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Supporting a systems approach to scaling for all; insights from using the Scaling Scan tool

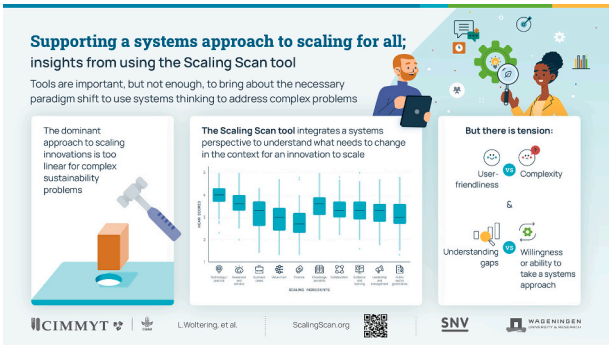
Lennart Woltering [a,b,c,*], Eva M. Valencia Leñero [a], Maria Boa-Alvarado [d], Jelle Van Loon [a], Jan Ubels [e], Cees Leeuwis [c]

[a] International Maize and Wheat Improvement Center (CIMMYT), Carretera México-Veracruz Km. 45, El Batán, Texcoco C.P. 56237, Mexico
[b] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Friedrich-Ebert-Allee 32 + 36, 53113 Bonn, Germany
[c] Knowledge, Technology and Innovation (KTI) Group, Wageningen University and Research, Hollandseweg 1, 6706, KN, Wageningen, the Netherlands
[d] Department of Global Development, Cornell University, 137 Reservoir Ave, Ithaca 14850, USA
[e] SNV Netherlands Development Organisation, Parkweg 83, 2514 JC The Hague, the Netherlands

HIGHLIGHTS

- Dominant approaches to scaling ignore context and fail to support sustainable development at scale.
- The Scaling Scan integrates systems perspectives under the guise of scaling innovations.
- Scaling interventions need early consideration of market and public support.
- Accessibility for many users is in tension with the need to embrace complexity.
- Organizations are not automatically willing or able to adopt a systems approach.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Approaches to scaling are persistently linear and focus on a single innovation, an innovator to control the scaling process, and a purpose driven by donor accountability. Alternative approaches that better reflect the complexity involved in sustainable development draw on systems thinking theory, but are hardly used. The Scaling Scan tool facilitates the integration of a systems approach to scaling to a broad public.
OBJECTIVE: This study draws from almost six years of experience using and adapting the Scaling Scan tool to deepen the theoretical and empirical understanding of what a systems approach to scaling is and what challenges project teams and organizations face to embrace this.
METHODS: This study uses data retrieved between 2017 and 2023 from 54 workshops where the Scaling Scan was used to scale innovations for sustainable development. Data were complemented with a literature study and SWOT analysis to understand the use, users, and user adaptations of the Scaling Scan tool.
RESULTS AND DISCUSSION: The Scaling Scans' focus on context, unintended consequences and the facilitation of collective understanding and collective action are important components of a systems approach to scaling.

* Corresponding author at:
E-mail addresses: L.Woltering@cgiar.org (L. Woltering), e.valencia@cgiar.org (E.M. Valencia Leñero), mdb339@cornell.edu (M. Boa-Alvarado), J.VanLoon@cgiar.org (J. Van Loon), jubels@snv.org (J. Ubels), cees.leeuwis@wur.nl (C. Leeuwis).

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Multiple adaptations to the tools have been made by users to facilitate even more collective understanding. However, the early focus on "the" innovation to scale and the intrinsic assumption that this innovation addresses a key root cause or leverage point in the system risks to perpetuate a linear approach to scaling. The scoring of the scaling ingredients show a tendency to focus on familiar disciplines (mostly technical), limiting progression beyond a "bigger pilot" and engage with what or who is required for innovations to contribute to large scale change, such as market and public support. Transitioning from a linear to a systems approach to scaling is challenging because business models of research organizations depend on high adoption of "their" innovations. We find that, there are far-reaching implications of embracing a systems approach to scaling which not everyone may want or can accept.

SIGNIFICANCE: We can no longer assume that complex systemic problems such as hunger and poverty will be solved by having more of an innovation. Yet this is still the dominant approach for research for development organizations to contribute to the Sustainable Development Goals. The experience with the Scaling Scan contributes to a deeper understanding of the role of tools to facilitate the integration of systems thinking in innovation and scaling initiatives aimed at sustainable development.

1. Introduction

1.1. The promise and realities of scaling innovations

Despite the widespread acceptance to present scaling of innovations as the way to achieve sustainable development (Begimkulov and Darr, 2023; Sachs, 2005) the large majority of interventions to scale innovations and pilots fail across sectors, such as agriculture (IIRR, 2000; Leeuwis et al., 2021; Röling, 2009), education (Perlman Robinson and Winthrop, 2016), health (Ghiron et al., 2021; Koorts et al., 2022; Spicer et al., 2018) or humanitarian support (Elrha, 2018). These authors point to a prevailing simplistic linear narrative of cause and effect between innovation and impact that dominates approaches, policies and investment patterns, but that does not represent reality. Four dominant phases can be distinguished in how scaling has been approached. First, for a long time, scaling was assumed to happen automatically when a successful innovation is identified (Chandy et al., 2013). Second, scaling was seen as a matter of "larger" diffusion, dissemination, innovation transfer and adoption based on the premise "what works here, will work there"(Wigboldus et al., 2016). This approach has been challenged because adoption is often presented as a simple substitution of an existing to a new practice, while it ignores that adoption of innovations requires a much more profound reconfiguration of existing practices, organizations and routines (Glover et al., 2019; Leeuwis and van den Ban, 2004; Lie and Soerensen, 1996). Third, over the last decade, it became clear that innovation and scaling cannot be seen in isolation from the context; the cultural, socio-economical, and politico-institutional dimensions in the area of intervention. Not only does the context determines if scaling is successful (Cooley and Howard, 2019; Geels, 2002) but the context is also affected positively, or negatively, by scaling (de Roo et al., 2019; McClure et al., 2018). However, defining what contextual factors make up an enabling environment for scaling is a challenge and under-investigated (Gibbs et al., 2021; Glover et al., 2021; Kanger and Schot, 2019; Muilerman, 2019).

Ubels and Jacobs (2016) found ten scaling ingredients that model the enabling environment for scaling innovations. These ten scaling ingredients (such as awareness and demand, business cases, evidence, public sector governance) were deemed so practical that three people; the two developers of the scaling ingredients at the PPPlab[1] (one of which is the fifth author of this paper; JU) and the first author of this paper, LW, developed a tool around these; the Scaling Scan (Jacobs et al., 2018). The tool's development was motivated not only by a desire to shift the understanding of scaling from an innovation and innovator-driven to a context-driven process, but also by the desire to make the learnings more accessible to a broader public so that stakeholders affected or involved in scaling could participate in decision making on scaling. The tool was developed and tested over the course of six months in 2017. At that time, the organizational narratives were largely informed by a linear approach to scaling with a strong tendency to focus on a single innovation, an innovator to control the scaling process, and the purpose of scaling strongly linked to the accountability to donors to "reach" hundreds or thousands of end users by project closure date (Woltering et al., 2019). Interest in scaling was mainly fueled by a sense that common lessons could be drawn across initiatives to be more efficient in increasing adoption of "our" innovations, for example as an argument to justify the existence of research for development organizations (Leeuwis et al., 2018). There was a latent demand for methods that could bring experiences together and give guidance on how to scale innovations more successfully, but by 2017 only two tools, by Cooley and Kohl (2016)[2] and ExpandNet and World Health Organization (2011), could be considered user-friendly for practitioners, and these tools were mostly informed by experiences in the health and education sectors.

In the fourth, and current phase, the narratives around scaling are shaped around the idea that scaling innovations should contribute to systems transformation. This goes beyond an explicit attention to the context as the purpose goes beyond "scale more" to one where scaling innovations is a means to an end, or scaling outcomes (Schut et al., 2020) or scaling impact (McLean and Gargani, 2019). Scaling thus conceptualized as an integral part of a systemic approach to innovation and change (Klerkx et al., 2012; Sartas et al., 2020; Wigboldus et al., 2016). Calls for a more holistic take on innovation and change are not new, but COVID-19 and climate change increased the interest in systems thinking in research and development organizations (Hynes et al., 2020). Yet, despite intentions to "change systems" and "transform food systems", approaches to scaling in research for development are stuck in the past, and remain largely focused on linear adoption pathways and do not sufficiently draw from systems thinking, not in agriculture (Hall and Dijkman, 2019; Leeuwis et al., 2021; McGuire et al., 2022), nor in health (Braithwaite et al., 2018; Koorts and Rutter, 2021), for example. Although the Scaling Scan was designed to draw more attention to the role of context, it did harbor dimensions of systems thinking, which became more explicit over time when subsequent editions of the tool were published. The practical experience to integrate a systems informed approach to scaling into agricultural research and development provides important insights in ways to deal with the complex systemic nature of reaching the Sustainable Development Goals (SDG) (Hall and Dijkman, 2019).

[1] The PPPlab stands for the Public Private Partnership Lab, a time bound (2016–2020) consortium of research and development organizations (SNV Netherlands, Aqua4All, Erasmus university and Wageningen University & Research)

[2] The first edition of the Management Systems International scaling framework was published in 2006

1.2. Objective, research questions and structure of this paper

This paper capitalizes on almost six years of experience using the Scaling Scan as a tool to support a stronger systems approach to scaling in agricultural research and development. The aim is not to provide substantiation of the efficacy of the tool or if projects have been more successful in scaling after using the tool, but rather to concentrate on the learnings from its use, adaptations and results. These learnings are important for the necessary shift from linear to systems approaches towards innovation and change to inform efforts to transform food systems. This study aims to foster a deeper theoretical and empirical understanding of the persistence of dominant linear approaches to scaling for sustainable development and the challenges and opportunities of promoting a systems approach to scaling.

The research questions are:

1. How is the integration of systems thinking manifested within the Scaling Scan tool?
2. Who has been using the Scaling Scan and how?
3. What patterns arise in the outputs of Scaling Scan workshops and how do they inform current and future scaling efforts?
4. What are the strengths, weaknesses, opportunities, and threats associated with the use of the Scaling Scan tool?
5. What challenges and opportunities emerge from the use of the Scaling Scan tool to adopt and implement a stronger systems approach to scaling for sustainable development?

In Section 2, we describe the characteristics of a systems approach to scaling and how it differs from the dominant approach to scaling, as well as the importance of co-creation of knowledge in scaling processes. We elaborate how this, and its institutional embedding, have governed the design of the Scaling Scan in Section 3. Both sections substantiate a response to research question 1. Research questions 2, 3 and 4 are responded to in Section 5. Sections 6 and 7 discuss findings and present conclusions.

