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Principles for guiding research and innovation toward sustainable and equitable agrifood systems

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Investments in research and innovation are critical for transformations toward sustainable agrifood systems and for meeting the Sustainable Development Goals and the Paris Climate Agreement. However, the frequent neglect of environmental and social goals by investors remains a major challenge. System-oriented approaches to designing and monitoring innovations can be a promising solution to guide innovations and allow investors to identify those that are more sustainable. This article presents a set of eight 'Principles for Agrifood Research and Innovation' developed by an international multi-stakeholder task force including staff of research agencies, funders and impact investors, private sector, non-governmental organizations, and benchmarking organizations. The article explains the rationale for the selection of the principles and describes potential ways forward for their uptake and implementation, building on pilots done by several research and funding organizations.

KEYWORDS

principles for research, principles for innovation, sustainable food systems, agrifood systems, sustainable agriculture, social equity, ethical, environmental sustainability

1. Introduction

Today's agrifood systems require urgent transformation to better provide food and nutrition security to global consumers while minimizing their negative environmental and social impacts (Zurek et al., 2022a). Agrifood systems "encompass the entire range of actors, and their interlinked value-adding activities, engaged in the primary production of food and non-food agricultural products, as well as in storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal and consumption of all food products including those of non-agricultural origin" (FAO, 2022).[1] Innovation constitutes a critical component for

1 The definitions of *food* systems and *agrifood* systems differ in that the latter explicitly also includes the production of agricultural non-food products.

initiating and sustaining transformations of agrifood systems (Herrero et al., 2020; International Energy Agency, 2022) and in relation to agrifood systems, "innovation is the process whereby individuals or organizations bring new or existing products, processes or ways of organization into use for the first time, in a specific context, in order to increase effectiveness, competitiveness, resilience to shocks or environmental sustainability, and thereby contribute to food security and nutrition, economic development or sustainable natural resource management" (FAO, 2022).[2] In the context of this work, innovation includes research that aligns with this definition.

A recent review of the 'innovation investment landscape' in agrifood systems found that less than 7 % of innovation funding for agrifood systems had explicit environmental objectives and less than 4.5 per cent also contained explicit social objectives (Prasad et al., 2023). Contributions of agrifood research and innovation have often been siloed, prioritizing production processes and food security while failing to adequately consider interconnected outcomes (den Boer et al., 2021). Future innovations must therefore begin to consider the whole agrifood system, including environmental and social outcomes, in order to contribute to a transformation toward *sustainable* agrifood systems (SAFS) (Herrero et al., 2020). SAFS are agrifood systems that contribute to food and nutrition security, economic opportunities, and secure livelihood opportunities for agrifood system actors while contributing to the sustainable management and utilization of natural resources as well as social equity (adapted from Sage, 2018). In other words, innovation must consider more complex causal mechanisms that address trade-offs, emerging system properties, and dynamic feedback mechanisms (Foran et al., 2014; den Boer et al., 2021). However, in practice undertaking this is difficult. It is challenging for actors to reliably steer an innovation toward promoting SAFS and understand whether it is worth investing the required time, financial and other resources (Zurek et al., 2021), meaning the lack of guidance here is a major shortcoming.

To address this shortcoming and the related neglect of environmental and social objectives, a diverse task force of experts in agrifood innovation from academia, international organizations, farmers organizations, and the private sector developed actionable principles for guiding innovation toward contributions to SAFS. The aim of the task force was to support research and innovation actors, including investors, managers, implementers, and benchmarking actors, in planning, implementing, and monitoring progress against SAFS objectives. The principles are underpinned by a scoring system that allows users to monitor their progress in realizing the goals set out.

This article elucidates the work of the task force, the principles, and the associated scoring system. It starts with a review of the key challenges for transformative innovations in agrifood systems. Following this, the participatory approach taken in developing the principles is described and the task force's conceptual perspectives on agrifood systems, agrifood innovation, and related principles is outlined. Subsequently, the article presents the eight developed principles and the scoring system supporting their operationalization. It concludes with a set of recommendations for further work in this area and a short discussion on some of the limitations of the principles.

2. Challenges for transformative innovations in agrifood systems

The diverse actors within agrifood systems are interested in varying combinations of outcomes. However, current agrifood systems fall short in both providing adequate food and nutrition security and an equitable distribution of food, resulting in simultaneous malnutrition, hunger, and overconsumption (the 'triple burden of malnutrition') (Holt-Gimenez and Patel, 2012; FAO, IFAD, UNICEF, WFP, WHO, 2021). Concurrently, agrifood systems have a huge environmental footprint, being affected by and driving climate change (Vermeulen et al., 2012b; Mbow et al., 2019), biodiversity loss (Frison et al., 2011; Daskalova et al., 2020), land use change, water use and pollution, and soil degradation (Campbell et al., 2017; OECD, 2019). In addition, they fail to provide equal economic opportunities to food system actors or social equity at large (Mannar et al., 2020; Downs and Fox, 2021; Hebinck et al., 2021; Jacobi et al., 2021). At the household level, they support the livelihoods of 3.83 billion people – many of whom suffer from hunger and poverty (UN DESA, 2021; Davis et al., 2023). These simultaneous demands urgently necessitate a drastic transformation (Béné et al., 2019; Webb et al., 2020). They require new tools, concepts, and management options for change, that is, they require innovations. Currently, there are two major challenges in developing innovations and innovation systems that address sustainability and equity challenges in agrifood systems while safeguarding productivity gains.

The first challenge relates to difficulties in designing innovations for complex systems and knowing whether they are likely to contribute to intended objectives in the long-term (Klerkx and Begemann, 2020; Klerkx and Rose, 2020; Zurek et al., 2021). This complexity is recognized by the growing body of research that builds on agrifood systems thinking – a central springboard for addressing persistent, interdependent challenges. Agrifood systems thinking is an approach for visualizing and analyzing the interconnected nature and dynamics of agrifood system activities and actors, as well as the outcomes and drivers of these activities. Tools, such as visual frameworks, guide users in establishing foundations and finding entry points for new insights and ideas for better system governance (see Section 4 of this paper) (Ericksen, 2008; Ingram and Zurek, 2018; van Berkum et al., 2018).

Understanding systemic interactions in today's complex agrifood systems is key for governance toward sustainability (Brouwer et al., 2020). For example, innovations for nutritional outcomes may also have environmental, economic, or social implications. Here it becomes evident that innovations must consider the interdependence of different activities and how they interact with and impact different system goals and emerging system properties through dynamic feedback mechanisms (Foran et al., 2014). However, predicting and managing the long-term effects of innovations in line with this understanding is a challenge (Zurek et al., 2022b) that complicates planning and assessment, accentuating questions about trade-offs and unintended consequences.

