Andrieu, & Bonilla-Findji, 2018). The project targets various household members (e.g., male/female, youth) to co-produce knowledge on climate smart agriculture (CSA) and to deliver climate services through a variety of ICT tools and platforms. By doing so, project managers aim to understand the different roles of men and women on the farm and in the home, how responsibilities are distributed, and who is likely to benefit from CSA interventions.[9] Among the CSA activities that the project has implemented are home vegetable gardens, traditionally the responsibility of women in Colombia. The project's gender training work facilitates joint work between men and women in home vegetable gardening. The process seeks to break down social norms that ascribe this activity to women and to foster mutual social collaboration among people. The project also encourages youth participation, teaching them how to use GIS apps to collect climate information (seasonal and 10-day weather forecasts) for their specific location. Engaging young people in CSA activities is intended to not only create job opportunities, but to sustain youth interest in agriculture in a context where large numbers are leaving the rural areas for the cities (see footnote 9).

Overall, the project's knowledge co-production efforts created usable knowledge that was both useful from a scientific perspective and practical for informing people's decision making that addresses their specific needs (see also Harvey, Cochrane, & Van Epp, 2019). Project staff recognized that farmers could improve the utility of CSA technologies and practices, and thus adopted flexible programming that included local knowledge in the innovation process. In so doing, implementing organizations adopted the role of facilitator to ensure that targeted local partners and beneficiaries had a thorough understanding of project objectives and played a key role in the design and delivery of climate information and agro-advisory services (see footnote 9). This approach helped drive program adoption among farmers and has been critical to validating their sense of agency and empowerment (see footnote 9). This approach also reflects broader notions of scaling, with the potential to foster systemic change at scale, which requires long-term engagement to harness the strengths of local partners and beneficiaries, even when the results such as in food and nutrition security are not always apparent or easily quantifiable.

7. Interview with project officer, April 2, 2019.
8. This regional project is being implemented in Colombia, Nicaragua, Honduras, and Guatemala.
9. Interview with project coordinators, March 18, 2019.

Conclusion

This study contributes to the discussion on mapping impact evidence from ICT-enabled scaling-up initiatives in agricultural development by examining closely the activities of several projects that targeted low-income smallholder farmers, primarily in sub-Saharan Africa. These projects aimed to deliver agricultural information and services to a broad base of smallholder farmers in a timely fashion using a wide range of ICT-enabled innovations to improve household food security and incomes. The evidence demonstrates that interactive ICT tools and platforms can improve the quality of agricultural extension and climate information services, which can help smallholder farmers better manage predicted risks on the farm. To drive the scaling process, most projects initiated modest efforts to build up the capacity and skills of local stakeholders (e.g., radio stations, government agencies) who in turn helped to effectively deliver custom-tailored agricultural extension to large numbers of smallholder farmers.

Yet the scope of impact in most of these projects was largely premised on the number of beneficiaries reached (e.g., with information pertaining to an innovation) as a key metric for successful development intervention. Such a limitation might be attributed to the narrow ways in which scaling and impact at scale are commonly conceptualized and applied: to reach large numbers of people with best practices once successfully tested and refined in pilot locations (see Rogers, 2003).

Broader notions of scaling exist that primarily seek to effect systems change at scale by engaging with contextual and relational dynamics that influence the spread or adoption of innovations. In such efforts ICT tools can facilitate information transfer and choice for farmers as illustrated by the Developing Climate Smart Villages in Latin America project. However, ICT tools and platforms are unlikely to be primary agents of change that will transform smallholder food security, nutrition, and gender relations unless projects adopt a system-wide approach to better understand smallholder farming challenges and use ICTs in tandem with other actions that support farmers. Lasting and meaningful change requires a thorough understanding of specific smallholder agriculture system dynamics, followed by a realignment of innovations to contribute positively to such processes, in a manner that works collaboratively with target populations and local partners. The scaling process here requires long-term attention, even if impacts are not immediately apparent. ■

Acknowledgments

This research was funded by the International Development Research Centre (IDRC). The authors would like to thank three anonymous reviewers and the editors for their constructive feedback on earlier drafts of this article.