2. Key concepts and considerations in the design of the Scaling Scan

2.1. The dominant linear scaling approach vs. a systems approach to scaling

2.1.1. Systems thinking and systems change

The dominant approach to scaling is linear, which is based on two premises; first that when innovations go to scale, (positive) impact will scale with it (Wigboldus et al., 2016), and second that research evidence and innovations advance in a rational, step-wise manner into practice (Braithwaite et al., 2018). This may be appropriate for addressing simple, output-oriented problems and where the capacity and desire to impact or change the target system(s) is limited, such as the simple replacement of one hybrid crop variety with another hybrid variety (Glover et al., 2019; Kohl, 2021). But, it is not an appropriate approach to deal with complex, wicked problems such as land degradation, poverty, food security that have are comprised of tightly coupled physical, social and ecological sub-systems which, due to interdependences, resist unilateral solutions and call for a new approach to conceptualizing and addressing the problem (Hall and Dijkman, 2019; Haynes et al., 2020). A persistent focus on introducing new technology to fix problems ignores the complex nature of why the problems exist in the first place (Hölscher et al., 2019; Schot and Steinmueller, 2018). Despite significant efforts, these single point interventions are rarely adequately embedded in the wider system where trade-offs play out, risking unexpected and perverse outcomes for the environment and social groups (Benton and Bailey, 2019; Mausch et al., 2020; Smil, 2023). Scaling then happens at the expense of sustainability and of local actors' ability to decide on or drive change. Koorts and Rutter (2021) define a systems approach to scaling as "an approach that prioritizes the behavior and function of the system, with a focus on relations between a number of system elements, using system-level levers and dynamic system changes to drive impact at scale". It means that scaling of innovations explicitly aims to contribute to systems change, a permanent shift in outcomes generated by the system's behavior.

The purpose of systems change is to bring about *lasting* change by altering underlying structures and supporting mechanisms (e.g. policies, routines, relationships, resources, power structures and values) that make the system operate in a particular way (Foster-Fishman et al., 2007). It means that whatever is perceived as the problem; food insecurity, poverty and so forth, is the result of a system working perfectly well at reproducing that problem over and over. Scaling of innovations in the service of systems change thus changes the trajectory of the system so that it stops reproducing the problem. As opposed to the reductionist, linear approach, a systems approach to scaling treats scaling of the innovation as important, but only as a means to an end, whereby the "end" could be the international agenda of sustainable development, and not having for an innovation to have as much market share as fast as possible (Pfotenhauer et al., 2022; Wigboldus et al., 2022). Rather than the readiness of innovations to scale into an existing system, it shifts the focus to the system and if it is "ready" to be changed through innovations or other interventions. This opens up to the idea that systems change can be unlocked when technologies or practices downscale (Hebinck et al., 2022), or if it is the right time or place for innovations to provoke change (Wagner, 2023). Systems approaches put emphasis on a deeper understanding of the context, the deep roots of the problems, and the resistance of the system to change (Fazey and Leicester, 2022; Seelos and Mair, 2018). Leeuwis et al. (2021) argues that system change depends primarily on agency and human interaction and the willingness and capacity of interdependent actors to accommodate and navigate differences (competing interests, values, and perspectives), towards a mutually acceptable future. The incorporation of a systems approach to scaling into the Scaling Scan focuses on the relevance and adaptability of the context and the important roles stakeholders play in this.

2.1.2. Context matters

A defining feature of systems thinking is the importance of context (Meadows, 2015). In this paper, context is defined as the set of circumstances surrounding a particular event, which includes actor dynamics such as power, relationships, and history in a certain environment; for example, around the introduction of an innovation. Primed by the seminal work of Rogers (1962) on diffusion, scaling methods (Kohl, 2018; Kuehne et al., 2017) put a disproportionate amount of attention on the end-users and the attributes of the innovation such as its performance, affordability, and adaptability, compared to the role of the context in which the innovation should scale. In addition, projects tend to create controlled and enabling contexts in which it is hard for innovations to fail. These pilot environments do not reflect normal conditions and are a major reason for the adage "pilots never fail, pilots never scale" (Woltering et al., 2019). A good example of the importance of the enabling environment is the large-scale adoption of chickpea varieties in Ethiopia which Verkaart et al. (2019) attributed to farmers' good access to knowledge, functioning value chains, and other conducive conditions. Similarly, the adoption of chickpeas in India was largely successful because of conducive conditions well beyond any (un) intended actions by projects to promote the chickpeas (Glover et al., 2021). Or, in the case of cocoa in Cameroon, not the scaling of the innovation, but the amplification of the positive contextual factors (such as interactions between actor, institutions) is responsible for scaling of successful outcomes (Muilerman et al., 2018). The success of a technological innovation is not based on its intrinsic robustness but on the interaction between technology, society, and the environment, as well as changes in beliefs, values, priorities, and governance that co-evolve with technological changes (Goulet, 2021; Kemp et al., 2007; Schot and Geels, 2008). From this understanding, innovations are not good or bad,

and their success or failure is rather a consequence of social choices (Smil, 2023) and the scalability is highly dependent on the time and place of introduction (Wagner, 2023). Conversely, scaling can also have an impact on the context, as evidenced by the fact that agriculture is the world's largest polluter of water and cause of biodiversity loss (National Academy of Sciences, 2021). These reciprocal effects of scaling show how it serves as a feedback loop to the system and can result in intended or unintended consequences.

2.1.3. Reconfiguring the context

The context for scaling can be improved, albeit temporarily, to "create an enabling environment for scaling." For example, the scaling of Vitamin A-enriched orange fleshed sweet potatoes was not possible without interventions to create demand, develop capacity, and develop enabling policies (Low and Thiele, 2020). But, disappointing adoption results are often simply attributed to a deficient, but non-defined, enabling environment that is claimed to be outside the direct influence of practitioners (Muilerman, 2019). The recent concept behind innovation packages (Sartas et al., 2020), baskets of options (Ronner et al., 2021), or socio-technical innovation bundles (Barrett et al., 2022) capture the idea that other technical, organizational, and social innovations need to scale in parallel to support the scaling of the core innovation of interest. The Scaling Scan facilitates the identification of areas of expertise in the context that hold back scaling and require innovation or change.

2.1.4. Capacity to scale and make change

Innovators and those that fund them feel a strong obligation to show that the innovation gets adopted by as many as possible (Leeuwis et al., 2017). But there are limitations to how far an innovation, an innovator, a project team, and a group of stakeholders can and should scale, as there may be systemic barriers to scaling that are far outside of the control of those actors (de Roo et al., 2019; Elrha, 2018; McClure et al., 2018; Glover et al., 2021; Wagner, 2023). The desire to exert control over scaling processes that aim to benefit the public good is unproductive, as success depends on contributions from a wide range of actors (McLean and Gargani, 2019; van Lunenburg et al., 2020). After all, scaling can take decades (Cooley and Howard, 2019; Low and Thiele, 2020) and can require multiple initiatives from different sources to come together. Furthermore, not every team, organization or partner is able or willing to scale (van Lunenburg et al., 2020); for example, due to lack of incentives to disrupt the status quo, a lack of necessary business functions to scale, or an underestimation of the financial and staffing implications for an organization (Fehlenberg et al., 2023; Kohl, 2023a; Meehan and Jonker, 2018; Westley et al., 2014). For example, efforts to design research programs in the CGIAR from a systems thinking perspective failed recently, largely because the mindsets and structures were oriented towards the linear scaling logic (Douthwaite and Hoffecker, 2017; Leeuwis et al., 2017). Building up and upon local capacities and being intentional about collaboration appear to be critical success factors for scaling (Woodhill, 2010). It is thus important to be reflexive, self-critical, and realistic in determining whether scaling is desirable and feasible for oneself, one's team, one's organization, or the target community.

2.2. Co-production of knowledge for scaling

Scaling and the resulting societal changes must be desired, designed, and/or implemented by the problem-owners — the local actors or those whose lives will be most significantly impacted by the changes. It can only be sustainable if these actors are willing and able to sustain and grow that scale after external support ceases (Cooley and Howard, 2019). But, more often than not, a central leadership, often the innovator, funds or mobilizes funding and coordinates collaborators to scale "their" solution to society. When dealing with complex development challenges, there is agreement that knowledge production and decision-making should be much more community-based, interactive and transdisciplinary (Lang et al., 2012; Norström et al., 2020). Stakeholder participation has been a recurrent topic of debate in agricultural research. On the one hand, local stakeholders integrate the best available knowledge, reconcile values and preferences, and create ownership for problems and solution options while, on the other hand, participation can be traditions or perception-based, time-consuming, costly, and opposed by scientists, who may view it as carrying the cost of reducing scientific rigor (Kohl, 2023b; Neef and Neubert, 2011; Norström et al., 2020). Existing guidance on scaling has been very academic, and little attention has been paid to how various stakeholders, such as practitioners, scientists, and civil society, engage with scaling concepts in practice (Shilomboleni et al., 2019; Woltering and Boa-Alvarado, 2021). Norström et al. (2020) refer to "knowledge co-production for sustainability" as a process that should be context-based, pluralistic, goal-oriented, and interactive. Making theoretical frameworks applicable to practice and applying them in collaborative ways is an important step to generate inclusive actionable knowledge (Hölscher et al., 2023; Kaljonen et al., 2023). Only in the last decade have models and tools become more available and accessible to engage non-academics in questions of why to scale, what to scale, how to scale, and who should take part, including who should pay and actually do the scaling (CGIAR (2020); Sánchez Rodríguez et al. (2021), and Woltering et al. (2019). Scaling tools can help the development community to reflect continuously on bottlenecks and opportunities for scaling and explore options, actions and partnerships to improve the functioning of an innovation system, both short- and long-term (Schut et al., 2020). Gebreyes et al. (2021) stress the important role of these tools to engage local partners meaningfully around these issues.

3. The scaling scan

The Scaling Scan (Jacobs et al., 2018) is an assessment tool for individuals and groups to explore what is required to scale an innovation in a specific context, the implications this has for project management and collaborations, and the potential trade-offs on the environment and social dynamics. The Scaling Scan (Fig. 1) consists of three steps, each with questions that prompt reflection and help users transition from a linear to a systems perspective on scaling.

Step 1: Develop a scaling ambition

The scaling ambition briefly describes what you want to scale and for whom, where, when, how many, by whom, and why. The goal is to draft a large-scale vision of change that will be scrutinized for practicality and responsibility in subsequent steps. The scaling ambition puts an innovation (what to scale) in a context (where, for whom, by whom) and these simple questions help to set system boundaries (Savaget et al., 2018). The boundaries, implicitly assumed to be the same for all stakeholders, are re-discussed and agreed upon among users. The *responsibility check* (Step 1c) opens up important discussions and reflections on potential unintended consequences for society and the environment of going to scale. This starkly contrasts linear scaling approaches that focus on the attributes of the innovation and if it is "ready" to scale irrespective of the context and the (negative) influence scaling may have on that same context.

