Development in Practice

ISSN: 0961-4524 (Print) 1364-9213 (Online) Journal homepage: https://www.tandfonline.com/loi/cdip20

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To cite this article: Helena Shilomboleni & Renaud De Plaen (2019): Scaling up research-for-development innovations in food and agricultural systems, Development in Practice, DOI: 10.1080/09614524.2019.1590531

To link to this article: https://doi.org/10.1080/09614524.2019.1590531

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Published online: 29 Mar 2019.

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DEVELOPMENT IN PRACTICE
https://doi.org/10.1080/09614524.2019.1590531

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ABSTRACT

The last decade has seen a growing interest in scaling up innovations to realise wider benefits from development investments. While numerous proven technologies, products and models have been successfully piloted, scaling them up through expansion, adoption and replication has proved challenging, particularly in poor regions of the world. The low uptake of innovations is partially attributed to the design of technologies, in a manner that is not compatible with local farming practices. At the same time, proven innovations fail to generate large impacts at scale because implementing actors have not sufficiently understood or effectively engaged with the scaling process. This article shares lessons from the Canadian International Food Security Research Fund (CIFSRF) that supported applied research to develop, test and scale up promising food and nutrition security innovations. Key lessons include ensuring that innovations are embedded within local socio-ecological systems; engaging end users throughout the research process and enabling participatory decision-making; and considering the investment returns of innovations for end-users.

ARTICLE HISTORY
Received 1 August 2018
Accepted 2 January 2019

KEYWORDS
Aid – Capacity Development; Civil society – Participation, Partnership; Environment (built and natural) – Food security

Introduction

Over the past decade, scaling up innovations to "achieve impact at scale" has garnered enormous interest among researchers, donor agencies and policymakers. These actors have embraced language around scaling as it relates to tackling climate change, food insecurity, and achieving the Sustainable Development Goals (Jonasova and Cooke 2012; Hartmann et al. 2013). With a rise in private sector funding in agriculture development, moreover, there is a shift towards supporting "impact investments" that are able to deliver tangible results both in terms of financial returns and social good (Koh, Karamchandani, and Katz 2012). Such pressure has ushered in an imperative to scale for maximum reach and benefit, that is, to target large numbers of people across different geographical spaces.

In smallholder food and agricultural systems, however, the uptake and impact of new innovations has been limited and many agricultural technologies particularly in Sub-Saharan Africa remain "on the shelf" (IAASTD 2009; Ajayi, Fatunbi, and Akinbamijo 2018). On one hand, the low uptake of innovations is largely attributed to the design of technologies, in a manner that is not compatible with, or relevant to, local socio-ecological systems and producers' capabilities (Feder, Just, and Zilberman 1985; Rogers 2003; Shiferaw, Okello, and Reddy 2009; Glover, Venot, and Maat 2017). On the other hand, proven innovations see a low uptake because implementing actors have not sufficiently understood or effectively engaged with the scaling process. Often, questions surrounding contextual and relational factors that influence the spread or adoption of innovations are not adequately addressed, including economic incentives, political objectives and social learning.

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Indeed, prominent assumptions about how scaling up happens is that it involves the deployment of innovations (i.e. dissemination, transfer or diffusion of a technology, product or model) on a broader scale once successfully tested and refined in pilot locations (Rogers 2003; Cooley and Linn 2014; Cook and Fujisaka 2004). The deployment of innovation approach to scaling up tends to focus on niche-level factors that are necessary to optimise the efficiency, or promote the effective delivery, of specific technologies, products or models for predetermined groups (Middleton, de la Fuente, and Ellis-Jones 2005). Such factors mainly pertain to affecting specific attributes of an innovation, user preferences and behaviour that can help to move it from the research design and pilot testing phases to the adoption stages of scaling. While this approach to scaling provides valuable insights into the attributes that facilitate the spread of innovations, it does not sufficiently capture the complex dynamics and systemic interactions involved in, and resulting from, scaling processes (Wigboldus et al. 2016).

