CoSAI
Commission on Sustainable Agriculture Intensification

Supporting innovation pathways for sustainable agriculture intensification: Lessons from cross country evidence

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Contents

Acronyms

AGRA	Alliance for a Green Revolution in Africa
AP1MC	One Million Cisterns Program Association
ASA	Articulation in the Brazilian Semiarid Region
ASAT	Agricultural Scalability Assessment Tool
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
IFAD	International Fund for Agricultural Development
ILPF	Integrated Livestock, Crops and Forestry
M&E	Monitoring and Evaluation
MEAL	Monitoring, Evaluation, Adaptation and Learning
MSI	Management Systems International
NGO	Non-Governmental Organization
P1+2	One Land Two Waters
PICS	Purdue Improved Crop Storage
RySS	Rythu Sadhikara Samstha
SAI	Sustainable Agriculture Intensification
SDG	Sustainable Development Goals

Executive summary

Innovation pathways, and particularly the scaling of innovations, has become a highly active area of the global agri-food systems debate. Widespread theoretical work is being driven by a turn to innovation confronting the steep challenges of the Sustainable Development Goals – and by critiques of just how many innovation-driven efforts still fail to achieve sustainable impact at a large scale.

The proposals that have emerged call for an understanding of agri-food systems as complex, dynamic and multidimensional, and they call for integrated, inclusive, transformative and systemic approaches. However, little of this has yet been implemented or tested at large scale or in national systems, let alone with multiple types of innovations in different contexts. Moreover, even when there is significant consensus around one component or specific principle of the broader approach, e.g., (greater) attention to systems or a systems perspective, the lack of applied and empirical research means that there is limited evidence-based guidance on *how* to apply and operationalize it.

This paper takes a first step in filling that gap in terms of assessing whether there is evidence to support proposals about how agricultural innovation pathways should be pursued. We have looked at the recent literature that proposes principles and approaches to achieving large-scale sustainable agriculture intensification (SAI), and disaggregated these all-inclusive approaches into individual components and hypotheses. We then tested six hypotheses through case studies of innovation pathways, trajectories, scaling and other attempts at achieving large-scale SAI. These cases come from three CoSAI-commissioned country studies in Brazil (Chiodi Bachion et al. 2022), India (Khandelwal et al. 2022) and Kenya (Mati et al. 2022), and five studies of the scaling of individual agricultural innovations commissioned by USAID's Bureau of Resilience and Food Security (Kohl 2016a, 2016b, 2016c; Foy 2017; Foy and Wafula 2016).

Our review of the case study evidence confirmed that the six hypotheses below are indeed important to innovations moving successfully along innovation pathways and achieving large-scale SAI. While this is not surprising in itself – the elements are widely assumed to be important, and each has been discussed and promoted at length in recent years – we have investigated their presence in a variety of case studies and looked further into the design and implementation of these cases to derive more useful conclusions about how each element contributes. We use the results of this hypothesis testing to make recommendations to the numerous actors working toward sustainable impact in SAI – innovators and researchers; funders, investors and donors; and implementers of efforts to scale, affect systems changes and find other pathways of achieving large-scale SAI.

Hypothesis 1: Innovation pathways must be participatory and inclusive. This was perhaps the hypothesis where the evidence was most ambiguous, but there is clear evidence that consulting with farmers and involving farmers in the developing, testing and refining of innovations produces better innovations in two senses. They are more likely to have greater impact, and they are more likely to scale. For both reasons, they are also more likely to be sustainable, in the sense that end users will continue to use them. We thus recommend that:

- Participation of end users in multiple phases of innovation pathways, starting with mapping and analyzing systems and context and especially co-creation, can have substantial benefits.

- The extent of involvement must be weighed against significant costs of organizing, convening and aligning interests and vision, i.e., the cost–benefit balance of broad and inclusive participation.
- Greater comparative or controlled research is needed on how the extent of participation affects outcomes in terms of improvements in productivity and incomes.

Hypothesis 2: Leaders, intermediaries and champions are key to innovation pathways. In most of the cases, individual leadership played an important role at some stage. While more research is needed on the roles of leadership and other actors in innovation pathways, one of our major findings is that the role of intermediaries who facilitate scaling and/or systems change needs to be included and receive greater attention as part of leading innovation. Cases where one actor can lead the whole innovation process to the end of the pathway are notably rare, suggesting that not all of the skills, resources and capacities of both leading innovation and facilitating scaling (intermediation) are likely to be found in one actor, especially when the innovator is a research organization. Leadership needs to be disaggregated by the stages or phases of innovation pathways, and by the different skills and resources needed depending on the phase, type of innovation package, extent of bundling with systems changes, and level of scale at a given moment.

- Investors in SAI innovation pathways can take one of three approaches: a) identify and support existing innovation leaders with the capacity and skills to take end-to-end[1] innovation pathways to scale and/or affect the necessary systems changes; b) ensure that innovators who lack intermediary skills are partnered with appropriate public or private actors from the beginning who can take innovations to scale; or c) support intermediaries that function in between innovators and large-scale Doers and Payers.[2]
- While partnerships, hand-offs and exit strategies between researchers/innovators and intermediaries or large-scale partners make sense in principle, these are also difficult to achieve, given limited actual experience with intermediaries.[3] Much more applied research and many more case studies on these critical points are needed.

Hypothesis 3: Innovation pathways should be iterative, adaptive and flexible. The evidence for an adaptive approach[4] to developing innovations was almost universal, and these adaptive approaches need to equally apply to scaling and systems change.

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[1] Koerner and Duda (2021) define end-to-end innovation as "approaches that work across the innovation system for agriculture, where research efforts are targeted towards end user needs". In this paper, we use this in a more general sense of beginning with the end in mind (see Kohl and Linn 2021; WHO and ExpandNet 2010), in the sense that there are clear goals in terms of the sustainable large-scale change to be effected and that the entire innovation process, beginning with R&D, is congruent with those goals and particularly the systems and context implied at scale.

[2] Payers are those actors who provide sustainable funding for an innovation or systems change at scale; Doers are the actors who have the capacity and skills to sustainably implement or operationalize an innovation or systems change at scale.

[3] While in principle accelerators, with whom there is substantial experience, could function as intermediaries, the support they provide generally covers only the earliest stages of scaling or systems change.

[4] Many development efforts take the form of projects with rigid sets of activities, workplans and targets. By contrast, an adaptive approach starts with the premise that innovation pathways are ultimately involved in transformation of the agro-food systems, and therefore are inherently complex and dynamic. To be effective,

- Innovation pathways should iterate, learn and adapt based on evidence in all phases. Particularly for scaling and systems change, such efforts need to constantly reexamine assumptions, revise the scaling vision and strategy, and adapt activities and tactics accordingly.
- Innovation pathways should include multiple and continuous feedback loops and evidence generation to support these activities, building on monitoring and evaluation (M&E) with adaptation and learning (MEAL).
- Funders need to balance accountability for the overall goals and mission with flexibility in terms of specific crops, activities, pathways and strategies. If, as is suggested by several of the cases, a more mission-driven approach seems to make sense, then funding mechanisms need to align with this flexibility as opposed to pre-determined meso- or micro-level activities, pathways and results.

Hypothesis 4: Innovation should strive to have characteristics that facilitate progress along innovation pathways and achieving large-scale SAI. A large literature[5] suggests that innovations with specific characteristics have greater potential for achieving SAI, but we found that for innovations that didn't have these, bundling with systems changes or developing alternative business or delivery models did allow for scaling and advancement along innovation pathways – at a generally higher cost.

- Technical innovations of products and services should be designed and developed to align with characteristics that facilitate scalability, including:

  Relevance to an important and subjectively felt need

  Tangible and easily observable impact

  Relative simplicity with few components

  Benefits offered along multiple tangible and intangible dimensions

  Alignment with existing norms, practices, tools and equipment

  Benefits felt from some elements of the innovation bundle or imperfect adoption

  Relatively robust and reliable benefits

  Superior effectiveness relative to current and emerging alternatives

  Reduced risk and increased resilience.
- Innovations lacking some of these characteristics can also be scaled, but innovators, funders and implementers should make explicit choices to devote the additional time, effort and resources that are usually required. These often imply changes to Doers, Payers, business and delivery models.

Hypothesis 5: Innovations must be packaged with viable funding and implementation models and bundled with systems change. Packaging comes out clearly in the case studies, and bundling a bit less so. Many innovations fail to scale not because the innovation combination doesn't produce value for end users, but because it isn't packaged with a viable business, funding or delivery model. The

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that systems transformation or innovation pathway process needs to adapt to this emergent, dynamic process by constantly reexamining its assumptions based on actual experience and monitoring, and revising its vision, strategy, activities and tactics accordingly (see Kohl and Linn 2021; Woltering et al. 2019; Minh et al. 2021).

[5] See Cooley and Kohl (2005), Kohl (2018) and Jacobs et al. (2018).

evidence was also supportive, though less strong, for the importance of bundling with systems analysis and change; sustainable scale can be achieved, but bundling can often take it much further than would otherwise be the case. Several CoSAI cases were in fact institutional changes bundled with technology packages and technical assistance, while the three most successful USAID cases involved major efforts at strengthening value chains or were combined with extensive support and changes in the public sector enabling environment. The importance of bundling seems to depend heavily on the type of innovation, choice of scaling pathway (public, private, NGO, or some mixed approach), and alignment with the relevant systems implied by that scaling pathway.

- Innovations must be packaged with viable business or funding and delivery and implementation models at scale – a dynamic and iterative process. For innovations scaling through commercial pathways, that implies that all actors in the value chain be able to make money from the innovation.
- Goals for an innovation need to identify from the beginning whether the innovation is already aligned with existing systems constraints or whether it needs to be bundled with systems change. If the latter, what time and resources are required, and who could lead that effort effectively? For systems changes and institutional innovations, do these require additional adjustments such as changes in social norms?
- Mapping and analysis of systems and the ambition of systems change – while important in a world of complexity and multiple, interrelated goals – need to be a careful balancing act between the urgency of local and global goals and a practical assessment of feasibility, costs and benefits.
- Provision of public goods such as certification, standards or dissemination of information is often key to successful scaling. This provision needs to be put in place and is unlikely to be created by individual commercial actors; it is the role of the public sector, private sector collaborations, public–private partnerships or donor partners.

Hypothesis 6: Partnerships are critical for innovation, scaling and systems change. The evidence confirming the critical role of partnerships was very strong, though it also underlined how much work these involve. Successful partnerships reinforce and interact with some of the other recommendations, particularly the role of a lead actor or organizations in being willing to absorb the costs and compromise on some of its own interests for the greater good and to create public goods, and to mobilize the diverse resources needed at scale that are rarely found in one actor.

- Even when a single Payer or Doer is feasible, partnerships have significant advantages for sustainable impact at large scale by creating shared buy-in and ownership. In many cases, partnerships are the only feasible option for mobilizing sufficient financial resources, implementation or both.
- Partnerships take substantial time, effort and resources to create, manage and sustain, and require aligning a shared vision and creating trust.
- Another overlooked part of partnerships that needs support, again interacting with other findings, is the issue of intertemporal tradeoffs and complementarity: funders, donors and the public sector are well placed to absorb initial risks and engage in risk mitigation that can then allow the private sector to invest and assume the role of Doers and Payers.

1. Introduction

Recent years have seen more and more discussion in the literature on sustainable agriculture intensification (SAI) of the poor performance of research and innovations being translated into sustainable impact at large scale. While it is being widely recognized that the innovation and particularly scaling parts of innovation pathways are flawed[6], different authors use different language to describe both the problem and the solutions (see the key literature cited in Table 1 below). They may locate the problem in research institutions, scaling, innovation pathways or trajectories. Their proposed solutions are often similar in substance but are presented in different terms: agricultural innovation systems, innovation pathways or end-to-end integration.

There are three reasons why this discussion is happening so broadly right now. First and foremost, there is a consensus that innovation can play a lead role, if not the lead role, in transforming agriculture and food systems in low- and middle-income countries (see, for example, World Bank 2019; Khan et al. 2021; Butler 2021). Secondly, this belief has been accompanied by significantly increased focus on investments in such innovations following the food crisis of 2007-2008, heavily influenced by technology sector in general and the Bill & Melinda Gates Foundation's focus on technology innovations).[7] Third, if the current rate of progress toward the Sustainable Development Goals (SDGs) – particularly those that relate to agriculture, nutrition and food security – continues, it is generally acknowledged that in most lower-income countries those goals will not be met (see FAO 2020). The same is true for addressing and reducing agriculture's huge contribution to climate change in line with the Paris Agreement. This has created a global sense of urgency and recognition that existing approaches are not working, and reform or new approaches are required.

In response to these drivers, authors have proposed numerous reforms or transformative changes, drawing on the agricultural innovation literature (agricultural innovation systems, innovation platforms); the scaling literature (scaling science, scaling principles); or in a few cases attempting to integrate both (adaptive scaling, end-to-end innovation). These examples (as listed in Table 1) have several claims in common:

- For innovation to be meaningful it should lead to sustainable large-scale change.

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[6] See for example Woltering et al. (2019).

[7] Other major players are the Skoll, Hewlett, Packard and especially Rockefeller Foundations. The key link here is Dr. Raj Shah, who while at the Gates Foundation led the launch of the Alliance for a Green Revolution in Africa (AGRA), and then served as the USAID Administrator from 2010 to 2015. While at USAID, Dr. Shah oversaw a fivefold increase in USAID's investment in food security through the Obama Administration's flagship program Feed the Future, which over its lifespan has spent well over US$1 billion supporting innovation, primarily through the CGIAR and innovation laboratories at major US agricultural universities. He also created the US Global Development Lab, one of whose primary focuses is "to produce breakthrough development innovations by sourcing, testing, and scaling proven solutions to reach hundreds of millions of people" (https://usaid.gov/GlobalDevLab/MERLIN/DEPA-MERL/uptake-depa-merl). In that context, USAID increased investment in science, technology and innovation from roughly US$130 million to over US$600 million. The influence of the Gates Foundation, USAID and also the Rockefeller Foundation (which had been instrumental in funding the innovations of the Green Revolution) led many other donors and investors to finance agricultural innovation, and in 2015 the Rockefeller Foundation instigated the creation of the International Development Innovation Alliance. See Gewin (2014).

- This needs to occur through scaling of technological innovations in products or services, through systems changes and institutional innovations, or a combination of both.
- Scaling in its most narrow sense of getting more end users to adopt an innovation is likely to at best achieve limited impact in terms of direct effect on adopters, sustainability, or simultaneously addressing the multiple issues that concern agriculture and food systems – i.e., productivity, resilience, livelihoods and poverty, hunger and food security, nutrition and health, and environmental sustainability.
- Last and most importantly, there is a growing consensus in the literature that the innovation process itself needs to thoroughly integrate all of these concerns of scaling, systems change and institutional innovation.[8] Thus in adaptive scaling, innovation processes need to "treat scaling as a systemic change process" (Minh et al. 2021).

Part of the consensus is that the development of an innovation needs to start with analyzing systems, clearly identifying the problem(s) to be addressed, and setting a vision and clear goals as to what sustainable large-scale change might look like. All those processes, and the processes that follow, need to be participatory and inclusive, and thus take the form of some sort of collective consultation or action process.

Another common point in the consensus is that when we refer to systems in this context, we need to acknowledge that the systems we are referring to are complex, dynamic and multidimensional. In this case, it is worth quoting from the adaptive scaling literature at length:

> *Scaling food innovations is embedded in complex socioeconomic, ecological and political contexts consisting of multiple subsystems. These subsystems include, for example, the characteristics of farming systems themselves, the policy and institutional environment, the existence (or lack) of effective agricultural value chains (both input markets, e.g., making technologies available, and output markets for the resulting products), availability of reasonably priced capital for investment and equal access to resources…. (Minh et al. 2021)*

> *We need a systems approach to apply holistic system thinking since it allows multilevel, multiscale and multi-actor approaches…. Co-creation of system, target and transformation knowledge between researchers and societal actors is indispensable. (Hubeau et al. 2017)*

If consensus has emerged on the importance of all of these elements, there is still substantial disagreement as to how necessary each is, and in what degree.[9] The quotes above are surpassed by even more expansive views in articles by Laurens Klerkx and co-authors over the last decade (Klerkx and Gildemacher 2012; Klerkx et al. 2017; Klerkx and Begemann 2020) and other scholars, often in academic or research institution, who seem to suggest that more comprehensive is always better:

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[8] For sake of brevity, from here on we use the term *systems change* to include institutional innovation taking place in the context of large-scale systems like value chains, market systems or the public sector enabling environment. Many other types of institutional innovation, however, are small in scale and do not affect whole systems.

[9] For a brief summary of the issues and contending points of view about the role of systems in scaling and large-scale change, see Kohl (2021).

multiple actors, multiple systems and subsystems, multiple outcomes, multiple information pathways.[10]

This view has also led to pushback from critics stating that, while systems are important and have historically been underappreciated in scaling, the pendulum has swung too far (see Seelos 2020; Seelos et al. 2021; Starr 2021). The critics argue that proponents of emphasizing and combining participatory, inclusive, multistakeholder processes with systems analysis, goal setting, strategizing and bundling of scaling and systems change grossly underestimate the time, effort and resources required to do all of this. For academics, adding one more dimension to the multiple dimensions of a previous article on systems and scaling can always be justified because something has inevitably been neglected or left out; however, for actors actually funding and implementing innovation, scaling and systems change on the ground, practical considerations and marginal costs matter much more.

In response, proponents of a more expansive view argue that practicality is not the only consideration. Participation, inclusion and addressing complexity are important for reasons of ethics and human rights, as well as reasons of indirect or unintended consequences – which demand responsible scaling. They involve issues of power and equity: the question of who gets to decide and prioritize; the presumption that systems analysis is subjective and depends on who you are and where you sit; and the tradeoffs between multiple objectives that necessarily invoke issues of values.[11]

Unfortunately, few of the proposals for an integrated broad, inclusive, transformative systemic approach have actually been implemented or tested in terms of application at large scale or to national systems, let alone with multiple types of innovations in different contexts. Even if such applied research is under way, scaling and systems change is commonly acknowledged to take 10-15 years, so it is still too early to assess whether (or under what circumstances) such research can distinguish between or shed much light on the competing claims and methodologies. Moreover, even when there is significant consensus around one component or specific principle of the broader approach, e.g., (greater) attention to systems or a systems perspective, the lack of applied and empirical research means that there is limited evidence-based guidance on *how* to apply and operationalize it.

The purpose of this paper is to take at least a first step in filling that gap in terms of assessing whether there is evidence to support proposals about how agricultural innovation pathways should be pursued. We start in Section 2 by looking at the recent literature that proposes principles and approaches to achieving large-scale SAI. We disaggregate these all-inclusive approaches into individual components and hypotheses. As most of these sources propose comprehensive approaches, we draw out individual testable hypotheses.

In Section 3, we review the experience of case studies of innovation pathways, trajectories, scaling and other attempts at achieving large-scale SAI. We draw on two sources of case studies. First are three country studies – in Brazil, India and Kenya – commissioned by the Commission on Sustainable

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[10] Klerkx and Begemann (2020), as part of their argument for mission-oriented agricultural innovation systems, suggest looking at "forces, catalysts, and barriers, …. missions and sub-missions, … within and across countries, …. drivers, networks, governance, theories of change, evolution and impacts" at multiple geographic scales.

[11] Thus in recent years the terms *responsible scaling* and *optimal scaling* have been used to characterize how scaling is about more than goals of increased productivity and income. For instance, McLean and Gargnani (2019) describe optimal scale as one of their four guiding principles, writing: "Optimal scale balances the magnitude, variety, sustainability, and equity of impacts in ways stakeholders endorse."