Helena Shilomboleni, Postdoctoral Fellow, Scaling Specialist, CGIAR Research Program on Climate Change, Agriculture and Food Security East Africa, International Livestock Research Institute, Kenya. H.Shilomboleni@cgiar.org

Bernard Pelletier, Manager, Knowledge Management, Farm Radio International, Canada. bpelletier@farmradio.org

Berhane Gebru, Digital Development Program Director, FHI 360, USA. bgebru@fhi360.org

References

Aker, J. C., & Ksoll, C. (2016). Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. *Food Policy, 60,* 44–51. doi.org/10.1016/j.foodpol.2015.03.006

Brown, A. N., & Skelly, H. J. (2019). How much evidence is there really? Mapping the evidence base for ICTD interventions. *Information Technologies & International Development, 15,* 16–33.

Caine, A., Clarke, C., Clarkson, G., & Dorward, P. (2018). Mobile phone applications for weather applications for weather and climate information for smallholder farmer decision-making. In R. Duncombe (Ed.), *Digital technologies for agricultural and rural development in the Global South* (pp. 1–13). Oxfordshire, UK: CABI.

Chipidza, W., & Leidner, D. (2017). *ICT4D research—Literature review and conflict perspective.* Paper presented at the 23rd Americas Conference on Information Systems, Boston, MA. Retrieved from https://aisel.aisnet.org/amcis2017/ICTs/Presentations/17/

Deichmann, U., Goyal, A., & Mishra, D. (2016). *Will digital technologies transform agriculture in developing countries?* (Policy Research Working Paper 7669). Washington, DC: World Bank Group. Retrieved from https://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-7669

Duncombe, R. (Ed.). (2018). *Digital technologies for agricultural and rural development in the Global South.* Oxfordshire, UK: CABI.

Farm Radio International. (2017a). *Inception workshop report: Harnessing ICT to scale-up agricultural solutions* (IDRC Project #108451). Ottawa, Canada: Farm Radio International.

Farm Radio International (2017b). *Her Farm Radio in Ethiopia, Malawi, Tanzania and Uganda* (Final report). Ottawa, ON: Farm Radio International. Retrieved from https://publications.farmradio.org/final-project-report-her-farm-radio-in-ethiopia-malawi-tanzania-and-uganda/

Frieden, R. (2013). Identifying best practices in financing next generation networks. *The Information Society, 29*(4), 234–247.

Gray, B., Babcock, L., Tobias, L., McCord, M., Herrera, A., & Cadavid, R. (2018). *Digital farmer profiles: Reimagining smallholder agriculture.* Washington, DC: Grameen Foundation. Retrieved from https://www.usaid.gov/sites/default/files/documents/15396/Data_Driven_Agriculture_Farmer_Profile.pdf

GSMA. (2017). *Creating scalable, engaging mobile solutions for agriculture: A study of six content services in the mNutrition Initiative portfolio.* London, UK: GSM Association. Retrieved from https://www.gsma.com/mobilefordevelopment/wp-content/themes/theme_mobilefordevelopment/magri-repo/Creating-engaging-scalable-solutions-for-agriculture.pdf

Hartmann, A., Kharas, H., Kohl, R., Linn, J., Massler, B., & Sourang, C. (2013). *Scaling up programs for the rural poor: IFAD's experience, lessons and prospects (phase 2)* (Brookings Global Economy & Development Working Paper 54). Washington, DC: Brookings. Retrieved from https://www.ifad.org/en/web/knowledge/publication/asset/40279951

Harvey, B., Cochrane, L., & Van Epp, M. (2019). Charting knowledge co?production pathways in climate and development. *Environmental Policy and Governance, 29*(2), 107–117. doi.org/10.1002/eet.1834

Horton, S., Saleh, N., & Mosha, T. (2017). *MASAVA: Promoting fortified sunflower oil through eVouchers* (CIFSRF project number 107790). Ottawa, Canada: International Development Research Centre. Retrieved from https://www.idrc.ca/en/project/promoting-locally-fortified-sunflower-oil-using-e-vouchers-cifsrf-phase-2

Howland, F., Andrieu, N., & Bonilla-Findji, O. (2018). *Understanding socioeconomic aspects influencing CSA adoption* (CCAFS Working Paper no. 247). Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security.

Huggins, C., & Valverde, A. (2018). Information technology approaches to agriculture and nutrition in the developing world: A systems theory analysis of the mNutrition Program in Malawi. *Food Security, 10,* 151–168.