2 Types of innovation include technological, social, policy, institutional and financial innovations, as well as adaptation of longstanding (e.g., indigenous) methods to larger-scale applications, as with some sustainable agricultural approaches (e.g., agroecology) (FAO, 2022).

The second challenge is that the majority of current investments in agrifood systems do not explicitly target social or environmental objectives (nor a combination of the two) (Prasad et al., 2023). They instead prioritize production and food security (den Boer et al., 2021). Additionally, the agrifood 'research and publications landscape' shows that there are massive research gaps in relation to social equity and inclusion outcomes (Hebinck et al., 2021), including those for health and nutrition, women and elderly people, and indigenous and youth populations (Porciello et al., 2021). These research gaps have implications for innovation processes and contribute to de-prioritization of these issues among other reasons. Conventionally, people who invest in or guide innovation processes follow linear and siloed approaches with few targeted outcomes (den Boer et al., 2021). However, because of the interdependent nature of agrifood systems, innovations designed in this way carry the risk of maintaining or exacerbating adverse non-targeted outcomes (Zurek et al., 2021). Seeing the current investment landscape, it is clear that these trade-offs are more likely to occur in social or environmental areas. The goal therefore is to embed the diversity of outcomes and actors in public and private investment decisions so that investors can identify the potential sustainability of an innovation (FAO, 2020; den Boer et al., 2021).

Recognizing and addressing these two challenges is critical for developing and deploying transformative innovations in agrifood systems. This article describes the development of a set of principles that guides innovation toward enabling SAFS. Principles that follow sustainability goals are a promising tool to guide innovation options in this direction (Leach et al., 2012; Herrero et al., 2020; Mottet et al., 2020; de Boon et al., 2022). They enable innovators to contribute to the transformation of agrifood systems more systematically and intentionally while increasing synergies and properly considering trade-offs along the way. The presented principles apply agrifood systems thinking to steer both investments, and the design and implementation of innovations, toward integrating environmental and social objectives, alongside conventional economic and productivity considerations.

3. The task force and methods used

In October 2021, the Commission on Sustainable Agriculture Intensification (CoSAI)[3] established a voluntary international Task Force on Principles and Metrics for Innovation in Sustainable Agrifood Systems (the Taskforce). Guided by CoSAI, over one year, the Taskforce worked on developing a set of principles for operationally guiding and monitoring innovation from an agrifood systems perspective in order to contribute to equity and sustainability objectives. The Taskforce was supported by an Expert Team who organized and summarized meetings, conducted background research, wrote proposals for the principles, and addressed disagreements and ambiguities. The principles were subsequently named 'Principles for Agrifood Research and Innovation'(PARI).

3 The Commission on Sustainable Agriculture Intensification (CoSAI) was a two-year international independent Commission supported by the CGIAR (CoSAI Secretariat, 2022).

3.1. Task force composition

Designing PARI required the Taskforce to incorporate diverse expertise in designing, implementing, or financing research and innovation for agrifood systems. Thus, Taskforce member selection was based on proven knowledge and practical experience in those contexts. However, Taskforce members were invited in their 'individual capacity' (rather than on behalf of their affiliated institution) to provide a level of freedom of expression. Ensuring diverse representation was also a critical requirement because the individual backgrounds of experts strongly influence both the outputs and the later uptake and support by the broader public (Knol et al., 2010). As a result, Taskforce member selection aimed to maximize diversity in stakeholder groups (i.e., research, private sector, civil society, etc.), gender, geographical region, and country-income classification (Zurek et al., 2022b). The balance between private sector and civil society organizations was carefully considered in recognition of their mutually dependent roles in agrifood innovation; Private sector actors carry economic power necessary to establish new industry standards in practice, while civil society organizations are crucial for legitimizing standards through their influence on public opinions about social and environmental challenges (Lambin and Thorlakson, 2018).

Despite a consistent effort to increase diversity during the selection process, representation across the Taskforce's 30 members was not equal. Variety was limited by structural inequalities in the agrifood sector, the necessary expertise criterion, and individual availability. This imbalance was partially mitigated through an additional public consultation. Membership included research organizations (40%), development partners (23%), non-governmental organizations (10%), and UN agencies, farmer organizations, private sector/private investor organizations, and private sector benchmarking organizations (7% each). The gender profile was similarly skewed with 70% of the group identifying as male. Regional representation was led by Europe and Central Asia (30%), followed by Latin America and the Caribbean (20%), North America (17%), South Asia and Sub-Saharan Africa (both 13%), and East Asia and Pacific (7%). The Middle East and North African region were not represented. Most participants (53%) originated from high-income countries, followed by lower- and upper-middle-income countries (both 23%) and one expert (3%) originating from a low-income country (Zurek et al., 2022b). See Annex 1 for a complete list of Taskforce members and categories of representation.

3.2. Methods used and process

For developing PARI, the Expert Team coordinated a participatory process with the 30 Taskforce members over seven 90-120-min meetings. To facilitate participation across disperse geographies, meetings were virtual. They followed the form of 'consensus development panels' (i.e., organized expert meetings), a method that is frequently used as a tool for developing guidelines such as policies and decision protocols in various sectors (Waggoner et al., 2016). However, the Expert Team chose to exceed the typical group size for this method (5–10) to ensure input from various agrifood sector stakeholder groups and to diversify

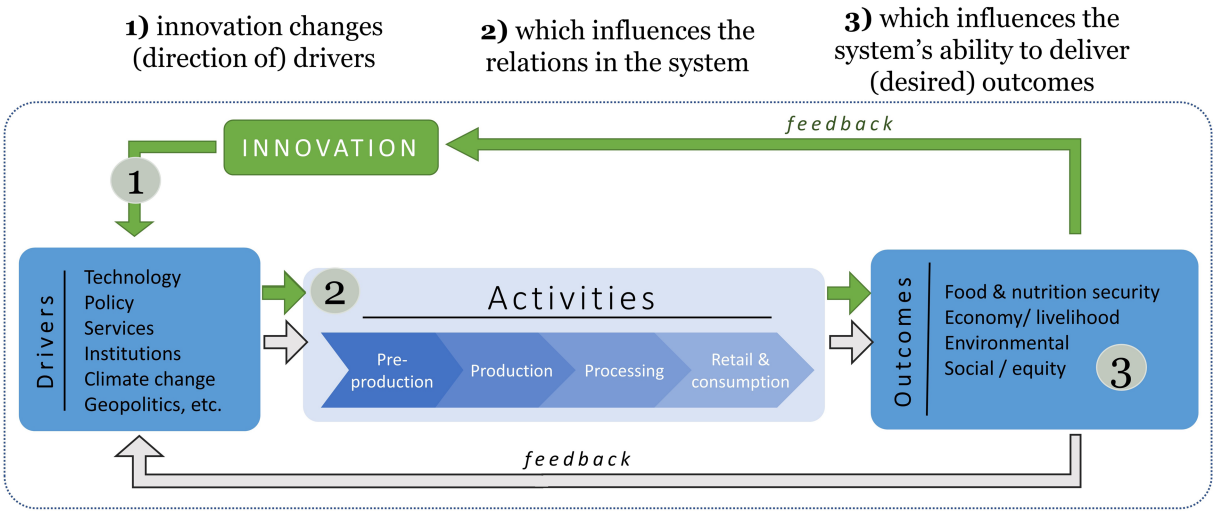

FIGURE 1
Process for developing the Principles for Agrifood Research and Innovation.

representation (Zurek et al., 2022b). Capitalizing on one of the strengths of consensus development panels, the larger group size also granted increased legitimacy to PARI and encouraged advocacy and ownership from within the sector (Waggoner et al., 2016).