In recent years, several scholars have drawn theoretical insights from multi-level perspective (MLP) to explain the dynamic interplays between different actors that help to facilitate scaling up processes in food and agriculture systems (Wigboldus and Leeuwis 2013; Hinrichs 2014; Wigboldus et al. 2016; Pitt and Jones 2016; Hall et al. 2016). The ways in which innovators engage with, or leverage existing or new opportunities in, the public and private sectors and target beneficiaries determine the scope of impact of their innovations in terms of breadth (e.g. the number of beneficiaries reached) and depth (the change or difference that solution made in the lives of end users). This article draws parallels to this literature to share key lessons from the Canadian International Food Security Research Fund (CIFSRF) on the complex processes involved in scaling up and on achieving impact at scale.

Jointly funded by the International Development Research Centre (IDRC) and Global Affairs Canada (GAC), CIFSRF was a nine-year, two-phased programme (2009–2018) that supported applied research to develop, test and scale up promising food and nutrition security innovations. CIFSRF invested CA$124.5 million in 39 projects that were selected and implemented in 24 Global South countries by multi-stakeholder partners from research institutions and universities, the private and public sectors and civil society groups. CIFSRF Phase 2 (2013–2018) aimed to support the scaling up of research results to generate large-scale positive impact. Cross-sector partnerships in CIFRSRF Phase 2 fit within the broader IDRC mandate to support collaborative research that aims to build the capacity of stakeholders, promote knowledge sharing, and foster innovative change (Cochrane and Cundall 2018; Carter and Currie-Alder 2006).

A total of 18 projects (with 10 extensions from Phase 1) were selected to test and scale up their innovations in CIFSRF Phase 2, ranging from "discovery sciences" engaged in technological breakthroughs (e.g. livestock vaccines) to business or social models focused on improving service delivery

Table 1. Sample overview of CIFSRF Phase 2 project innovations developed and tested for scaling.

Innovations and countries of implementation
• Salt fortified with iron and iodine (India)
• Sunflower oil fortified with vitamin A (Tanzania)
• Hexanal Enhanced Freshness Formulation (EFF) pre-harvest spray (India, Sri Lanka, Kenya, Tanzania, Trinidad and Tobago)
• Menu of Sustainable Agricultural Kits (Nepal)
• Improved nutritious yellow potato varieties (Colombia)
• Fertiliser micro-dosing and water management for indigenous vegetables (Nigeria, Benin)
• Enhanced homestead food production model (Cambodia)
• Aquaculture and fisheries production of *pacu* and *paiche* (Bolivia)
• Complementary fortified food for children (Vietnam)
• Probiotic yoghurt (Uganda, Kenya, Tanzania)
• Multi-component vaccine for five diseases for sheep, goats and cattle (Kenya, South Africa)
• Sub-unit vaccine for protection of cattle against CBPP (Kenya)
• Small-millet dehuller machines (India)
• Value added pulse-based foods for households (Ethiopia)
• Disease management model for CILY disease control (Cote D'Ivoire)

(Table 1). From a food security perspective, these innovations were designed to boost food production, improve nutrition, and foster effective policies. They included 36 technologies, products and models that are either new inventions or old ones but applied in new ways, intended to address a specified need (Rogers 2003).

This article is divided into three sections. The first section provides a brief overview of the literature on scaling up innovations and employs MLP to describe how socio-technological transitions come about. Section two elaborates on CIFSRF Phase 2's approach to scaling as well as the methodological approach used to analyse project results. The third section outlines key lessons from CIFSRF Phase 2 on how contextual conditions can enable (or constrain) the scaling process to help generate positive, long-lasting impact at scale results.

