Commentary

Research and Innovation as a Catalyst for Food System Transformation

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Abstract

Background: Food systems are associated with severe and persistent problems worldwide. Governance approaches aiming to foster sustainable transformation of food systems face several challenges due to the complex nature of food systems.

Scope and Approach: In this commentary we argue that addressing these governance challenges requires the development and adoption of novel research and innovation (R&I) approaches that will provide evidence to inform food system transformation and will serve as catalysts for change. We first elaborate on the complexity of food systems (transformation) and stress the need to move beyond traditional linear R&I approaches to be able to respond to persistent problems that affect food systems. Though integrated

transdisciplinary approaches are promising, current R&I systems do not sufficiently support such endeavors. As such, we argue, we need strategies that trigger a double transformation – of food systems and of their R&I systems.

Key Findings and Conclusions: Seizing the opportunities to transform R&I systems has implications for how research is done – pointing to the need for competence development among researchers, policy makers and society in general – and requires specific governance interventions that stimulate a systemic approach. Such interventions should foster transdisciplinary and transformative research agendas that stimulate portfolios of projects that will reinforce one another, and stimulate innovative experiments to shape conditions for systemic change. In short, a thorough rethinking of the role of R&I as well as how it is funded is a crucial step towards the development of the integrative policies that are necessary to engender systemic change – in the food system and beyond.

Key words: *Food system transformation, Complexity, Research & Innovation systems, Transdisciplinarity, Governance interventions, Competence building*

1. Introduction

Food systems evolved successfully during the 20th century in response to the growing and changing demand for food but are currently associated with severe and persistent problems worldwide. These include, inter alia, diet-related poor health outcomes, high greenhouse gas emissions, environmental degradation, biodiversity loss, and food losses and waste (Table 1). These problems are amplified by long-term drivers of change, such as climate change, urbanisation, population growth, and consumerism (Haddad, et al. (2016). Responding to these intertwined dynamics is critical to achieve the United Nation's Sustainable Development Goals (SDGs) and the targets of the Paris Climate Agreement (Caron et al., 2018) and points to the need to combine all possible levers to foster transformation (Editorial, 2019). But implementing effective intervention strategies is challenging: though food systems are linked globally, many challenges and solutions are context-dependent and there are differences between the global North and the global South, as well as between urban and rural areas (Willet et al., 2019). Hence, there are no blueprint interventions in food systems that work towards the SDGs, even though food systems are interconnected globally. Furthermore, governance approaches that foster sustainable transformation face challenges due to the complex nature of food systems. Major challenges include increasingly problematic trade-offs and interdependencies within and beyond food systems, difficulties in integrating and aligning responses at different scale levels, conflicting values and interests, and problematic power imbalances (Moragues-Faus, Sonnino & Marsden, 2017).

Table 1. Persistent challenges in the food system worldwide.

Persistent challenges	Evidence (worldwide)
Undernourishment	821 million in 2019 (FAO, IFAD, UNICEF, WFP & WHO, 2019)
Adult obesity	Over 600 million (13.2%) in 2016 (FAO, IFAD, UNICEF, WFP & WHO, 2017)
Childhood overweight and obesity	40 million children under five were overweight in 2018 (FAO, IFAD, UNICEF, WFP & WHO, 2017)

Greenhouse gas emissions	21-37% of total net anthropogenic greenhouse gas emissions (IPCC, 2019)
Water scarcity	Agriculture's share of water usage: 75–84% (Wada, van Beek & Bierkens, 2011)
Biodiversity loss	16.5% of vertebrates and pollinators threatened with extinction (FAO, 2011)
Food losses and waste	1.3 million tons yearly (Gustavsson, Cederberg, Sonesson, Otterdijk & van Meybeck, 2011)

Addressing these governance challenges requires the development and adoption of novel research and innovation (R&I) approaches that will provide evidence to inform food system transformation and will serve as catalysts for change (Gill et al., 2018). Such R&I approaches should move beyond a narrow focus on production or consumption to embrace complexity and account for different actors, sectors, governance levels, and academic and policy fields. In short, we argue that to deliver a 'Great Food System Transformation', as referred to by the EAT-Lancet Commission (Willett et al., 2019), R&I systems need to be changed fundamentally as well.