During meetings, all decisions were made in plenary. Consensus was reached when a majority of participants actively agreed or had no objection to the inclusion or removal of aspects from the principles or guidance materials. Disagreements or raised concerns were evaluated by the Expert Team and were either resolved immediately or included in the agenda of the next group discussion. Given the larger group size and to mitigate risks of overly vocal Taskforce members (Waggoner et al., 2016), the Expert Team preemptively split the panel into smaller break-out groups of 4–7 experts for important discussion topics. Furthermore, the Expert Team encouraged Taskforce members to raise additional comments between meetings.

Overall, PARI was developed over four phases spanning 1.5 years: *(1) Ideation, research, strategy; (2) development of principles; (3) development of scoring framework and role of metrics; (4) piloting* (see Figure 1).

During the first and second phases, the Expert Team reviewed (grey) literature on innovation principles as well as principles on sustainable agriculture (see Annex 2). It then worked with the Taskforce to prepare a draft set of principles for innovation in agrifood systems. As part of phase two, a public consultation gathered initial feedback on the first version of PARI. Here, a survey, open for one month, was distributed through professional networks and websites reporting on agricultural innovation. This diversified conceptual inputs and provided opportunities for other stakeholders to contribute. In total, 51 experts contributed (predominantly from international organizations, NGOs, government, and academia). Participants provided feedback comprising the need for definitions and enquiries about the operationalization of PARI, especially regarding measurability and monitorability. This feedback was reviewed by the Taskforce, resulting in an improved version of the principles and the subsequent development of the scoring system as a tool for operationalization.

PARI and its scoring system were piloted in 'real world' external projects before the final Taskforce meeting. Piloting included independent applications of PARI to an innovative project (18 in total, mostly small-scale) and/or usability testing (7 sessions).[4] During usability testing, participants were observed by two members of the Expert Team while familiarizing themselves with the principles and guidance materials, taking first application steps, sharing impressions, and asking questions. Feedback from both formats was collected through direct calls, filled-in scoring frameworks as well as a feedback survey.

During the final meeting in March 2022, the Taskforce agreed on the final set of principles (Zurek et al., 2022b). It also discussed handing over PARI to an appropriate lead organization with a global mandate, that could continue their development and promotion. The successor organization would likely finetune individual principles, develop a pertinent catalog of metrics, disseminate PARI among public and private stakeholders, and support them in integrating the tool in existing reporting and benchmarking processes. While an operational set of metrics could not be developed within the time frame of the Taskforce, their role is reflected in the principles and a limited collection (sorted according to sub-principles) was made available to the public.

A visually polished online version of the guidance materials was developed to improve usability of PARI in their current form and support their promotion. This includes two introductory videos that further increase accessibility and user-friendliness (CoSAI Secretariat, 2023).

4 The 18 projects came from the following stakeholder groups: development partner (3), non-governmental organization (5), private sector (4), research organization (6) and were sourced from the Taskforce network and responses to a public call by CoSAI.

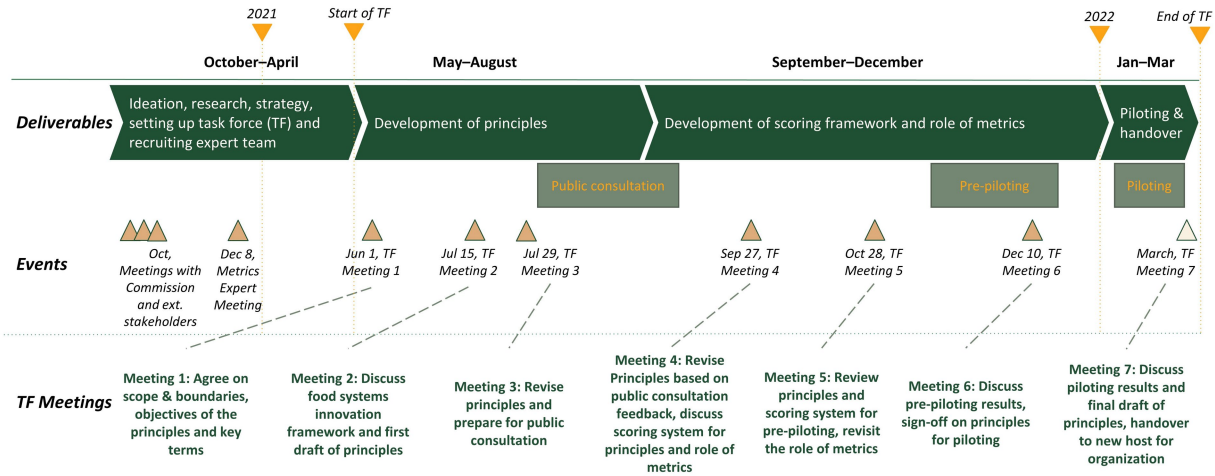

FIGURE 2
Conceptualizing innovation in agrifood systems using three lenses: drivers, activities, and outcomes.

4. Conceptualizing innovation in agrifood systems and related principles

Because "[agri]food systems approaches must be useful to decision makers, and performance can only be improved if decision makers have a better understanding of these underlying interactions and dynamics of food systems change" (Brouwer et al., 2020), it was important that the Taskforce shared a conceptual understanding of innovation's impacts on agrifood systems. To facilitate this, innovation in agrifood systems was considered through a framework comprised of three lenses: drivers, activities, and outcomes of agrifood systems (and their interactions) (see Figure 2). For outcomes to be improved actors must change the driving forces (e.g., institutions and policies, available technologies or cultural habits) that shape how agrifood systems function and which activities are carried out by whom (Ericksen, 2008; Ingram, 2011; van Berkum et al., 2018). Despite the framework simplifying agrifood systems and omitting the feedback loops within innovation processes, it does illustrate how innovation continuously impacts agrifood systems and shows the trajectory of innovation in relation to both its triggers (i.e., desired outcomes) and agrifood system drivers.[5] This provided the Taskforce with a starting point for developing principles that both aligned with innovation's interaction with agrifood systems and had the potential to transform the direction and intensity of the innovation's impact on SAFS outcomes.