Literature review: scaling up socio-technological innovations

Widely used definitions of scaling up tend to reflect notions of broader reach – more people, geographical space, political institutions, or commodity output. According to the World Bank (2004), "*scaling up means expanding, adapting and sustaining successful policies, programs or projects in different places and over time to reach a greater number of people*" (in Hartmann and Linn 2008). This scaling up trend is especially striking in the agriculture sector, where "*well-intended [experts] are looking for new solutions to the 'great balancing act' (Searchinger, Hanson, and Ranganathan 2013) of feeding 9 billion, reducing environmental and climate harms, and distributing economic development gains more widely and fairly*" (Hinrichs 2014, 144). There are questions about how these goals would be achieved considering the global footprint of agriculture on the earth's planetary boundaries (and impact on climate change) and social inequalities associated with accessing adequate and nutritious food, including the long-term marginalisation of small-scale food producers (Schot and Kanger 2018; IPES-Food 2016; IAASTD 2009).

Various scholars look to the *sustainability transition* field to understand how food and agricultural systems might be reoriented towards more sustainable practices in production and consumption (Markard, Raven, and Truffer 2012; Hinrichs 2014; Pitt and Jones 2016). Transitions are concerned with fundamental shifts in processes and structures that underpin socio-technological systems; that is, in ways that can facilitate investments in, and spread of, innovations that respond to development and sustainability challenges (Marsden 2013). MLP is a well-established theory used to conceptualise transitions and is increasingly applied to the scaling up literature (Wigboldus and Leeuwis 2013; Wigboldus et al. 2016). MLP explicates that socio-technological transitions occur as a result of continuous interaction between various actors at three levels: niche, regime and landscape.[1] The niche level is the protected spaces in which promising innovations are developed (Geels 2002, 2011). The regime level constitutes dominant practices and rule-based structures (industry standards, government regulations, etc.) that often create stability in a system through path dependencies and lock-ins (Hinrichs 2014). The landscape level embodies the broader bio-physical environment and macro-political economy context in which socio-technological activities are situated. Pressures and opportunities, for example, oil price shocks or food security crises, arising at the landscape level can also catalyse shifts at the other levels, enabling transitions to occur (Geels and Schot 2007).

The complex interactive processes involved in MLP socio-technological transitions are comparable to how new innovations scale up – from early stages of research and development to broader uptake and reach (Middleton et al. 2002; Hartmann and Linn 2008; Wigboldus and Leeuwis 2013; Hartmann et al. 2013; Hall et al. 2016). Most scaling up interventions starts with an idea that seeks to address a specific challenge, developed in a niche space such as a laboratory or an experimental field site. As such an idea evolves into a product, technology or model, its innovators must build a network of supporters around it, comprised of end users, supply chains, policymakers, and so on (Kemp, Schot, and Hoogma 1998). Innovators must collaborate, advocate, negotiate with or put pressure on these various actors in order to create space for their solution within the regime, and in the long-run influence political and cultural perspectives (at the landscape) (Geels 2011).

The scaling up of innovations, much like transition processes in MLP, tend to focus on individual socio-technological systems (i.e. that revolve around the innovation in question). However, this approach pays less attention to the interconnections of multiple socio-technological systems and how they coalesce to form common directionalities in (globalised) economies, polities, cultural frameworks and every day practices over time (Schot and Kanger 2018, 1046). Indeed, the historical expansion of innovations in fossil fuels (oil or coal), synthetic materials and mechanisation in production have facilitated mass consumption of pervasively low-cost goods, particularly in the West (Schot and Kanger 2018). However, their impact on the earth's systems has been detrimental, as evident in the rapid depletion of natural resources, greenhouse gas emissions, pollution, and so on (Markard, Raven, and Truffer 2012). These challenges suggest that socio-technological transitions, and scaling up interventions, are not always desirable and at times can drive societies towards unsustainability (Pitt and Jones 2016). A follow-up paper will critically examine the transformative potential of scaling up innovations in low-income agricultural systems.