Step 2: Score the Scaling Ingredients

Step 2 is the core of the tool, and it builds on two important insights. First, merging streams of innovation and cross-fertilization between different fields of expertise are essential for the success of any innovation (Wagner, 2023). Second, the context in which is being scaled is critical for success. In contrast, the linear scaling approach is highly influenced by the simplistic idea that one innovation drives change, and that adoption relies only on the quality of the innovation and on individual decision making by end-users to adopt (or not) (Leeuwis and van den Ban, 2004). The enabling context for scaling is modeled by 10 scaling ingredients (Table 1) that were initially proposed by Ubels and Jacobs (2016). Users score four tactical questions for each scaling ingredient

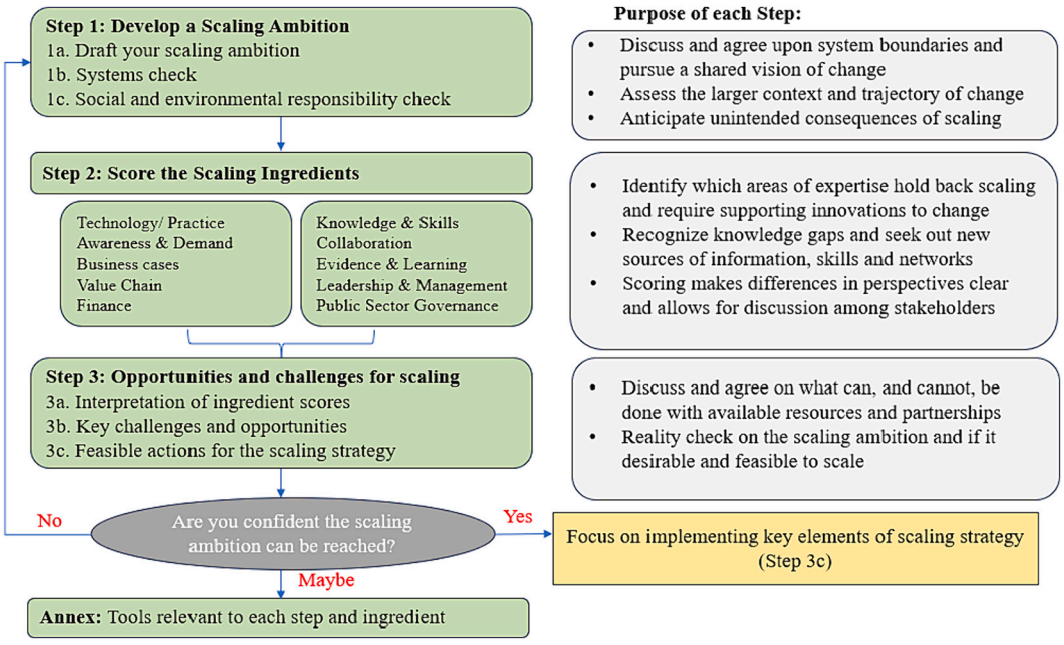

Fig. 1. The three steps of the Scaling Scan tool and their purposes.

Table 1
Scaling "ingredients" assessed in the Scaling Scan tool and their justification. *Adapted from* (Jacobs et al. (2018)).

Ingredient name	The ingredient is conducive for scaling if...
Technology/practice	The innovation is easy to adopt by your target group and better than alternatives.
Awareness & demand	Stakeholders recognize that a new innovation is necessary and are genuinely interested in achieving the scaling ambition.
Business cases	There are viable business cases for the innovation for all stakeholders along the value chain.
Value chain	The value chain is adequately organized to supply the innovation in the right quality, quantity, and in a timely manner.
Finance	Finance mechanisms are available, accessible, and affordable for the target group and other stakeholders to use and promote the innovation.
Knowledge & skills	Knowledge and skills required to use, adapt, and scale the innovation are available.
Collaboration	All relevant stakeholders to achieve and sustain the scaling ambition are engaged and collaborating adequately.
Evidence & learning	There is useful and credible information on the scaling process for learning, adaptive management, and buy-in.
Leadership & management	There is and will be effective coordination and navigation of the scaling process now and in the future.
Public sector governance	Local and national strategies, policies, and regulations actively support the scaling process.

(see Supplementary Material 1 for a description of the scaling ingredients and the four questions per ingredient) and can motivate their choice, based on their perception and knowledge about how conducive each field of expertise is to support scaling of the innovation. Low scoring ingredients are regarded as bottlenecks for scaling.

Step 3: Opportunities and challenges for scaling

The results from Step 2 are interpreted in Step 3 to formulate actionable responses to achieve the scaling ambition. This step builds on the idea of addressing the weakest link first and dealing with bottlenecks sequentially (Gebreyes et al., 2021). Users are asked if high-scoring ingredients can be leveraged to improve low-scoring ingredients, what a project team can do to address bottlenecks for scaling, given available human and financial resources, how collaboration can help and what is beyond the project's and partners' control. As a result, users may need to revise their scaling ambition. Alternatively, they could use additional tools and frameworks provided in the workbook Annex to better understand or strengthen capacities in the domains of selected scaling ingredients. One such tool is the business model canvas. In Step 3, users come to terms with the importance of collective action and long term and multi-sectoral development and reflect on how they can or cannot contribute to foster a more conducive system for scaling the innovation in question.

The three steps of the Scaling Scan are not that different from the first three steps of the Scaling Readiness tool (1. Characterize, 2. Diagnose, 3. Strategize, 4. Agree 5. Navigate) that came out in 2019 (Sartas et al., 2020). The tools are complementary (Dror and Wu, 2020) and the major difference lies in their rigor and therefore their accessibility. The Scaling Readiness methodology is data and evidence-heavy, each step consisted of 6 to 20 pages of instructions and questions and the purpose is to come up with rigorous scaling strategies. The Scaling Scan is experience based, targeted at non-academic audiences, light, and focuses on identifying key issues for (responsible) scaling that should be addressed in the project's overall implementation strategy. The Scaling Scan is a workbook of 17 pages available in multiple languages since 2018. The development of the Scaling Scan over time has focused on improving accessibility.

In 2019 a rapid, condensed version became available that requires only 30 min to go through. The biggest difference with the standard version is that, instead of four questions per ingredient, there is only one question that encapsulates an ingredient's essence. The first four authors have intermittently led the further development and promotion of the tool up to 2021, from when GIZ started supporting financially to hire third-party support for design, digitalization and training. A collaboration comprising development organizations (SNV Netherlands and GIZ), FAO and CGIAR (CIMMYT, Alliance Bioversity CIAT) developed a third edition of the Scaling Scan which was released digitally in September 2023. The number of questions are reduced from four to three per ingredient, it puts a stronger focus on the effects of scaling on social inclusion and climate change and includes the X-curve (Hebinck et al., 2022), a systems thinking tool to assess how intentional breaking down of dominant practices makes space for the scaling of new practices. The different versions are freely available under a Creative Commons license at www.scalingscan.org and users can choose to invest anywhere from thirty minutes (rapid version) to three days in the standard version of the tool. This paper focuses on the use of the Standard and Rapid versions

before the 3rd edition came out.

4. Method, data collection and analysis

A mixed methodology was used to retrieve qualitative and quantitative data on the use of the Scaling Scan between October 2017 to April 2023, a period of 5,5 years. The authors retrieved documentation from 34 workshops that they (co-)facilitated. Given that the tool, facilitation guides, and other supporting materials have been Open Access, and the Scaling Scan has been presented at numerous conferences, lectures, and meetings, it was necessary to inquire with personal connections and perform online and literature searches to collect experiences with the tool and workshops facilitated by other people. Important sources of data were workshop reports, papers, interviews, focus group discussions, informal meetings, and personal observations. Data was aggregated and anonymized. The first type of data collected on Scaling Scan workshops was factual:

- Basic sex-disaggregated information on who participated, when, where, for how many days (workshop duration), and in what language.
- Information on the facilitation (virtual or live), whether the rapid or the standard version was used, who led the facilitation, and if CIMMYT was involved.
- The innovation to be scaled, the scaling ambition, and the scores per ingredient.

The second type of data was interpretative, which included the views and experiences of users and facilitators that worked with the tool and attended workshops. In 2023, an online survey with open questions with 15 participants, 4 individual interviews, and 3 virtual focus group discussions were conducted with experienced Scaling Scan users and facilitators from Spanish, French and English-speaking countries for use in a "Strengths, Weaknesses, Opportunities, and Threats" (SWOT) analysis. The analysis was enriched with information from participants workshop evaluations, workshop reports, papers, and formal and informal feedback, as well as authors personal experiences with the tool and observations from the workshops and interactions with participants.

The data may over-represent the use of the tool by research organizations from CGIAR, which is the most readily available source for the authors. No funding was available for an external evaluation of the use of the tool and therefore this study was led by authors heavily involved with the tool since its beginning.

5. Results

This section is structured in three parts. First, on the users and workshop facilitation; second, on the outputs of the tool; and, finally, on the experiences of regular users and moderators of the Scaling Scan.

5.1. Scaling scan workshops and formats

5.1.1. Workshop participation

We obtained data from 54 Scaling Scan workshops. Half of those were held in English, 37% in Spanish, and 13% in French. 25 workshops took place in Africa, 9 in Asia, and 20 in the Americas, of which 11 in Mexico. Two-thirds of the workshops were facilitated by or with a CIMMYT Scaling Scan facilitator. 35 workshops were implemented with CGIAR projects, and 12 workshops with GIZs' One World No Hunger Initiative. The duration of the physical workshops (80%) ranged from 0.5 to 3 days, while virtual workshops (20%) could be spread out over five to six weeks (Kangethe et al., 2021b). The workshops involved 1208 participants, an average 28% of whom were women. Project staff took part, or the tool had been used for project internal discussions, in 85% of the workshops. The participation of end users in one third of the workshops- generally smallholder farmers or their group representatives- was impaired by the lack of simultaneous interpretation services for their local languages.

Groups of participants in a scaling workshop can assess multiple scaling ambitions in one workshop, this way 73 scaling ambitions were assessed in the 54 workshops. In 26% of the cases, the innovation to scale was a technology, defined as a tangible object: a crop variety, a vaccine, or a machine. In 26% of the cases, the innovation to scale was a practice, either for a farming system (e.g., good agricultural practices), or a way of organizing, marketing, or sharing information, for example. In almost half of the cases, the innovation to scale was a combination of the two: for example, conservation agriculture different technologies (machinery, seeds, mulching) and practices such as minimum tillage, diversification, and crop rotation. Most scaling assessments focus on conservation agriculture, mechanization, or animal husbandry.