The Taskforce's framework was complemented by a complex and non-linear understanding of both agrifood systems (e.g., FAO, 2014, 2018; van Berkum et al., 2018; Zurek et al., 2022c) and innovation (e.g., HLPE, 2019; Koerner and Duda, 2021 based on various frameworks). Viewing agrifood systems from varying angles provides the foundation for developing new insights and ideas for better management practices (Ericksen, 2008; Ingram and Zurek, 2018; van Berkum et al., 2018; Hebinck et al., 2021). These varying angles imply different functionalities for agrifood system actors and have implications for the way they interact with the system. The Taskforce concluded that various agrifood systems perspectives can serve innovations and that the choice depends on the context, including the scale at which an innovation is implemented. Taskforce members utilized this diversity of understandings on agrifood systems and innovation to consider how best to guide innovators and related actors, catering to differing needs.

This perspective on innovation in agrifood systems strengthens the case for a well operationalized set of principles that can continuously and iteratively guide innovation-related actors in balancing intended outcomes and trade-offs at all scales. In the above framework, principles function as both procedural and normative anchors for innovations. They highlight the path to best practice for innovation processes ('the how'), while helping actors align their innovations with their desired outcomes through a systems perspective ('the what'), altering drivers, activities, and the configurations of agrifood system actors.

Various principles on SAFS as well as innovation already exist. CoSAI had however identified a gap in the intersecting area of *innovation principles for SAFS*. To compose such principles, the Taskforce reviewed existing principles based on guidelines and grey literature within the two identified types (see Annex 2). Principles on SAFS usually relate to the goals and outcomes of agrifood systems, e.g., soil health, labor standards, and gender equality. Principles on innovations typically specify procedural steps to support goals and outcomes (e.g., developing a theory of change or undertaking stakeholder consultation) or provide guidance for creating an enabling environment (i.e., innovation systems). For reviewing innovation principles, the Taskforce included principles from various sectors outside of agrifood systems.

5 The Taskforce also used the framework to set their scope of work on pre-production, production and post-harvest activities.

BOX 1: EIGHT PRINCIPLES FOR AGRIFOOD RESEARCH AND INNOVATION (EXCLUDING SUB-PRINCIPLES).

1. Set out a clear theory of change defining intended impacts, based on a food systems perspective and reflexive learning.
2. Design transparent and evidence-based innovation processes.
3. Conduct innovation processes in an inclusive and ethical manner.
4. Address potential trade-offs, synergies, efficiencies, and unintended effects.
5. Consider contribution to improved food and nutrition security and health.
6. Consider contribution to sustainable and circular management and utilization of natural resources.
7. Consider contribution to a viable economy and sustainable livelihoods.
8. Consider contribution to an ethical, equitable, and adaptive agrifood system for current and future generations.

The two types of principles, *in combination*, are required to support innovation in contributing to SAFS (Zurek et al., 2022b). In isolation, each type has limitations. Outcome principles are useful for defining and pursuing objectives but cannot be measured at the beginning of innovation processes. Here, it may only be possible to track intentions and the quality and depth of the processes used to develop the innovation. As a counterpart, process principles provide methodological guidance in the form of best practices for developing innovations. These help steer the development of innovations, though do not specify outcomes. Those innovation principles that facilitate innovation by promoting an enabling environment target conditions that are not necessarily directly influenced by innovators, nor do they account for investor demands around innovation's procedures and progress against outcomes. Hence, a combination of principles on SAFS and innovation process is required for effectively guiding agrifood system actors throughout all stages of the innovation process. In developing first iterations of the principles, the Taskforce reviewed 30 and 28 sets of SAFS and innovation process principles (e.g., the High-Level Panel of Experts' report *Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition* (HLPE, 2019) (for outcome principles), and the COP26 (2021) *Transforming Agricultural Innovation Campaign Steering Group's Principles for Transforming Innovation* (2020) or the *World Wildlife Fund's ESG Integration Indicators* (WWF, 2021) (for process principles)).

Three target groups that could use innovation principles for SAFS were identified to help guide the development of PARI. Identifying these target groups allowed the Taskforce to consider how the principles would be used by different groups, how appropriate they would be for each group's needs, and where potential gaps lay in terms of servicing their needs and uses.

- Public and private direct investors in innovation in agrifood systems who need to ensure that their funds are appropriately used to support their SAFS goals (e.g., Bayer CropScience, FAO, USAID).
- Managers and implementers of research for development and innovation, both public and private, who need to plan their work and track progress against SAFS objectives (e.g., CGIAR, Syngenta).
- Certification, benchmarking, and watchdog organizations promoting investment in innovation for environmentally sustainable and socially positive outcomes (e.g., Verra, World Benchmarking Alliance).

5. Actionable principles for research and innovation in sustainable agrifood systems

The Taskforce composed a set of eight principles (i.e., PARI) for guiding innovation projects in targeting sustainable and equitable agrifood system outcomes (see Box 1).

The first four principles focus on best practice *processes* for managing innovative projects. The last four principles focus on *outcomes* of innovation. Each principle is delineated through subprinciples that further guide implementation.[6] Despite being numbered, all principles are of equal importance and their interlinked nature means addressing one can affect others. While the principles are normative, that is, they require users to consider elements of their innovation processes and outcomes, they never stipulate specifics (e.g., modes of production such as agroecological production). The following section presents PARI and the literature underpinning their scientific relevance in guiding agrifood systems' innovation processes. In addition, prominent aspects of discussions within the Taskforce are included. Note that the version of PARI here is a work-in-progress, likely to undergo further changes in the future.

Principle 1: Set out a clear theory of change defining intended impacts, based on a food systems perspective and reflexive learning.
1.1. Clear and flexible theory of change defining intended impact of proposed innovation.
1.2. Applied systems thinking at different scales, including all impacted actors and activities.
1.3. Reflexive monitoring and evaluation to adapt route to impact to changing conditions.

Agrifood innovations are developed in diverse systemic contexts that include a variety of outcomes, objectives, targeted populations, and mechanisms for change. Thus, it is important to specify an innovation's rationale, direction, and mechanism of change from the outset (Hekkert et al., 2020; Klerkx and Begemann, 2020; Mazzucato et al., 2020). Here, constructing a clear theory of change that defines impact pathways and is responsive to potential constraints is key in supporting actors to realize intended goals and impacts (Koerner and Duda, 2021; Zurek et al., 2022a).

6 For example, Principle 6 guides R&I projects in managing natural resources in a sustainable and circular manner, thus requiring the consideration of sustainability and circularity in each thematic dimension of its sub-principles.