CIFSRF Phase 2's approach to scaling up

Scaling up research results was a cross-cutting theme in CIFSRF Phase 2 (2013–2018). At the early set of its implementation, the Agriculture and Food Security (AFS) programme at IDRC conducted a series of training workshops for project grantees to build a common understanding around scaling up innovations to generate impactful results. CIFSRF Phase 2 supported 18 projects to test and scale up 36 research-for-development innovations that comprised diverse products, technologies and models.[2] These projects were implemented through multi-stakeholder arrangements involving a combination of private and public sector actors, university and/or research institutions, NGOs and civil society entities. Collaboration with these partners at the regime and landscape levels is emblematic of MLP efforts needed to facilitate the transition of project innovations from protected niche spaces into mainstream settings.

Moreover, given the complexity of socio-ecological problems affecting food and agriculture systems in poor regions of the world, CIFSRF was designed on the premise that generating impact at scale in these areas requires partnerships which can harness the strengths, capacities, and resources of different actors. While private sector channels may deliver some products more efficiently, other solutions might require policy-based systems (i.e. public sector) for scaling. At the same time, some innovations might be well-served to be deployed through a combination of approaches. These different delivery mechanisms upon which innovations are diffused to reach their intended audience and answer to local conditions are known as scaling up pathways. The AFS programme identified three commonly used scaling up pathways that proved relevant to the diversity of CIFSRF innovations: (1) public/policy-based approaches; (2) market-based approaches; and (3) knowledge-exchange approaches (IDRC AFS 2016).[3]

Public or policy-based pathways are associated with political processes that project teams can engage with to inform, influence or lobby policymakers to incorporate their innovations into existing institutions. Market-based pathways follow commercialisation routes that generally rely on private sector companies to produce and distribute innovations, either independently or through ventures, franchises, licence leases, and so on. Knowledge-exchange pathways rely on information sharing mechanisms to influence end users' attitudes and decisions about particular innovations. Agricultural innovations are disseminated through various channels including extension systems, such as farmer field schools, innovations platforms that bring multiple stakeholders together and information communication technologies (ICTs). Working with strategic partners in these different arenas can support the scaling up process to help achieve large-scale impact without necessarily allocating more financial resources to lead grantee organisations (Gugelev and Stern 2015).

The research results presented here draw from an intensive year-long study on scaling up innovations in small-scale food and agriculture systems, taking CIFSRF Phase 2 projects as a basis for empirical analysis. Over 100 CIFSRF project documents and academic publications were analysed using grounded theory methodology. The first author also conducted 17 semi-structured interviews with IDRC project officers responsible for CIFSRF Phase 2 projects and three focus group discussions with grantees to extract key lessons from individual projects' scaling up activities and on achieving impact at scale. An inducive approach to data analysis generated patterns in the gathered information that were categorised into themes and subthemes of key results and lessons learnt.

The analysis found that projects generated different outcomes based on the scaling up approach taken. Some projects took a *deployment of innovations* approach (dissemination, transfer or diffusion of technologies) to reach large numbers of beneficiaries. Other projects used their innovations as an entry point to *catalyse systemic change* in specific food and agricultural systems. In both approaches, implementing projects engaged with different actors, at the niche, regime and landscape levels, to help spread their innovations from pilot phases to broader scales. Such engagement ranged from advocating, lobbying or collaborating with policymakers to integrate their innovations into domestic programmes, to strengthening the technical capacity and socio-political agency of local actors in ways that enable them to articulate their needs more effectively.

The analysis also found that the efficacy of scaled up results, and potential to generate positive long-lasting impacts at scale, depended largely upon each project's ability to answer to several important contextual conditions. Whereas MLP attributes of collaborating with various actors at different levels are critical to help move innovations from niche spaces into mainstream settings, the successful uptake of innovations in low-income communities require greater attention to local socio-ecological systems, the economic viability of innovations for end-users, and other contextual considerations.

Key lessons from CIFSRF Phase 2 on scaling up research-for development innovations

There is a great need to better understand how promising research-for-development agricultural innovations can achieve positive, long-lasting impacts for poor rural communities that are disproportionately affected by high levels of food and nutrition insecurity and have limited access to resources needed to improve their lives (FAO et al. 2018). CIFSRF supported projects with proven innovations that could benefit especially rural and poor populations, particularly women and smallholder farmers. The programme's work in low-income food and agricultural systems generated several important lessons for development practice and policy.