In this paper, we will first elaborate on the complex nature of food systems and their transformations. Then we will discuss what kind of R&I efforts can serve as catalysts for enabling food system transformation and will also explain why current R&I systems do not sufficiently support these efforts. We will conclude by highlighting some implications for research practice and governance.

2. Complex Food System Transformation

Food systems are increasingly conceptualised as complex systems (Zhang et al., 2018) comprising multiple actors (e.g., consumers, policymakers, farmers, researchers, industry), encompassing multiple processes and practices (e.g., food production, processing, packaging, distribution, consumption), spanning multiple policy sectors (e.g., agriculture, environment, health), and having multiple societal functions (e.g., food security, welfare, environmental conservation) that are connected at and between multiple governance levels (e.g., local, regional, national, global). As defined by the EC FOOD 2030 Expert Group (2018), food systems can thus be conceptualised as incorporating *"all elements and activities that relate to the production, processing, distribution, preparation and consumption of food, as well as its disposal. This includes the environment, people, processes, infrastructure, institutions and the effects of their activities on our society, economy, landscape and climate"*. The interactions between all these elements are key to understanding food system dynamics (Ingram, 2011). Acknowledging the fundamentally complex interactions between food system components means moving beyond both linear and circular conceptualisations of food systems, such as the value chain, the supply chain, or food-cycle conceptualisations, which do not adequately capture the complex dynamics of food systems (Ingram,

2011; HLPE, 2014; Jagustović et al., 2019). These different 'modes' of thinking about systemic structure and dynamics are depicted in Figure 1.

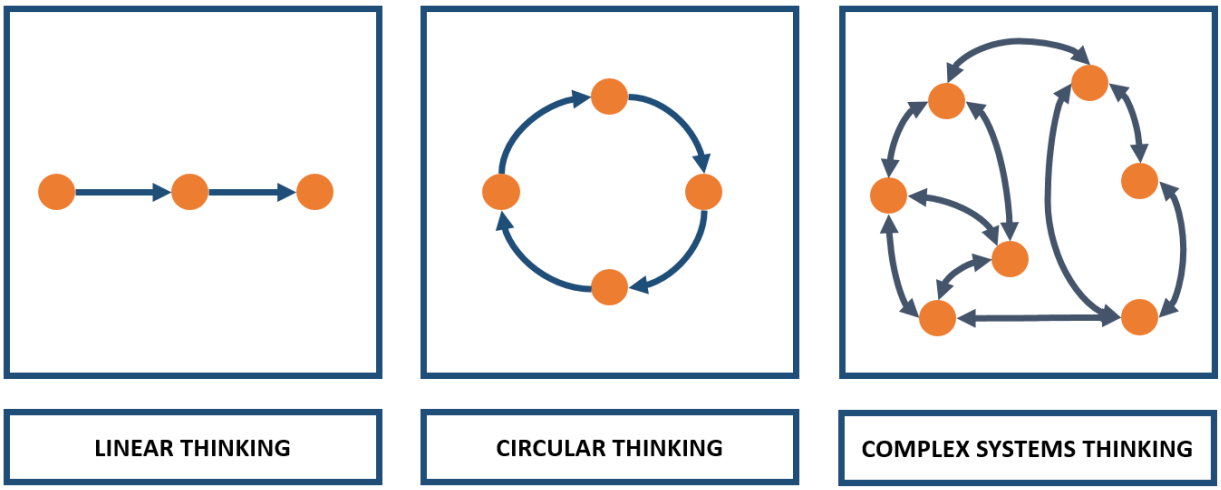

Figure 1. Schematic depiction of conceptualisations of food systems representing different modes of thinking about the structure and dynamics of food systems.