Building on this, the Taskforce recommended that theories of change be designed and conducted using systems thinking. Analyzing agrifood system actors' interactions with their socio-economic and biophysical environments can reveal overlooked outcomes and impact pathways. This is important because these interactions are often complex, non-linear, multi-relational, and have significant feedback effects (van Berkum et al., 2018). Hence, systems thinking can set a foundation for developing more holistic 'systems innovations'. When identifying the area for analysis within the system, the Taskforce posited that systems thinking be applied at different scales and from different angles covering all impacted actors and activities (Zurek et al., 2022b).

However, it was acknowledged that the complexity of agrifood systems impedes the immediate identification and measurement of all interdependencies and relations. Consequently, the Taskforce suggested a reflexive and adaptive approach for developing theories of change. Iterative data and results monitoring at strategic points facilitates learning and minimizes the risk of unintended consequences, allowing for course corrections (Beers and van Mierlo, 2017). Using a flexible and adaptive theory of change from an agrifood systems perspective continuously verifies that an innovation project aligns with its objectives under changing circumstances.

Principle 2: Design transparent and evidence-based innovation processes.
2.1. Information on innovation goals, key intended outcomes, and budgets publicly available.
2.2. Analysis of needed resources and capabilities, and the ability to obtain them.
2.3. Evidence-based processes including use of credible metrics.
2.4. Sharing of knowledge/insights, as appropriate, with others (public or private entities).

Transparency is recognized as an important factor for abetting accountability, enhancing traceability, supporting coordination, building trust, enhancing learning across sectors, and supporting socially responsible entrepreneurship and governance (Piechocki, 2004; Zakutniaia and Hayriyan, 2017; Gupta et al., 2020). While intellectual property rights need to be preserved, sharing some information on innovation processes allows others to review the cogency of the approach taken. In doing so, transparency promotes downward accountability by providing impacted stakeholders with an entry point for engagement.

In achieving transparency, determining needed resources and capabilities, as well as innovators' ability to obtain them, is important because resource limitations can strongly influence innovation outcomes and trade-offs. Transparency on resources and capabilities, particularly budget, has demonstrated positive impacts on human development (Cuadrado-Ballesteros and Bisogno, 2021) and was shown to strengthen innovation when coupled with security measures (Brown and Martinsson, 2019).

In abetting transparency, the Taskforce emphasized that innovation processes should be informed by credible and comprehensive evidence, ideally in the form of output and outcome metrics.[7] This is important for fostering the measurability and impact of innovations – not only as an end result, though also during the innovation process. Further, when actors work toward similar objectives (e.g., the SDGs), transparency and evidence-based decisions significantly improve impact, strengthening the case for information sharing. However, because innovation is so diverse, the Taskforce did not dictate specific metrics for use. In lieu of this, some metrics, proposed as standards in particular domains, can be used, for example on small-scale agriculture in the Global South (Musumba et al., 2017).

Principle 3: Conduct innovation processes in an inclusive and ethical manner.
3.1 Inclusive, fair, and transparent decision-making within innovation processes, ensuring all relevant stakeholders are included.
3.2. Fair and inclusive partnerships, and fair and ethical apportioning of benefits.
3.3. Active consideration of all relevant types of knowledge.
3.4. Ethically conducted innovation processes in compliance with human rights and other relevant international standards.

Considering inclusivity and ethics is paramount for agrifood innovations that often impact actors in complex ways (Leach et al., 2012; Klerkx and Rose, 2020). While human rights and other international standards form a widely recognized ethical foundation, current approaches to transform agrifood systems tend to be top-down and lack downwards accountability (UNSCN, 2019). In countering this, the Taskforce recommended including mechanisms for integrating inclusivity equity, and human rights, as well as other standards, into innovation processes, to prevent unintended consequences for vulnerable actors (Zurek et al., 2022b). This principle provides a starting point for going beyond 'participation tokenism' and 'box-checking' to address power asymmetries within innovation processes.

Here, multi-stakeholder or participatory processes are such mechanisms that can minimize negative impacts for minorities and other marginalized groups (Norström et al., 2020). Inclusion and participation of 'all relevant stakeholders' is a complex undertaking that can be limited by biases in stakeholder identification (Lelea et al., 2015). Still, it can also benefit innovation processes as diverse and inclusive work teams and partnerships tend to produce more innovative ideas (Fan and Swinnen, 2020; Asmal et al., 2022), much like the positive contributions of indigenous knowledge to conventional science (Uprety et al., 2012).

Principle 4: Address potential trade-offs, synergies, efficiencies, and unintended effects.
4.1. Transparent and systematic analysis of inputs, outputs, and agrifood system outcomes (Principles 5 to 8).
4.2. Transparent monitoring of winners and losers in innovation processes and outcomes (including unintended).

Standalone innovations are often designed to target specific agrifood system outcomes, meaning they can have unintended consequences and potentially be detrimental to sustainability within and beyond agrifood systems (Oliver et al., 2018; Herrero et al., 2021). Here, environmental and social outcomes are particularly likely to be neglected (Prasad et al., 2023) making managing and addressing such trade-offs a major challenge in advancing sustainability (Grass et al., 2020). Trade-off analyses, based on a clear theory of change from an agrifood systems perspective, and coupled with monitoring (Herrero et al., 2021; Zurek et al., 2021), can identify unintended consequences, including winners and losers of innovations as well as potential synergies and efficiencies.

7 Metrics are standards for measuring or evaluating that help to collect and display evidence.

Trade-off analyses enable open and honest discussions about the affected actors and why certain negative consequences may have to be accepted (Mausch et al., 2020). They can guide innovators in balancing the various outcomes that agrifood system actors want to bring about (Herforth et al., 2014; Kanter et al., 2018; Ridgway et al., 2019; UNSCN, 2019; Zhang et al., 2021) and help decision makers distribute trade-offs across geographies, groups of people or landscapes.

Principle 5: Consider contribution to improved food and nutrition security and health.
5.1. Food security.
5.2. Adequate nutrition.
5.3. OneHealth.

Principle 5 underlines the need for agrifood innovation to contribute to the outcomes of food security and adequate nutrition which are conventionally considered the core objectives of agrifood systems (Willett et al., 2019; Hebinck et al., 2021). However, most global regions' agrifood systems currently fall short in providing their populations with access to sufficient, safe, and nutritious food, to meet their food preferences and dietary needs necessary for a healthy life. Poor-quality diets cause multiple forms of malnutrition across the globe and constitute a main cause of global deaths (Lindgren et al., 2018; Lancet, 2020).

The Taskforce chose to complement these two sub-principles with the concept of OneHealth. While health in agrifood systems is often considered a result of food security and nutrition, agriculture's contribution to the emergence of zoonotic and transboundary diseases as well as antimicrobial resistance is increasingly recognized (Mackenzie and Jeggo, 2019). OneHealth constitutes "an integrated, unifying [systems] approach that aims to sustainably balance and optimize the health of people, animals and ecosystems" acknowledging their interdependence (FAO, OIE, WHO, 2021). In practice, the complementarity of these three sub-principles can be seen in the influence of OneHealth matters on food security (Garcia et al., 2020).