1. Ensure that an innovation is embedded within local socio-ecological structures and practices and are amenable to end users' skills and capacities, including various constraints that poor households face (e.g. land availability and tenure, farm size, capital and risk and uncertainty).

An important enabling factor that affects the sustainable spread or adoption of an innovation is its compatibility with socio-cultural practices and the bio-physical environment (Rogers 2003). Innovations which see successful uptake are those that collaborate with end users throughout the research and design process, not merely as "affected stakeholders" but as actors with agency and capabilities in their own right (Glover, Venot, and Maat 2017). Technology transfer is enacted within situated practice, that is, in people's capabilities to alter an innovation so that it becomes embedded in their social structures, material conditions, and symbolic practices (Glover, Venot, and Maat 2017). This approach takes into consideration the complex nature of household decision-making and the fluidity of social and ecological constraints that poor households face, including farm size, risk and uncertainty, capital, labour availability and land tenure (Feder, Just, and Zilberman 1985; Bachmann et al. 2016). For CIFSRF Phase 2, 11 projects engaged in measures to ensure that their innovations were compatible with local socio-ecological systems.

For example, the Nepal Terrace Farmers and Sustainable Agriculture Kits (SAK*)* project scaled up a menu of 20 low-cost technologies, products and practices aimed at reducing female drudgery and increasing farm productivity in smallholder agricultural systems.[4] Prior to CIFSRF, this project pre-tested 47 potential SAK innovations for hillside terrace farming, but worked closely with Nepalese farmers to select those that were best suited for individual household circumstances (labour, capital, skills, etc.) (Pudasaini, Chapagain, and Raizada 2018). A sample of farmers (1,682 women and 1,218 men) tested and rated each of these scaled up innovations based on six criteria: relative advantage; visible effectiveness; amenable to trial; simple; compatible; affordable (Rogers 2003, in Sthapit and Pudasaini 2017). This enactment rigour helped to wean out innovations that could not be embedded within farmers' socio-ecological environments. For example, two types of corn shellers, tabletop and handheld, were developed but only the latter was scaled up. This was because hand-held shellers are portable and allowed female farmers to continue a social practice of helping each other with shelling corn (Sthapit and Pudasaini 2017).

The SAK project's participatory research process is illustrative of a deployment of innovations approach that engages with niche-level conditions to facilitate the uptake of innovations. Working with target populations to ascertain their preferences and the socio-economic and ecological constraints they face, helped the project to develop custom-tailored innovations that respond more effectively to their needs. However, the project also collaborated with various actors at the regime level, for example, Ministry of Agriculture district branches and a private sector company, to incorporate some of the SAK innovations into their extension programmes. Such collaboration helped the project to achieve broader impact at scale, reaching and benefiting 60,288 households (far above its initial target of 25,000) (Pudasaini, Chapagain, and Raizada 2018). The partnerships also demonstrate a potential to transition the project's innovations from niche spaces into mainstream institutions.

2. Engage end users throughout the research process and enable flexibility in project design to facilitate participatory decision-making to respond more effectively to local demands.

There are two important features associated with applied research which focuses on the capacity development of end users. On one hand, researchers build up the technical capacities of beneficiaries in the process of improving the efficiency and/or sustainable uptake of an innovation. SAK project activities are a case in point. On the other, the research process can strengthen the socio-political capacity and agency of beneficiaries to leverage new opportunities and to advocate for their needs and priorities more effectively (Leeuwis, Schut, and Klerkx 2017). This approach can help to drive an impact that is more demand-driven and relevant to local conditions. A total of nine CIFSRF Phase 2 projects engaged with end users throughout the research process and three of these fostered the socio-political agency of their target population.