5.1.2. Use of the Scaling Scan

In most cases, project teams invited stakeholders to jointly assess scaling opportunities and bottlenecks for a particular innovation they have piloted or tried to scale. Other uses of the Scaling Scan can be summarized in five categories.

1. **Cross-regional comparisons of enabling environments for scaling one particular innovation**. This is exemplified by van Lunenburg et al. (2020), who assessed the scalability of for-hire mechanization services in three projects in Bangladesh, Mexico, and Zimbabwe, to inform strategic entry points for scaling the innovation globally.
2. **Rapid portfolio analysis to select best-bet options**. Organizations often work with a portfolio of many innovations. The rapid Scaling Scan was used to quickly scan a range of innovations and identify one or more with the greatest scaling potential. Those selected were then subjected to a more thorough standard Scaling Scan.
3. **Pre-scalability assessment.** The Scaling Scan was used as a filter to assess an innovation's potential scalability, before investing time and resources in the more thorough Scaling Readiness tool (Dror and Wu, 2020; Sartas et al., 2020).
4. **Capacity development**. In 70% of the workshops, stakeholders external to the project team were invited to participate foremost to enrich the scalability assessment with more diverse views. Other motivations have been to develop capacity on a more systemic perspective on scaling across partners, thereby challenging traditional mindsets on scaling (such as the innovation bias, "more is better") and arriving at a common understanding and language to engage with a more complex notion of scaling (Galloway McLean et al., 2023). Finally, the rapid Scaling Scan has been used by CIMMYT in conferences and lectures as an exercise for participants to make a quick assessment of their own scaling case, thereby raising interest in being more deliberate about scaling.
5. **Planning and evaluation.** The scaling ingredients have served as a checklist for projects to pay attention to diverse areas of expertise. Recurrent use of the tool may identify changing bottlenecks for scaling over time. A management consulting company in Norway used the scaling ingredients to develop Scaling Key Performance Indicators (KPIs) for UN organizations.

5.1.3. Customizations to the scaling scan methodology

In 35% of the workshops, users deviated from the rapid or standard version of the tool, mostly to save time and lower the perceived entry barriers for participation. Five different motivations for customizations to the original Scaling Scan methodology were identified.

1. Save time: A recurring challenge in Scaling Scan workshops is the time and focused effort required to go through the standard version systematically, particularly the 40 questions of step 2. To save time, the systems and responsibility checks (steps 1b and 1c) were often

omitted, or the scaling ambition was prescribed by the project lead team before the workshop started.
2. Include different groups:, the International Center for Agricultural Research in the Dry Areas (ICARDA) lumped scaling ingredients and questions together in only five scaling ingredients, to save time and facilitate participation by farmers and extension agents (Frija and Idoudi, 2020). Similarly, FAO and GIZ reduced and adapted Scaling Scan questions to suit the case of women group ownership of cassava processing machines in Benin. Questions were adapted to be more cognizant of the issues around gender responsiveness, participation, inclusion, and empowerment (Flores Rojas and Grassi, 2023).
3. Qualitative analysis: Workshop participants in CIMMYT in Yucatan, Mexico, ILRI in Ethiopia (Kangethe et al., 2021a) and the Philippine Rice Research Institute (Manalo et al., 2022) did not score the scaling ingredients, but chose to qualitatively appraise them.
4. Elaborate more on the innovation: the International Livestock Research Institute (ILRI; Dror and Wu, 2020), the Innovation Package and Scaling Readiness (IPSR) team of CGIAR, and the USAID Development Innovation Ventures (DIV) (Fehlenberg, personal communication) complemented steps 1 and 2 of the Scaling Scan with questions taken from the Agricultural Scalability Assessment Tool (ASAT) (Kohl, 2018) to elaborate more on the inherent qualities of the innovation. Furthermore, the IPSR methodology prescribes a literature review on the innovation and requires supporting statements regarding scalability with evidence.
5. Prioritize action: The IPSR version of the scaling ingredients, were weighted by workshop participants to simulate the relative importance of specific ingredients in a particular context and prioritize (collective) action. The DIV team weighed scaling ingredients as a method to value local priorities and promote local buy-in (Fehlenberg, personal communication).

5.2. Scalability assessment results

Figure 2 below lumps all results over innovation and contexts across workshops together to show an overall trend. The scaling ingredients "technology/ practice" scores high on a scale from 1 (poor status) to 5 (very conducive for scaling) (Supplementary Material 1). This was followed by "awareness & demand" and "knowledge & skills" "Finance," scored lowest on average, while "value chain," "business models," and "public sector governance" tend to have a larger spread and lower scoring.

5.3. Scaling scan SWOT results

Based on the SWOT analysis with experienced Scaling Scan users and facilitators, the tool's strengths lie in capacity development, interdisciplinary thinking, and stakeholder collaboration (Fig. 3). Customization and enhanced features offer growth opportunities and link directly to the previous section on how complementary objectives are found, through use of the tool. The analysis revealed the importance of addressing the tool's weaknesses in efficiency, focus, and guidance; latter two relating strongly to the questions "what" and "how much" to scale (Box 1). Furthermore, representation and scope to improve the gender responsiveness and inclusion of the Scaling Scan was also highlighted by Sánchez Rodríguez et al. (2021). Mitigating threats related to subjective recommendations and bias were found to be important, going forward. The results from the SWOT analysis are interpreted in the Discussion section.

6. Discussion

In this section, the results from the study are interpreted to respond coherently to the research questions on the extent to which the Scaling Scan holds a systems approach (6.1). Analyzing who uses the tool, and how, leads to a discussion on the balance between user-friendliness and embracing complexity in Section 6.2. The patterns in outputs of the Scaling Scan (research question 3) are linked to the larger societal and scientific debate on how scaling is dealt with (6.3). Finally, in Section 6.4, the discussion revolves around the challenges organizations face in taking into consideration greater complexity. The interpretations draw significantly from the SWOT analysis (research question 4).

6.1. Opportunities and challenges in integrating a systems approach to scaling in the Scaling Scan

The Table 2 below summarizes the main differences between the dominant linear scaling approach, a systems approach to scaling and how that is manifested in the Scaling Scan as described in Sections 1-3.

The tool holds many elements that are considered important in systems thinking. First, the idea that the status of the context determines if innovations scale or not, rather than the innovations' intrinsic robustness. The status of the context is modeled by ten scaling ingredients in step 2 of the tool. Second, the tool is explicit about unintended consequences over time and place, and the responsibility that comes with that.

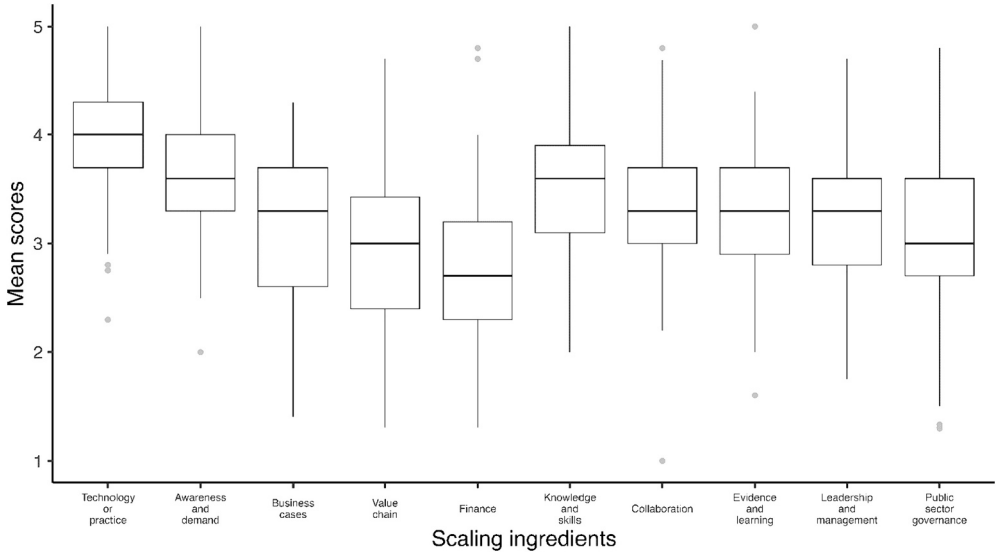

Fig. 2. Box plot showing average scores and distribution of scores of the scaling ingredients over 72 scaling ambitions (2017–2023), where a score of 1 indicates a poor status and 5 indicates that the ingredient is very conducive for scaling the innovation.

Strengths	Weaknesses
• **Capacity Development**: The Scaling Scan tool facilitates step-by-step learning enabling users to understand the crucial aspects of responsible scaling. • **Big Picture Mindset**: Overcoming bias towards "our" technology and prompts participants to think holistically across various disciplines, scales, and contexts. • **Stakeholder Collaboration**: Facilitates discussions, collaboration and ownership for inclusive scaling strategies. • **Rapid and Repeatable:** Can be quickly applied and customized to select from multiple innovations, or can be repeated regularly to assess shifts in bottlenecks to scaling over time.	• **Time-Consuming:** The 4-question, 10-ingredient format is time consuming and may reduce participant engagement . • **Narrow Focus:** The tool's single innovation entry-point might not suit broader systems-oriented cases. • **Limited Definitions**: Lack of definitions on innovation and scaling and guidance on "what/how much to scale?" (See Box 1) • **Stakeholder Representation:** Balanced, multi-disciplinary stakeholder representation is essential for meaningful and actionable outcomes. • **Scaling Strategy Guidance**: More detailed guidance on "how to scale?" (strategy) is required, to help users translate insights into actionable scaling strategies. • **Gender responsiveness and inclusiveness**: Issues of gender and intersectionality should be more explicit.
Opportunities	**Threats**
• **Customization and Innovation**: Developing tailored versions with different durations, digital interfaces (e.g., gamification) and user interactions can boost engagement. • **Enhanced Features**: Package the tool along with other tools on target group assessments, stakeholder engagement, and business model development, for more informed outcomes.	• **Subjective Recommendations**: Acknowledge that recommendations are influenced by the opinions and experiences of participants in the room, rather than objective evidence. • **Biased Initiators**: Guard against bias towards technical partners and innovation developers, ensuring diverse expertise participation and decision-making.

Fig. 3. SWOT analysis by Scaling Scan users and facilitators.