Although there are many views on what exactly constitutes a 'complex system' (Ladyman, Lambert & Wiesner, 2013), it is generally recognised that 'complex systems thinking' emphasises (1) the dynamics of the system as being emergent, meaning that one needs to consider the behavioural complexity of the whole system rather than focusing on its constituent components (Behl & Ferreira, 2014), and (2) the interrelatedness of components and processes in the system that result in (responsive) non-linear dynamics (Jagustović et al., 2019). Applying complex systems thinking to food allows for the identification of non-linear dynamics between different elements in food systems, such as systemic feedback loops, that can generate synergies but also trade-offs and, subsequently, unintended consequences of specific (policy) interventions (Zhang et al., 2018; Oliver et al., 2018). An example of such a complex trade-off is competition for land use between agricultural, social, and economic needs, while implicating the environment too (EEA, 2017).

Complex characterisations of food systems also encompass their *"undesirable resilience"*, whereby dominant regimes and unsustainable system configurations tend to reproduce themselves into *locked-in* states, making sustainable transformation difficult (Geels, 2002; Grin, Rotmans & Schot, 2010). It is increasingly being recognised that both inertia and transformative dynamics in food systems are co-shaped by power relations in the system (Grin et al., 2010; Spaargaren, Oosterveer & Loeber, 2013; Rossi, Bui & Marsden, 2019). Problematic power imbalances can further reinforce vested interests and status quo configurations (Grin et al., 2010; Avelino & Rotmans, 2009) . This, for instance, entails a shift in power from primary producers to input providers (seed, fertiliser and pesticide manufacturers), food companies, and retailers (Rayner, Barling & Lang, 2008), allowing retailers and supermarkets to *"dictate the terms of contracts and act as gatekeepers to (and by implication buyers for) the large majority of food consumers*" (Rayner et al., p. 155).

These complexities call for the development, implementation and evaluation of integrated governance strategies. There are many different definitions of governance (see also Kooiman, 1999), and we understand governance to refer to the *"ensemble of rules, processes, and instruments that structure the interactions between public and/or private entities to realise collective goals"* (Termeer et al., 2011: 161). This means that governance moves beyond 'formal arrangements by governments', but includes the collaborative efforts of networks of government agencies, societal stakeholders and private entities at and across (local, regional, national, supranational) governance levels. Multi-level governance efforts are needed to develop integrated food policies that can mitigate negative trade-offs, while enhancing synergies between different sectors and policy fields (Moragues-Faus, Sonnino & Marsden, 2017; Parsons & Hawkes, 2018; SAPEA, 2020). As Candel and Pereira (2017: 89) explain, while in the past *"food policy was primarily used to indicate the whole range of policy efforts that affect food system outcomes", today the notion has more and more come to be used to emphasize the need for integrative strategies that align these policy efforts into a concerted whole".* Food policy integration also raises the need for novel ways of using and combining policy instruments in policy mixes for food system transformation (Galli et al., 2020). A concrete examples of such interventions is the development of urban and regional Food Policy Councils (FPCs) that aim to integrate and develop holistic local food policies by fostering collaboration between a range of stakeholders (Mendes & Sonnino, 2018).

To be able to transform and future-proof complex food systems through integrated governance interventions, it is necessary to better understand the technological, biophysical, political, economic and social dimensions of the dynamics that shape food systems and to identify the *leverage points* where intervention will be most effective. Identifying these points requires a systemic approach that takes into account multiple actors, governance levels, and policy fields (EEA, 2017), which also raises the need for novel transformative R&I policies and strategies (Schot & Steinmuller, 2018). R&I efforts are of paramount importance to identify systemic interdependencies, lock-ins, as well as possible solutions and leverage points. Indeed, the R&I system can act as a catalyst in shaping future food systems, provided that R&I (policy) efforts are aligned and well equipped to contribute effectively to complex food system transformations. As addressing complexity implies moving away from "one size fits all" solutions and considering contextual specificity, designing and implementing transformative pathways are knowledge intensive processes calling for original learning approaches that embed scientific knowledge into local innovation systems (Caron et al., 2014).