Agriculture Intensification (CoSAI) in 2021 explicitly with the purpose of looking at what factors drive successful large-scale SAI. These CoSAI studies cover diverse types of innovations and innovation pathways; three each in India and Kenya, and four in Brazil. The second source is a set of five case studies that were commissioned by USAID's Bureau of Resilience and Food Security in 2015 and 2016 to identify factors driving successful scaling of agricultural innovations. Compared with the CoSAI studies, the USAID studies focus more narrowly on innovations in products, varieties and breeds and only on commercial pathways. However, as the studies reveal, even a commercial approach to scaling, narrowly defined, turns out to involve systems and institutional innovations and a substantial role for the public sector and civil society.

Finally, in the concluding Section 4 we use the results of this hypothesis testing to make recommendations to the numerous actors working toward sustainable impact in SAI. These recommendations are aimed at innovators and researchers; funders, investors and donors; and implementers of efforts to scale, affect systems changes and find other pathways of achieving large-scale SAI.

2. Methodological approach

In this section, we describe the methodological approach used in this study. We begin by defining the basic concepts and terms we will be using. We then briefly review the relevant literature and draw from that a set of hypotheses that will be assessed in Section 3. Finally, we describe the methodological approach and set of case studies to be used to evaluate those hypotheses.

Key definitions

As noted in the introduction, **the overarching goal of this study is to understand how to improve innovation pathways, thereby increasing the likelihood that agricultural innovations will have greater impact on agri-food systems, sustainably and at large scale**. There are several concepts used in the previous sentence which we now define to clarify their utilization in the rest of the paper.

To start with the end in mind, we are targeting impact in agri-food systems. For the rest of this paper, we use the term **agri-food systems** as a catch-all phrase to refer to the multiple global goals that food and agriculture can contribute to in the SDGs and climate change agenda. This begins with SDG 2 (zero hunger), and thus includes a positive impact on hunger, food security, nutrition and health, sustainable agriculture and rural incomes. In terms of **impact**, we focus on innovations in SAI, as the UN (n.d.) itself states that "eradicating poverty and hunger are integrally linked to boosting food production, agricultural productivity and rural incomes" and also has strong commitment to the other components of SDG 2 and social equity. We use **innovation** to refer to any interventions, be they products, services, technologies, institutions or systems changes, that have impact on the target problem, regardless of the source. Notably, an innovation is considered "new" when it is either new in the given context or it effects change.

The SDGs and the ambitions of the Paris Agreement can only be achieved if these innovations achieve impact at **large scale**. Large scale covers a variety of mechanisms or pathways, to which we turn shortly. In the traditional model of diffusion of innovations, scale is defined in terms of the numbers of end users, adopters or beneficiaries. We take this a step further to define "large" as affecting a significant proportion of the people affected by a problem or challenge. Combining terms, we define the goal to be achieved as large-scale SAI.

Having defined the goal, we turn to how to get there. As noted in the Introduction, the literature has become full of proposed solutions and titles: scaling and scaling up; innovation platforms; end-to-end innovation approaches; optimal, responsible or adaptive scaling; agricultural innovation systems; inclusive and participatory innovation pipelines, pathways and trajectories; and so on. We choose to refer to all of these through the simple term of **innovation pathways** and the goal as affecting sustainable impact at large scale.

To begin with, we define pathway to include a broad definition of scaling. While scaling, in rare cases, can be as simple as achieving large-scale adoption by individual end users of an individual product, service, practice or package of those elements, in most cases it does appear to require being bundled with institutional innovations and changes to systems, social norms and mindsets (a hypothesis we make explicit and test below). More importantly, institutional innovations and changes to systems,

social norms and mindsets can themselves affect large-scale SAI, and as such, pathways can also be activities that affect those changes.

The key to a definition of an innovation pathway is not its ability to reach large numbers, but its sustainable impact, i.e., that it is ongoing and durable. We define **sustainable** as having five dimensions: **environmental**, **financial**, **institutional**, **political** and **social**. **Environmental sustainability** means a pathway is consistent with the constraints and limitations of natural systems. The other four are perhaps less commonly understood as critical to large-scale impact.

By **financial sustainability**, we mean there is a viable funding or business model that can support the continued application of the innovation over time, with an individual or package of products, services and practices, a systems change, or both. Financial sustainability requires a Payer or Payers. **Institutional sustainability** refers to the fact that some actor has to produce, deliver or otherwise implement the innovation at scale on an ongoing basis. This requires one or more actors – a Doer – with the capacity and capability to implement at scale. **Political sustainability** refers to the fact that whatever actors are involved in using, adopting, Paying or Doing, they must do so willingly. In other words, that role must be aligned with their individual or organizational incentives, and often both. **Social sustainability** means that any necessary changes in culture, mindsets or social norms have been made, or are at least under way and have reached a critical mass or tipping point. This very much can, and in many cases does, include social equity; a huge literature shows that high levels of income inequality correlate with lower levels of human development (see Castells-Quintana et al. 2018), and many believe the relationship is causal.

We include financial, institutional, political and social sustainability as goals of large-scale SAI and as integral parts of the overall pathway toward achieving large-scale SAI. However, we take their roles in its achievement as working hypotheses to be tested against empirical evidence. We turn to this in the next subsection.

Hypotheses and literature review

We assess approaches and pathways by testing hypotheses regarding what leads to success in an innovation pathway for large-scale SAI. It elaborates a longer list of hypotheses, and then divides them into those we had sufficient evidence to pursue (combining some) and those we did not.

The nature of the evidence we have available (not necessarily designed to evaluate these hypotheses) does not allow for rigorous scientific testing in terms of statistical confirmation or falsification. Rather, we are using a weaker standard: finding cases where either (a) the principle or practice was important to the success of an innovation moving through a pathway to sustainable impact at large scale; or (b) where the absence of or failure to apply that principle or practice seems to have limited the innovation's success. As such, we are explicitly applying a counterfactual approach.

There are several recent proposals as to how to approach achieving large-scale SAI through innovation pathways or the equivalent. We do a brief and selected review of some of the more recent approaches and proposals. Some are drawn from the scaling literature, others are drawn from agricultural innovations, and an increasing number are based on the introduction and application of various types of systems analysis and change to agricultural transformation. We exclude frameworks which focus

solely on innovation[12] and ignore scale or systems-level change and impact.[13] The approaches we do include are listed with citations in Table 1.

Table 1. Key literature reviewed to identify hypotheses.

Approach	Citation
Sustainable systems change at scale	Woltering et al. (2019)
Adaptive scaling	Minh et al. (2021)
Scaling principles	Kohl and Linn (2021)
Agro-ecology, agricultural innovation systems, social-ecological systems, political ecology	Foran et al. (2014)
Sustainable intensification	Pretty et al. (2011)
End-to-end innovation	Koerner and Duda (2021)
Scaling science	Shilombenia et al. (2019)
Bundling innovations	Barrett et al. (2020)

The hypotheses that emerged from this review are summarized in Table 2. The most common among these themes were the importance of systems and institutions; participation; contextualization; leadership and intermediation; incentives; financial models; ethical and equity considerations; and to a lesser extent the role of politics and power inequities and their interactions with markets and capitalist agri-food systems more generally.

Fifteen hypotheses were more than a feasible number given the time and resources available. To narrow them down we did a preliminary assessment of to what extent we could provide evidence about *whether* these factors were important and *how* good practices in the area could be identified from the 15 case cases we used to assess them (described in the next subsection). Based on these considerations,[14] we combined four overlapping themes into one hypothesis and chose which of the others to assess. Those decisions are also shown in Table 2.

[12] Note that many calls for "integrated" approaches to agricultural research and innovation do not include scaling or do so in a superficial way. A good example of this is Lacombe et al. (2018), who focus solely on how to engage in farmers and increase participation in research on agro-ecological approaches to farming. The authors make no mention of scaling or large-scale systems change. In fact, this seems to be representative of the agro-ecology approach in general, in that its emphasis on niche innovation design, local adaptation and context-specific singularities has yet to develop a methodology to apply this at scale.

[13] Thus we only include innovation approaches that include scale and systems change explicitly. See Wigboldus et al. (2016).

[14] An additional reason to exclude the last hypothesis is that power, equity and ethics are as much ends in themselves as they are means to the end of large-scale SAI.

Table 2. Hypotheses and evidence availability.

Hypothesis	Evidence Available	Evidence Supports/ contradicts	Decision
Innovation should follow a planned, explicit, well-thought-out and **deliberate process** based on identification of the problem (**mission driven**), **a solution** and **a clear theory of change**.	No	N/A	Not assessed
Innovation pathways should **begin with the end in mind**.	Some	Unclear	Not assessed
Innovation pathways should specify **what** is being scaled or effecting systems change, a **vision** of scale/impact, and a **clear strategy and pathway** to achieve them.	Little	Unclear	Not assessed
Innovation pathways must be **participatory and inclusive** from the beginning, especially of end users, in terms of co-creation of innovations and/or systems changes, and identifying a vision and goals for large-scale change.	Yes	Supports	Assessed
Leaders, intermediaries and champions are critical to successfully achieving sustainable impact at large scale.	Some	Supports	Assessed
Innovation pathways should be **iterative, adaptive and flexible** using rapid testing and failing fast apply a cycle of experimentation, learning and strategic adjustments.	Yes	Supports	Assessed
Innovations should have **characteristics aligned with criteria that facilitate scalability,** especially the needs, context and constraints faced by end users.	Yes	Supports	Assessed
Institutional and individual **incentives** of all stakeholders, from end users to private value chain actors and the public sector, **must be aligned** with innovation and scaling goals.	Some	Supports	Not assessed
Viable financial and/or business models and **implementation mechanisms** are necessary; product and service innovations need to be packaged with financing and delivery mechanisms. **Who** will play key roles of Payer and Doer (operationalizing or implementing) needs to be specified.	Yes	Supports	Combined into one hypothesis
Innovations must be **bundled** with analysis and changes in markets, value chains and policy enabling environment institutions and systems.	Yes	Supports	
Analyze systems taking into account complexity and unintended consequences. Identify **systemic opportunities, constraints and risks**; plan to align with them or address them through system change along the scaling pathway.	Some	Supports	
Partnerships are critical to innovation pathways, both for innovation, systems change and scaling; bringing multiple perspectives to the table; mobilizing resources beyond those of one actor; and aligning incentives and political support.	Yes	Supports	Assessed
Social capital needs to be leveraged and/or created where necessary e.g., farmers' organizations, women's organizations.	Yes	Supports	Not assessed
Diverse types of **evidence** are necessary for successful scaling and innovation well beyond standard proof of concept or proof of impact.	Some	Mixed	Not assessed
Innovation and scaling affect, and are affected, by **considerations of power, equity and other ethics**. These should be considered in addition to impact on goals like productivity, income and food security.	No	N/A	Not assessed

The resulting six hypotheses we assess here are:

1. Innovation pathways must be participatory and inclusive.
2. Leaders, intermediaries and champions are key to innovation pathways.
3. Innovation pathways should be iterative, adaptive and flexible.
4. Innovations should have characteristics that facilitate progress along innovation pathways and achieving large-scale SAI.
5. Innovations must be packaged with viable funding and implementation models and bundled with systems change
6. Partnerships are critical for innovation, scaling and systems change.

Hypothesis testing: A case study approach

To assess whether the six resulting hypotheses are indeed important to the success of achieving large-scale SAI through innovation pathways, we used a case study approach. As such, the methodology used was qualitative. We were able to leverage two sets of case studies: three country studies commissioned by CoSAI for Brazil (Chiodi Bachion et al. 2022), India (Khandelwal et al. 2022) and Kenya (Mati et al. 2022), which collectively covered ten cases; and five country studies of individual cases commissioned by USAID's Bureau of Resilience and Food Security (Kohl 2016a, 2016b, 2016c; Foy 2017; Foy and Wafula 2016). The CoSAI studies covered cases of successful progress of SAI innovations that had explicitly affected large-scale change and proved sustainable with donor funding. A particular advantage of the CoSAI studies is that they represent a variety of types of innovations, innovators, innovation pathways and types of agriculture, such as small versus large and urban/peri-urban versus rural. While the CoSAI studies focused on both the innovation and scaling phases of innovation pathways, they didn't go into much detail about the innovation process.

The five USAID studies also focused on successful scaling of agricultural innovations. They differed from the CoSAI studies in that they focused solely on technological innovations in products and services, though in several cases scaling ended up requiring bundling with institutional innovations and other forms of systems change. They also looked solely at commercial innovation pathways (where the primary source of financing is end user pays), though in several cases the public sector did play an important role. They had as their primary focus increasing the productivity, incomes and food security of impoverished and marginalized smallholder farmers located in poor rural areas. Perhaps most importantly, there was no ability to assess long-term financial, political or institutional sustainability (though in some cases that could be inferred), and environmental sustainability was not a consideration. In fact, two of the innovations involved extensive use of chemical fertilizer and other agrochemicals as part of production.[15]

The USAID cases had several advantages in terms of reaching scale (or in terms of availability of information on scale), largely due to the greater resources available from donors for either the innovation or scaling parts of the pathway, and in some cases both. These resources allowed for greater production and availability of information such as ongoing monitoring and evaluation of certain indicators, including adoption, scale and impact on productivity and profitability of farmers and other actors. Similarly, innovators, project staff and local partners (e.g., local implementing

[15] We included sources on agroecology in our review, such as Mier y Terán Giménez Cacho et al. (2018) and IPES-Food (2018), but did not find adequate evidence on scaling to include these in our hypothesis testing.

partners, farmer organizations or private actors in the relevant value chain) were available and had incentives to be interviewed by and cooperate with researchers sponsored by the US Government. Their greater resources also meant that these interventions were able to reach populations in the hundreds of thousands, and they could invest in creating demand, building or strengthening institutions, and other types of systems change. Finally, in four of the five cases there was a clear central actor leading or driving the effort, either the Chief of Party of a development project or actors from the research organization that had developed the innovation.

Table 3. Summary of cases.

CoSAI cases	Innovation package type/components	Innovating organization	Description
Balde Cheio – Full Bucket ***Brazil 1998-Present***	Innovative extension approach	Brazil Agricultural Research Corporation (Embrapa)	Farmer-oriented innovation program with an experimental and incremental approach to improve dairy productivity by training local rural extension technicians, using farms as schools
One Land Two Waters (P1+2) ***Brazil 2007-Present***	Technology, social capital	Articulation in the Brazilian Semiarid Region (ASA), One Million Cisterns Program Association (AP1MC), Ministry of Social Development	Improved water access through harvesting and storage for farming
Integrated Livestock, Crops and Forestry (ILPF) ***Brazil 2008 - Present***	Integrated technology	Embrapa, ILPF Network	An integrated approach for livestock and crop production (ILP), in some cases also adding forests (ILPF).
Aqua Digital Irrigation Monitoring System ***Brazil 2014-Present***	Technology, extension	Agrosmart	Digital monitoring irrigation system with a platform to support farmer decisions
Andhra Pradesh Natural Farming ***India 2016-Present***	Integrated technology	Rythu Sadhikara Samstha (RySS) (farmers' empowerment association)	Distributed innovation to decrease or eliminate agrochemical use and adopt zero budget natural farming.
Safe Harvest ***India 2009-Present***	Production, market links	Safe Harvest (triple bottom line private company)	A farm-to-kitchen model for certified pesticide-free food, supporting farmers.
Trustea ***India 2013-Present***	Production, standards, market links	Consortium of private tea processors and sellers with support from non-governmental organizations (NGOs)	Verifiable standards for sustainable tea production, along with extension and capacity support for farmers.

Water Harvesting ***Kenya 2009-Present***	Technology	External innovation promoted by multiple NGOs and county governments	Water storage ponds for irrigation.
Solar Powered Irrigation ***Kenya 2005-2021***	Technology, finance	External innovation with multiple private sector variations	Solar powered pumps and panels, sometimes combined in kits, and some innovative financing.
Upper Tana–Nairobi Water Fund ***Kenya 2012-2020***	Technology, finance	Multistakeholder: county governments, private sector, NGOs (Nature Conservancy)	A partnership and coordination mechanism between downstream water users and upstream land users to promote water conservation and management through blended financing.
USAID cases	Innovation package type/components	Innovating organization	Description
Sahel Rice ***Senegal 2009-2015***	Technology	AfricaRice, Projet Croissance Economique (PCE)	Interventions to realize the production potential of improved varieties of rice that were first introduced and scaled in the 1990s.
Purdue Improved Crop Storage (PICS) Bags ***Kenya 2013-2018***	Technology	Purdue University	Large hermetically sealed bags for post-harvest storage to reduce losses due to moisture, mold and rot.
Kuroiler Chickens ***Uganda 2010-2017***	Technology	Arizona State University Ugandan National Animal Genetic Resource Centre	A hybrid chicken breed introduced from India, with much higher meat and egg production in a shorter time period than local chickens.
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia 2006-2015***	Technology	International Maize and Wheat Improvement Center (CIMMYT), International Institute of Tropical Agriculture (IITA), African national research agencies	Over 200 hybrid and open pollinated maize varieties that are able to tolerate some drought conditions during certain periods of the growing season.
Mechanization Initiative ***Bangladesh 2013-2018***	Technology	iDE, CIMMYT, IRI, Machinery originally imported from East Asia; scaling by CIMMYT's Cereal Systems Initiative for South Asia (CSISA) in partnership with private machinery producers/importers	Innovations intended to improve rice production or allow for greater uptake of maize and wheat production through irrigation and cost, time and labor savings: a reaper, improved irrigation pump, planter/tiller attachment for two-wheeled tractors and a bed planter, which either improved on existing machinery or replaced hand labor.

3. Testing hypotheses

This section reports on evidence from the case studies and uses it to test the hypotheses outlined in the previous section about principles and good practices in innovation pathways for large-scale SAI. For each hypothesis, we first flesh out in greater detail what the literature says, and where appropriate identify sub-hypotheses. We then tabulate the evidence from the case studies regarding that hypothesis. Finally, we propose lessons and conclusions based on the evidence.

Innovation pathways must be participatory and inclusive

Hypothesis

Participatory agricultural research, and more broadly participatory rural development, has a long literature going back to at least the early 1980s. In each decade since, a review of the literature reveals advocates calling for greater participation by end users in agricultural research for normative, ethical and instrumental reasons. Focusing on participation as a means to other ends, advocates argue that local stakeholders need to be incorporated because they have a better understanding of local needs, demands, contexts, conditions and existing practices, especially when natural resource management is at issue.

Application of participation to agricultural innovation pathways has at a minimum meant that farmers are consulted in the innovation process, and more and more are part of learning alliances and the identification and/or co-creation of promising innovations and their testing.[16] They also participate in analysis of the larger systems as the foundation for subsequent decisions about what is to be scaled or about systems changes. In terms of challenges, these include:

- Participatory wins remaining as limited-scale "islands of success"[17]
- Naïveté about the complexity of communication processes, group dynamics and power relations
- Reduction of participatory methods to the diagnostic stage
- A myth of instant analysis of local knowledge
- The tyranny of techniques: a predominance of short-lived fads based on instrumental claims, for example, that the application of inclusive innovation platforms will lead to an intervention's success
- Underestimation of the time, effort and cost of participation – in particular for end users who may not benefit directly from the results of an innovation that may only be available years later

[16] See World Bank (2012: 440): "Considerable progress has been achieved in giving farmers access to innovation resources and in building their capacity." This publication also emphasizes the growing role of innovation funds available to local farmers or farmer organizations.

[17] As used by Neef and Neubert (2011), quoting El-Swaify et al. (1999).