International Fund for Agricultural Development (IFAD). (2015). *Sustainable inclusion of smallholders in agricultural value chains. Scaling up note.* Rome, Italy: Author. Retrieved from https://www.ifad.org/documents/38714170/40264252/Scaling+up+note+-+Sustainable+inclusion+of+smallholders+in+agricultural+value+chains.pdf

KIT, Agri-ProFocus, & IIRR. (2012). *Challenging chains to change: Gender equity in agricultural value chain development.* Amsterdam, Netherlands: KIT Publishers, Royal Tropical Institute.

Lambrecht, I., Vanlauwe, B., Merckx, R., & Maertens, M. (2014). Understanding the process of agricultural technology adoption: Mineral fertilizer in eastern DR Congo. *World Development, 59,* 132–146.

Massler, B. (2012). Empowering local communities in the Highlands of Peru. In J. Linn. (Ed.), *Scaling up in agriculture, rural development, and nutrition. 2020 Focus Brief 19* (Brief 4). Washington, DC: International Food Policy Institute.

Menter, H., Kaaria, S., Johnson, N., & Ashby, J. (2004). Scaling up. In D. Pachico, D. Fujisaka, & S. Fujisaka (Eds.), *Scaling up and out: Achieving widespread impact through agricultural research* (pp. 9–23). Cali, Colombia: International Centre for Tropical Agriculture.

Middleton, T., de la Fuente, T., & Ellis-Jones, J. (2005). Scaling up successful pilot experiences in natural resource management. Lessons from Bolivia. In M. Stocking, H. Helleman, & R. White (Eds.), *Renewable natural resources management for mountain communities* (pp. 221–238). Kathmandu, Nepal: International Centre for Integrated Mountain Development.

Njuki, J., Parkins, J., Kaler, A., & Ahmed, S. (Eds.). (2016). Introduction—Gender, agriculture, and food security: Where are we? In J. Njuki, J. Parkins, & A. Kaler (Eds.) *Transforming gender and food security in the Global South* (pp. 1–18). London, UK: Routledge.

Pircher, T., Almekinders, C., & Kamanga, B. (2013). Participatory trials and farmers' social realities: Understanding the adoption of legume technologies in a Malawian farmer community. *International Journal of Agricultural Sustainability, 11*(3), 252–263.

Quisumbing, A., Meinzen-Dick, R., Raney, T., Croppenstedt, A., Behrman, J., & Peterman, A. (Eds.). (2014). *Gender in agriculture: Closing the knowledge gap.* Dordrecht, Netherlands: Springer.

Rogers, E. (2003). *Diffusion of innovations* (3rd ed.). New York, NY: McMillan.

Sachs, J. D., Modi, V., Figueroa, H., Machado Fantacchiotti, M., Sanyal, K., Khatun, F., . . . , Spencer-Cooke, A. (2017). *How information and communications technology can accelerate action on the Sustainable Development Goals. ICT & SDGs* (Final Report). New York, NY: The Earth Institute, Columbia University. Retrieved from https://www.ericsson.com/assets/local/news/2016/05/ict-sdg.pdf

Shilomboleni, H., & De Plaen, R. (2019). Scaling up research-for-development innovations in food and agricultural systems. *Development in Practice, 29*(6), 723–734. doi.org/10.1080/09614524.2019.1590531

Theis, S., Lefore, N., Meinzen-Dick, R., & Bryan, E. (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agriculture and Human Values, 35,* 671–684.

Trendov, N. M., Varas, S., & Zeng, M. (2019). *Digital technologies in agriculture and rural areas.* Rome, Italy: United Nations Food and Agriculture Organization. Retrieved from http://www.fao.org/3/ca4985en/ca4985en.pdf

Westermann, O., Förch, W., Thornton, P., Körner, J., Cramer, L., & Campbell, B. (2018). Scaling up agricultural interventions: Case studies of climate-smart agriculture. *Agricultural Systems, 165,* 283–293.

Wigboldus, S. (2018). *To scale, or not to scale—That is not the only question: Rethinking the idea and practice of scaling innovations for development and progress* (Doctoral dissertation)., Wageningen University, Netherlands. Retrieved from https://edepot.wur.nl/449586

World Bank. (2017). *ICT in agriculture: Connecting smallholders to knowledge, networks, and institutions* (Updated ed.). Washington, DC: World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/27526

Woltering, L., Fehlenberg, K., Gerard, B., Ubels, J., & Cooley, L. (2019). Scaling—From "reaching many" to sustainable systems change at scale: A critical shift in mindset. *Agricultural Systems, 176,* 102652. doi.org/10.1016/j.agsy.2019.102652