Principle 6: Consider contribution to sustainable and circular management and utilization of natural resources.
6.1. Biodiversity and integrated habitats.
6.2. Climate change mitigation.
6.3. Clean water.
6.4. Clean air.
6.5. Soil health.

Agrifood systems are dependent on a suitable climate and sufficient natural resource availability (Vermeulen et al., 2012a). However, their contribution to global environmental challenges including climate change and the degradation of natural resources such as biodiversity is substantial (Newbold et al., 2015; Crippa et al., 2021). The present dilemma evokes a strong call for more sustainable management and use of natural resources (Caron et al., 2018; Springmann et al., 2018; Rockström et al., 2020). Principle 6 and its sub-principles stress the importance of utilizing and managing natural resources in a sustainable and circular fashion.

Actors in agrifood innovation occupy a key role in shaping the transition toward sustainable natural resource management but they rarely follow environmental objectives (Prasad et al., 2023). Key here is the preservation of natural areas outside agrifood systems, which innovation can impact positively and negatively (Pirard and Belna, 2012; Villoria et al., 2014).[8] When innovators deliberately address the use and management of natural resources, positive contributions to environmental outcomes can be made [for example, mitigating biodiversity loss and global warming, ensuring clean air and water, and maintaining soil health (Hebinck et al., 2021)].[9] Moreover, the Taskforce highlighted that agriculture can contribute to regenerative processes in ecosystems which is especially relevant for – but not limited to – soil health (Schreefel et al., 2020).

In implementing these environmental considerations, circular approaches to natural resource management have the potential to alleviate environmental pressure (Muscio and Sisto, 2020). While there is a split between theory and practice in applying circular economy approaches in many fields, agrifood systems are a suitable ground for testing and implementing this concept, building on existing examples (Fassio and Tecco, 2019).

Principle 7: Consider contribution to a viable economy and sustainable livelihoods.
7.1. A viable agrifood systems sector contributing to the wider economy.
7.2. Secure and stable livelihoods of actors within the agrifood sector.

The agrifood sector remains of central importance to the economies of both the Global South and Global North (van der Ploeg et al., 2019). The businesses and public entities within those economies must innovate and take up transformative practices (FABLE, 2020; Herrero et al., 2020) to permit the economy's continuous harnessing of the various benefits arising from the agrifood sector. However, in a market-economy, sustainable innovations often have higher immediate production costs or require more initial investments. This means actors prioritizing private benefits (allocating resources in accordance with technical and allocative efficiencies), are less likely to apply sustainable innovations, even if public benefits are significant in the long run. However, the economic pathway to supporting welfare in a broad sense (which is the ultimate purpose of the economy) requires balancing market priorities with the creation and sustainable management of common goods (Johansson, 1991). Therefore, together with policy makers, innovators should consider how they can contribute to a healthy and stable economy at large, characterized by financial and price stability, the effective use of natural resources, and employment opportunities (among other characteristics).

A key issue in global agrifood systems is that the distribution of economic benefits is unequal. Negative developments (e.g., the COVID-19 pandemic) affect poor and marginalized populations more severely than their wealthier counterparts, especially in the Global South (Power et al., 2020; Swinnen and McDermott, 2020). In aiming to promote the mitigation of this inequality, the Taskforce included a principle emphasizing that the economic development and opportunities resulting from innovations need to create secure and

8 Mechanization and pesticides can drive increased deforestation through increased labor efficiency but increased productivity per hectare can simultaneously reduce the demand for additional land (Vadez et al., 2008).

9 Various tools exist to address the use and management of natural resources such as the drivers, pressures, state, impact, and response model of intervention (DPSIR) or the Tool for Agroecological Performance Evaluation (FAO, 2019).

stable livelihoods of actors. Innovation-driven productivity increases in farm labor will raise wages but also reduce labor demand. Many smallholder farmers will therefore be forced to switch to work outside the farm sector requiring a gradual transition based on education, mobility and urban development (FAO, 2014).

Principle 8: Consider contribution to an ethical, equitable, and adaptive agrifood system for current and future generations.
8.1. Human rights and decent working conditions.
8.2. Distribution of risks, benefits, and decision-making power within the household and along the value chain.
8.3. Inclusiveness.
8.4. Animal welfare.
8.5. Adaptation, that is equitable, including to climate and environmental change.

Ethics and equity represent a typical blind spot of innovation in agrifood systems (Hebinck et al., 2021; Herrero et al., 2021; Porciello et al., 2021; Zurek et al., 2021; Prasad et al., 2023), with the notable exemption of agroecological innovations (e.g., Barrios et al., 2020). Even with appropriate trade-off tools that guide social equity measurement, monitoring social objectives remains highly subjective and context-specific (Mottet et al., 2020). Due to their frequent neglect and the challenge of measurability, social outcomes of agrifood systems tend to include trade-offs that imply direct negative impacts on certain, often marginalized, groups such as smallholders, women, youth, conflict-affected people and refugees, elderly, disabled people, lower castes, religious and ethnic minorities as well as indigenous groups (McShane et al., 2011; Adams et al., 2014; Ellis et al., 2019). While Principle 8 shares thematic similarities with Principle 3 (ethical and equitable innovation processes), ethics and equity are also important as outcomes of innovation.

Human rights as well as safe and healthy working conditions are among the direct and indirect prerequisites for achieving all food system outcomes (Anderson, 2008) and innovation contributing to SAFS must therefore abide by them (Caron et al., 2018). Though, despite the transformative potential of national and international human rights systems, in practice, they are still not strong enough to effectively protect various agrifood actors from harm, especially from non-state actors (Kennedy and Liljeblad, 2016). This deficit is evident in the increasing precariousness of employment conditions in the agrifood sector which is closely linked to value chain power dynamics (Malanski et al., 2022a). Resultingly, innovations must consider how they are contributing to or affecting human rights and working conditions, both directly and indirectly.

Power imbalances between groups significantly influence decisions within agrifood systems including on innovations' risks, benefits, and associated decision-making power (Davila and Dyball, 2017). Therefore, innovations need to address inherited privileges and discursive disadvantages among the target population – and the intersectionality of these – including on economic, geographic, demographic, and other social levels (Allen, 2010; Kepkiewicz et al., 2015). Without these considerations, there is a considerable risk of agrifood systems transformation being carried out 'on the backs' of the poor and other marginalized groups (Mustafa et al., 2021; Davis et al., 2022). Currently, global value chains shift power away from local producers and toward retailers and supermarkets, mostly by establishing market standards (Barrett et al., 2020; Malanski et al., 2022a,b). Deliberately addressing power differences (e.g., in the household) makes agricultural interventions more impactful in various areas (Gillespie and van den Bold, 2017). Innovations and their complementary resources, such as access to land and markets, must therefore be created and distributed in a way that is accessible to low-income and other vulnerable populations (WRI, 2018). Inclusive innovation can help people escape intergenerational cycles of poverty, hunger, and malnutrition and contribute to education and political stability (Fan and Swinnen, 2020).