- Pushback from researchers judging that innovations developed through participation do not meet scientific standards of rigor[18]
- Participatory approaches in innovation as a substitute for good governance.[19]

A second complicating factor in terms of assessing participation is defining "good" participation (see Neef and Neubert 2011). In many cases end users do participate, but minimally, such as by taking small roles in learning alliances or platforms.[20] For example, the World Bank (2012) guide on agricultural innovation systems states:

> *In these cases, public sector research is increasingly divorced from farmers as the primary clientele, relying instead on input markets as the mechanism for articulating farmer demand. Occasionally the interests of farmers and input companies do not coincide, however, as exemplified by the tensions surrounding pesticide use and the scaling up of integrated pest management programs in Asia. Under these market-driven conditions, investments in public agricultural research tend to focus more on institutional innovations that reinforce the ties between research and the private sector.*[21]

Other complications include deciding *who* participates and the power imbalances in their participation, such as between marginalized groups and those who control financial resources or make policy decisions. A final complication is that, with few exceptions, the case studies do not describe participation in the innovation, scaling and systems change processes that make up an innovation pathway in much detail. Consultation with end users was present in most of the Brazilian and Indian cases, and in the Upper Tana–Nairobi Water Fund in Kenya. This included the purely private pathway case of the Aqua Digital Irrigation Monitoring System in Brazil, but not so much the Water Harvesting or Solar Powered Irrigation cases in Kenya. Only in a couple of cases, such as ILPF in Brazil and Andhra Pradesh Natural Farming in India, did farmers' roles in innovation go beyond consultation in the development of the innovation.

For the purposes of this paper, things are further complicated when looking at the other phases of the innovation pathway: scaling and systems change. Consistent with the literature reviewed for articulating the hypothesis above, the discussion of participation and inclusion in the context of agricultural innovation systems and innovation pathways focuses almost solely on identifying, (co-)creating, testing and refining innovations, and indeed progress has been made in this area. While

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[18] Carberry (2001): "This debate could be depicted as being polarised between research rigour (data integrity, replicability) and industry relevance (currency, responsiveness)." See also Gwaze et al. (2011).

[19] See Neef (2003) and also Carberry (2001), who cites as additional challenges: "the high time cost of participation, a reliance on qualitative data, unfamiliar data analysis techniques, poorly appreciated evaluation procedures, publication barriers and a lack of career and reward structures".

[20] These, like many aspects of participation or multistakeholder consultations, have other challenges. The World Bank (2012: 273) warns that "learning alliances are particularly intensive in the use of facilitation and information synthesis and require external funding to operate". As is illustrated in some of the CoSAI case studies, this often requires transforming informal consultations into a formal association or process, which needs to be managed and resourced. That said, the World Bank (2012: 345) goes on to note that "jointly developed proposals are also more attractive for funding agencies as they have a higher potential for scaling out and up".

[21] World Bank 2012, p. 266

there is a growing consensus that participation and inclusion of end users/farmers is critical to analyzing systems and setting goals (see Kohl and Linn 2021), that is a recent development for which most actual experience is on horizontal scaling, but much less so on the vertical dimension. End users, often farmers, do play vital roles as lead farmers, resource persons or in farmer-to-farmer extension or diffusion for large-scale change. Similarly, farmer organizations are often key partners in implementing scaling, but here participation quickly shades into partnerships, and it is not clear how much decision-making authority or input they have on strategy or tactics; these partnerships often are led by large public and private actors and not end users or their organizations.[22]

Evidence

Table 4. Support to hypothesis: Innovation pathways must be participatory and inclusive.

Case	Evidence	Support to hypothesis
Balde Cheio ***Brazil***	The innovation package was largely developed by Embrapa with farmers in a consultative role at best; the same went for setting scaling goals and implementation. However, there was a strong emphasis on customizing the package for individual farmers or communities. In terms of scaling and large-scale implementation, it involved the government at multiple levels – federal, state and municipal – as well as local NGOs, civil society and farmers' organizations.	Some support
P1+2 ***Brazil***	The most participatory of the Brazilian public sector pathway cases, this was a social technology program driven by the mobilization and organization of family farmers, rural communities, the social movement ASA and other civil society actors. Its express goal was "democratizing, accessing and building technological solutions that advance social inclusion". The case study characterizes the choice of technologies as a "bottom-up innovation process", but the initial selection of technologies was done by technicians based on the technologies and knowledge of local people. The process was at least action-oriented for individual farmers, and social organizations had a clear say in decision making. ASA was a full partner in goals, strategies and large-scale implementation.	Strong support

[22] At least one exception appears to be farmer field schools, which are often implemented by local lead farmers and/or farmer organizations. In the meta-analysis by van den Berg et al. (2021), "farmer involvement in the design and planning of interventions was found to be critical" and programs increasingly relied on farmers as field school facilitators. See also World Bank (2012); however, in this 648-page document, where scaling is mentioned 46 times, there is no mention of farmer participation in decision making. Perhaps this is not surprising given that ultimately World Bank loans and grants are made to governments.

Case	Evidence	Support to hypothesis
ILPF ***Brazil***	The innovation package was largely developed by Embrapa, with the model of integration and the technology used for the integration depending on the conditions and needs of individual farms. This might be considered both a plus and a minus as individual farmers had to develop their own technology proposal as part of their loan application, which favored larger, more commercial farmers with this capability or ready access to technical assistance. Scaling and large-scale implementation involved the government at multiple levels as well as local NGOs, civil society and farmers' organizations.	Some support
Aqua - Digital Monitoring Irrigation System ***Brazil***	The start-up, Agrosmart, included early-adopter farmers in the initial demonstration of results and subsequent adjustments. These participants conducted pilot tests and provided feedback to improve the monitoring system and its usability. In scaling up, Agrosmart has retained an unofficial committee of test customers for each of their products and keeps weekly contact with these farmers, who are rewarded with the opportunity to customize the service to their needs.	Strong support
Andhra Pradesh Natural Farming ***India***	The technological innovations focused on chemical-free practices and leveraging traditional methods, and were as much about social mobilization and empowerment as increasing productivity and resilience. The program used a distributed innovation approach in which "farmers become experimenters and innovators to find solutions suitable to their context," and a farmer-to-farmer extension model to diffuse and scale the innovations to more farmers. It was successful in lowering input quantities and therefore costs, and had clear environmental benefits.	Strong support
Safe Harvest ***India***	Safe Harvest seems to occupy a middle ground in terms of participation – of organizations, but not of individual farmers. It worked with and empowered an existing network of NGOs supporting non-pesticide management in terms of production, but Safe Harvest itself appears to have been the driving force and decision maker in terms of addressing the challenges of linkages to markets and consumers and creating non-pesticide management certification standards.	Some support
Trustea ***India***	Farmers' organizations seem to be passively receiving technology packages delivered through technical assistance and extension by experts, rather than empowering farmers as innovators or as agents of diffusion.	Contradicts

Case	Evidence	Support to hypothesis
Water Harvesting ***Kenya***	Participants were included in implementation, at least, from the beginning.	Some support
Solar Powered Irrigation ***Kenya***	Inclusion and participation were not significant elements. The case did not follow the conventional project-push with lists of beneficiaries, etc.; rather, it followed a market-pull-technology-push route.	No significant evidence
Upper Tana–Nairobi Water Fund ***Kenya***	Farmers living in the upstream watershed were involved in the multistakeholder consultations and program design that led them to receive "in-kind ecosystems services activities". Had farmers had more decision-making power, they would have preferred to receive money.	Some support
Sahel Rice ***Senegal***	Of the USAID case studies, this featured the greatest involvement of end users. All of the implementation was done working closely with farmers' organizations, in this case irrigation user groups, and the development of institutional innovations such as the innovative financial mechanisms (contractualization, discussed in detail below) was done in close consultation with farmers. Some farmers' organizations themselves played the role of social entrepreneurs, presenting solutions to obstacles within the rice value chain as they arose.	Strong support
PICS Bags ***Kenya***	Inclusion and participation were not significant elements.	No significant evidence
Kuroiler Chickens ***Uganda***	Farmers were not involved to any degree in the initial selection and testing of technical innovations, and this proved quite problematic. The innovation involved changing a lot of poultry rearing practices from what Ugandan farmers were accustomed to; the chickens had to be penned and needed supplemental feed and vaccinations, being very disease-susceptible as chicks. At least initially, many farmers couldn't afford these, and some suffered heavy or complete losses. Farmers also bred Kuroilers with other chickens, with unpredictable results. In addition to the lack of inclusion of end users, by and large neither the commercial sector nor the public extension systems were involved in providing technical assistance or extension support, which means that farmers had no one to inform them or help them deal with the above and other problems.	Strong support

Case	Evidence	Support to hypothesis
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia***	Inclusion and participation were not significant elements.	No significant evidence
Mechanization Initiative ***Bangladesh***	Because farmers were not involved at all in the initial selection and testing of machines, project staff had to spend several years retroactively modifying and adapting the four machines that had been imported to meet farmers' needs and utilization constraints, and that proved successful with only three of the four.	Strong support

Lessons and conclusions

Participation and inclusion take many forms and degrees, from passive to active to empowering, from consultative and action-oriented to co-creative. Testing innovations with actual end users under realistic conditions is clearly necessary to ensure that they are aligned with those users' needs. The same is also true in iterative, adaptive and flexible processes, discussed below.

However much greater involvement leads to empowerment and ownership by end users, such as co-creation, it seems to be *necessary* in terms of some goals but not others. In the two cases where farmers were the most empowered, Andhra Pradesh Natural Farming and P1+2, this seems to have been critical to meeting the social equity objectives of SAI, but it may be less essential to other objectives like addressing climate change or ecological sustainability.[23] While social equity is part of CoSAI's definitions of sustainability and SAI, those definitions are not universally shared. In terms of more narrow objectives of productivity improvements and greater resilience, other cases such as PICS Bags, Drought Tolerant Maize for Africa, Water Harvesting and Solar Powered Irrigation were developed and achieved some level of sustainable impact without end users having significant roles or power in decision making in either innovation or scaling. Advocates of responsible scaling have called for making explicit tradeoffs between these multiple objectives and greater participation in both systems analysis and decision making. While there is a strong ethical and normative case for this, the evidence from these case studies is that the positive evidence is weak at best. Moreover, such considerations do not factor in that broader and deeper participation (more actors, more empowerment) clearly entails additional costs in terms of time, effort and resources to put in place the necessary processes, facilitation, capacity building and resolution of potential conflicts of priorities and interests, among others. Many of these same points are equally relevant to partnerships, as discussed below. Further comparative research is required, such as with the same innovation scaled

[23] Potentially a more important controversy in Andhra Pradesh is that farmers have gained mainly by saving inputs, at a cost in productivity (Smith et al. 2020).

with greater participation or not, to see whether it leads to greater scale, impact or sustainability even on these narrower criteria.[24]

Leaders, intermediaries and champions are key to innovation pathways

Hypothesis

Leadership is widely seen as essential to innovation pathways. Kohl and Linn (2021) specify two types of leadership as essential to scaling in particular. One type, what they refer to as *leaders*, are actors who are "committed to seeing scaling through to success, willing to make decisions, and able to mobilize others to support of scaling goals, strategy and tactics." A second type, what they call *intermediaries*, engage in "undertaking or facilitating activities like convening, systems analysis, boundary spanning, strategic planning and goal setting, advocacy and communication, process facilitation and people management, networking and coordinating, monitoring and evaluation, and financial and costing analysis."[25]

While one actor or organization can play both roles, leaders are often innovators who own the innovation and therefore have power to make decisions about the innovation or scaling goals and strategy, but sometimes lack the skills, knowledge or incentives to serve as intermediaries or affect implementation. For example, leaders may lack the necessary political network and contacts or knowledge of the policy enabling environment and underlying political economy to design effective advocacy strategies and messaging, though they may be essential to doing advocacy. This skills or knowledge gap can particularly be the case as scale increases; innovators or local/district/regional leaders may be less effective in other parts of the country or at a national scale, especially when macro-level institutional innovation or systems change is involved.

In addition to their potential limitations as intermediaries, reliance on charismatic leaders can be inimical to institutional and political sustainability. This is particularly true in political economy contexts where patron–client relationships predominate; scaling can be limited by the extent of the

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[24] One intriguing study that suggests the answer may be yes has been done by CARE (2021). CARE has built on the innovation of farmer field and business schools by adding a central gender equity component. It found in a controlled comparative study that those schools with the gender component were more effective in achieving narrow agricultural goals of improving income, productivity and resilience than schools without the gender component. This is a case where there is evidence that greater participation not only addresses social equity considerations but also other goals; rather than tradeoffs, there are positive synergies.

[25] Intermediaries are similar to the concept of brokers introduced by Klerkx and Gildemacher (2012; see also Klerkx et al. 2009), but much more broadly defined. Klerkx and Gildemacher assign brokers three principal roles in innovation: bringing together actors, facilitating their interaction (including building coalitions or partnerships), and promoting the flow of information. As applied to the scaling phase, we find that intermediaries do play these roles *and also* undertake many other tasks that innovators might lack the skills, capacity, resources, motivation or incentives to do. This concept was first developed by Cooley and Kohl (2005), simultaneously with a similar concept, the resource team, developed by WHO and ExpandNet (2010) in their scaling approach. As an example, Klerkx and Gildemacher (2012: Box 3.25) call iDE a broker in the same case we refer to here as the Mechanization Initiative in Bangladesh. We agree, but maintain that iDE went much further as an intermediary for CIMMYT. iDE arranged partnerships with agricultural machinery companies, managed those relationships, promoted demand, refined the business and delivery model, advocated with the government for political and in-kind support and cooperation, developed the local service provider business case, identified local entrepreneurs to act as service providers, and arranged microfinance support. In roles like these intermediaries come closer to the role that venture capitalists play in helping investments go to scale, except they don't bring investment capital with them.

leader's personal network or by that network falling out of power with changes in government or national leadership.[26]

Evidence

Table 5. Support to hypothesis: Leaders, intermediaries and champions are key to innovation pathways.

Case	Evidence	Support to hypothesis
Balde Cheio ***Brazil***	Embrapa was the lead agency, and in particular two individuals were cited as playing critical roles, one "as the initiative's major unifying factor, because of his tremendous charisma, passion for the subject, proactivity, easy communication with farmers, great motivational skills, and solid theoretical and practical knowledge." These comments imply that the relevant leadership skills are technical, to guide the innovation process; personal, to inspire innovators; networking and advocacy, to mobilize and engage with partners; and boundary spanning, to effectively facilitate collaboration and cooperation between diverse actors and constituencies, and particularly to form and manage effective partnerships. However, it is not possible to determine from the evidence how much of a role each played.	Strong support
P1+2 ***Brazil***	ASA was the lead agency. The case lacks any mention of individual leadership, but ASA as an organization was important in advocating for this program and getting funding from the government, creating an implementing organization under its lead, and mobilizing and coordinating a multilevel partnership.	Some support
ILPF ***Brazil***	Embrapa was the lead agency. The CoSAI study concluded that leadership was critical for innovation pathways in two ways: mapping and selecting local organizations that have a good interlocution with local farmers, governments and industries to lead the innovation process; and maintaining a focus on institutional arrangements and the incorporation of innovation into the institutional agenda.	Some support

[26] See Kohl and Linn (2021) under Lesson #6 about leaders and especially Lesson #18 on Sustainability. Charismatic leaders are not replicable or reproducible, and usually have limits on the size of their networks and scope of influence. Similar to Founder's Syndrome, turnover in leaders can be fatal to innovation and scaling efforts that rely heavily on the role of one individual.

Case	Evidence	Support to hypothesis
Aqua Digital Irrigation Monitoring System ***Brazil***	The idea was developed by a multidisciplinary team of a business administrator, a graphic designer and an electrical and electronics engineer. They came up with the innovation, created a company to commercialize and scale it, and mobilized funding from various sources. The CEO has been particularly important in media, marketing and fundraising drawing on her skills as a gifted speaker and communicator.	Some support
Andhra Pradesh Natural Farming ***India***	Leadership was important both at the top of RySS as an organization driving the innovation and scaling, and at the community level. Looking more closely at the community level, this type of leadership turns out to comprise local champion farmers who become examples to other farmers. This illustrates a third role in leadership in addition to leaders and intermediaries, namely champions in a distributed leadership model, which is appropriate for a distributed innovation approach. Kohl and Linn (2021) explicitly acknowledge this role in calling to "complement leaders with champions at all levels and parts of the ecosystem to support advocacy."[27]	Strong support
Safe Harvest ***India***	Leadership in Safe Harvest's innovation of pesticide-free food was provided by the company itself. The company both led the effort and worked as intermediary; trained and organized farmer organizations to grow pesticide-free food for a supply chain; developed a credible certification system; *and* developed downstream marketing and distribution opportunities to consumers and stores. The original leaders of Safe Harvest came from a well-established NGO, bringing years of field experience working with small and marginal farmers and networks to build partnerships (collaborative capacities in the case study) for implementation and financing.	Some support

[27] Champions are usually people of influence in the relevant sphere because of their social status, position, power, control of or access to resources, connections and social network, or other forms of legitimacy that allow them to influence others.

Case	Evidence	Support to hypothesis
Trustea ***India***	Leadership in creating and scaling self-regulation of the Indian tea industry came primarily from Hindustan Lever and a few other large tea processors and sellers, with an important organizing role by a Dutch sustainable trade initiative. As with Safe Harvest, they worked as intermediaries training and organizing farmer organizations to grow tea, developed a credible certification system and created demand. Much of this involved mobilizing partnerships with a variety of growers, NGOs involved in certification and the public sector. Notably, the case study never mentions the word leadership nor the name of any individual as a leader.	Some support
Water Harvesting ***Kenya***	While the original introduction of water harvesting was achieved by a single individual, efforts to scale the innovation quickly diffused to a variety of actors and efforts in the three counties studied. The lack of a single driving force may explain why the extent of scale reached by these two innovations has been limited compared to either the need or potential demand.	Unclear support
Solar Powered Irrigation ***Kenya***	There has been no single actor or organization leading the introduction and scaling of the innovation, whether a market leader or an industry association, so that creating market awareness and building demand has been slower than optimal. Now that multiple suppliers and early adopters are in place, demand growth should accelerate.	Unclear support
Upper Tana–Nairobi Water Fund ***Kenya***	Leadership by The Nature Conservancy was instrumental in convening the partners needed to build up the Water Fund. In fact, the NGO's role seems to have gone well beyond that: it led and managed the initial proof-of-concept phase, bringing its international expertise from water funds elsewhere. Critical steps were mobilizing sustainable funding; setting up institutional structures; implementation of capacity building of farmers; and putting in place a robust monitoring, evaluation and learning system and Water Fund secretariat to manage ongoing implementation.	Some support

Case	Evidence	Support to hypothesis
Sahel Rice ***Senegal***	USAID's PCE project both led the scaling effort and played a key intermediary role. The Chief of Party and project team identified bottlenecks as they arose; partnered with individual organizations or groups to innovate and implement solutions to address those obstacles; convened and facilitated multistakeholder partnerships where necessary; and engaging in risk mitigation to incentivize private actors to develop and implement their innovations. Particularly key was creating and leading multidonor coordination to divide up responsibility for addressing different parts of the value chain. PCE co-created an innovative cashless financing mechanism – contractualization – with parastatal banks, rice millers and farmers organizations. It also encouraged private entrepreneurs to develop a viable machinery services and repair, seed certification, and greater investment in rice milling capacity and quality.	Strong support
PICS Bags ***Kenya***	PICS bags were developed by a Purdue University research team. The team was the driver for the initial introduction in Kenya (and several other countries) and establishing a foundation for scaling. This included identifying a manufacturer/wholesale distributor and supporting initial awareness building. Scaling after that was driven by a combination of a USAID project and local and international NGOs. Because of the bags' unique characteristics – affordability, huge return on investment, ease of use with training and relevance to important challenges facing farmers – spontaneous diffusion and adoption quickly became the driving forces.	Unclear support
Kuroiler Chickens ***Uganda***	Arizona State University led the introduction of this Indian breed in Uganda and worked closely with Uganda's National Animal Genetics Research Centre. As both were primarily research organizations, neither had the mandate, motivation or resources to function as an intermediary organization or direct implementer in terms of commercialization. They initially failed to engage commercial actors in partnerships and to address gaps in the value chain and other systemic and institutional issues. It was not until those gaps threatened the entire scaling effort that a third, commercial partner was brought in. The case confirms the need for some actor to play the intermediary role who has the skills, resources and mandate, in this case relevant to commercialization and extension support because the chosen pathway was a commercial one.	Strong support

Case	Evidence	Support to hypothesis
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia***	CIMMYT, which led the development of the varieties, provided little support for commercialization and scaling in Zambia and elsewhere beyond sharing its germplasm with private and public seed breeders and providing technical assistance for seed multiplication. Scaling, especially market creation and demand, was left to diverse actors, and it became very apparent that they had little incentive to do so as these were among many maize varieties in their portfolios. This lack of leadership in the scaling phase was a clear detriment to scaling up.	Strong support
Mechanization Initiative ***Bangladesh***	The CSISA team combined leadership and facilitation of partner actions with the roles of an intermediary. It was a partnership between CIMMYT, a research organization, and iDE, a market facilitation NGO. The former played more of a leadership role and the latter more of an intermediary one. CIMMYT identified technologies and engaged in action research to modify, adapt and improve them. IDE carried out *inter alia* marketing and awareness building; mobilizing and managing partnerships with private agricultural machinery companies; training, capacity building and support to local entrepreneurs; creating viable repair services and parts supply; engaging microlenders to provide financing for machinery purchases; and engaging with the government to ensure support and approval, including subsidies for some of the machines (and to prevent political interference).	Some support

Lessons and conclusions

The evidence confirms the basic hypothesis that leadership and particularly intermediary roles are important. The CoSAI cases in particular tend to emphasize leadership as key in terms of being either charismatic and inspiring or committed to changing the way things are done, such as emphasizing bottom-up, distributed and decentralized innovation. For more specific and useful insights it seems helpful to disaggregate leadership by the phases of innovation, scaling and large-scale implementation phases, and leadership versus intermediary skills.