In Bolivia, Amazon Fish for Food project's (or *Peces para la Vida* – PPV II) research team recognised from the onset that developing effective strategies to address food security challenges faced by poor populations required facilitating their access not only to resources that they need to improve their lives, but to knowledge tools and power (Flaherty et al. 2013). Thus, the project's capacity building activities encompassed inclusive learning processes that promoted bottom-up, grassroots organising to help women and men raise their consciousness around socio-political issues of justice (e.g. to productive resources, community management roles and reproductive responsibilities, etc.) (Macnaughton et al. 2017). For example, peer-to-peer methodologies were applied to various technical assistance efforts geared towards family fish farmers, such as the Technical Aquaculture Assistant programme. This entailed participatory decision-making in project implementation that involved iterative learning, shaped by debate negotiation, and even conflict (Macnaughton et al. 2017). This kind of engagement is emancipatory because it is based on mutual respect and trust between project teams and poor people whose knowledge is often undervalued in solving practical problems.

A key outcome was that PPV's project activities to strengthen the socio-political agency of family fish farmers enabled their participation in the fisheries sector and the project as more equal partners. Legal permits for aquaculture associations and a fisheries federation, as well as involving family fish farmers into multi-stakeholder fisheries platforms has helped to raise their profile as legitimate actors in public policy spaces with bargaining power. Flexibility in project design and the openness of the team facilitate participatory decision-making also enabled new initiatives, such as the processing and selling of fish leather, to emerge, which grew from a demand from beneficiary fishers seeking innovative ways to address the invasive *pacu* fish (Carolsfeld et al. 2018).

3. Consider the investment returns of an innovation for end users (e.g. smallholder farmers), including the competitiveness of price and supply and demand conditions in domestic and/or international markets.

Another important factor that influences the sustainable spread or adoption of an innovation is its profitability, which is the tangible economic benefit of a technology for end users (e.g. farmers) in the short run (Bachmann et al. 2016). For example, various agricultural technologies introduced to address low-productivity in Sub-Saharan Africa have boosted crop yields (Adekunle and Fatunbi 2014). However, increased produce output in the absence of a commensurate expansion of markets have at times led to a collapse of prices and production (Hartmann et al. 2013). The International Fund for Agriculture Development's (IFAD) West African Root and Tubers Expansion Programs implemented from 2005 to 2013 experienced negative scaling up outcomes whereby production gluts saw sharp declines in output prices, and a reduction in farmers' incomes (Hartmann et al. 2013, 29).

A couple of CIFSRF 2 projects implemented in Sub-Saharan Africa have mainly focused their activities on helping smallholders to increase their farm productivity but have not dedicated adequate resources to address market access concerns. For example, the Achieving Impact at Scale through ICT-enabled Extension Services in Ghana (AIS) project supported smallholder farmers to increase food production through private sector-led ICT-based extension services (Agro-Tech). The Agro-Tech innovation is a package of integrated agriculture extension services, delivered through mobile-enabled agents, SMS, video and radio. This innovation also connected farmers to agri-business services to gain access to productivity-enhancing technologies for six crops: maize, rice, yam, cowpeas, soybeans and leafy greens.

The project reports that is has achieved success results, in terms of significant yield increases for smallholder farmers in project locations as well as having reached an additional 300,000 farmer beneficiaries by radio and another 10,000 via mobile agent (Chidiac 2018). However, discussion on the profitability and net investment returns for farmers with regards to the Agro-Tech innovation was less clear. The project estimates a 40-50% profit increase from maize and rice crops with the Agro-tech innovation, based on several focus group discussions with beneficiary smallholder farmers (Chidiac 2017, 11). Yet, this information was not substantiated with any other research data.[5] Further, while the project has identified locally-based aggregator companies that could serve as a market for farmers' produce, there was scarcely any analysis on how much farmers will earn or what the terms and conditions for engagement in these markets entailed. These market-access challenges raise serious concerns that need deeper reflection and assessment in terms of the profitability and net investment returns of certain agricultural products in poorer regions of the world. Compelling research evidence show that farm gate prices of agricultural commodities (particularly cereal crops like maize and rice) have faced a downward trend over the last 20 years and have become increasingly volatile in the last 10 years (Akram-Lodhi 2013). This is largely due to distorted macro-economic and trade policies in the global agri-food system. Extensive research has also shown that commercially-based agricultural innovations carry a risk of exposing Africa's smallholders to debt relations in part due to low net returns from the produce they sell (McMichael 2013). This risk demonstrates a clear need for more systematic approaches to addressing market access issues for smallholder farmers.