Third, scaling for sustainable development requires collective understanding and collective action. After all, local actors are the only ones who can maintain and grow scale after the project ends so it is important they understand the implications of scaling. Furthermore, the innovator is confronted with specialized areas such as finance and business models that demand attention but in which they have limited competence, necessitating the acquisition of new knowledge, skills and relationships for scaling to be successful. The tool exposes not only capacity gaps, but also information gaps, such as an insufficiently deep understanding of the problem, user needs, stakeholder dynamics. The Annex of the Scaling Scan workbook provides an elaborate list of easy-to-use tools to strengthen analyses for each step and ingredient.

But the tool also perpetuates the linear scaling approach by jumping over important root cause analysis thereby risking to address symptoms or issues that do not have the most leverage for change. Furthermore, the tool quickly focuses on one solution, one innovation to scale, while systems change comes about when different development from different sources merge to gradually shape a new configuration of the system (Schot and Geels, 2008). This early focus on "the solution" may well not be informed by an in-depth analysis of leverage points in the system and scaling may thus not lead to any change. It also risks impeding awareness of existing — and possibly more suitable — solutions or innovations from other sources (Woltering et al., 2016). Moreover, the guidance in the Scaling Scan on how to deal with the questions "what to scale" and "how much" (Box 1) may reinforce the idea that high adoption of a "good" innovation leads to good change. This may be counterproductive in fostering a systems mindset and scaling enabling conditions (trust, policies, capacities, mindsets) for a range of innovations to break through.

The first time the early focus on one innovation was heavily challenged was in October 2020 with the NGO Catholic Relief Services. They found it a regression to reduce their multi-disciplinary and multi-level work aimed at large scale land restoration to one innovation. These discussions prompted the creation of the System Scan. Inspired by the simple structure of the Scaling Scan, a complementary System Scan tool is being tested that focuses on a deeper understanding of problems' systemic nature and the multiple leverage points for systems change. The Scaling Scan can then be used to support the scaling of selected leverage points. Scaling innovations can be useful if the innovation is identified as an important lever in a transformative Theory of Change (Palavicino et al., 2022) where cultural change, power dynamics, relationships, policies and many other dimensions are addressed as well.

6.2. *Balancing user-friendliness and complexity of scaling*

The Scaling Scan has been used in diverse situations in different countries, under varied facilitation methods and levels of participation, and involving different types of innovations. An important opportunity the tool offers is to engage on-the-ground problem owners and those affected by scaling into discussion regarding what to scale, where, why, and how. The tool's availability in English, French, and Spanish is important, especially given the scarcity of scaling literature or related guidance in French or Spanish. The SWOT analysis suggest that the Scaling Scan responds to what Norström et al. (2020) finds important for co-production for sustainability by being context-based and goal-oriented (Step 1: the Scaling Ambition), pluralistic (accessible to enable broad participation), and interactive (different versions available and rapid enough to be repeated multiple times). In nearly half of the workshops, organizations customized the tool to their needs, either to fit their organizations' existing models and tools or to better suit target users (see Section 5.2). In most cases customizations involved condensing and simplifying content (e.g. prioritizing steps, combining scaling ingredients) to enable more and broader participation. It is not uncommon to simplify a method and implement workshops in less time McClure et al. (2018). User demands for simplification and enhanced accessibility are countered by calls for explicit requirements for evidence (Kangethe et al., 2021a, 2021b), more supporting analyses (e.g. stakeholder maps, value chain analysis), and greater guidance on

Box 1
What and how much to scale.

In developing the scaling ambition (Step 1) users are asked "what to scale" and "how much to scale". These questions seem simple but can lead to extended discussions in Scaling Scan workshops.

What to scale?

The Scaling Scan and other scaling tools are designed to assess the "scalability" of an innovation, which is defined as a technology or process new to a context. In practice, organizations often work on multiple innovations simultaneously, or on innovations that have multiple technical and process components, such as conservation agriculture (CA), a production system based on multiple agricultural practices and inputs (Thierfelder et al., 2018). Organizations may also aim to scale the project itself or a specific outcome, such as land restoration. Existing guidance on "what to scale" is limited and ranges from narrowing an innovation to its minimum viable product (Cooley and Kohl, 2016) to taking entire packages of technical and organizational innovations to scale (Sartas et al., 2020). The problem with the latter is that, as in the case of CA, the affordability, stakeholders involved, policy environment and other system factors differ for each component — machinery, new practices, and new varieties — making it hard to assess their combined scalability. In the Scaling Scan, users are asked to focus on a single innovation, or component, and assess the scalability for each t separately. Out of a potential range of innovations and components, users are advised to start with the innovation that sits at the interface between expertise, evidence, and potential.

- **Expertise:** The organization should have a high level of expertise and experience regarding the innovation's performance under diverse circumstances (users, contexts, etc.).
- **Evidence:** There is enough credible evidence from the pilot phase that the innovation visibly and directly responds to the target group's needs and addresses the persistent development problem when applied on a large scale.
- **Potential:** The innovation is affordable and accessible and there is already interest in important local stakeholders, public and private, to support scaling.

How much to scale?

A common question in workshops is how much growth in use or adoption is necessary to be considered "scaling?" Palmié et al. (2023) found scaling studies that recommend at least 20% growth. Users of the Scaling Scan regularly set the scaling target as doubling or tripling the amount of people reached in a pilot project. This approach is detached from the size of the problem, which according to the www.scalingcommunityofpractice.com, is at the heart of the definition of scaling "to design and deliver sustainable solutions *that match the scale of the need.*" In the adoption curve of Rogers (1962), there is a tipping point somewhere around 15–30% of the total population when a critical mass is reached and further scaling should be easier. More recently, Centola (2021) found that at 25% of the target group, there is enough feedback through social interactions to reach that tipping point. While related to the size of the target group, these figures are detached from the wider social, political and economic context (Palmié et al., 2023). Yet users are advised to aim to achieve adoption by 25% of the target group. Users are asked to quantify; 1) the size of the total target group, 2) 25% of that total group, 3) the number of the target group already reached in the pilot phase, and 4) the number the project *could* reach and if that is about 25% of the target group.

developing the scaling strategy (as per the SWOT analysis). An important trade-off in further development of the Scaling Scan was between accounting for complexity vs. demands to simplify even more. It is often necessary to portray scaling as a controllable, step-by-step, "evidence-based" process to obtain buy-in from collaborators and partners, which does not reflect the iterative, risky and lengthy process of scaling in reality (Koorts et al., 2022), nor that of the politics and contested nature of systems change (Béné et al., 2019). Complexity thinking adds a real-world, multidimensional appreciation of the system and its density and dynamics, but it does not make it easier to effect change; in fact, the opposite is true (Braithwaite. Yet we can no longer assume that complex systemic problems such as hunger and poverty will be solved by having more of an innovation.

Given that so many people are still applying simple linear scaling approaches to complex problems (Moore et al., 2015), the developers of the Scaling Scan have opted to focus on accessibility, making it easier for anyone to start using the tool, either as a facilitator or a participant. The drive to accessibility includes the digitalization of the rapid and standard version of the tool, thereby condensing content to its essence and allowing users to skip certain steps, for user-friendliness. This decision was also informed by a growing availability of scaling tools and more practical tools for dealing with systems change and transformation (https://tipresourcelab.net/ and https://www.systemsinnovation.network) allowing the Scaling Scan to occupy its niche. This niche is for a user-friendly tool for a broad scaling community to open a more nuanced and systems-aware discussion on what it takes to scale, while for the systems thinking community it offers a practical guide on scaling particular solutions identified as key levers for systems change.

6.3. Patterns in current scaling approaches

Across workshops the ingredients "technology/practice", "awareness and demand," and "knowledge and skills" score high on average, implying that these areas of expertise are conducive to scaling. This is mostly because projects have invested from the beginning in fine-tuning and creating demand for the innovation, as well as training end-users how to apply it, for example through diffusing demonstration plots. This focus on adapting innovations to different contexts and training of users and intermediaries are typical activities in pilot projects (Hartmann and Linn, 2008; Woodhill, 2010).The ingredients "finance," "value chain," "business models," and "public sector governance" typically score low, suggesting that insufficient attention is paid to a conducive market environment and public support for scaling. Fund raising, product placement, advocacy, and so on (Cooley and Howard, 2019; Westley et al., 2014) gain importance over time as scaling occurs in distinct phases ((Low and Thiele, 2020). This suggests that the innovations that were assessed were still at an early stage of proving their feasibility rather than testing their viability in the real world. However, conservation agriculture (related) innovations constituted the vast majority of innovations assessed and those have been around for more than half a century. This suggests that scaling is treated as a "bigger" pilot rather than a phased process that requires different capacities along the scaling pathway. Extrapolating expectations of success and ways of working from the pilot to the scaling phase is a common pitfall in scaling

Table 2
Comparing linear scaling to an systems approach to scaling and how the latter is promoted in the Scaling Scan.

Characteristic	Linear scaling	Systems approach to scaling	How the Scaling Scan promotes a systems approach to scaling
Drivers for scaling	Quality/ attributes of the innovation and innovator	Quality of the social, political and economic context	Step 1 puts the innovation in a context (where, why, for whom to scale) and Step 2 assesses the "readiness" of the context
Approach to adoption of innovations	Maximum adoption as fast as possible Overlooks unintended consequences	Adoption as a means to an end Health of system takes priority over one particular "solution"	Step 1c: asks if scaling is actually desirable and if there is an optimal, rather than a maximum level of scale to be pursued
Change achieved through	Positive effects of an innovation can be extrapolated to a higher scale Large adoption of positive innovation = positive change at scale	Change the (architecture) of the system that produces the problem Innovation as one of many levers for change	An innovation as entry point to drive change
Discipline	Top-down expert-based and single-disciplinary	Collective action and multi-disciplinary	Experience-based tool targeted at non-scaling experts and accessible to a wide range of actors for collective understanding to lead to collective action
Role of scientist/ practitioner	Innovator and project leader	Partner and facilitator	Step 3: shows that change requires much more than just one individual or organizations' actions to scale innovation for systems change

initiatives (Spicer et al., 2014). It also indicates that project teams lack diversity and multi-disciplinarity, both in staffing and partnerships. For example, projects to scale improved farm practices are typically implemented only by agronomists, without adequate involvement of the experts in finance, private and public sector engagement, or social differentiation (McGuire et al., 2022). Although the data show that external stakeholders were represented in 70% of the workshops, further research is required to understand why were those innovations selected and if participation, actually leads to knowledge co-production or if innovators maintain control.

The findings match with literature showing that scaling projects are still too often designed and implemented with a narrow focus on the innovation and the innovator (Hall and Dijkman, 2019; Moore et al., 2015), raising questions about the ability and willingness to use a systems approach. This narrow focus may also be responsible for other persistent problems in AR4D with embracing participatory methods (Neef and Neubert, 2011) and multi-level capacity development (Woltering et al., 2022).