In scaling and implementation there are several specific intermediary skills that show up repeatedly. These include systems analysis and identification of gaps or weaknesses in systems that need to be address though systems changes; mobilizing resources and political support; and creating and institutionalizing partnerships. These take skills in boundary spanning, strategic planning, goal setting, advocacy, communication, networking and coordination. Additional intermediary skills and resources are specific to the innovation pathway, whether public, commercial or mixed. For public pathways, an understanding of the political economy and public sector enabling environment and advocacy skills are key. For commercial pathways, risk mitigation and supply of public goods such as creating initial demand and demonstrating the presence of a large potential market are examples.

Based on the evidence analyzed, these cases and the literature[28] suggest that one of the major reasons that large-scale SAI does not occur, whether through scaling or systems change, is that many research organizations that do innovation lack both the skills and the motivation to play the leadership role, especially beyond the early stages of innovation. This is even more the case in terms of the intermediary roles to guide scaling or systems change. Given that CIMMYT was the key actor in both the Drought Tolerant Maize case in Zambia and Mechanization Initiative case in Bangladesh, this creates a natural experiment as to why achieving sustainable impact was more successful in the latter than the former. The key difference appears to have been that in Zambia, CIMMYT confined its leadership to the traditional role in research and innovation, and left scaling and the intermediary roles for other actors to notice. By contrast, in Bangladesh it created a partnership with iDE, an NGO that specializes in business approaches and market facilitation. It was iDE who undertook most of the partner mobilization, convening and other intermediary roles as well as direct implementation to fill value chain gaps where needed.

This seems to be consistent with Koerner and Duda's (2021) end-to-end framework of an innovation pipeline integrated from foundational science to delivery at large-scale, but in their article how that will be institutionalized and led is quite vague.[29] The current thinking as part of the One CGIAR reform process, and similar changes to USAID's Innovation Labs, seems to suggest that both market and end-user considerations should play roles from the beginning of innovation, and scaling and/or systems change should be done through some sort of hand-off to private sector leaders or champions rather than by internalizing that capacity within research organizations, who will continue to lead the process. However, how this hand-off in leadership will be affected, who will do it, and how incentives will be aligned across that hand-off remain to be defined.

Innovation pathways should be iterative, adaptive and flexible

Hypothesis

The notion that innovation and scaling should be iterative, adaptive and flexible has now reached wide currency. In great part this is due to two reasons. First, approaches and culture from Silicon Valley around innovation and social entrepreneurship have increasingly influenced international development theory and practice, especially as large foundations whose fortunes come from the technology space play an ever more important role. Ideas like lean innovation, failing fast and often, rapid prototyping, and being customer-oriented and responsive have become fashionable.[30] Secondly, despite this, many international donors and research actors are aware that they continue to practice a rigid approach to innovation and scaling, often driven by legal, regulatory and bureaucratic contracting requirements. Their projects are often required or incentivized to adhere to fixed deliverables, workplans and timelines using such tools as results frameworks with detailed and inflexible goals, metrics and activities. At the same time, these efforts have for the most part not

[28] See Kohl and Linn (2021: 11): "The intermediary role is often either ignored entirely, or inadequately filled because the most likely candidates – innovators or funders – lack the necessary incentives, motivation or capacity."

[29] They do mention the role of boundary organizations, which seems to partly cover the intermediary role referred to in this study in that they connect research organizations to businesses and enterprises, though "connect" seems insufficient to describe the intermediary or brokerage role required.

[30] For a recent and compelling example, see Chang (2018).

achieved either sustainable scale or transformative systems change, the putative goals of these same donors. This has led many observers to attribute this failure to this very same inflexible approach.[31]

To articulate a specific hypothesis regarding the importance of adaptability, we draw from Minh et al. (2021). They define five components of an adaptive scaling framework which they developed through "an iterative, action-research-for-development program on farmer-led irrigation", and we draw on two of these components to specify our hypothesis. According to these, innovation pathways should be:

1. *Reflective, i.e., reflects, manages and responds to dynamic and changing circumstances throughout the scaling processes.*
2. *Adaptive, i.e., adjusts … the scope, capacity, and responses to and management of the strategy to the evolving dynamics of new system properties throughout the scaling processes.*

We examine whether there is evidence to support the hypothesis that innovation and scaling which is responsive to dynamic and changing circumstances and adjusts its scope, capacity, strategy and activities to those circumstances is likely to be more successful in achieving large-scale SAI.

Evidence

Table 6. Support to hypothesis: Innovation pathways should be iterative, adaptive and flexible.

Case	Evidence	Support to hypothesis
Balde Cheio ***Brazil***	The technical assistance delivered by the demonstration units and instructors was "adapted to the regional condition, producer needs for financing, property management, content and technical assistance" and to each property. The delivery structure was shaped progressively, as those interested in technologically developing the chain organized several arrangements for local implementation. In sum, it appears to have been adaptive in terms of the content of the innovation, a dynamic process and the technology being introduced step by step according to farmer needs and reality. There is less evidence of either in terms of the scaling strategy in the face of obstacles and challenges.	Strong Support

[31] Woltering (2019: 3) for example argues that this rigid approach is to "the detriment of meaningful 'systems work' (people and relationships)" and that "although strong numbers may be gained through temporary project efforts and outside support, these quantitative outputs do not necessarily build sustainability and ownership (and in the worst cases undermine them).… the current narrative is stuck in a productionist and technology-centric perspective determined by linear and component change logics, leading to piecemeal innovation."

Case	Evidence	Support to hypothesis
P1+2 ***Brazil***	Adaptation was central to this model. The original approach was adapted from a Chinese model, and the actual "package" is constantly being modified, complemented and extended using a bottom-up innovation process and "adapted to regional characteristics, weather conditions, the local market and farmers profiles". Similarly, "important adjustments were made in the first years of the program (2007-2011) based on evaluations that identified recurrent problems". There is some evidence of flexibility in terms of the scaling strategy in the face of obstacles and challenges.	Some support
ILPF ***Brazil***	The ILPF was constantly evolving, adopting to "regional characteristics, weather conditions, the local market and farmers profiles", and so was the financing approach, which required complex adaptations by the banks who were not accustomed to financing an integrated systems model. The innovation was adapted through an iterative "interaction between farmers' knowledge and 'formal' knowledge".	Strong support
Aqua Digital Irrigation Monitoring System ***Brazil***	The innovation process itself was described as experimental with "much improvisation and testing", but there is no mention of iteration, flexibility or any kind of dynamic feedback learning loop.	Some support
Andhra Pradesh Natural Farming ***India***	Adaptation is inherent in the program's distributed, co-creative and demand-driven (customer) approach to innovation. Farmers themselves experiment with various natural farming approaches and principles, developing their own innovations and applications, and the farmer-to-farmer diffusion and scaling approach encourages new adopters to do likewise. "Thus, Andhra Pradesh Natural Farming evolves as farmers find new crop combinations and apply natural inputs in different ways." At the same time, the case illustrates one of the tensions in using an adaptive approach: that constant innovation and adaptation to local and individual circumstances and contexts makes it difficult to benefit from economies of scale and scope.	Strong support
Safe Harvest ***India***	Other than the change in structure to a more commercial orientation and restructured Board of Directors when the whole effort was at risk, there is no evidence on this issue in this case.	No significant evidence

Case	Evidence	Support to hypothesis
Trustea ***India***	Other than tailored capacity-building solutions for farmers and the current change toward a business model that facilitates more tea producers adopting the Trustea code, there is no evidence on this issue in this case.	No significant evidence
Water Harvesting ***Kenya***	Dam liners were added to the innovation when it began to be implemented in places where the soil was more permeable than in the original locations.	Some Support
Solar Powered Irrigation ***Kenya***	Private providers of SPI quickly responded to customer demand by diversifying their product offerings to include everything from simple pump/solar panel combinations to entire solar irrigation packages to even offering installation, maintenance and servicing. They also reacted to the challenge that many farmers interested in purchasing needed financing, but traditional lending models didn't sufficiently address the risks of default or delays and disruptions in payment, by innovating new financing models such as pay-as-you-go.[32]	Some support
Upper Tana–Nairobi Water Fund ***Kenya***	Adaptation included tree planting for agroforestry and reforestation, terracing, water harvesting and planting vegetated buffer zones	Some support
Sahel Rice ***Senegal***	Despite the description of the program as scaling Sahel Rice, it quickly became apparent that the core focus needed to be on addressing weaknesses or gaps in the rice value chain. Managers adopted what the case study author characterized as a virtuous spiral model, identifying and addressing the most important immediate bottleneck. When this led to increased production or throughput in the value chain, it revealed the next bottleneck, which was addressed through new institutional and systems innovations or strengthening. This appears to be a form of the plan–do–study–act approach that has become foundational to startups and social entrepreneurship. One consequence, however, of the logic of finding first adopters and creating viable service markets and economies of scale was that it required starting with larger, wealthier and more commercial farmers.	Strong support

[32] In pay-as-you-go financing models, the provider sells the solar system in exchange for monthly payments; in Kenya, where mobile money systems like MPesa are omnipresent, these payments are made by transfers through such systems. An electronic switch is built into the systems that the provider can use to turn off or disconnect the system remotely in the case of non-payment. See IRENA (2020) for a full description.

Case	Evidence	Support to hypothesis
PICS Bags ***Kenya***	The success of PICS made adaptation and iteration largely unnecessary. The major adaptation made was to be more responsive to the rapid and enthusiasm for the product which led to excess demand.	No significant evidence
Kuroiler Chickens ***Uganda***	The mixed success of this case is due to initial failures that did lead to subsequent changes to the scaling strategy to address them, specifically engagement of a commercial partner to produce, market and deliver Kuroiler chicks. Few formal monitoring, evaluation, adaptation and learning processes were in place, however, and this is a useful negative example of what happens when there is a lack of adaptation, iteration and flexibility.	Strong support
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia***	While there was likely substantial iteration in the development of drought tolerant maize, the innovation process was not described in the paper. As there was no conscious scaling process driven by CIMMYT, there is no evidence on this issue.	No significant evidence
Mechanization Initiative ***Bangladesh***	This is a standout case of adaptation, iteration and flexibility in both innovation and scaling. The initial machines selected all had problems, and CIMMYT worked with farmers to adapt and modify them to suit farmers' needs and constraints. The business model was also adapted to change from direct sales to farmers to a service delivery model. Similarly, the target market was iteratively changed once it became clear that the initial targets were not responsive. As a result the project put into place a dynamic, near-real-time monitoring dashboard of who was buying what machines for what crops and purposes, and adjusted its marketing targets and activities accordingly and frequently. USAID Bangladesh supported these changes to the project's goals and strategy to "follow the market."	Strong support

Lessons and conclusions

The evidence from the cases reviewed provides very strong support for the need for an iterative, adaptive and flexible approach to innovation and scaling. Thus Kohl and Linn (2021) incorporate into their paper two related scaling principles:

> *Principle #7: Iterate, learn, adapt and sustain the scaling pathway as long as needed.*
>
> *Lesson #17: Iterate and adapt – apply a cycle of experimentation, learning and strategic adjustments supported by evidence. Regularly revisit decisions about scaling goals and whether and how to scale.*

They advise:

> *Managing and driving scaling needs to take such changes as likely and constantly reexamine assumptions, revise the scaling vision and strategy, and adapt activities and tactics accordingly. For these reasons, scaling almost always involves multiple and continuous feedback loops.*

One possible approach that allows for this kind of flexibility is mission-driven (or oriented) agricultural innovation and scaling, as has been proposed by Laurens Klerkx and others in numerous papers (for example, Klerkx and Begemann 2020). In one interpretation of the mission-driven approach, rather than scaling up a particular technology or innovation with a sole focus on the number of primary adopters, the focus should be both on making a positive impact on the (usually big picture or large scale) problem to be addressed. This mission is then achieved by a process that includes: systems analysis to identify and prioritize leverage points, rapid prototyping and experimentation, monitoring, evaluation and learning, and adaptation and feedback loops. While the Mechanization Initiative in Bangladesh did not explicitly adopt a mission-driven approach, when confronted with unexpected market reactions to the initial introduction of machinery in the first few years, they sought and were granted permission from the USAID mission to adapt to the changed reality as long as the ultimate outcome was to improve the livelihoods of small farmers. This decision by both the project and the mission was no doubt facilitated by the fact that achieving the existing targets using the original activities and pathways would have clearly undermined any chance of attaining sustainability and an effective hand-off to private sector partners. They applied that approach successfully thereafter.

One of the critical elements in terms of *how* they did this in practice was to create a nearly real-time monitoring, evaluation, adaptation and learning (MEAL) dashboard which reported regularly on who was buying or using machinery services, where, for what purposes and crops, with what funding, and other relevant details about the market reaction. This allowed them to modify strategy and tactics on an ongoing basis, rather than having to wait, at best, for annual reviews of the workplan.

While the Sahel Rice project in Senegal did not use a formal dashboard, they had frequent and regular interactions with stakeholders from the entire value chain, and when an obstacle to scaling came to their attention, they worked with these same actors to develop and implement institutional innovations or systems strengthening to address it. Other lessons on that adaptation include:

- Benefits from inclusion and participation, particularly of end users and local actors who are most familiar with the problem, local context and systems. For example, in Senegal rice farmers were able to identify that their inability to sell their harvest in a timely way prevented them from repaying loans from the previous season which created long delays in getting a new loan to buy inputs and do land preparation and planting. This significantly reduced yields and increased the risks of a poor harvest. The PCE project, working with farmers' organizations, parastatal banks and rice millers and processors developed contractualization, a version of warehouse receipts.
- Requires regular information and feedback loops to inform adjustments in innovations, goals and strategy. While this can be perceived as adding additional monitoring and evaluation (M&E) costs, it appears likely that such costs are more than offset by the increased chance of achieving sustainable impact at large scale, though this tentative conclusion would benefit from further research. Nonetheless, it is no accident that some development actors have recognized this and converted from M&E to MEAL, as USAID did in Bangladesh.
- Requires flexibility in financing and the terms of such financing. Funders need to be actively engaged on an ongoing basis to support adaptation, especially changes in pathways and strategies as is commonly the case with private venture capitalists; not to sign a check and wait years for results. They need to be more focused on meta-goals, mission driven, and ensure that innovation pathways are producing value addition without specifying crops, activities and pathways.

Unfortunately many funders do not currently operate this way, even those pursuing a social enterprise approach, and this would require investing in internal capacity and a physical presence on the ground, probably resulting in fewer funds available for grants themselves. For example, the International Fund for Agricultural Development (IFAD) found that "scaling up was three times more prevalent in countries where IFAD had an office: scaling up featured in 62 per cent of the evaluations in countries with an IFAD presence, compared to only 21 per cent in countries without one" (IFAD 2017).

One solution to this challenge is to pool resources, such as potentially investing with other donors in intermediary actors (as discussed above) who have local knowledge and presence as well as the other skills needed. This has been used successfully in donor consortia such as the Alliance for a Green Revolution in Africa (AGRA). While AGRA has been subject to numerous criticisms for its emphasis on market-based and mostly agro-chemical-based agricultural approaches, it is based in Africa (Ghana and Kenya) and has effectively leveraged the strong role of national and local African governments and institutions that have brought both local knowledge and credibility with other stakeholders on the ground.[33]

At the same time, the need for an adaptive approach has several tensions that need to be navigated. First and foremost, it implies significant changes in behavior for many development actors, especially researchers/innovators and international donors. While some of these changes are unavoidable,

[33] See for example comments in *The Guardian* by the head of AGRA, who stated: "While we exist due to generous funding from the Gates Foundation and other donors, we are African-led and headquartered in Africa. Over 95% of our staff is African, working across the 17 African countries where we have programmes. And 96% of our grants go to African organisations, universities, scientists and small businesses" (Kalibata 2014).

others do present real tradeoffs. First, adaptation can sometimes serve as an excuse for continued investment – throwing good money after bad – especially when there are institutional incentives not to recognize failures. Secondly, pursuing an adaptive or mission-driven approach will in some ways require funders to accept greater risk and increased rates of failure. The tradeoff is that those efforts that do succeed will affect sustainable impact at large scale, which most current efforts don't do despite their putative success. This means, as with venture capitalists, pursuing a portfolio approach whereby maybe seven in ten innovation and scaling efforts fail, two do acceptably, but one is a huge, game-changing success.

Perhaps most importantly, many organizations currently measure success in terms of what is achieved by their own projects in limited fixed time frames where they can control strategy, implementation and many other variables, and thus report very high success rates. For example, IFAD (2020: 26) reported that 74% of its agriculture and rural development projects were rated moderately successful or better in terms of project performance between 2007 and 2017.[34] Adaptation and flexibility that truly confronts complexity, uncertainty and the dynamic quality of innovation and scaling may or may not increase *project* success; what it will do is achieve greater success rates in terms of *large-scale SAI*, but these rates are likely to be much lower than project success. In other words, taking on adaptation only makes sense if development actors are willing to be held accountable for broader international development goals that require embracing the greater risk and uncertainty that comes with effecting systemic change, sustainability and results at large scale. Unfortunately, while this is necessary to achieve global goals like the SDGs, collective action issues mean that individual actors have limited incentives to embrace adaptation, so that the whole remains less than the sum of its parts. Once again, having donors and other investors take on more of a portfolio approach with co-investment would also allow for collective responsibility and mitigate the collective action problem. The Sahel Rice case was *de facto* an informal donor consortium that divided up responsibility for different parts of the value chain, but such examples of cooperation, let alone consortia and portfolio approaches, are rare. Given that there are few existing examples of these kinds of efforts, this calls for experimentation and evaluation by investors.