4. Identify and engage with regulatory dimensions that are required for the commercialisation of an innovation from the beginning of project design and implementation.

Some innovations must go through lengthy regulatory procedures prior to commercialisation in host countries. Intellectual property concerns and/or restrictions can also slow down the commercialisation and dissemination of such innovations even further. A couple of CIFSRF 2 projects faced complex regulatory procedures which in some cases delayed the scaling up process of their innovations.

For example, the Enhanced Preservation of Fruits Using Nanotechnology project developed nine hexanal-based technological innovations[6] to increase the shelf life of fruits in six countries and in 15 types of fruits.[7] While these hexanal-based innovations proved to be effective in reducing post-harvest loss, the products faced regulatory hurdles in host countries and as a result have not been commercialised during the project phase. In India, where the project progressed the furthest, the research team faced difficulty obtaining registration permits for hexanal as a pre-harvest/post-harvest application product for fruit, specifically the Enhanced Freshness Formulation (EFF).[8] India has classified EFF as an insecticide under the Central Insecticide Board (CIB), and not as an organic compound (e.g. like ethelyne) that can be used to increase fruit retention. Therefore, a new registration (or classification) of EFF under the CIB would have to follow a lengthy three to four-year regulatory process prior to product commercialisation, which was beyond the project life cycle. During the last few weeks of the project, however, the team successfully negotiated with the state of Tamil Nadu, India as well as the Sri Lankan government to commercialise EFF (for sprays and dips).

Nonetheless, hexanal-based technologies were unable to generate large-scale impacts that involved wide-scale adoption by farmers during the programme timeframe of CIFSRF Phase 2. The project team, comprised entirely of academic researchers, were unlikely prepared for the regulatory challenge that EFF encountered, while struggling to engage a policy-based pathway, given that it was not initially part of the project's objectives. Likewise, a pre-existing patent associated with EFF slowed the scaling up process as private sector companies were hesitant to enter into licencing agreements with the project, particularly in the face of unresolved regulatory issues.

Conclusion

Current trends in global agriculture development emphasise the scaling up innovations to generate large impact at scale for many people across vast geographical scopes. However, agricultural innovations, particularly in poor regions of the world, have not lived up to expectations of achieving significant impact at scale. In Sub-Saharan Africa, for instance, the uptake of new innovations has been limited. While the low uptake of innovations is partially attributed to technological design styles that are unsuitable for local socio-ecological systems, the capacity of implementing actors to clearly understand and sufficiently engage with the scaling process also influence the efficacy of the generated impact at scale.

The experience and lessons derived from CIFSRF Phase 2's efforts to scale up proven research-for-development innovations reveal some useful insights on achieving impact at scale. Foremost, moving an innovation from a research lab into the hands of end users takes collaborative effort and interaction between multiple actors (researchers, public servants, private sector agents, and civil society groups) at the niche, regime and landscape levels. The smooth transfer of innovations demands research teams to understand the roles that these various actors can play to facilitate the scaling process and to engage them from projects inception, design to implementation. Such knowledge is especially important for innovations that must comply with regulatory requirements before dissemination in national jurisdictions. The process requires research teams to identify, early on, potential bottlenecks to the dissemination of their innovations and seek advisory services of actors with the acumen to navigate in-country regulatory procedures in order to facilitate the scaling process.