3. What Kind of R&I Do We Need for Food System Transformation?

The urgent problems in food systems and associated governance challenges point to the need to develop and adopt R&I approaches that embrace complexity and stimulate different ways of knowledge production and usage. Recently, Schmidt-Traub, Obersteiner and Mosnier (2019) argued that we could ''fix the broken food system'' by developing integrated approaches that simultaneously consider the following: *1) Efficient and resilient agriculture systems, 2) Conservation and restoration of biodiversity, and 3) Food security and healthy diets.* Such integrated approaches should stimulate (global) coordination and knowledge sharing between different scientific and technical communities, aligning and integrating different methods, models, and tools. As several scholars have recently highlighted (Abson et al., 2017;

Boström et al., 2018), experimenting with such approaches can help us to learn how to stimulate transformative change.

We argue that such integrated approaches need to be even more ambitious if food system transformation is to be achieved. Embracing complexity not only requires a shift from mono- and multidisciplinary research approaches towards interdisciplinary ones; it also requires a shift towards trans-disciplinary research approaches (Figure 2) that are action- and solution-oriented, bring together different epistemics or communities of knowledge (including non-academic actors such as policymakers, entrepreneurs, civil society organisations, farmers, and citizens), and form a 'real-world laboratory' for experimentation (Luederitz et al., 2017).

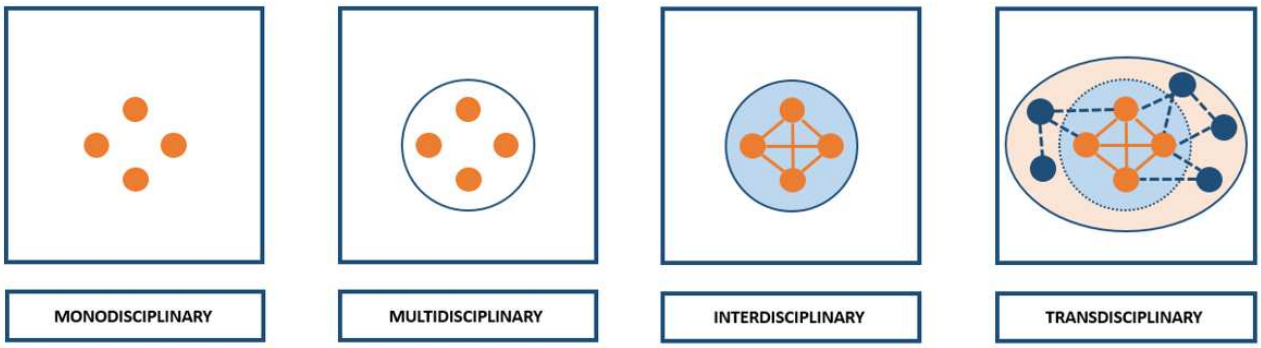

Figure 2. From mono-, multi-, and interdisciplinary approaches towards holistic transdisciplinary research and innovative approaches to systemic food system transformation.