This would require a huge change in organizational mindset, but also need to be mainstreamed into the organizational culture and particularly incentives for individual staff: failure would have to be rewarded if done well. The same would have to happen in governance structures. Funders are accountable to their governments or boards and directors, and thus reasonably use M&E for purposes of accountability. Balancing or blending M&E for accountability with MEAL is very much a work in progress and will require changes in internal and external incentives and organizational culture for innovators, funders and their boards.

[34] Interestingly, the IFAD portfolio's average scores on sustainability, at 3.65, are much lower than its scores on relevance, IFAD performance, innovation and gender equality, all of which were well above 4.00. Given a sample size in the hundreds and standard deviations of around 0.7-0.9, these are highly significant differences.

Innovations should have characteristics that facilitate progress along innovation pathways and achieving large-scale SAI

Hypothesis

Ever since the seminal work of Everett Rogers on diffusion of innovation,[35] there has been a recognition that innovations may possess characteristics that facilitate successful diffusion, or, to put it into the current context, scaling or successful progress along an innovation pathway. Rogers in his work identified five characteristics of innovations that facilitated adoption and diffusion by end users:

- Relative advantage over current or competing approaches
- Compatibility with the current practices, values, experiences and needs of potential adopters
- Complexity (or simplicity) – how easy is it for adopters to understand why it might be of benefit to them, and how to use it properly to achieve those benefits
- Small Initial scale, facilitating investment or financial commitment necessary to try it
- Observability – the extent to which the results or impact produces visible, tangible results that can be causally attributed to the innovation.

Since this seminal work in the 1960s a vast literature has developed on innovation characteristics that favor scaling. That literature has become increasingly differentiated by sector, type of innovation, innovation pathway, and characteristics that are context dependent or not. In the past decade in particular, a number of assessment tools have been developed for application to scaling rather than diffusion of innovations, and agricultural innovations in particular. Cooley and Kohl (2005) developed the first such tool in the Management Systems International (MSI) Scaling Up Management Framework and have refined it in subsequent editions (Cooley et al. 2016). More recently Kohl (2018) developed the Agricultural Scalability Assessment Tool (ASAT) for USAID's Bureau of Resilience and Food Security. The ASAT is currently being applied to the thousands of innovations developed by researchers funded under Feed the Future to decide which have enough potential for large-scale sustainable impact to merit further investment. CIMMYT and the PPPLab have most recently developed another tool called the Scaling Scan (Jacobs et al. 2018). While it is too soon to tell whether these tools will be predictive in practice, as scaling often takes 5-10 years to achieve fruition, a recent analysis applying these tools along with other scaling principles to three case studies, two of them retrospectively, suggests that they do in fact at least correlate with success (Linn 2022).

Both the ASAT and the Scaling Scan have roughly 40 criteria – a granularity far too fine for the purposes of this paper. However, in both tools many of the criteria are not about the innovation itself, but about the external environment, such as the market system or the public sector enabling environment. By eliminating criteria which are context dependent, refer to the strength or weakness of the external environment, or refer to financial considerations (which are considered under the next hypothesis),[36]

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[35] See Rogers (2003).

[36] There are several financial and economic characteristics, as these will depend on what business or financing model and innovation pathway is being used – commercial, public, public/private or some other alternative. It is also important to note that these characteristics have been developed to largely apply to products, services and practices, but not so much to institutional innovations or changes in the policy enabling environment. While clearly some of these characteristics would also apply to such innovations, additional research would be required to develop criteria specifically for such innovations.

we were able to shorten the ASAT list to **nine criteria for innovation characteristics that facilitate progress along an innovation pathway:**

- The innovation addresses a felt (subjective) need that is important to potential adopters.
- The impact is tangible and easily observable to potential adopters.
- The innovation is relatively simple with few components.
- Adopters can expect benefits along multiple dimensions, either tangible (e.g., productivity, income, time-saving, health) and/or intangible (e.g., ease of use).
- The innovation aligns with existing social norms, agricultural practices, tools and equipment, and thus requires little behavior change or additional complementary investment.
- In cases of a combination or bundle of innovations, it generates significant benefits even if the entire bundle is not fully adopted or implemented correctly.
- The benefits are relatively robust and reliable, i.e., are relatively consistent over time with low risk or variance.
- Superior effectiveness is established relative to current solutions and emerging alternatives in similar contexts.
- The innovation reduces risk or increases resilience, in addition to any increase in returns it may have.

Some of these may seem like common sense, yet they remain overlooked in many agricultural innovation efforts where they are not considered from the start: there may be no clear demand in terms of proven willingness-to-pay or a market; innovations may be complex with multiple components; or it may well be that no one has compared them to alternatives, especially in cases such as institutional innovations or equipment.

Evidence

Table 7. Support to hypothesis: Innovation should have characteristics that facilitate progress along innovation pathways and achieving large-scale SAI.

Case	Evidence	Support to hypothesis
Balde Cheio ***Brazil***	The initiative clearly addressed a felt need, had a tangible and visible impact, produced benefits across multiple dimensions, were better than current practices, and reduced risk and improved resilience. The downside was that it was complex with multiple components, required significant changes from current practice. Adaptation to local circumstance is a characteristic, making scaling more challenging. These latter characteristics are all consistent with the fact that implementation required significant and ongoing training, technical assistance and extension support.	Some support

Case	Evidence	Support to hypothesis
P1+2 ***Brazil***	The initiative clearly addressed a felt need, had a tangible and visible impact, produced benefits across multiple dimensions, were better than current practices, and reduced risk and improved resilience, It required less customization than Balde Cheio but arguably more extension support.	Some support
ILPF ***Brazil***	The initiative clearly addressed a felt need, had a tangible and visible impact, produced benefits across multiple dimensions, were better than current practices, and reduced risk and improved resilience.	Some support
Aqua Digital Irrigation Monitoring System ***Brazil***	The innovation addresses a need for timely information and guidance to inform agricultural decision making, especially around irrigation during times of drought. It fits with some criteria but not others; it does require significant changes in behavior, is complex, is complex and requires technical support to ensure accurate application of the entire package. On the other hand, it provides multiple benefits, is easy to use and reliable, and especially improves resilience. This mix of characteristics, along with high expense, is why it is best suited for more sophisticated medium and large farmers.	Some support
Andhra Pradesh Natural Farming ***India***	This case is more of a process than a technology, and thus difficult to assess on these criteria. Because it is demand driven, it by definition addresses (multiple) felt needs, and presumably farmers will only co-create innovations with manageable complexity, observable benefits and superiority to existing practices.	Strong support
Safe Harvest ***India***	The case confirms the importance of aligning the innovation with the needs and demands of horticulture producers. Because this innovation spanned the value chain from producers to consumers, alignment with the needs of end users was equally important. As an institutional innovation of pesticide-free products and certification, the benefits were multidimensional: improved and more stable market access, better soil health, water management, increased incomes and productivity, and better health for farmers not using chemicals. It also improved resilience. On the other hand, learning pesticide-free practices is a significant change in behavior, complex, and only feasible because of the financing and support available.	Some support

Case	Evidence	Support to hypothesis
Trustea ***India***	The case confirms the importance of aligning the innovation with the needs and demands of tea processors and, equally, of consumers. Its alignment with the proposed criteria is similar to Safe Harvest and therefore mixed. Like Safe Harvest its relative success was dependent on the high levels of profitability involved and ability to finance significant technical support and extension services to change growing practices.	Some support
Water Harvesting ***Kenya***	The innovation clearly met a strongly felt need among small-scale farmers practicing rainfed agriculture, had clear benefits that were better than existing alternatives, had multiple benefits (useful for crops and personal consumption), had tangible benefits in terms of reducing time for getting and carrying water, was relatively simple to use, and reduced risk and increased resilience. While it did require some changes in behavior and adaptation to different agro-ecological conditions, it appears that these could be achieved with minimal training and modifications, respectively.	Strong support
Solar Powered Irrigation ***Kenya***	The innovation does well on these criteria; it met a need and it is tangible, relatively simple, robust and reliable, superior to existing solutions, and supportive of resilience.	Strong support
Upper Tana–Nairobi Water Fund ***Kenya***	The criteria were not relevant to this institutional arrangement.	No significant evidence
Sahel Rice ***Senegal***	This was a mixed picture. The intervention was complex, required significant changes in behavior, and much of the package had to be adopted, with fidelity, to be effective. However, it clearly improved outcomes and resilience. As with other cases, significant extension and technical assistance were necessary, here financed by the USAID project leading the effort.	Some support

Case	Evidence	Support to hypothesis
PICS Bags ***Kenya***	The innovation aligns with almost all of the criteria. Post-harvest losses were a huge problem for farmers throughout the year. The bags were extremely simple and easy to use with only one component, and the only behavior changes were to dry the crop to low moisture content and to store it away from rodents. The results were easily visible: a farmer could see in a few months that his crop had not rotted. The bags last a few years without a loss of effectiveness or impact. By allowing farmers to store their harvest over several months with few losses and sell when prices are higher, they significantly increased food security and resilience and improved income.	Strong support
Kuroiler Chickens ***Uganda***	Kuroiler Chickens had several of the positive characteristics, such as significant and highly visible benefits in their increased and more rapid meat and egg production compared to indigenous breeds. However, they also had important negatives that impeded successful scaling, most importantly that they required significant changes in animal husbandry practices including fencing and supplemental feed, vaccinations of chicks and in general are more complicated to take care of. Moreover, their impact was not robust or stable without strict adherence to these practices. Combined with the fact that they are hybrids, and therefore new chicks have to be bought from a breeder at regular intervals, they probably increased the riskiness of production and reduced resilience.	Some support
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia***	This case and its difficulties prove the hypothesis as a counterexample. In particular, it did not address a felt need, and the impact was only observable in drought conditions. The package was complex and required behavior changes, and the benefits were two-dimensional: improved harvest under poor rain conditions, and greater resilience.	Strong support

Case	Evidence	Support to hypothesis
Mechanization Initiative ***Bangladesh***	The project formed a natural experiment as it introduced four machines that differed in all of the innovation characteristics. Perhaps the most impactful at large scale were axial flow pumps, which met a clear need by rice and fish farmers and required almost no change in behavior or agricultural practices. By contrast, self-powered reapers were much less successful due to being more expensive, replacing the labor of migrating workers (who pushed back by refusing to do other work), being difficult to use especially in muddy conditions, and being dangerous. The innovations that were easier to use, simple, addressed existing felt needs, superior outcomes and required minimal changes in agricultural practices were more likely to be adopted than those that did not have those characteristics.	Strong support

Lessons and conclusions

Some cases positively confirmed that characteristics we identified are important, such as Water Harvesting and Solar Pumps in Kenya. Other cases confirmed by counterexample: Drought Tolerant Maize in Zambia and Kuroiler Chickens in Uganda were constrained by multiple negative characteristics. Some of the characteristics were irrelevant to cases of institutional innovations, e.g., the Upper Tana–Nairobi Water Fund in Kenya and India's Safe Harvest and Trustea. But the latter two, along with several of the Brazilian innovations, were successful despite not being aligned with the criteria; in all such cases this was directly related to the time, effort and resources available to invest in significant agricultural extension support, training and technical assistance. In the Brazilian cases this was made possible because of public funding, while in the two Indian cases the relevant component – teaching farmers pesticide- or chemical-free farming – was financially viable for their high-value products with significant profit margins. Thus innovations that don't meet these criteria are nonetheless scalable if extension and technical assistance are available and affordable, and some actor has the capacity and incentive to provide them.

The hypothesis that innovation characteristics with certain criteria facilitate progress along innovation pathways is thus largely validated by the evidence, but the caveats are important. Of the nine criteria assessed, four have strong evidence that they contribute to success: (i) alignment with users' felt needs, (ii) tangible and observable impact, (iii) superiority to alternatives, and (iv) multiple uses and benefits all appear to have universally contributed to success.

The other criteria are somewhat more complicated to apply. Innovations that are more complex, require significant changes in behavior or practices and/or adaptation to local circumstances, and increases risk do appear to be more challenging to scale. However, those challenges can be successfully addressed by good practices in scaling, such as greater adaptation and flexibility, the choice of an appropriate innovation pathways e.g. public, commercial or mixed, and packaging with different financing and delivery mechanisms.

Innovations must be packaged with viable funding and implementation models and bundled with systems change

Hypothesis

The innovation and scaling literature uses *package*, *bundle* and related terms to discuss elements of innovation pathways that go beyond the introduction of a single technology. The meanings often overlap – so much so that we have combined them here under one hypothesis. In our assessment, however, we follow two specific definitions:

- Packaging refers to adding to an innovation, or combination of innovations, a viable delivery method and payment/business/funding model to form an innovation package.[37] The delivery method and funding or business model can themselves be innovations, and are often more innovative than the other components.
- Bundling refers to the fact that moving a specific innovation or package further along the innovation pathway often requires it to be supported by what can be broadly characterized as systems changes and/or institutional innovations (fairly similar to the concept of vertical scaling).[38] These systems changes can range from strengthening or filling in gaps in value chains or market systems, to changes in the public policy and institutional enabling environment, to affecting change in social or cultural norms or mindsets (see Minh et al. 2021; Woltering et al. 2019).

To start with, whether an innovation is a product, service, institution or combination, it requires some source of funding to pay for it. This can take the form of a purely private sector model where the user pays, a purely public sector model where the resources come completely from one or more government budgets, or various mixed models where partners contribute different resources, whether in cash or in kind. This is true even of systems changes which only require temporary funding to change policies, laws and regulations, though in fact many of those types of innovations also require some funding for ongoing implementation. Similarly, one or more organizations has to have the capacity to produce, implement or deliver the innovation, again the relevant verb varying with the type of innovation (the shorthand names for these roles in the social enterprise literature are Payers and Doers, respectively; see Starr and Hattendorf (2015). Indeed, as discussed under the next hypothesis, the principal rationale for partnerships in achieving large-scale SAI is that it is often the case that there is no single organization that has all the necessary resources and capacity to play the Doer and Payer.

Packaging poses two critical challenges for achieving large-scale SAI. First, given goals or targets in terms of SAI and the resource and implementation requirements of an innovation combination, along with any systems change it is bundled with, who has those resources and capacity? Secondly, how can those organizations be persuaded to play those roles and commit those resources, i.e., be convinced

[37] This definition of package differs than what is often called a technical package (e.g. Balde Cheio at the technical level packaged feed, animal housing and health).

[38] This is in the context of horizontal, vertical and functional scaling up (also referred to as scaling out, scaling up or scaling deep). This is used by many authors; Hartmann and Linn (2007) define vertical scaling up as "creating the organizational and political framework needed to permit going to a larger scale," and horizontal scaling up as "the expansion of coverage of a project, program, or policy across more people and greater space".

that doing so is aligned with their interests, incentives and mission? These considerations are reflected in the various scaling and innovation literature. Starting again with Kohl and Linn (2021), they appear in two lessons.

> *Lesson #11: Develop a viable, long-term business or funding model for scaling and for sustainable delivery/implementation at scale. Align the costs of the innovation and other resources needed with the funding and resources available and with financing mechanisms suitable for each specific stage of scaling pathway.*
>
> *Lesson #15: Align the incentives, interests and priorities of all stakeholders, especially Doers and Payers.*

While Kohl and Linn (2021) don't refer to bundling by that name, they also emphasize the importance of systemic analysis and change as fundamental and essential to scaling.

> *Principle #4: From the outset, identify systemic opportunities, constraints and risks; plan to align with them or address them through system change.*

Other authors emphasize this larger framing of the hypothesis that we call bundling: that to achieve sustainability broadly defined, social, economic and other systems considerations must be part of an innovation pathway. For example, Barrett et al. (2020) state that achieving global agri-food system goals will require "building socio-technical innovation bundles of mutually reinforcing technologies, policies, knowledge, social institutions and cultural norms". They argue that while not widely acknowledged, narrowly defined examples of large-scale SAI like the Green Revolution would not, in fact, have been successful without policy, institutional and sociocultural changes in land tenure, infrastructure and extension services. This view of bundling is reinforced by the guidance the international NGO CARE uses in terms of achieving impact at scale. For CARE (2021), achieving impact at scale has six components, of which four are most relevant to this discussion:

3. *Scaling and adapting proven models [narrowly defined scaling]*
4. *Advocacy to influence policies and programs [affecting the policy enabling environment]*
5. *Promoting social norms change: Helping address discriminatory and harmful social norms in the economic, social and political spheres, through community dialogue and other norms-shifting interventions, as well as through broad media campaigns*
6. *Systems strengthening and social accountability: Transforming and supporting institutions to increase their capacities to provide inclusive, effective and accountable services.*

Evidence

Table 8. Support to hypothesis: Innovations must be packaged with viable funding and implementation models and bundled with systems change.

Case	Evidence	Support to hypothesis
Balde Cheio ***Brazil***	There was no packaging, as the financing model was a mix of funding from Embrapa, various federal agencies concerned with food security, rural poverty, etc., some farmer cooperatives and milk enterprises and state and municipal governments. The sources of funding for these projects was through increased milk yield and quality to increase farmer incomes, based on the goal of massive poverty reduction.	Unclear support for Packaging No Support for Bundling
P1+2 ***Brazil***	P1+2 was able to reach over 200,000 families through a public investment of US$356 million between 2007 and 2020 under two successive Workers' Party governments. The implementation model was done by contracting under the Brazilian Tenders Law (8.666/1990) and the federal government's agreement model. When these latter two structures became an obstacle to implementation, the government effected changes in the legal framework that were critical for the functioning and expansion of the program.[39] However, when political parties and leadership shifted in 2016, funding evaporated, suggesting that in public financing and scaling pathways, financial and implementation sustainability is directly tied to political sustainability. Thus the reliance on Federal funding appears to have been both a blessing and a curse in terms of financial sustainability, as a change in government led to a 180-degree shift in political priorities, and therefore funding.	Strong support for Packaging Some Support for Bundling
ILPF ***Brazil***	The financing model was the creation of specific credit and financing lines – an institutional innovation – in the context of a sectoral plan for agriculture. In other words, ILPF was bundled with systems changes in policy, sectoral plans and financing mechanisms. Public sector and private partners cover the costs of	Strong Support for Packaging (counter-example)

[39] Specifically, the changes in the legal framework "made it possible to formalize contracts by means of bidding waivers with private non-profit entities previously accredited by the [Ministry for Social Development] and conferred agility in accountability by shifting the focus from services to the final product (delivered technology)" (Chiodi Bachion et al. 2022: 26).