Meaningful and long-lasting impacts at scale also depend on implementing actors' ability to answer to various contextual conditions. Low-income rural households face myriad socio-economic and ecological constraints, including climate variability, credit, labour availability, land tenure security, which can make their uptake of new agricultural innovations often more challenging. Thus, increasing the likelihood of successful technology uptake requires working with potential adopters to situate new innovations within local socio-ecological practices. CIFSRF's SAK project in Nepal demonstrates that providing small-scale producers with a variety of innovations to pick from can help to broaden their choice in adopting those that best suit their circumstances. Another important factor related to the sustainable scaling up and uptake of innovations pertains to understanding their overall economic profitability for beneficiaries. How much more would households need to spend in order to achieve maximum (productivity) benefits from a certain innovation compared to the farm gate price they earn? New agricultural innovations, for example improved hybrid seed varieties, often work most effectively when used in combination with other inputs, such as fertilisers, herbicides, irrigation, and so on. Might poor household's investments in less profitable innovations (e.g. staple commodity crops) "invite" the scaling of negative effects, for example, household debt levels and social differentiation? Over the last decade, there has been an overemphasis on increasing smallholder agricultural productivity as a primary way to achieve their food insecurity. Lessons from CIFSRF's productivity-focused innovations in Africa, however, suggest that increasing yields without addressing (local and global) market access concerns could create problems elsewhere along the production cycle. Agricultural interventions must therefore undertake more holistic assessments that account for the overall net returns of innovations for poor households.

Finally, the successful uptake of innovations also depends on capacity building efforts, which at times require long-term attention. The process helps to strengthen the technical skills and the socio-political agency of end users, allowing them to affect change in addressing complex social problems. Moreover, such end-users can help drive impact which is more demand-driven and relevant to local conditions. Overall, CIFSRF Phase 2 has made significant contributions to support solutions that invest in rigorous research; facilitate collaboration between different partners; advance scaling up pathways that leverage socio-political and institutional opportunities in specific contexts; and nurture local leadership to champion innovations.

Notes

1. Geels (2002) draws on the historical life cycle of steamships in the UK (1780s–1900s) to illustrate this trend in transitions.
2. Although all 36 innovations were tested for scaling, not all went to scale by the end of CIFSRF programme cycle. As discussed below, some innovations faced regulatory challenges that could not be resolved during project phases.
3. AFS also identified a fourth pathway: financial services, which extends financial products to end users. This pathway, however, was not widely used across CIFSRF Phase 2 projects and thus is not a focus of this research.
4. Among these were products that included corn sheller, farm rake, hand gloves, super grain bag and electric millet thresher as well as practices such as maize-cowpea intercropping, ginger-maize-soybean intercropping, drip irrigation and tarpaulin greenhouses.
5. A different study by Quaye et al. (2017) appraised the performance of the Agro-Tech model based on the awareness and capacity to use among farmers and the agricultural extension agents, willingness to pay for extension services delivery and perceptions of performance of the model. The study carried out 402 structured interviews with farmers, agents and out-grower businesses. Farmers' perceived performance of the Agro-Tech model were evidently influenced by factors such as timely supply of inputs, cost implications, improvement in yield and value addition that translate into additional income to commit themselves to the terms of the intervention. The study reported that more than one-third of farmers rated the performance of the AgroTech model as excellent (above 70%) while 27% rated the performance as good (70-50%), deducing overall that the model has high-performance rating among interviewed farmers.

6. Enhanced Freshness Formulation (EFF) (pre-harvest spray, dips and vapour treatment), Bio wax, and Nano-packaging (Nano-stickers and sachets.)
7. The countries were India, Canada, Sri Lanka, Kenya, Tanzania, Trinidad and Tabago. Among the types of fruits were mango, stone fruits (peach and nectarines), strawberry, banana and papaya.
8. India, alongside Sri Lanka and Canada were part of an earlier project in CIFSRF Phase 1 that developed and tested pre-harvest and post-harvest application of EFF. The work in Kenya, Tanzania and Trinidad and Tobago focused on testing the innovation for the first time.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by International Development Research Centre [Canadian International Food Security Research Fund].

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