6.4. *Willingness and ability to embrace a systems approach to scaling*

Especially in the last decade the term scaling has gained popularity and people are attracted to the idea of maximizing the adoption of their innovation as fast as possible. Scaling "our" innovation is a major motivation for project teams to participate in scaling workshops. But a systems approach requires a problem-first vision and a much stronger engagement with the context in which scaling takes place, which not everyone is able or willing to do (Kohl, 2023a; Meehan and Jonker, 2018). For example, the Scaling Scan advocates for an optimal level of scale whereby the effect of the use of the innovation at scale on social and environmental issues limits relentless growth. Furthermore, a common conclusion from the Scaling Scan workshops is that participants need to invest time and resources in understanding often unfamiliar scaling ingredients, including finance or business model development. This can imply a fundamental change in focus from a technical to a finance approach, which has big implications for the leadership, resource flows, and team constitution of a scaling project. In the absence of networks and experience in these newer focal areas, organizations may not always be willing or able to set up projects that address the scaling needs. This happened at least in one of the scaling workshops organized by a CGIAR center to develop a second (scaling) phase of a project. The project team consisted largely of agronomists that had been finetuning and testing the technology in phase 1. Yet, the major bottleneck for scaling was identified as value chain development, and the project leader refused to change the constitution of the team to include more value chain experts and continued in the second phase with the same team as from phase 1.

This example confirms what Westley et al. (2014) found; that the most important barrier to scaling is internal, because this can often mean having to leave behind something integral to the organization. A major challenge is to shift mindsets from the conventional "adoption" mindset to one that takes on the radical implications of systems perspectives (Ubels and Hoijtink, 2024).

Many researchers face incentive structures privileging disciplinary science that does not engage with society (Dilling and Lemos, 2011) and many practitioners work within organizations that do not incentivize critical reflection, ongoing learning, or revision of actions (Norström et al., 2020). For example, Ubels and Hoijtink (2024) found that few practitioners go beyond their organizations' doctrine to justify and propel their own existence and way of working and honestly unpack the question "why does the problem still exist and have all (ours and others') previous efforts failed?". Furthermore, despite reasonable representation of diverse stakeholders in the scaling workshops, power dynamics favor those who control the innovation ((Pfotenhauer et al., 2022). Mostly, the innovator organizes a scaling workshop and has particular interest and knowledge on one or a few scaling ingredients.

We hypothesize that a desire to control the innovation process combined with a mindset of tech-optimism is holding back AR4D organizations to embrace a more complex notion of scaling that challenges the status quo. The dominance of the linear approach to innovation and scaling in the CGIAR has been criticized for over 30 years (Glover et al., 2019; Röling, 2009), and alternative approaches that draw from systems thinking have by and large been ignored (Hall and Dijkman, 2019; Leeuwis et al., 2021; Schut et al., 2020). Also, the new narrative on scaling that was introduced by the Scaling Scan, one that puts context first and sees scaling innovations as a means to an end was not at par with the entrenched linear approach to scaling in CIMMYT at that time. The semi-external introduction through SNV and GIZ may have contributed to avoid organizational path dependencies in how scaling is conceptualized. But while CIMMYT and the CGIAR endorsed the tool, it never received strong organizational support to actively promote broader use, further development or develop research agendas around its use. Basically, a two-person team has been driving the use of the Scaling Scan on demand of particular project teams within and beyond CIMMYT.

The Scaling Scan opens up discussions on shifting leadership for scaling to local actors that are affected by scaling and on their willingness to invest their own political, financial, social capital in scaling. Thus, the Scaling Scan may provide an initial, covert step to take a more

holistic approach to scaling, which does not mean that all the recommendations from the Scaling Scan are automatically adopted. Further research is required to understand if and why (or why not), scaling strategies and outcomes have become more oriented towards systems change, after using the Scaling Scan, and what more is necessary.

7. Conclusions

Scaling innovations is an acclaimed and important process for organizations that aim to contribute to achieving the SDGs. But conventional approaches to scaling are failing and often do more harm than good by creating dependencies, unrealistic expectations, and unintended consequences for the environment and society. The Scaling Scan, as the name implies, is a "scan", an initial diagnostic tool to assess the extent to which scaling considers context and their actors, and trade-offs in reaching and sustaining a scaling of innovations commensurate with the problem. It prioritizes user-friendliness, inclusion, simplicity and speed over rigorous and elaborate data collection, and generates leads for subsequent in-depth analysis. From the analyses, it appears that the Scaling Scan can be a starting point and a way to develop capacity for a more thoughtful integration of systems thinking in agricultural research and development to do justice to the complex nature of scaling innovations for sustainable development. It does so by guiding users through the development of a scaling ambition, assessing the range of factors and actors that are relevant to achieve the scaling ambition, and reflecting on the ability of their organization and through collaboration to make change happen.

The experience with the Scaling Scan also provides a lens to deeper issues that get in the way of embracing systems thinking. Results from the use of tool show that scaling initiatives often do not engage enough with disciplines that go beyond those that were required to prove a successful pilot. A tendency to focus on tweaking the technology, awareness raising and trainings may hint to a persistent belief that "if we build it, they will come" underestimating the efforts that need to go in shaping an enabling market and public context for scaling. Or, despite at least a decade of a growing availability of practical and scientific guidance on scaling, interventions are still designed without proper consideration of the broader systemic context in which innovations are expected to be taken up sustainably and enable or contribute to sustainable development. The persistency and scope of this problem urged the tool developers to make the tool ever more accessible by developing different (shorter) version and digitizing content.

Despite flexibility in use and accessibility, not all can or want to follow through with the recommendations coming from the tool. Tensions have been observed between a focus on addressing problems vs. narrowing down to one envisioned solution, or controlling a scaling process vs. promoting ownership by those most affected by the problem, or between an organization's and donors interest vs. their capacities to navigate the scaling process through its different phases. These tensions may provide important insights in the persistence of challenges to scale and path dependencies preventing the acceptance of systems approaches. The Scaling Scan may thus not help innovations scale to a level where they transform food systems, it rather raises awareness and develops capacity of project teams, partners, and allies on the need for a systems thinking approach to large change.

With the current popularity of the term "food systems transformation," there is an urgent need to get more clarity on what it means for organizations to sign up for this grand systems change ambition. Research organizations have an important role in translating complex theories in practical and inclusive ways to get everyone on board. The experience from the Scaling Scan shows that practical, accessible tools are an important vehicle, not only to assess the gaps, but also to develop capacity, build networks, and foster social capital for change. For now, the tool serves as a bridge for a critical mass of people comfortable with developing innovations to venture into the complex realities of achieving results and moving the dial on the SDGs. Instead of focusing on scaling the innovation, let us focus on scaling appropriate approaches that do justice to the complex global problems that have been lingering for too long and use those to scale impact.

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CRediT authorship contribution statement

Lennart Woltering: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Eva M. Valencia Leñero:** Writing – review & editing, Writing – original draft, Project administration, Data curation. **Maria Boa-Alvarado:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Jelle Van Loon:** Formal analysis, Conceptualization. **Jan Ubels:** Methodology, Conceptualization. **Cees Leeuwis:** Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

Barrett, C.B., Benton, T., Fanzo, J., Herrero, M., Nelson, R.J., Bageant, E., Buckler, E., Cooper, K., Culotta, I., Fan, S., Gandhi, R., James, S., Kahn, M., Lawson-Lartego, L., Liu, J., Marshall, Q., Mason-D'Croz, D., Mathys, A., Mathys, C., Wood, S., 2022. Socio-Technical Innovation Bundles for Agri-Food Systems Transformation. Springer International Publishing. https://doi.org/10.1007/978-3-030-88802-2.

Begimkulov, E., Darr, D., 2023. Scaling strategies and mechanisms in small and medium enterprises in the Agri-food sector: a systematic literature review. Front. Sustain. Food Syst. 7 https://doi.org/10.3389/fsufs.2023.1169948.

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I.D., de Haan, S., Prager, S.D., Talsma, E. F., Khoury, C.K., 2019. When food systems meet sustainability – current narratives and implications for actions. World Dev. 113, 116–130. https://doi.org/10.1016/j.worlddev.2018.08.011.

Benton, T.G., Bailey, R., 2019. The paradox of productivity: agricultural productivity promotes food system inefficiency. Global Sustain. 2, e6 https://doi.org/10.1017/sus.2019.3.

Braithwaite, J., Churruca, K., Long, J.C., Ellis, L.A., Herkes, J., 2018. When complexity science meets implementation science: a theoretical and empirical analysis of systems change. BMC Med. 16 (1) https://doi.org/10.1186/s12916-018-1057-z.

Centola, D., 2021. Change: How to Make Big Things Happen. Hachette Book Group.

CGIAR, 2020. Scaling Brief #3- Scaling Approaches and Tools.

Chandy, L., Hosono, A., Kharas, H., Linn, J., 2013. Getting to Scale: How to Bring Development Solutions to Millions of Poor People. Brookings Institution Press.

Cooley, L., Howard, J., 2019. Scale Up Sourcebook.

Cooley, L., Kohl, R., 2016. Scaling Up-From Vision to Large-Scale Change. A Management Framework for Practitioners.

Dilling, L., Lemos, M.C., 2011. Creating usable science: opportunities and constraints for climate knowledge use and their implications for science policy. Glob. Environ. Chang. 21 (2), 680–689. https://doi.org/10.1016/j.gloenvcha.2010.11.006.

Douthwaite, B., Hoffecker, E., 2017. Towards a complexity-aware theory of change for participatory research programs working within agricultural innovation systems. Agric. Syst. 155, 88–102. https://doi.org/10.1016/j.agsy.2017.04.002.

Dror, I., Wu, N., 2020. Scaling Better Together The International Livestock Research Institute's Framework for Scaling. https://hdl.handle.net/10568/107911.

Elrha, 2018. Too Tough to Scale? Challenges to Scaling Innovation in the Humanitarian Sector. http://www.elrha.org/wp-content/uploads/2018/10/Elrha-TTTS-A4-FINAL.pdf.

Expandnet, & World Health Organization, 2011. Beginning with the End in Mind: Planning Pilot Projects and Other Programmatic Research for Successful Scaling up. World Health Organization.

Fazey, I., Leicester, G., 2022. Archetypes of system transition and transformation: six lessons for stewarding change. Energy Res. Soc. Sci. 91 https://doi.org/10.1016/j.erss.2022.102646.

Fehlenberg, K., Eissler, S., Turner, K., Norton, P., 2023. Development Innovation Ventures (DIV): Portfolio Review - Digital Agriculture Grants.

Flores Rojas, M., Grassi, F., 2023. Sustainable mechanization as a means to empower women processors in Benin. Food and Agriculture Organization United Nations. https://www.fao.org/3/cc5930en/cc5930en.pdf.