Case	Evidence	Support to hypothesis
	developing and improving the technology package and of creating and running its technical referral units. However, most of the cost is borne as individual investment by rural farmers. The CoSAI study therefore concludes that the scale achieved is still low compared to the potential of areas that can apply the system. Adoption appears to be confined to larger and medium farmers who can afford it.	Strong support for Bundling
Aqua Digital Irrigation Monitoring System ***Brazil***	Scaling of this model was funded largely by private financing sources and customer fees. It was not bundled with any systems changes, being a private sector social enterprise model.	Strong support for packaging No support for Bundling
Andhra Pradesh Natural Farming ***India***	The program did not have a sustainable funding model and has relied on a combination of donor and state government financing, which has limited scale. Implementation has had an effective model of leveraging farmer organizations and other social capital.	Some support for packaging No Support for Bundling
Safe Harvest ***India***	Safe Harvest's funding model has relied on a mix of private, impact and philanthropic investors and has allowed for some scaling but also been a constraint. Implementation, at least on the supply side, has relied on existing farmer organizations, many of which are in nascent stages of operation, also constraining scale. While the innovation itself can be seen as a systems change in terms of value chain linkages and in pesticide-free certification, it was not bundled with other systems changes.	Some support for Packaging No Support for Bundling
Trustea ***India***	Trustea created an institutional innovation in the face of existing demand. Funding for Trustea came from the large private tea processors and distributors. The principal innovation itself, a chemical-free certification standard and a traceable chain of custody, can be seen as an institutional or systems change, but it wasn't bundled with other systems changes. It was aligned with existing policy but no policy changes were made, and the government only came in as a partner after the fact. The funding and implementation model has relied on working largely with tea plantations and has only recently been modified, at least in principle, to provide support for small tea growers who couldn't afford the training.	Some support for packaging No support for bundling

Case	Evidence	Support to hypothesis
Water Harvesting ***Kenya***	A mix of partial donor, NGO, public and end-user financing characterized water harvesting in the three counties in Kenya, with some of the end-user contribution being in-kind labor. The Kenya country study estimates that by 2021 10,000 farm ponds had been excavated in the three counties studied, reaching at least 100,000 people. By comparison, the rural population of the three counties is approximately 2.1 million, suggesting that scale was a fraction of potential demand. In sum, the innovation is a telling counterexample that lacked a viable funding model for scale, and was also not bundled with any systems changes.	Strong support for packaging (counter-example) No support for bundling
Solar Powered Irrigation ***Kenya***	This case illustrates what happens when the challenge of a viable business and delivery model is only partially addressed. It does have a viable private sector delivery model and there is a small and growing market in the one county studied, and probably elsewhere in the country. However the CoSAI study concludes that sustainable impact would be much greater if some actor invested in increasing market awareness, achieving lower prices through economies of scale and subsidized or otherwise lower financing costs. It was not bundled with systems changes.	Some support for packaging No support for bundling
Upper Tana–Nairobi Water Fund ***Kenya***	Upper Tana included a viable funding model – a donor-financed trust fund – and an implementation model using a secretariat set up by The Nature Conservancy and through its partners in terms of electricity, water and sanitation companies and local NGOs. While itself an institutional innovation, it was not bundled with other systems changes.	Strong support for packaging Unclear support for bundling
Sahel Rice ***Senegal***	Improved varieties of rice were widely adopted in the Senegal River Valley in the 1990s, but most farmers never came close to meeting the productive potential. A USAID project, in partnership with other donors, sought to remedy the situation with a long list of systems changes, including a certified seed system, rehabilitating rice milling, reviving urban market links, encouraging private machinery entrepreneurs, and reviving	Strong support for packaging

Case	Evidence	Support to hypothesis
	irrigation infrastructure. Particularly critical was a financial innovation, contractualization, which was basically a warehouse receipt system. The success of all of these was preconditioned on and facilitated by a highly supportive policy enabling environment, which the government put in place following the world food crisis of 2008/09 to achieve national food security in rice. Policies included a variety of price supports, subsidies and regulatory controls along with an implicit "guarantee" that reduced risk for investors and international donors. The systems changes have endured, but the "commercial" system remains heavily reliant on government support and intervention.	Strong support for bundling
PICS Bags ***Kenya***	PICS Bags went to large scale, sustainably, based solely on an end-user-pays model with no elements of packaging or bundling. The project identified a domestic plastics manufacturer for production and then leveraged existing delivery mechanisms, both traditional agro-dealers and independent distributors on bicycles and motorcycles. Central to this was the very low unit cost and high returns for end users, such that it was affordable for them while allowing producers and distributors to make a good return.	Contradicts packaging and bundling
Kuroiler Chickens ***Uganda***	The innovation was not bundled with systems changes, and this, at least of the time of writing, put achieving large-scale SAI in serious jeopardy. Among the systems changes lacking was putting in place an effective upstream supply chain of baby Kuroiler chicks and providing some sort of extension support to teach/inform farmers who tried to raise Kuroilers as to their proper care.	Strong support for packaging (counter-example) No support for bundling
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia***	A viable "commercial" business and delivery model was created by massive public sector subsidies for both the purchase of seeds and fertilizer and a guaranteed market for hybrid maize but did not specifically target drought tolerant maize. A donor-funded national seed certification system was foundational not only for the widespread adoption of hybrid maize but for Zambia	Strong support for packaging

Case	Evidence	Support to hypothesis
	becoming a major exporter of maize seed for Southern and Eastern Africa. Public policy played a critical role in this success, as did price subsidies for hybrid maize seed and fertilizers, and a government purchasing scheme that guaranteed profitability even for remote small-scale farmers. The policies were broadly similar to those present in the Senegal case, but not in size or impact. In Zambia, precisely because they were so large, they were both fiscally unsustainable and created severe distortions that virtually eliminated private commercial buyers of maize.	Strong support for bundling
Mechanization Initiative ***Bangladesh***	The project had to engage in several systems changes and create a viable market for machinery services. In the early years the number of local service providers, and therefore demand for machines, was much smaller than anticipated because calculations about potential market size had been made based on ecological considerations rather than a clearly defined business and delivery model. Even though firms had invested their own money in importing initial consignments of machinery, they were unwilling to invest their own money in marketing or filling in gaps in the value chain until they were convinced of the size of the market. In fact, they were largely motivated by the potential to sell machines to more commercially oriented farmers than the project's target rice farmers. In response the project had to engage in risk mitigation both for dealers and service providers.[40] This proved successful after a second project to achieve critical mass of demand, finish strengthening the value chain and broaden the end-user base beyond cash crops. The case confirms the importance of creating demand and viable business and delivery models, and it illustrates that even on a commercial pathway, these systems changes are in fact forms of public goods.	Strong support for packaging No support for bundling

Lessons and conclusions

The issues of packaging and bundling depend very heavily on the innovation pathway itself, the presence (or lack) of intermediaries and leaders, and to a lesser extent the nature of the innovation. Both examples and counterexamples among the case studies show how the presence or lack of viable

[40] Even though several public sector agencies were partners, the public sector played a more minor role than in Senegal and Zambia. While the government did ultimately offer subsidies for some machinery purchases, these did not play an important role. Public extension agents were influential in marketing and awareness building but lacked numbers and transportation resources.

funding models and implementation capacity affected the success of scaling. Many of the cases were funded by the public sector, and sustainability was affected by the political duration of policy support. The same thing was true of lack of viable delivery models.

The evidence in this section confirms that packaging within a viable financing and delivery model is necessary for, or seriously influences and constrains, large-scale SAI. Commercial models have their drawbacks, especially for innovations for which there is currently no existing demand or that are too expensive for small farmers.

The evidence for bundling is more complex. Much of the literature advocating for bundling makes its case based on two facts: agri-food systems are collections of interdependent subsystems; and these systems and subsystems have implications for multiple global goals. In this view, it is unrealistic to expect achievement of large-scale SAI through narrowly defined scaling to successfully impact not only agricultural productivity and income, but also food security, resilience, climate change, environmental sustainability, health, nutrition, equity and gender empowerment. This section examines a narrower claim: that to achieve even one of the global goals also often requires bundling.

In terms of the narrower claim, the cases reviewed confirm the impression that bundling is quite critical to achieving large-scale SAI. Four types of bundling are represented. First is strengthening or filling in gaps in either upstream or downstream value chains, i.e., access to the innovation and to complementary inputs and markets. Second is providing or strengthening complementary services, such as financial or machinery services. Third is improving profitability or reducing risks for private actors, particularly for early adopters or initial investors in other parts of the value chain. In the context of innovation pathways, if applied carefully and phased out, subsidies can play an important role in mitigating risk and signaling policy credibility. In the Sahel Rice case in Senegal and Drought Tolerant Maize case in Zambia, input subsidies and support for output markets played important roles in encouraging innovation and scaling by private investors.[41] On the other hand, agricultural subsidies are often used by governments for many reasons, with well-known risks; these risks were eventually realized in the Drought Tolerant Maize case, as subsidies became fiscally unsustainable while crowding out the private market. The fourth and final type of bundling is the provision of public goods like standards and certification – and seed certification was also critical in the Sahel Rice and Drought Tolerant Maize cases.

While bundling appears to be critical for many or most innovations in the form of products or services, there is less evidence to suggest that this is true for public policy, systems or institutional innovations. For the CoSAI cases that involved institutional innovations – Trustea, Safe Harvest and the Upper Tana–Nairobi Water Fund – bundling was limited to providing off-the-shelf technology and facilitating market linkages (if one can call the connection between water users and upstream actors a market linkage, in the last case).

Perhaps bundling is implicit when the actor driving progress along an innovation pathway is the public sector itself, such as in three of the CoSAI cases from Brazil. Here the ideal, at least, is that public policy, laws and regulations are already aligned, public financing is in place, and if delivery succeeds via national, state and local parts of the public sector, then the capacity and profitability of private

[41] Interview by the author with the Chief of Party of the Projet Croissance Economique, which implemented the Sahel Rice case.

actors in the value chain is less important. This is asking a lot, however, and the one exception in Brazil is noteworthy. Systems change and alignment were instrumental in P1+2, and took the form of a change in the Tenders Law to support the program. This suggests that when public–private partnerships or other cross-sectoral coalitions are mobilized to effect scale, changes in tendering, procurement and other laws and regulations affecting the ability to partner or procure are likely to be required.

Another lesson is that bundling, even regarding our narrow definition, can involve provision of public goods, and that may not make sense for private actors. It is difficult for private actors to capture sufficient benefits to justify the investment or exclude others from the benefits – the free rider problem. To support this claim, it is noteworthy that institutional innovations like the standards in Trustea came about through a coalition of multiple large tea processors and distributors who had a sizable share of the market. It may also be a question of resources as well as incentives. In the USAID cases of Sahel Rice and Drought Tolerant Maize, large, well-funded development projects had both the resources and mandate for creating seed certification systems; in some cases this was through the public sector and in other cases through industry associations. While this is also true of governments, the public sector in lower-income countries may have neither the financial nor implementation capacity to do so. Perhaps the most common "public good" is the creation of large-scale for a new product; this was true for all five of the USAID cases, though not done successfully with Drought Tolerant Maize in Zambia. The clear examples of bundling in the CoSAI cases come from Brazil, where the public sector has greater resources and capacity than in India and Kenya.

A final lesson comes back to how narrow or broad our definition of successful large-scale SAI is. Since this is a continuum, more bundling is likely to improve the chances of narrow success, and broad success even more so. At the same time, it comes at a price. As Kohl (2021) and others have noted, as more subsystems and objectives are involved, the complexity of analysis alone will increase at least multiplicatively, and so will the number, level and extent of interventions necessary to be included in the bundle. Still, doing *some* analysis does have the advantages of allowing actors to anticipate and avoid negative unintended consequences from ignoring complexity and second-order effects, and to make explicit tradeoffs between multiple goals or impacts, as proposed by advocates of optimal scale (see Gargani and McLean 2017, 2019).

Partnerships are critical for innovation, scaling and systems change

Hypothesis

Partnerships are often combined with systems change and participation and inclusion in recommendations regarding good practice in moving forward along innovation pathways. This is in large part because participation and partnership are interdependent and mutually reinforcing. In terms of achieving impact at large scale, partnerships are seen as critical because often no one actor has the necessary resources, be they financial, operational or political, to succeed on their own. This is particularly true when innovators are researchers and lack those resources, or when the innovation itself is institutional or a form of systems change, bundled with such changes, or packaged with financing models.

Coming up with a concise definition of the critical role of partnerships in innovation pathways is challenging. First, partnerships for innovation versus scaling tend to have their own separate

literature. For that reason, we cover partnerships in innovation under participation and inclusion, and focus on partnerships in scaling or systems change in this section.

The scaling literature has identified partnerships as fundamental to success since its early days. The original MSI Scaling Up Management Framework (Cooley and Kohl 2005) identified collaboration or partnership as one of its three core alternative methods, and this is still found in the third edition (Cooley et al. 2016: 5-6). Partnerships were defined broadly to include everything from formal joint ventures and strategic alliances to informal collaborations, networks and coalitions, and we adopt the same language here. Partnerships were contrasted with expansion, where the originators of an innovation take it to scale and retain full control, and replication, where the innovators give up control and hand off scaling to a third party such as a national government. In this definition of a scaling partnership, the innovator or originating organization works with other organizations to achieve large-scale SAI.

To anticipate our findings, and therefore better refine our hypothesis, partnerships were found in most of the CoSAI and USAID case studies. We can say with some confidence that partnerships in most cases facilitate success, and the more interesting questions revolve around what constitutes a good partnership and how to create or sustain one. Drawing on several sources (notably Barrett et al. 2020, the literature suggests the following are principles or characteristics of good partnerships:

1. A shared commitment to a common vision and alignment of that collective vision with individual incentives and interests. This can certainly be challenging among diverse actors, especially between the public and private sector and civil society, and when these actors see themselves as adversarial in other contexts and fear that their core mission or values are being co-opted or compromised. Maintaining alignment in the face of the dynamic nature of innovation pathways can be an even bigger challenge, not to mention ongoing agreement about how decisions are made, particularly about contributions and distribution of resources.
2. Mechanisms to ensure effective coordination of individual actions.
3. Clear definition of individual roles and sharing of responsibilities and risks. For example, the public sector partner might provide formal and informal approval, sanction and legitimacy; financial and in-kind resources; oversight, management and coordination; production and delivery; adoption and integration into government systems; or more likely some more precise combination of these.
4. Effective accountability mechanisms based on monitoring of mutually agreed key performance measures and enforcement of agreed actions.
5. Sufficient financial and other resources, management and governance structures to operate effectively and sustainably. This includes one or more leaders or intermediaries to drive initial organization and ongoing governance, including bearing a disproportionate burden of the costs and effort involved.

Finally, the literature (e.g., Capable Partners Program 2011) suggests two sub-hypotheses. These are:

6. More informal partnerships with numerous members are better for policy advocacy, consultations and coordination, whereas more formal, structured partnerships with fewer members are required for actual implementation and delivery.

7. Partnerships are more important for innovations that are either systems changes or institutional, or bundled with such innovations, as opposed to innovations in products and services.

Evidence

Table 9. Support to hypothesis: Partnerships are critical for innovation, scaling and systems change.

Case	Evidence	Support to hypothesis
Balde Cheio ***Brazil***	Partnerships were essential to dissemination and sustainability, with "public institutions (technical assistance and rural extension agencies, linked to State and Municipal Agriculture Secretariats, teaching and research institutions etc.), as well as with private institutions (cooperatives, dairy product companies, associations, agricultural federations …)". Local extension agents were paid for by local public or private partners and the costs of the master trainers who trained the extension agents was covered by farmers' organizations. A strong governance mechanism was also important after Embrapa decided to transform the informal partnerships into a formal relationship and strengthen administration – a good illustration of the benefits of organizational over individual leadership in a partnership context. These efforts allowed for additional scaling to 50% more states and a 25% increase in both the number of technicians trained and in local partnerships.	Strong support
P1+2 ***Brazil***	P1+2 was *de facto* a public–private partnership between the Ministry of Social Development and ASA, the latter a coalition of more than 3,000 grassroots organizations. It was "the result of a long process of institutional maturation … and the recognition of the importance of civil society's participation in implementing public policies." Like Balde Cheio, it also benefited from an existing alignment of interests between a Workers' Party government and these grassroots entities. ASA led efforts to develop the concept and methodology and advocated for federal policy, programmatic and financial support and implementation. The design of the technology package was also done through a partnership of governmental and non-governmental institutions. Funding came from the Ministry of Social Development and Ministry of Cities, the Fundação Banco do Brasil, and private and parastatals actors like PepsiCo and Petrobras.	Strong support

Case	Evidence	Support to hypothesis
ILPF ***Brazil***	The ILPF model used partnerships for design, implementation and monitoring. Unlike the other Brazilian public sector cases, partners were primarily private actors like Syngenta and John Deere rather than NGOs and civil society. Here the government was perhaps less successful in aligning interests. But as with the above cases, there was sufficient funding and capacity available to manage the partnerships (from Embrapa), and technologies were packaged with various forms of training and extension support supplied by partners.	Some support
Aqua Digital Irrigation Monitoring System ***Brazil***	Partnerships played less of a role for Agrosmart but were still important. It partnered with other private actors to access their customers and dealer networks, e.g., NaanDanJain, a global leader in drip irrigation systems. It also partnered with research institutions and universities in product development.	Unclear support
Andhra Pradesh Natural Farming ***India***	This was a partnership between a non-profit corporation spun off by the state government as a farmers' association, and the state government itself. It implemented in partnerships with local governments and women's self-help groups; the latter also were an important source of financing for individual farmers. The state government provided funds that the association could use to manage these partnerships effectively. Partnerships with local communities, resource persons and farmers were co-creative, and scaling was largely horizontal and farmer-to-farmer.[42]	Some support

[42] This however needs to be seen in light of the large organizations and significant money involved in rapidly scaling the 'co-creation' and priming it as an investment opportunity, which has raised some potential contradictions with its horizontal partnership approach, not to mention its 'zero-input' basis (Saldanha 2019).

Case	Evidence	Support to hypothesis
Safe Harvest ***India***	Partnerships were critical because the major innovation was institutional and involved the whole value chain. The company emerged from the creation of a non-pesticide management network of farmers and continued to work in partnership with that network to teach production practices. Safe Harvest also worked with downstream organizations for distribution and marketing. Its major difference from Trustea was that it was a self-contained social enterprise, not a multistakeholder organization. Perhaps not surprisingly, given its more arms-length partnerships, Safe Harvest had early coordination problems. These were eventually addressed by becoming a more commercial social enterprise with formal partner relationships and a more businesslike financing structure through impact investors. The case confirms the importance of effective coordination, financing model and mechanisms, and formalized roles and responsibilities.	Some support
Trustea ***India***	Trustea began as a partnership between corporate tea processors and the Sustainable Trade Initiative, a Dutch organization comprising private companies, NGOs, trade unions and the Dutch Government. This then expanded to work with NGOs with standards and verification expertise, and eventually took the form of a multistakeholder governing council that also included the regulatory agency. It worked with growers of various sizes to support compliance. Funding came largely from the initial corporate founders. Despite the lack of pre-aligned interests between corporate processors and NGOs, the case validates the importance of a shared vision, clear mechanisms and governance structures, monitoring of key performance measures (standards compliance), integration with government systems, clearly defined complementary roles, and formal partnerships.	Strong support
Water Harvesting ***Kenya***	This case involved a largely unorganized and uncoordinated mix of actors, the key being county governments and NGOs. It lacked the organized, ongoing leadership it needed to advance along the innovation pathway, and suffered from a minimal role of effective partnerships, thus representing an illustrative counterexample.	Some support

Case	Evidence	Support to hypothesis
Solar Powered Irrigation ***Kenya***	Partnerships played a minimal role, as the key actors were an uncoordinated mix of private importers, suppliers and service providers. The sole role of partnerships was that several financial institutions, along with private companies and NGOs, developed financing packages including the innovative pay-as-you-go approach. The case highlights the success of atomistic producers in driving down prices, creating a more diversified set of products and packages, and promoting steady growth in demand. However, market growth would likely have been more rapid if there were a more concerted information, education and awareness-building campaign about the technology, precisely the kind of "public good" that collective action can solve.[43]	Unclear support
Upper Tana–Nairobi Water Fund ***Kenya***	The Fund is a strong example of partnerships in multiple dimensions, in this case across a water supply chain. The partnership between upstream farmers in the catchment area and downstream users was initially managed by the Nature Conservancy, and eventually took the form of a Water Fund that was a fully incorporated Trust including public, private and development actors and communities. This has succeeded despite the interests of upstream and downstream users not being clearly pre-aligned. It is run by a Board of Management under a Board of Trustees, the latter representing diverse stakeholders that range from water, sewage and electricity parastatals to NGOs and community organizations. Management includes a thorough monitoring system for financial and environmental outcomes. As such it is both a financing and governance mechanism; the funding was initially endowed by donor partners and downstream users and is replenished in payment for improved water quality.	Strong support

[43] While there is an industry association for irrigation technologies – the Association of Irrigation Acceleration Platform – it doesn't focus on solar in particular and seems to have very limited resources to address these collective action issues.