Animal welfare is another ethics-related outcome of agrifood systems with links to the sustainability and customer acceptability of a product (Blokhuis et al., 2019; Willett et al., 2019). Across all types of animal production systems, harmful conditions continue to constitute a problem despite the existence of protocols and indicators to monitor and avoid these (Fraser, 2008; Buller et al., 2020). Production in all countries can benefit from changes and innovations to alleviate poor conditions for animals (Temple and Manteca, 2020). While digital technologies hold promises in this areas, current animal welfare innovations still tend to put too much emphasis on physical health and productivity (Buller et al., 2020). The sustainability effects of related innovations are complex and need to be analyzed from an agrifood systems perspective (Broom, 2019).

6. Operationalizing the principles

Clear, simple, and straightforward operationalization is essential for ensuring a set of principles becomes a tool that facilitates transformational change. Current principles often do not overcome the status of a declaration of intent (Losch, 2022). Even in cases where organizations endorse principles or guidelines, without clear support and guidance on how to apply these in real work contexts, there is a risk that the principles will sit idle.

To solidify the link between theoretical guidelines and operationalized practice, the Taskforce developed a tool for operationalizing PARI. Three criteria were stipulated; the tool must allow for (1) an assessment of progress within any project or workstream, (2) a comparison across possible innovation options for strategic decision making, and (3) (in the longer term) benchmarking of one organization or company against others. To meet the first two criteria, PARI users must be able to assess their innovations against each principle. For the third, it must allow external users to conduct or review those assessments in a replicable manner. Adding to these criteria, the Taskforce called for guidance on addressing unintended consequences and trade-offs between principles, which was directly integrated as a principle of its own (Zurek et al., 2022b). Following this, the Taskforce developed a scoring system to support the integration of PARI into key decision-making processes. The scoring system allows users to assess the degree to which a (sub-)principle has been successfully applied to their innovation. To further assist users, the system is complemented by supporting documents, including a detailed step-by-step guide, a glossary, and a scoring template (CoSAI Secretariat, 2023).

Inspired by the scoring guideline of the Food and Agriculture Benchmark from the World Benchmarking Association (WBA, 2021), the Taskforce chose a four-step scoring system (0, 1, 2, 3) where each (sub-)principle is scored individually. Higher scores imply a more thorough and evidenced application of the (sub-)principles'

TABLE 1 Scoring system to assess the implementation of principles by an innovator/organization (CoSAI Secretariat, 2022).

Score	Level of implementation
0	No evidence that action has been taken to implement the principle.
1	*Some activities have been carried out in line with the principle*, but these are insufficient to justify a score of 2.
2	There is evidence that activities have been carried out in line with the principle and its sub-principles. *Information on the issues has been regularly and systematically collected and analyzed.*
3	There is evidence that activities have been carried out in line with the principle and its sub-principles. Information on the issues has been regularly and systematically collected and analyzed and *needed changes have been implemented.*

components. The lowest score (0) signifies that 'no action has been taken in implementing the (sub-)principle', while the highest score (3) indicates that all activities align with the (sub-)principle and are evidenced (Table 1). To achieve a score of 3, information on the innovation's application of the (sub-)principle must be regularly and systematically collected and analyzed and all needed changes must already be implemented at the point of scoring.

The overall score for a principle is the lowest *non-zero* score of all relevant sub-principles (e.g., if sub-principles are scored at 2 and 3, the overall score for that principle will be 2). However, if one of the sub-principles is scored zero, the overall score cannot be higher than 1 (e.g., if sub-principles are scored at 0, 2 and 3, the overall score for that principle will be 1).[10]

With guidance from the scoring template, users conduct the scoring using evidence from their innovation processes. This helps determine the degree to which a (sub-)principle has been fulfilled. Irrelevant sub-principles can be omitted from the scoring process if users are able to justify that choice and support it with evidence.

The scoring process helps users identify specific process or outcome areas that can be improved or where they require additional evidence (as the basis for any score higher than 1). Through iterative scoring, PARI become a potent management tool for course corrections over an innovation's project cycle. Users are guided to apply PARI from the ideation and design stages onwards and thereafter at strategic points (e.g., mid-term review, ex-post evaluation) depending on project duration and other characteristics.

The step-by-step guide (CoSAI Secretariat, 2023) informs users on additional aspects of PARI's application, such as the right assessment level (i.e., when the scope of a project is too narrow or too broad). It also includes a glossary, a frequently asked questions section, and introduces the *score aggregation* feature in more detail which is particularly relevant for integrating PARI on the level of organizations or larger programs. The latter aggregates scores from a selected number of projects where each principle is weighted proportionally to project budgets.

The scoring system and supporting documents form the overall operational approach of PARI. They guide individuals in organizations or companies pursuing agrifood innovation to apply each principle in the context of their work. These materials are essential to concretely transform operational practice. Nonetheless, it is the uptake of PARI in the sector that is pivotal for impact and requires further reflection and recommendations.

7. Actionable recommendations

Because CoSAI was an ephemeral Commission, ending in 2021, a new champion agency is required for improving PARI and for upscaling their use. Without a clear champion, there is a risk that PARI will only be adopted sporadically by individual organizations. Here, several recommendations for upscaling the use of PARI are presented.

An agreement to champion PARI, by an agency or set of agencies, is required to take them forward. Ideally, this should be an organization with a wide reach in the agrifood sector, convening power across relevant stakeholders, a long-term and normative mandate, and expertise in setting standards. United Nations organizations such as the Food and Agriculture Organization (FAO) would be suitable here, particularly because FAO already champions other Principles for the agriculture sector.[11] Other potential champions include organizations like CGIAR, which could bring together various research investors and innovators interested in the Global South, or the World Business Council for Sustainable Development (WBCSD), which could convene large companies in the food and agriculture space.

A key priority for the new lead agency would be to link PARI to new initiatives on tracking agrifood innovation. Transparent tracking of investment in agrifood innovation can incentivize public and private sector investors to focus on developing sustainable innovations that support agreed global goals (Compton et al., 2022). A key undertaking in this space is FAO's new Agrifood Technology and Innovation Outlook (FAO, 2022). In addition, the World Benchmarking Alliance conducts the 'Food and Agriculture Benchmark' – an assessment process that seeks to stimulate major agrifood companies to choose sustainable business practices throughout their operations. The benchmark currently does not integrate parameters on innovation providing an opportunity for PARI to complement it in the future (WBA, 2021).