Foster-Fishman, P.G., Nowell, B., Yang, H., 2007. Putting the system back into systems change: a framework for understanding and changing organizational and community systems. Am. J. Community Psychol. 39 (3–4), 197–215. https://doi.org/10.1007/s10464-007-9109-0.

Frija, A., Idoudi, Z., 2020. *Self-Sustained "Scaling Hubs" for Agricultural Technologies: Definition of Concepts, Protocols, and Implementation*.

Galloway McLean, K., Gorring, A., Macleod, M., Austin, L., 2023. Scaling & systems change: fundamentals. Insights Case Study Rev.

Gebreyes, M., Mekonnen, K., Thorne, P., Derseh, M., Adie, A., Mulema, A., Kemal, S.A., Tamene, L., Amede, T., Haileslassie, A., Gebrekirstos, A., Mupangwa, W.T., Ebrahim, M., Alene, T., Asfaw, A., Dubale, W., Yasabu, S., 2021. Overcoming constraints of scaling: critical and empirical perspectives on agricultural innovation scaling. PLoS One 16 (5 May). https://doi.org/10.1371/journal.pone.0251958.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Policy 31 (8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8.

Ghiron, L., Ramirez-Ferrero, E., Badiani, R., Benevides, R., Ntabona, A., Fajans, P., Simmons, R., 2021. Promoting scale-up across a global project platform: lessons from the evidence to action project. Glob. Implement. Res. Appl. 1 (2), 69–76. https://doi.org/10.1007/s43477-021-00013-4.

Gibbs, E., Jones, C., Atkinson, J., Attfield, I., Bronwin, R., Hinton, R., Potter, A., Savage, L., 2021. Scaling and 'systems thinking' in education: reflections from UK aid professionals. Compare 51 (1), 137–156. https://doi.org/10.1080/03057925.2020.1784552.

Glover, D., Sumberg, J., Ton, G., Andersson, J., Badstue, L., 2019. Rethinking technological change in smallholder agriculture. In: Outlook on Agriculture, Vol. 48, Issue 3. SAGE Publications Inc., pp. 169–180. https://doi.org/10.1177/0030727019864978

Glover, D., Mausch, K., Conti, C., Hall, A., 2021. Unplanned but well prepared: a reinterpreted success story of international agricultural research, and its implications. Outlook Agricult. 50 (3), 247–258. https://doi.org/10.1177/00307270211043542.

Goulet, F., 2021. Characterizing alignments in socio-technical transitions. Lessons from agricultural bio-inputs in Brazil. Technol. Soc. 65, 101580 https://doi.org/10.1016/j.techsoc.2021.101580.

Hall, Andy, Dijkman, J., 2019. Public Agricultural Research in an Era of Transformation: The Challenge of Agri-Food System Innovation. https://iaes.cgiar.org/sites/default/files/pdf/syntetic-study-web-def.pdf.

Hartmann, A., Linn, J.F., 2008. Scaling Up a Framework and Lessons for Development Effectiveness from Literature and Practice, vol. 5. www.brookings.edu/global.

Haynes, A., Rychetnik, L., Finegood, D., Irving, M., Freebairn, L., Hawe, P., 2020. Applying systems thinking to knowledge mobilisation in public health. In: Health Research Policy and Systems, vol. 18, Issue 1. BioMed Central Ltd. https://doi.org/10.1186/s12961-020-00600-1.

Hebinck, A., Diercks, G., von Wirth, T., Beers, P.J., Barsties, L., Buchel, S., Greer, R., van Steenbergen, F., Loorbach, D., 2022. An actionable understanding of societal transitions: the X-curve framework. Sustain. Sci. 17 (3), 1009–1021. https://doi.org/10.1007/s11625-021-01084-w.

Hölscher, K., Frantzeskaki, N., Loorbach, D., 2019. Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands. Reg. Environ. Chang. 19 (3), 791–805. https://doi.org/10.1007/s10113-018-1329-3.

Hölscher, K., Wittmayer, J.M., Olfert, A., Hirschnitz-Garbers, M., Walther, J., Schiller, G., 2023. Creating actionable knowledge one step at a time: an analytical framework for tracing systems and agency in niche innovation pathways. Environ. Innov. Soc. Trans. 46, 100682 https://doi.org/10.1016/j.eist.2022.11.007.

Hynes, W., Lees, M., Mueller, J., 2020. In: Hynes, W., Linkov, I., Love, P. (Eds.), Systemic Thinking for Policy Making: The Potential of Systems Analysis for Addressing Global Policy Challenges in the 21st Century. OECD. https://doi.org/10.1787/62830370-en.

IIRR, 2000. In: Julian, Gonsalves (Ed.), Going to Scale: Can We Bring More Benefits to More People More Quickly?. International Institute for Rural Reconstruction, Y.C. James Yen Center. https://iirr.org/wp-content/uploads/2021/10/Going-to-Scale-scanned-copy_compressed_compressed.pdf.

Jacobs, F., Ubels, J., Woltering, L., 2018. The Scaling Scan: A Practical Tool to Determine the Strengths and Weaknesses of Your Scaling Ambition. PPPlab and CIMMYT. https://repository.cimmyt.org/handle/10883/20505?locale-attribute=en.

Kaljonen, M., Kortetmäki, T., Tribaldos, T., 2023. Introduction to the special issue on just food system transition: tackling inequalities for sustainability. Environ. Innov. Soc. Trans. 46, 100688 https://doi.org/10.1016/j.eist.2022.100688.

Kanger, L., Schot, J., 2019. Deep transitions: theorizing the long-term patterns of socio-technical change. Environ. Innov. Soc. Trans. 32, 7–21. https://doi.org/10.1016/j.eist.2018.07.006.

Kangethe, E., Sartas, M., Dror, I., 2021a. Small Ruminant Value Chain Transformation in Ethiopia Scaling Scan Report. www.ilri.org.

Kangethe, E., Sartas, M., Dror, I., 2021b. The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) in the Ethiopian Highlands Scaling Scan Report. www.ilri.org.

Kemp, R., Loorbach, D., Rotmans, J., 2007. Transition management as a model for managing processes of co-evolution towards sustainable development. Int. J. Sustain. Dev. World Ecol. 14 (1), 78–91. https://doi.org/10.1080/13504500709469709.

Klerkx, L., van Mierlo, B., Leeuwis, C., 2012. Evolution of systems approaches to agricultural innovation: Concepts, analysis and interventions. In: Darnhofer, I., Gibbon, D., Dedieu, B. (Eds.), Farming Systems Research into the 21st Century: The New Dynamic (pp. 457–483). Springer Netherlands. https://doi.org/10.1007/978-94-007-4503-2_20.

Kohl, R., 2018. Guide to the Agricultural Scalability Assessment Tool for Assessing and Improving the Scaling Potential of Agricultural Technologies. https://pdf.usaid.gov/pdf_docs/PA00T6KX.pdf.

Kohl, R., 2021. Scaling Community of Practice Scaling and Systems: Issues Paper. https://www.encyclopedia.com/social-sciences-and-.

Kohl, R., 2023a. Exploratory Study of Mainstreaming Scaling in International Development Funders: A Summary of Findings and Recommendations for the Scaling Community of Practice. https://www.scalingcommunityofpractice.com/wp-content/uploads/2022/11/Exploratory-Study-of-Mainstreaming-Scaling.pdf.

Kohl, R., 2023b. Key factors for advancing innovations to scale: evidence from multiple country case studies of agricultural innovations. Front. Sustain. Food Syst. 7 https://doi.org/10.3389/fsufs.2023.1053152.

Koorts, H., Rutter, H., 2021. A systems approach to scale-up for population health improvement. In: Health Research Policy and Systems, vol. 19, Issue 1. BioMed Central Ltd. https://doi.org/10.1186/s12961-021-00679-0.

Koorts, H., Bauman, A., Edwards, N., Bellew, W., Brown, W.J., Duncan, M.J., Lubans, D. R., Milat, A.J., Morgan, P.J., Nathan, N., Searles, A., Lee, K., Plotnikoff, R.C., 2022. Tensions and paradoxes of scaling up: a critical reflection on physical activity promotion. Int. J. Environ. Res. Public Health 19 (21), 14284. https://doi.org/10.3390/ijerph192114284.

Kuehne, G., Llewellyn, R., Pannell, D.J., Wilkinson, R., Dolling, P., Ouzman, J., Ewing, M., 2017. Predicting farmer uptake of new agricultural practices: a tool for research, extension and policy. Agric. Syst. 156, 115–125. https://doi.org/10.1016/j.agsy.2017.06.007.

Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., Thomas, C.J., 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain. Sci. 7 (1), 25–43. https://doi.org/10.1007/s11625-011-0149-x.

Leeuwis, C., van den Ban, A.W., 2004. Communication for Rural Innovation : Rethinking Agricultural Extension. Blackwell.

Leeuwis, C., Schut, M., Klerkx, L., 2017. Systems research in the CGIAR as an arena of struggle: Competing discourses on the embedding of research in development. In: Agronomy for Development: The Politics of Knowledge in Agricultural Research. https://doi.org/10.4324/9781315284057.