Case	Evidence	Support to hypothesis
Sahel Rice ***Senegal***	In all of the USAID cases, the USAID projects themselves played the partnership managing roles, and partner interests were aligned straightforwardly around profitability. The Sahel Rice project had partnerships with rice breeding research institutions, farmers' organizations, government agencies, and perhaps most importantly, informal coordination with other donors. The USAID project's lead role allowed for collective action and coordination of donor efforts and a multiplier effect on financial resources. The value-chain strengthening efforts by multiple donors were able to reach a large number of farmers. Farmers' organizations, rice millers and other value chain actors were key partners, as well as government parastatal banks and insurance companies.	Strong support
PICS Bags ***Kenya***	Partnerships were largely unnecessary because of the bags' unique characteristics. However, Bell Industries, a plastics manufacturer, was enlisted to produce the bags in Kenya.	No significant evidence
Kuroiler Chickens ***Uganda***	The Ugandan partner of ASU that helped bring in Kuroilers from India was a government research agency. While they were an enthusiastic supporter and did a lot of education and awareness building, they were not capable of creating a supply chain of chick breeders and incubators. ASU did not initially engage a private partner who could reliably supply chicks or provide training and extension support. While this oversight was eventually addressed with a private provider, this cause a shortage of chicks for several years and did not clearly address the extension issue, making this a useful counterexample.	Strong support
Drought Tolerant Maize for Africa/Hybrid Maize ***Zambia***	CIMMYT developed Drought Tolerant Maize with national agricultural research systems. However, once the genetic material was made available, CIMMYT did not engage in partnerships to promote adoption, market development or demonstration. As a result, Drought Tolerant Maize reached very limited scale, unlike hybrid maize generally which had support from donors, the Government of Zambia and private breeders.	Strong support

Case	Evidence	Support to hypothesis
Mechanization Initiative ***Bangladesh***	From the beginning, the vision of success was a hand-off to domestic companies to take over import, sale, distribution and marketing of the machines. Some of the largest companies were partners from the start, which included a commitment to invest their own money in the initial importation of machines. In turn, the project agreed to absorb the initial costs of public goods such as building customer awareness through outreach and demonstration sites; developing a local service provider business model and providing training; and developing a network of spare parts and repair providers. Over time the companies did find it profitable as the demand accelerated, and they now have their own supply chains and a sustainable business.	Strong support

Lessons and conclusions

The cases reviewed confirm that partnerships are particularly valuable in mobilizing resources beyond those of any individual actor, particularly actors with complementary strengths. They also evidence that creating viable and effective coordination and governance mechanisms is critical to the success of that mobilization. In their early days, both the Mechanization Initiative in Bangladesh and Safe Harvest in India struggled with these issues and had to adapt accordingly. Furthermore, the cases back up the idea that partnerships are particularly important where the innovation itself is institutional or systems change, or is bundled with either of those. In several of the cases studied, the innovation spanned the value chain. The Kuroiler Chickens project in Uganda suffered when it wasn't sufficiently comprehensive in addressing weaknesses in the value chain.

A shared vision was critical to the cases, too, or at least the alignment of diverse interests. In Bangladesh, the objectives of USAID as a donor seeking to support smallholder farmers had to be aligned with those of large private machinery companies. In India, the interests of tea (Trustea) and produce (Safe Harvest) producers had to be aligned with those of processors and consumers. Finally, the cases confirmed that leadership and financing of partnerships is key – especially in getting them started. The role of ASA in the P1+2 case is illustrative, or the USAID project teams in Bangladesh and Senegal, and these can be contrasted with the lack of effective leadership organization for Kuroiler Chickens. P1+2 in Brazil benefited (and suffered) from the fact that financing of innovation and scaling was largely from the federal government. When changes in government left that fiscal support to evaporate, implementation, let alone expansion, of the programs was limited.

4. Recommendations

In this study, we have sought to identify and assess the validity of hypotheses from the literature and practice of affecting large-scale SAI through innovations in agri-food systems. Here, based on that assessment, we provide recommendations to actors interested in funding or supporting such innovation pathways.

As noted in the introduction, recent years have seen a number of efforts to develop broad frameworks and guidance on how to achieve large-scale sustainable impact through an integrated approach to innovation, scaling and systems change. Because we were not able to identify applied research to test any one of those frameworks in its entirety, and because even if such an effort were under way it would take many more years to produce results, we disaggregated the frameworks to identify individual hypotheses that could be tested in the context of existing case studies of scaled innovations in agriculture. Our literature review produced 15 potential hypotheses which we eventually narrowed to six. Our criteria were that there was some evidence and experience relevant to the hypothesis in multiple case studies; that the evidence was sufficient to support or contradict the hypothesis; and ideally, that the evidence allowed for description of not only *whether* the hypothesis was important, but some insight or guidance as to *how* to apply the principle, or recognize that it was being applied.

Our review of the evidence from the CoSAI and USAID case studies confirmed that these six hypotheses are indeed important to innovations moving successfully along innovation pathways and achieving large-scale SAI. While this is not surprising in itself – these elements are widely assumed to be important, and each has been discussed and promoted at length in recent years – we have investigated their presence in a variety of case studies to derive more robust evidence of, and useful conclusions about, their contributions.

Innovation pathways must be participatory and inclusive

Perhaps the hypothesis where the evidence was the most ambiguous was on participation and inclusion, but there is clear evidence that consulting with farmers and involving farmers in the developing, testing and refining of innovations produces “better” innovations in two senses. First, they are more likely to have greater impact, especially because they are aligned with contextual factors and constraints. Secondly, they are more likely to scale, particularly because they are aligned with felt needs of end users. For both reasons, they are also more likely to be sustainable, in the sense that end users will continue to use them.

Implementation of scaling and systems change is greatly facilitated by using social capital in general and through farmers’ organizations in particular. The latter is particularly critical for lowering the transactions costs involved, usually through some form of cascade or training-of-trainers approach to knowledge dissemination, technical assistance and extension support. In most of the case studies, it appears that end users have not had decision-making power in most cases of innovation, setting scaling and systems change goals and strategy, or implementation.

Recommendations

- End users should be involved in defining the problem, i.e., setting the research agenda and what the vision of the end game looks like, and in mapping and analyzing systems and context. Seelos (2020) and others argue persuasively that systems are not objective truths to be mapped by experts but "subjective images that people hold about social situations and perceived problems". Given the high context-specificity of agriculture – for instance in terms of local agro-ecological zones and traditional and often highly effective practices – local involvement is critical. At the same time, it needs to be balanced with the cost, time and effort required as extensive involvement and adaptation can make scaling unaffordable.
- To be successful in achieving large-scale SAI, innovations should also go beyond taking end users' needs into account at the starting stages and have them involved in co-creation with voice and power in decision making. This includes undertaking the innovation process itself, selecting innovations for scaling, and creating scaling and systems change strategies.
- Participation is costly in terms of time, effort and resources. There are clear normative reasons for making participation as broad and inclusive as possible, in addition to the positive motivations listed in the previous points, creating an understandable bias that more participation is better. Nonetheless, care should be taken to assess the cost–benefit balance of how broad and inclusive participation should be in terms of the opportunity costs of the same reasons. This is especially true because at a certain point the costs, and more importantly the effort required, will likely increase more than additively while the additional benefits may decrease. While the sweet spot is difficult to determine, a general guideline is that participation should be somewhat proportional to the degree that significant changes in systems, behaviors and mindsets are anticipated or involved. In cases of scaling a product or service that requires little systems change, such as adopting a better seed variety, less participation may be required than where changes in value chains, market systems, public policy or institutions are required. The same is true for complexity: in cases where scaling or systems change is likely to have unanticipated or unintended effects, or by design affect multiple objectives, more participation is likely to be beneficial.
- Greater comparative or controlled research is needed on how the extent of participation affects outcomes in terms of improvements in productivity and incomes. In addition to the factors mentioned above, it seems that the optimal participation will likely vary across different agricultural objectives such as resilience, food security, nutrition and health, and environmental sustainability and climate change. Similarly it would be interesting to explore the hypothesis that innovation combinations or packages that contain multiple components or are more comprehensive, e.g., involving both changes in technology and practices, would also benefit from greater participation. Research should also look at participation at all stages of the innovation pathway, including problem definition, systems mapping, innovation itself, and the scaling goals and strategy.

Leaders, intermediaries and champions are key to innovation pathways

The case study evidence confirmed the importance of leaders, intermediaries and champions. A key quality of leadership appears to be a commitment and dedication to driving the innovation through all phases of the innovation pathway – innovation, scaling, systems change and sustainability. In the

cases where there was minimal leadership, or leadership only existed at the early stages of innovation, scaling and systems change were more limited and less sustainable.

However, the evidence suggests that one individual leader may not be well placed or suited to drive change through all stages of the pathway. The skills necessary for driving innovation itself are different from going to scale and affecting systems change, which in turn are different from achieving financial, political and institutional sustainability. In part, this is because many individual leaders lack the political networks and contacts to mobilize political support and resources beyond a certain scale, be it a particular county, state, agricultural subsector or value chain. Their knowledge of local systems and institutional arrangements may also be limited geographically, demographically or by levels of scale.

Similarly, as argued above, the charisma and passion that may be effective in inspiring others and mobilizing resources and political support for an innovation, pilot or proof of concept are not the same as intermediary skills necessary for scaling and/or systems change, i.e., process facilitation, convening, boundary spanning, advocacy, mobilizing resources, and mobilizing and managing networks, collaboration and partnerships. It also appears from some of the cases reviewed in this study that CGIAR research groups, national agricultural research services, universities and other research institutions often lack the skills, resources, motivation, contacts and networks to pursue scaling and systems change successfully, whether through public or commercial pathways.[44] The ideal cases are where a public or private actor, who have familiarity with government and market systems respectively, can lead innovation, scaling and systems change.

While more research is desperately needed on why scaling success is infrequent and the relevant importance of different factors (such as the others considered in this study), our cases here suggest that cases where one actor can lead the whole innovation process to the end of the pathway are positive examples – and notably rare. This is particularly true for public sector actors in countries with less effective governance and more limited fiscal resources than are available in a middle-income country like Brazil, which has a relatively effective public administration and stands in the top half of the World Bank's good governance ranking.[45]

- Leadership is too big a category to be operationally useful to funders and investors in deciding whether to support an innovation pathway effort. Leadership needs to be disaggregated by the stages or phases of innovation pathways, and by the different skills and resources needed depending on the phase, type of innovation package, extent of bundling with systems changes, and level of scale at a given moment.
- The distinctions between leadership narrowly defined, intermediaries and champions are useful ones. Intermediaries are often needed to undertake scaling activities when innovation leaders lack some or all of the skills and capacity to undertake scaling and cooperative,

[44] For example, HarvestPlus has been cited as a successful case of innovation pathways in areas such as biofortification. However, it did take substantial resources, such as support over three five-year cycles and over $400 million in investment through 2017, and was preceded by 10 years of research and preparation (CGIAR 2017: 9-13).

[45] See indicators for Government Effectiveness at http://info.worldbank.org/governance/wgi/Home/Reports. At the time of writing, Brazil ranked #112 out of 209 countries, higher than all but three African countries. China and India ranked #70 and #93, respectively, suggesting that leadership lessons from their experience may also be less relevant for African countries in particular.

coordinated systems change activities; these may involve relationships where ego and visibility are antithetical to what is needed. During this stage, champions can bring additional resources, such as status or legitimacy, to efforts to mobilize resources, political support and engagement of partners in supporting innovation and scaling.

- The findings support the notion of end-to-end innovation pathways where innovation, scaling and systems change are seen as an integrated whole that is sequential, iterative and dynamic. Leadership is particularly important in implementing this concept, but where continuity in leadership is not possible or desirable, planning for succession or hand-off is critical. This can be particularly challenging for two reasons. First, organizations whose primary mission and capacity is around innovation can lack the incentive and ability to engage in the scaling aspects of innovation pathways (see the next bullet). Second, even in the context of partnership and participation, leaders tend to have disproportionate power, and who has that power over decision making and ownership of the innovation pathway process can be contentious. The key point to focus on is that end-to-end innovation is about incentives: it's not possible to know which ideas in a portfolio will succeed from the start, but researchers and innovators should have incentives to design solutions that have scaling potential and to take systems constraints and feasible business and delivery models into account. Leaders establish these incentives and sort out the most promising ideas using these same criteria.
- Intermediary leadership is particularly important in strengthening value chains and affecting other forms of systems change. This is even more the case when it comes to ensuring political and institutional stability. Supporters and funders should ensure that as innovation proceeds to scaling and systems change, individuals and organizations are funded who have the necessary intermediary skills, and such actors work collaboratively with leaders. Where necessary, intermediaries may need to be supported to take over the leadership role from innovation leaders.
- At a minimum, supporters of SAI innovation pathways need to take one of three approaches: to start by supporting innovators with the capacity and skills to take their innovations to scale and/or affect the necessary systems changes; to ensure that innovators are partnered with appropriate public or private actors from the beginning who can take innovations to scale and serve in both the intermediary roles in scaling and large-scale Doers and Payers; or to support intermediaries that function in between innovators and large-scale Doers and Payers.
- While partnerships, hand-offs and exit strategies between researchers/innovators and intermediaries or large-scale partners make sense in principle, much more applied research and many more case studies are needed.

Innovation pathways should be iterative, adaptive and flexible

There is ample evidence of the importance of being adaptive and flexible in all phases of innovation pathways, including scaling and systems change. The evidence for adapting innovations was almost universal, certainly for all the cases which involved technologies, products and services. Less commonly recognized is that adaptation needs to apply to scaling and systems change goals, strategies and implementation.

However, there is a question of tradeoffs between adaptation to local circumstances and context and customization versus the need for efficiency and cost-effectiveness that often comes from standardization and other ways of achieving economies of scale and scope. This also creates a tension,

particularly for funders, between having agreed-upon goals and M&E systems designed for accountability, versus flexible goals, funding, and MEAL (monitoring, evaluation, adaptation and learning) systems designed to facilitate that.

- Innovation pathways should iterate, learn and adapt based on evidence in all phases. Particularly for scaling and systems change, such efforts need to constantly reexamine assumptions, revise the scaling vision and strategy, and adapt activities and tactics accordingly.
- Innovation pathways should include multiple and continuous feedback loops and evidence generation to support these activities. They need to move from M&E to MEAL.
- Funders need to balance accountability for the overall goals and mission with flexibility in terms of specific crops, activities, pathways and strategies. Funding mechanisms specifically need to be flexible in terms of innovations. If, as is suggested by several of the cases, a more mission-driven approach seems to make sense, than funding mechanisms need to align with that as opposed to pre-determined meso- or micro-level activities, pathways and results. This means that funders need to be actively engaged on an ongoing basis to support adaptation and have the local knowledge to themselves either adapt or support adaptation.

Innovation should strive to have characteristics that facilitate progress along innovation pathways and achieving large-scale SAI

In this hypothesis-testing section above we identified nine characteristics of innovations that potentially improve their potential for achieving and scaling SAI. The importance of these characteristics was confirmed by the evidence. However, that section also found that for innovations that didn't have these characteristics, bundling with systems changes or developing alternative business or delivery models did allow for scaling and advancement along innovation pathways.

For example, innovations that are very complex or involve significant departures from current behavior and practices tend not to be scalable through commercial pathways, because it is not profitable in most cases for a private actor to absorb the costs of substantial and/or prolonged technical assistance or extension support. This is especially the case when the innovation targets smallholder farmers who are not commercialized, or non-commercial crops. Yet several such innovations we considered were effectively scaled through the public sector.

Systems change and bundling for innovations that don't have facilitative characteristics comes at a cost, though, and even in middle-income countries public sector scaling is significantly constrained by limitations on fiscal resources. Thus while not having these characteristics doesn't eliminate the possibility of successfully achieving large-scale change, consideration needs to be given as to whether the additional costs are worth paying.

- Innovations should be designed and developed to align with characteristics that facilitate scalability (or recognize that the costs, time and effort of large changes from the *status quo* tend to increase exponentially, justify that choice of expending those resources, and ensure that commensurate resources are actually available to effect those large changes). The facilitative characteristics include:
  - Relevance to an important and subjectively felt need
  - Tangible and easily observable impact

- Relative simplicity with few components
- Benefits offered along multiple tangible and intangible dimensions
- Alignment with existing norms, practices, tools and equipment
- Benefits felt from some elements of the innovation bundle or imperfect adoption
- Relatively robust and reliable benefits
- Superior effectiveness relative to current and emerging alternatives
- Reduced risk and increased resilience.

- Innovations whose intrinsic characteristics do not facilitate scaling or large-scale SAI can also be scaled, but innovators, funders and implementers should make explicit choices to devote the additional resources and make changes to Doers, Payers, business and delivery models accordingly.

Innovations must be packaged with viable funding and implementation models and bundled with systems change

- Innovations must be packaged with viable business or funding and delivery and implementation models at scale. A viable business model requires a Payer whose motivation, interests and incentives are aligned with playing that role for the innovation in question. A viable delivery and implementation model requires a Doer whose interests are similarly aligned.
- A viable private or commercial pathway requires that all actors in the value chain, from upstream producers and distributors to downstream actors, be able to make money from the innovation. This favors innovations that are low-cost and affordable to end users and have very high returns on investment so that margins can be built in for various actors. For innovations that are particularly expensive, when possible, product innovations should either be converted to services, such as by machinery service providers, or accompanied by financial innovations so that the repayment stream matches the income stream. Such financial innovations also need to take into account default risk.
- Solving the packaging challenge is a dynamic and iterative process of changing the combination of innovations in terms of its cost, profitability and delivery implications; experimenting with different business and delivery models; exploring alternative scaling or implementation pathways, whether public, private or mixed; and analyzing the incentives and motivations of stakeholders who could play the roles of Doers and Payers in the different pathways, especially through partnerships that align specific roles to appropriately motivated actors. It is rather striking that in none of the three public sector cases from Brazil does it appear that implementing a lower-cost innovation combination was considered as a way to increase scale achieved.
- Financial resources, technical capabilities and the scale of implementation capacity are the most important criteria in selecting Doers and Payers, along with incentives. Incentives can go well beyond financial or political and include intangibles like social status, ability to dispense various forms of patronage, power and control over resources.
- Goals for innovation need to identify from the beginning whether an innovation, when it is a product or service, is already aligned with existing systems constraints, or whether it needs to be bundled with systems change. Alternatively, whether such goals can be best achieved by systems changes and institutional innovations on their own.

- Mapping and analysis of systems, and the ambition of systems change, needs to be a careful balancing act between the urgency of local and global goals and a practical assessment of feasibility, costs and benefits.
- Provision of public goods such as certification and standards, or dissemination of information about innovations, is often key to successful scaling and needs to be put in place. Because of their very nature as public goods, no individual private sector actor is likely to produce such goods, and these need to be handled by the public sector, private sector collaborations, or public–private partnerships.