The new lead agency would also have to further demarcate PARI's potential role in relation to existing tools and approaches in the agrifood sector. It would also allow for a more in-depth justification of the choices made regarding sub-principles beyond their general importance as outlined in this article. For example, sustainable value chain (SVC) development similarly addresses complex systems and various sustainability dimensions (FAO, 2014). However, in practice it often suffers from the key problem that PARI addresses: the neglect

10 More information and examples of how to fill in the scoring template can be found under (CoSAI Secretariat, 2023).

11 For example, the Principles for Responsible Agricultural Investment (CFS, 2014).

of social and environmental objectives. The typical perspective on the immediate value chain of a particular product also tends to exclude elements and entire subjects that go beyond this scope. In contrast to PARI, SVC approaches also prioritize other procedural properties and mechanisms such as commercial viability, governance and behavior change as well as the upgrading of value chain components and scalability (FAO, 2014). Although PARI facilitates scalability by guiding innovations to intended impacts (e.g., Principle 1), it does not guide scaling directly and allows users to adapt the details of their assessment to the appropriate scale in their context. This also differentiates it from other tools that focus on interventions at specific scales such as Verra's LandScale that is fitted for landscape-level assessments (LandScale, 2023).

Adapting PARI for use in the planning and reporting systems of large organizations – including by actors less interested in systems approaches to sustainability – will require further piloting and adaptation. Piloting to date has informed considerable improvements to the principles, but it has mostly been limited to enthusiastic, small-scale users. In the future, there is a risk of losing cohesion and comparability as different organizations express their preferences in prioritizing principles over others and interpreting scores differently. When working with users to refine PARI, the new champion must ensure that principles will be coherently applied across user types while also responding to user demands.

Overall, upscaling PARI requires a new lead agency that defines PARI's position in relation to other tools and makes improvements based on piloting on a large scale. Further work is also needed in the implementation of a systems perspective and the provision of assessment metrics (see Section 8).

8. Discussion

Researchers and innovators in agrifood systems must undergo a major shift in managing and thinking about innovation. They need to internalize and operationalize a systems perspective that reconciles the conventional focus on productivity increases with environmental and social objectives. To address this, a diverse international Taskforce of experts developed a set of principles and a complementary scoring system. By accounting for innovation processes (in Principles 1 to 4) and outcomes (Principles 5 to 8), PARI can guide innovators, researchers, and related actors such as investors in actualizing innovations that enable a transformation toward SAFS. Various questions and issues arise from this work that will hopefully be taken forward by others.

PARI is a highly flexible tool that aims to support different agrifood system actors and functions for various innovation types, stages and contexts at different scales. This broad applicability is a strength of PARI that enables them to address complex systems, but it also carries risks. Various aspects will determine eventual impact including the availability of context-specific guidance on implementing a systems perspective and selecting metrics, sufficient transparency, as well as a balanced approach to complexity.

Taking an agrifood systems perspective and thus considering multiple outcomes of an innovation was one of the central themes in discussions by the Taskforce. Still, PARI does not prescribe a specific framework because – depending on the innovation context – different frameworks imply different functionalities when assisting innovators. The principles only facilitate the identification of interdependencies rather than directly identifying them for the user. Given the centrality of agrifood systems thinking within PARI, it needs to be considered that some innovation actors tend to think in more linear and siloed manners (den Boer et al., 2021). Lack of experience in applying agrifood systems thinking can therefore be an obstacle to PARI's uptake and implementation.[12] A potential solution for this issue is the development of more context-specific guidance on complementary agrifood systems tools.

At this stage, matching 'credible' metrics to the type and stage of an innovation can be difficult (i.e., Principle 2). Assessing developmental impacts of interventions in complex environments (e.g., by adding up small results within a value chain) often only provides anecdotal evidence (FAO, 2014). While there have been some useful attempts to develop metrics for agrifood research (Musumba et al., 2017) more work is needed. An initial collection of over 300 existing metrics (unpublished: Yicong Luo, pers. comm.) and an expert discussion convened by CoSAI confirmed the lack of standards in this area as well as gaps in the areas of financial, policy and institutional innovations. A diversity of metrics is needed to cover various types and objectives of innovation at different stages and scales as well as from multiple stakeholder viewpoints, and with different levels of resources available for measurement. Ideally, users of PARI could choose from a large set of recommended metrics in order to monitor the four agrifood system outcome areas (Principles 5 to 8).[13] Individual indicators for each category of metrics could be flexible and tailored to organizational needs and data availability.

Another challenge is to establish sufficient transparency (Principle 2) among innovation-related actors that use PARI. When considering all four types of outcomes in agrifood systems, decisions on trade-offs are highly likely. Being transparent about why one domain has been prioritized over another can be challenging as actors usually have little incentives to elucidate negative aspects of their work. To the contrary, there is a lot of pressure to report positively on sustainability aspects depending on institutional, cultural and legal norms which may lead to 'greenwashing' (Coelho, 2023). Transparency in decision making is however of critical importance for PARI and, generally, for ensuring favorable outcomes for those affected by an innovation in the long term. As pointed out by Mausch et al. (2020), it is important to clarify societal values and thus the priorities given to certain principles, since trade-offs are inherent in the process of developing innovations.

When addressing the complexity and uncertainty regarding potential outcomes, relevant actors need to overcome the increased risk of 'paralysis by analysis' and be aware that accounting for multiple goals tends to make innovation processes and their management more complex, time consuming and onerous. PARI needs to tap into mechanisms that make the assessment process as accessible and straightforward as possible without reducing complexity to an extent that undermines functionality.

12 This limitation extends to trade-off analyses recommended under Principle 4.

13 The idea of a small set of high-level metrics may be attractive but assuming causality between an innovation and a high-level outcome (e.g., district-level poverty) is problematic.

The complexity of interdependencies furthermore poses the question whether innovators should only `consider' the potential unintended consequences or whether they also have to ensure they `do no harm' (possibly integrating mitigation measures). For either option, establishing practical processes and monitoring frameworks for organizations and companies needs careful consideration.

As discussed by the Taskforce, having a single index for PARI would allow actors to compare various innovations more easily (or projects that include several innovations) and thus, simplify the identification of those innovations with the highest potential for sustainable impact. However, aggregating scores across principles masks details that can contribute to an informed decision (e.g., specific strengths and weaknesses as indicated by individual principles). In addition, the question of how to aggregate the scores of distinct principles has no clear answer. Would organizations that prioritize certain (sub-)principles apply different weightings? There is a clear need for further reflection in this area.

The challenge of encouraging wider adoption of PARI needs further deliberation and other barriers will have to be explored along the way. Their integration into planning and decision-making processes will not be easy as current innovators typically do not apply a systems perspective. PARI are a promising tool in this space.

Author contributions

MZ led the writing efforts together with JW and JC and all provided substantial research and writing. AH and SC also contributed substantial research and writing while PL and PVVP co-chaired the TaskForce and provided comments and direction. PT and MH provided comments. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

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