Leeuwis, C., Klerkx, L., Schut, M., 2018. Reforming the research policy and impact culture in the CGIAR: integrating science and systemic capacity development. Glob. Food Sec. 16, 17–21. https://doi.org/10.1016/j.gfs.2017.06.002.
Leeuwis, C., Boogaard, B.K., Atta-Krah, K., 2021. How food systems change (or not): governance implications for system transformation processes. Food Secur. 13 (4), 761–780. https://doi.org/10.1007/s12571-021-01178-4.
Lie, M., Soerensen, K., 1996. In: Lie, M., Soerensen, K. (Eds.), Making Technologies our Own? Domesticating Technology into Everyday Life. Scandinavian University Press.
Low, J.W., Thiele, G., 2020. Understanding innovation: the development and scaling of orange-fleshed sweetpotato in major African food systems. Agric. Syst. 179 https://doi.org/10.1016/j.agsy.2019.102770.
van Lunenburg, M., Geuijen, K., Meijer, A., 2020. How and why do social and sustainable initiatives scale? A systematic review of the literature on social entrepreneurship and grassroots innovation. Voluntas 31 (5), 1013–1024. https://doi.org/10.1007/s11266-020-00208-7.
Manalo, A., Orcullo, L., de Leon, T., Baltazar, M., 2022. What happened to PhilRice's microtiller? A scaling study. Asian J. Agricult. Develop. 19 (2), 35–49. https://doi.org/10.37801/ajad2022.19.2.p2.
Mausch, K., Hall, A., Hambloch, C., 2020. Colliding paradigms and trade-offs: Agri-food systems and value chain interventions. In: Global Food Security, vol. 26. Elsevier B. V. https://doi.org/10.1016/j.gfs.2020.100439.
McClure, D., Bourns, L., Obrecht, A., 2018. Humanitarian Innovation: Untangling the Many Paths to Scale. https://www.elrha.org/wp-content/uploads/2019/07/Humanitarian-Innovation-Untangling-the-Many-Paths-to-Scale-GAHI.pdf.
McGuire, E., Rietveld, A.M., Crump, A., Leeuwis, C., 2022. Anticipating gender impacts in scaling innovations for agriculture: insights from the literature. World Develop. Perspect. 25, 100386 https://doi.org/10.1016/j.wdp.2021.100386.
McLean, R., Gargani, J., 2019. Scaling Impact; Innovation for the Public Good. https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/57605/Scaling%20impact.pdf?sequence=2&isAllowed=y.
Meadows, D., 2015. In: Wright, D. (Ed.), Thinking in Systems. Chelsea Green Publishing. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/climate-communications/psychology-amp-behavior/Meadows-2008.-Thinking-in-Systems.pdf.
Meehan, W., Jonker, K., 2018. Meehan and Jonker 2018- SSIR- earning the right to scale. Stanf. Soc. Innov. Rev. https://ssir.org/articles/entry/earning_the_right_to_scale.
Moore, M.-L., Riddell, D., Vocisano, D., 2015. Scaling out, scaling up, scaling deep: strategies of non-profits in advancing systemic social innovation. J. Corp. Citizsh. 2015 (58), 67–84. https://doi.org/10.9774/gleaf.4700.2015.ju.00009.
Muilerman, S., 2019. Innovating Service Delivery and Aligning with the State: The Co-Creation of Scaling Mechanisms for Cocoa Extension in Africa. Wageningen University.
Muilerman, S., Wigboldus, S., Leeuwis, C., 2018. Scaling and institutionalization within agricultural innovation systems: the case of cocoa farmer field schools in Cameroon. Int. J. Agric. Sustain. 16 (2), 167–186. https://doi.org/10.1080/14735903.2018.1440469.
National Academy of Sciences, 2021. The Challenge of Feeding the World Sustainably: Summary of the US-UK Scientific Forum on Sustainable Agriculture. The National Academies Press. https://doi.org/10.17226/26007.
Neef, A., Neubert, D., 2011. Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making. Agric. Hum. Values 28 (2), 179–194. https://doi.org/10.1007/s10460-010-9272-z.
Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., Campbell, B.M., Canadell, J.G., Carpenter, S.R., Folke, C., Fulton, E.A., Gaffney, O., Gelcich, S., Jouffray, J.-B., Leach, M., Österblom, H., 2020. Principles for knowledge co-production in sustainability research. Nature Sustain. 3 (3), 182–190. https://doi.org/10.1038/s41893-019-0448-2.
Palavicino, C., Matti, C., Witte, J., 2022. MOTION handbook. Develop. Transform. Theory Change. https://doi.org/10.13140/RG.2.2.20561.20325.
Palmié, M., Parida, V., Mader, A., Wincent, J., 2023. Clarifying the scaling concept: a review, definition, and measure of scaling performance and an elaborate agenda for future research. J. Bus. Res. 158 https://doi.org/10.1016/j.jbusres.2022.113630.
Perlman Robinson, J., Winthrop, R., 2016. Millions Learning- Scaling up Quality Education in Developing Countries.
Pfotenhauer, S., Laurent, B., Papageorgiou, K., Stilgoe, J., 2022. The politics of scaling. Soc. Stud. Sci. 52 (1), 3–34. https://doi.org/10.1177/03063127211048945.
Rogers, E.M., 1962. Diffusion of Innovations. Free Press.
Röling, N., 2009. Pathways for impact: scientists' different perspectives on agricultural innovation. Int. J. Agric. Sustain. 7 (2), 83–94. https://doi.org/10.3763/ijas.2009.0043.
Ronner, E., Sumberg, J., Glover, D., Descheemaeker, K., Almekinders, C., Haussmann, B., Kuyper, T., Posthumus, H., Ebanyat, P., Giller, K., 2021. Basket of options: unpacking the concept. Outlook Agricultl. 50 (2), 116–124. https://doi.org/10.1177/00307270211019427.
de Roo, N., Almekinders, C., Leeuwis, C., Tefera, T., 2019. Scaling modern technology or scaling exclusion? The socio-political dynamics of accessing in malt barley innovation in two highland communities in southern Ethiopia. Agric. Syst. 174, 52–62. https://doi.org/10.1016/j.agsy.2019.04.004.
Sachs, J., 2005. The End of Poverty. Economic Possibilities for Our Time. Penguin Books.
Sánchez Rodríguez, A.M., MacLachlan, M., Brus, A., 2021. The coordinates of scaling: facilitating inclusive innovation. Syst. Res. Behav. Sci. 38 (6), 833–850. https://doi.org/10.1002/sres.2740.
Sartas, M., Schut, M., Proietti, C., Thiele, G., Leeuwis, C., 2020. Scaling readiness: science and practice of an approach to enhance impact of research for development. Agric. Syst. 183, 102874 https://doi.org/10.1016/j.agsy.2020.102874.
Savaget, P., Geissdoerfer, M., Kharrazi, A., Evans, S., 2018. The theoretical foundations of sociotechnical systems change for sustainability: a systematic literature review. J. Clean. Prod. 206 https://doi.org/10.1016/j.jclepro.2018.09.208.
Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Tech. Anal. Strat. Manag. 20 (5), 537–554. https://doi.org/10.1080/09537320802292651.
Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Res. Policy 47 (9), 1554–1567. https://doi.org/10.1016/j.respol.2018.08.011.
Schut, M., Leeuwis, C., Thiele, G., 2020. Science of scaling: understanding and guiding the scaling of innovation for societal outcomes. Agric. Syst. 184 https://doi.org/10.1016/j.agsy.2020.102908.
Seelos, C., Mair, J., 2018. Mastering system change. Stanf. Soc. Innov. Rev. 35–41. http://christianseelos.com/Fall_2018_Mastering_System_Change.pdf.
Shilomboleni, 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. Agric. Syst. 175, 58–65. https://doi.org/10.1016/j.agsy.2019.05.012.
Smil, V., 2023. Invention and Innovation- a Brief History of Hype and Failure.
Spicer, N., Bhattacharya, D., Dimka, R., Fanta, F., Mangham-Jefferies, L., Schellenberg, J., Tamire-Woldemariam, A., Walt, G., Wickremasinghe, D., 2014. 'Scaling-up is a craft not a science': Catalysing scale-up of health innovations in Ethiopia, India and Nigeria. Soc. Sci. Med. 121, 30–38. https://doi.org/10.1016/j.socscimed.2014.09.046.
Spicer, N., Hamza, Y.A., Berhanu, D., Gautham, M., Schellenberg, J., Tadesse, F., Umar, N., Wickremasinghe, D., 2018. "The development sector is a graveyard of pilot projects!" six critical actions for externally funded implementers to foster scale-up of maternal and newborn health innovations in low and middle-income countries. Glob. Health 14 (1). https://doi.org/10.1186/s12992-018-0389-y.
Thierfelder, C., Baudron, F., Setimela, P., Nyagumbo, I., Mupangwa, W., Mhlanga, B., Lee, N., Gérard, B., 2018. Complementary practices supporting conservation agriculture in southern Africa. A review. Agronomy for Sustainable Development 38 (2), 16. https://doi.org/10.1007/s13593-018-0492-8.
Ubels, J., Hoijtink, L., 2024. Systems Transformation as a Deliberate Orientation in Development Projects and Programs: Key Mindsets and Practices.
Ubels, J., Jacobs, F., 2016. Scaling: From Simple Models To Rich Strategies. www.ppplab.org.
Verkaart, S., Mausch, K., Claessens, L., Giller, K.E., 2019. A recipe for success? Learning from the rapid adoption of improved chickpea varieties in Ethiopia. International Journal of Agricultural Sustainability 17 (1), 34–48. https://doi.org/10.1080/14735903.2018.1559007.
Wagner, A., 2023. Sleeping Beauties. The Mystery of Dormant Innovations in Nature and Culture. Oneworld Publications.
Westley, F., Antadze, N., Riddell, D.J., Robinson, K., Geobey, S., 2014. Five configurations for scaling up social innovation: case examples of nonprofit organizations from Canada. J. Appl. Behav. Sci. 50 (3), 234–260. https://doi.org/10.1177/0021886314532945.
Wigboldus, S., Klerkx, L., Leeuwis, C., Schut, M., Muilerman, S., Jochemsen, H., 2016. Systemic perspectives on scaling agricultural innovations. A review. In: Agronomy for Sustainable Development, vol. 36, Issue 3. Springer-Verlag France. https://doi.org/10.1007/s13593-016-0380-z.
Wigboldus, S., McEwan, M.A., van Schagen, B., Okike, I., van Mourik, T.A., Rietveld, A., Amole, T., Asfaw, F., Hundayehu, M.C., Iradukunda, F., Kulakow, P., Namanda, S., Suleman, I., Wimba, B.R., 2022. Understanding capacities to scale innovations for sustainable development: a learning journey of scaling partnerships in three parts of Africa. Environ. Dev. Sustain. https://doi.org/10.1007/s10668-022-02394-4.
Woltering, L., Boa-Alvarado, M., 2021. Insights on Scaling of Innovations from Agricultural Research for Development: Views from Practitioners. www.km4djournal.org/.
Woltering, L., Bachmann, L., Apina, T.O., Letty, B., Nyemba, J.A., Alaoui, S.B., 2016. Assessment of the demand-supply match for agricultural innovations in Africa. In: Bari, A., Damania, A., Mackay, M., Dayanandan, S. (Eds.), Applied Mathematics and Omics to Assess Crop Genetic Resources for Climate Change Adaptive Traits, 1st ed. Taylor & Francis Group, pp. 39–55. https://www.taylorfrancis.com/books/edit/10.1201/9781315369006/applied-mathematics-omics-assess-crop-genetic-resources-climate-change-adaptive-traits-abdallah-bari-ardeshir-damania-michael-mackay-selvadurai-dayanandan.
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. Agric. Syst. 176 https://doi.org/10.1016/j.agsy.2019.102652.
Woltering, L., del Refugio Boa Alvarado, M., Stahl, J., Van Loon, J., Ortiz Hernández, E., Brown, B., Kumar Gathala, M., Thierfelder, C., 2022. Capacity development for scaling conservation agriculture in smallholder farming systems in Latin America, South Asia, and southern Africa: exposing the hidden levels. Knowl. Manag. Dev. J. https://www.km4djournal.org/index.php/km4dj/article/view/510.
Woodhill, J., 2010. Capacities for institutional innovation: a complexity perspective. IDS Bull. 41 (3).