Partnerships are critical for innovation, scaling and systems change

The evidence confirming the critical role of partnerships was very strong. Successful partnerships reinforce and interact with some of the other recommendations, particularly the role of a lead actor or organizations in being willing to absorb the costs and compromise on some of its own interests for the greater good and to create public goods. This is not unique to the public sector, but leadership and intermediary roles and skills is even more important in organizing diverse private interests across the value chain – producers, processors and consumers.

- Partnerships should be the first choice in mobilizing financial and other resources and for implementation for sustainable impact at large scale. It is rare for one actor to have sufficient resources to act as the Doer and Payer.
- Partnerships do take substantial time, effort and resources to create, manage and sustain. In general, there has been a lack of acknowledgment of this fact and therefore under-investment in partnerships, especially resourcing governance structures. This is particularly true of partnerships that are not just temporary, such as in scaling an innovation, but with a long-term view toward ongoing implementation.
- Partnerships do require aligning a shared vision and creating trust. Creating and sustaining trust among actors with diverse agendas, incentives and motivation, especially public, private and civil society, is also easily underestimated and takes ongoing investment to renew and sustain.
- Another overlooked part of partnerships that needs support, again interacting with other findings, is the issue of intertemporal tradeoffs and complementarity. Funders, donors and the public sector are well placed to absorb initial risks and engage in risk mitigation that can then allow the private sector to invest and assume the role of Doers and Payers. Partnership in this form is key, but does require mechanisms to ensure that implicit contracts are fulfilled.
- Partnerships are critical to supporting systems changes and institutional innovations, as they almost always involve and impact multiple stakeholders.

Integrating all considerations on the innovation pathway

In the introduction to this study, we noted that many of the more recent proposals for achieving large-scale SAI through innovation platforms, pathways, trajectories, etc. combine many individual hypotheses into an integrated whole. We have cautioned that some of the emphasis on these components needs to be balanced with careful consideration of practicality, feasibility and the cost–benefit balance of the time and resources involved. The extent of systems analysis and change is a prime and particular example of this. Nonetheless, the importance of most of these individual

components, supported by our case studies, does confirm that an integrated approach combining them is likely to be most successful.

Despite their negative reputation for not achieving sustainable impact at large scale,[46] donor projects could in fact play a vital and major role in supporting large-scale SAI if the way they are done is substantially reformed. Woltering et al. (2019), Koerner and Duda (2021), Kohl and Linn (2021) and others have all outlined the key components of such an approach. This study, and especially the CoSAI cases which were neither donor-funded nor followed an explicit set of innovation and scaling principles, provide important additional evidence that these approaches are on the right track.

One of the key findings of this study, again reinforcing the findings of recent literature, is that advancing along an innovation pathway is complex and involves a number of principles to be followed; Kohl and Linn (2021) propose eight principles and 20 lessons, and Koerner and Duda (2021) make over 50 separate suggestions. Both this study and others all point out that these principles and guidance are synergistic and mutually reinforcing. While we have disentangled a systems perspective, bundling, packaging, participation and partnerships, these are all components of an integrated approach where the impact of the whole is greater than the sum of its parts.

The number of recommendations and complexity may be intimidating, so starting simple and following as many as possible is the place to start. As in innovation pathways themselves, a phased approach seems best. At the same time, it is strongly recommended that various permutations and combinations of the principles, guidance and recommendations be implemented, tested and evaluated through applied research with the hope that some can be prioritized or valorized over others.

[46] Woltering et al. (2019), for instance, write: "Countless development projects have piloted solutions that could make a difference if only applied at scale. The reality is that these pilot projects hardly ever reach the intended scale to contribute significantly to achieving the UN Sustainable Development Goals."

References

Barrett, C.; Benton, T.G.; Cooper, K.A.; Fanzo, J.; Gandhi, R.; Herrero, M.; James, S.; Kahn, M.; Mason-D'Croz, D.; Mathys, A.; Nelson, R.J.; Shen, J.; Thornton, P.; Bageant, E.; Fan, S.; Mude, A.G.; Sibanda, L.M.; Wood. S. 2020. Bundling innovations to transform agri-food systems. *Nature Sustainability* 3: 974-976.

Butler, C. 2021. *Agricultural innovation, the key for bridging R&D with impact at scale*. IFPRI Blog Post, June 21, 2021. Available at https://www.ifpri.org/blog/cip-discussion-agricultural-innovation-key-bridging-rd-impact-scale.

Capable Partners Program. 2011. *Partnerships for international development. NGO tips.* Available at https://www.ngoconnect.net/sites/default/files/resources/NGO%20Tips%20-%20Partnerships.pdf.

Carberry, P.S. 2001. *Are science rigour and industry relevance both achievable in participatory action research?* Available at https://www.gga.org.au/wp-content/uploads/2015/06/ASA-2001-Carberry-Are-science-rigour-and-industry-relevance-both-achievable-in-participatory-action-research.pdf.

CARE. 2021. *A win-win for gender and nutrition: testing a gender-transformative approach from Asia in Africa.* Available at https://www.careevaluations.org/evaluation/a-win-win-for-gender-and-nutrition-testing-a-gender-transformative-approach-from-asia-in-africa.

Castells-Quintana, D.; Royuela, V.; Thiel, F. 2018. Inequality and sustainable development: Insights from an analysis of the human development index. *Sustainable Development* 27(3): 448-460.

CGIAR. 2017. *CGIAR system annual performance report 2017*. Montpelier, France: CGIAR. Available at https://www.cgiar.org/cgiar-system-annual-performance-report-2017.

Chang, A.M. 2018. *Lean impact: how to innovate for radically greater social good*. Wiley.

Chiodi Bachion, L.; Barcellos Antoniazzi, L.; Rocha Junior, A.; Chamma, A.; Barretto, A.; Safanelli, J.L.; Araújo, M.; Takahashi, N.; Maule, R.; Martins, S.; Ranieri, S.; Alves, V. 2022. *Investigating pathways for agricultural innovation at scale: case studies from Brazil*. Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification. Available at https://wle.cgiar.org/cosai/sites/default/files/CoSAI_IPS_Brazil_final_0.pdf.

Cooley, L.; Kohl, R. 2005. *Scaling up – from vision to large scale change: A management framework for practitioners*. 1st Edition. Washington, DC: Management Systems International.

Cooley, L.; Kohl, R.; Ved, R. 2016. *Scaling up – from vision to large scale change: A management framework for practitioners.* 3rd Edition. Washington, DC: Management Systems International. Available at: https://msiworldwide.com/sites/default/files/additional-resources/2018-11/ScalingUp_3rdEdition.pdf.

El-Swaify, S.; Evans, D.; with an international group of contributors. 1999. *Sustaining the global farm: strategic issues, principles, and approaches*. 10th International Soil Conservation Organization Conference, West Lafayette, Indiana, USA.

FAO. 2020. *Tracking progress on food and agriculture-related SDG indicators 2020.* Available at https://www.fao.org/news/story/en/item/1307140/icode.

Foran, T.; Butler, J.R.A.; Williams, L.J.; Wanjura, W.J.; Hall, A.; Carter, L.; Carberry, P.S. 2014. Taking complexity in food systems seriously: an interdisciplinary analysis. *World Development* 61: 85-101.

Foy, C. 2017. *Scaling up of improved poultry breeds in Uganda. Review of successful scaling of agricultural technologies*. Produced for the United States Agency for International Development by Management Systems International, a Tetra Tech company, for the E3 Analytics and Evaluation Project. Available at https://agrilinks.org/sites/default/files/resource/files/BFS%20Scaling%20Review%20-%20Kenya%20Report%20REVISED%20508%2011-16-16.pdf.

Foy, C.; Wafula, M. 2016. *Scaling up of hermetic bag technology (PICS) In Kenya. Review of successful scaling of agricultural technologies*. Produced for the United States Agency for International Development by Management Systems International, a Tetra Tech company, for the E3 Analytics and Evaluation Project. Available at https://agrilinks.org/sites/default/files/resource/files/BFS%20Scaling%20Review%20-%20Kenya%20Report%20REVISED%20508%2011-16-16.pdf.

Gewin, V. 2014. *$100-Million federal lab will bring more science to bear on global poverty and development*. *Nature* April 5, 2014.

Gwaze, F.R.; Mwale, M.; Chimonyo, M. 2011. Challenges encountered in conducting farmer-oriented livestock research among resource-limited farmers of Sub-Saharan Africa: a review. *African Journal of Agricultural Research* 6(21): 4840-4851.

Hartmann, A.; Linn, J.F. 2007. *Scaling up: A path to effective development*. 2020 Focus Brief on the World's Poor and Hungry People. Washington, DC: International Food Policy Research Institute. Available at: https://hdl.handle.net/10625/37196.

Hubeau, M.; Marchand, F.; Coteur, I.; Mondelaers, K.; Debruyne, L.; Van Huylenbroeck, G. 2017. A new agri-food systems sustainability approach to identify shared transformation pathways towards sustainability. *Ecological Economics* 131: 52-63.

IFAD. 2017. *IFAD's support to scaling up of results. Evaluation synthesis*. Independent Office of Evaluation. March Report No. 4407.

IFAD. 2020. *2019 Annual report on results and impact of IFAD operations*. Independent Office of Evaluation. Available at https://www.ifad.org/documents/38714182/41331982/ARRI2019_Web.pdf/3a6b4016-3c6c-f040-a12f-3c46e8e82d5b.

IPES-Food. 2018. *Breaking away from industrial food and farming systems: Seven case studies of agroecological transition*. International Panel of Experts on Sustainable Food Systems. Available at: https://www.ipes-food.org/_img/upload/files/CS2_web.pdf.

IRENA. 2020. *Innovation landscape brief: pay-as-you-go models*. Abu Dhabi: International Renewable Energy Agency. Available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Pay-as-you-go_models_2020.pdf.

Jacobs, F.; Ubels, J.; and Woltering, L. 2018. *The Scaling Scan: a practical tool to determine the strengths and weaknesses of your scaling ambition*. Rotterdam, The Netherlands: PPPLab; Texcoco; Mexico: International Maize and Wheat Improvement Center (CIMMYT). Available at https://repository.cimmyt.org/handle/10883/20505.

Kalibata, A. 2014 *The Alliance for a Green Revolution in Africa is helping to build a better life for all Africans.* The Guardian. Available at https://www.theguardian.com/world/2014/nov/07/alliance-green-revolution-africa-helping-build-better-life-all-africans.

Khan, N.; Ray R.L.; Kassem H.S.; Hussain S.; Zhang S.; Khayyam M.; Ihtisham M.; Asongu S.A. 2021. Potential role of technology innovation in transformation of sustainable food systems: a review. *Agriculture* 11(10): 984.

Khandelwal, A.; Agarwal, N.; Jain, B.; Gupta, D.; John, A.T. 2022. *Investigating pathways for agricultural innovation at scale: case studies from India.* Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification. Available at https://wle.cgiar.org/cosai/sites/default/files/CoSAI_IPS_India_final_0.pdf.

Klerkx, L.; Hall, A.; Leeuwis, C. 2009. Strengthening agricultural innovation capacity: are innovation brokers the answer? *International Journal of Agricultural Resources, Governance and Ecology* 8(5): 409-438.

Klerkx, L.; Gildemacher, P. 2012. *Module 3: Thematic note 4: the role of innovation brokers in agricultural innovation systems in World Bank agricultural innovation systems: an investment sourcebook.* Available at http://www.bibalex.org/search4dev/files/417999/363989.pdf.

Klerkx, L.; Begemann, S. 2020. Supporting food systems transformation: the what, why, who, where and how of mission-oriented agricultural innovation systems. *Agricultural Systems* 184: 102901.

Klerkx, L.; Seuneke, P.; de Wolf, P.; Rossing, W.A.H. 2017. Replication and translation of co-innovation: the influence of institutional context in large international participatory research projects. *Land Use Policy* 61: 276-292.

Koerner, J.; Duda A. 2021. *Transformative end-to-end innovation (E2EI) in a new era for food and climate: insights and key actions supporting institutional change*. CCAFS Info Note. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security.

Kohl, R.; Linn, J. 2021. *Scaling principles*. Working Paper prepared for the Scaling Community of Practice. Available at https://www.scalingcommunityofpractice.com/wp-content/uploads/bp-attachments/8991/Scaling-Principles-Paper-final-13-Dec-21.pdf.

Kohl, R. 2016a. *Scaling up of drought tolerant maize in Zambia. Review of successful scaling of agricultural technologies*. Produced for the United States Agency for International Development by Management Systems International, a Tetra Tech company, for the E3 Analytics and Evaluation Project. Available at https://agrilinks.org/sites/default/files/resource/files/BFS%20Scaling%20Review%20-%20Zambia%20Report%20REVISED%202-8-16.pdf.

Kohl, R. 2016b. *Scaling up of agricultural machinery in Bangladesh. Review of successful scaling of agricultural technologies.* Produced for the United States Agency for International Development by Management Systems International, a Tetra Tech company, for the E3 Analytics and Evaluation Project. Available at https://agrilinks.org/sites/default/files/resource/files/BFS%20Scaling%20Review%20-%20Bangladesh%20Report%20FINAL%20508.pdf.

Kohl, R. 2016c. *Scaling up of Sahel rice varieties in Senegal. Review of successful scaling of agricultural technologies*. Produced for the United States Agency for International Development by Management Systems International, a Tetra Tech company, for the E3 Analytics and Evaluation Project. Available at https://agrilinks.org/sites/default/files/resource/files/BFS%20Scaling%20Review%20-%20Senegal%20Report%20FINAL%20508%2011-6-16.pdf.

Kohl, R. 2018. *Guide to the agricultural scalability assessment tool. For assessing and improving the scaling potential of agricultural technologies*. Produced under contract for US Agency for International Development, E3 Analytics and Evaluation Project. Available at https://agrilinks.org/sites/default/files/resources/asat_guide_revised_508_6-7-18.pdf

Kohl, R. 2021. *Scaling and systems: issue paper*. *Global community of practice on scaling development outcomes*. Available at https://www.scalingcommunityofpractice.com/wp-content/uploads/bp-attachments/8666/Scaling-and-Systems-Change-Issues-Paper.pdf.

Lacombe, C.; Couix, N.; Hazard, L. 2018. Designing agroecological farming systems with farmers: a Review. *Agricultural Systems* 165: 208-220.

Linn, J. 2022. *Three case studies: applying the scaling principles of the scaling community of practice*. Available at https://www.scalingcommunityofpractice.com/three-case-studies-applying-the-scaling-principles-of-the-scaling-community-of-practice.

Mati, B.M.; Sijali, I.V.; Ngeera, K.A. 2022. *Investigating pathways for agricultural innovation at scale: case studies from Kenya*. Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification. Available at https://wle.cgiar.org/cosai/sites/default/files/CoSAI_IPS_Kenya_final_0.pdf.

McLean, R.; Gargani, J. 2017. Scaling science. *Stanford Social Innovation Review* 15(4): 34-39. https://doi.org/10.48558/CX49-R467.

McLean, R.; Gargani, J. 2019. *Scaling impact: innovation for the public good*. New York: Routledge.

Mier y Terán Giménez Cacho, M.; Giraldo, O.F.; Aldasoro, M.; Morales, H.; Ferguson, B.G.; Rosset, P.; Khadse, A.; Campos, C. 2018. Bringing agroecology to scale: Key drivers and emblematic cases. *Agroecology and Sustainable Food Systems* 42(6): 637-665. https://doi.org:10.1080/21683565.2018.1443313.

Minh, T.T.; Schmitter, P.; Smith, M. 2021. *Adaptive scaling to achieve system transformation in One CGIAR*. Technical Brief. International Water Management Institute. Available at https://cgspace.cgiar.org/bitstream/handle/10568/113924/Adaptive%20scaling%20to%20achieve%20system%20transformation%20in%20One%20CGIAR.pdf.

Neef, A. 2003. Participatory approaches under scrutiny: will they have a future? *Quarterly Journal of International Agriculture* 42(4): 489-497.

Neef, A.; Neubert, D. 2011. Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making. *Agriculture and Human Values* 28: 179-194. https://doi.org/10.1007/s10460-010-9272-z.

Pretty, J.; Toulmin, C.; Williams, S. 2011. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability* 9(1): 5-24. https://doi.org/10.3763/ijas.2010.0583.

Rogers, E. 2003. *Diffusion of innovations*. 5th edition. New York: The Free Press.

Saldanha, L. 2019. Budget push for zero budget farming but contradictions mar Andhra's natural agri foray. *Down to Earth*. 9 July. Available at https://www.downtoearth.org.in/news/agriculture/budget-push-for-zero-budget-farming-but-contradictions-mar-andhra-s-natural-agri-foray-65503.

Seelos, C.; Farley, S.; Rose, A.L. 2021. The 'Thou shalt nots' of systems change. *Stanford Social Innovation Review*. 14 January. Available at https://ssir.org/articles/entry/the_thou_shalt_nots_of_systems_change.

Seelos, C. 2020. Changing systems? Welcome to the slow movement. *Stanford Social Innovation Review* 18(1): 40-47. https://doi.org/10.48558/4p1n-m957.

Shilombenia, H.; Owaygen M.; De Plaen, R.; Manchur, W.; Husak, L. 2019. Scaling up innovations in smallholder agriculture: Lessons from the Canadian international food security research fund. *Agricultural Systems* 175: 58-65.

Smith, J.; Yeluripati, J.; Smith, P.; Nayak, D.R. 2020. Potential yield challenges to scale-up of zero budget natural farming. *Nature Sustainability* 3(3): 247-252.

Starr, K. 2021. We're beating systems change to death. *Stanford Social Innovation Review*. 8 April. Available at https://doi.org/10.48558/DBP6-0H46.

Starr, K.; Hattendorf, L. 2015. The doer and the payer: A simple approach to scale. *Stanford Social Innovation Review*. 21 August. Available at https://doi.org/10.48558/ET3G-NY28.

UN. n.d. *Food security and nutrition and sustainable agriculture*. New York: United Nations. Available at https://sdgs.un.org/topics/food-security-and-nutrition-and-sustainable-agriculture.

van den Berg, H.; Phillips, S.; Poisot, A-S.; Dicke, M; Fredrix, M. 2021. Leading issues in implementation of farmer field schools: A global survey. *The Journal of Agricultural Education and Extension* 27(3): 341-353. https://doi.org/10.1080/1389224X.2020.1858891.

WHO and ExpandNet. 2010. *Nine steps for developing a scaling-up strategy*. Geneva: World Health Organization. Available at: https://hdl.handle.net/10665/44432.

Wigboldus, S.; Klerkx, L.; Leeuwis, C.; Schut, M.; Muilerman, S.; Jochemsen, H. 2016. Systemic perspectives on scaling agricultural innovations: a review. *Agronomy for Sustainable Development* 36: 46. https://doi.org/10.1007/s13593-016-0380-z.

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. https://doi.org/10.1016/j.agsy.2019.102652.

World Bank. 2012. *Agricultural innovation systems: an investment sourcebook*. World Bank.

World Bank. 2019. *Agricultural innovation & technology hold key to poverty reduction in developing countries, says World Bank report*, September 16, 2019. Available at https://www.worldbank.org/en/news/press-release/2019/09/16/agricultural-innovation-technology-hold-key-to-poverty-reduction-in-developing-countries-says-world-bank-report.

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The Commission on Sustainable Agriculture Intensification (CoSAI) brings together 21 Commissioners to influence public and private support to innovation in order to rapidly scale up sustainable agricultural intensification (SAI) in the Global South.

For CoSAI, innovation means the development and uptake of new ways of doing things – in policy, social institutions and finance, as well as in science and technology.

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