Bringing together different types of actors is essential to understand a system and focus on solutions and the implementation of change via processes of knowledge co-creation (Fazey et al., 2018; Abson et al., 2017). Strong R&I frameworks based on holistic and participatory approaches involving all stakeholders may help to identify opportunities but also vulnerabilities nested in the system, which are vital starting points from which to formulate resilience strategies (FAO, 2014). Furthermore, transdisciplinary approaches ideally provide space for underrepresented actors and their perspectives (Abson et al., 2017) and stimulate processes of individual and collective transformative learning (Luederitz et al., 2017), which are crucial to unlock inertia and, consequently, to accelerate food system transformation (Boström et al., 2018). An example of a real-world laboratory that aims to work as an incubator for innovation at the city level is the so-called 'Urban Transition Lab' (Nevens et al., 2012), which focuses on transdisciplinary research approaches to stimulate learning and reflexivity among a diverse range of actors. System analysis, visioning and an investigation of how different multi-level interventions might result in synergies or trade-offs form key activities within Urban Transition Labs, which essentially function as governance experiments focused on long-term envisioning as well as actual multi-actor experimentation for transformation (Nevens et al., 2012). Although research is needed to investigate the long-term impact of such real-world laboratories, studies already point out that those urban experiments contribute to more sustainable structures, cultures and practices within cities, by spreading knowledge, innovative practices and potential solutions beyond the labs' boundaries (e.g. by initiating spin-offs elsewhere and spreading innovative business models) (von Wirth et al., 2019).

Multi-actor experimentation also becomes visible within specific types of innovative initiatives for food system transformation, such as the Italian Solidarity Purchasing Groups (GAS, *'Gruppi di acquisto solidale*') (Grasseni & Hankins, 2014). These are fluid networks in which different types of actors co-design and co-create new systems of food provisioning that stimulate short supply chains and local food production. Through initiatives of this kind, citizens are encouraged to adopt active roles in transforming their food systems. Finally, socio-technical innovations can also originate from transdisciplinary or collaborative efforts. For instance, in the Netherlands collaborations between farmers, architects, animal welfare consultants, policy makers and researchers has led to the development of novel poultry husbandry systems (the *Roundel* hen housing system) that were designed to be more sustainable and animal-friendly than the conventional ones. The collaborative process behind these initiatives was facilitated through the methods of reflexive interactive design, which, again, confirms the importance of fostering reflexive learning amongst stakeholders (Groot Koerkamp & Bos, 2008).

4. Challenges of Current R&I Strategies

Conventional R&I systems fail to adequately respond to urgent systemic challenges in food systems precisely because they do not support transdisciplinarity (Gill et al., 2018). We provide below a non-exhaustive overview of limitations of current R&I systems, pointing to three issues that need to be addressed to maximise the potential of R&I systems as levers for food system transformation.

First, the food system R&I landscape is highly fragmented with regard to the scientific as well as the policy domain (SCAR, 2018; Serraj & Pingali, 2019; Reardon et al., 2019). So far, linear and siloed R&I efforts have contributed to improving specific parts of the food system, such as agricultural production and food safety, but have largely failed to offer solutions to persistent problems that affect food systems due to their lack of engagement with trade-offs, unforeseen and undesired side-effects, and systemic feedback loops (Zhang et al., 2018).

Second, R&I (funding) structures are not well aligned; indeed, investments are distributed unevenly across sectors and disciplines and there is a lack of incentives to develop holistic, integrated R&I approaches. A disproportionally high proportion of public R&I investments are directed towards production processes and food security (SCAR, 2018), while other parts of food systems, such as logistics and consumption, are underrepresented (Pray & Fuglie, 2015). Private investment, although considerable, is also fragmented, and investment in integrated food systems approaches is modest (Serraj & Pingali, 2019). Moreover, public and private funding are often not well aligned (Pray & Figlie, 2015; EC 2030 Expert Group, 2016) and they often fail to invest in the interconnectedness between the different elements within food systems (Haddad et al., 2016). As a result, R&I input is too low, especially when it comes to food consumption and healthy diets (Haddad et al., 2016), food waste, and distribution processes – including their interactions with production processes – and the impact of these diets and processes on the ecological, economic, and social dimensions of sustainability. In addition, academic incentive structures often do not support or reward integrated transdisciplinary research efforts that cross sectoral and disciplinary boundaries (FEC, 2015).

Third, R&I processes are traditionally the realm of researchers and policymakers, with an increasing involvement of industry actors – the so-called Triple Helix (Etzkowitz & Leydesdorff, 2000). Active involvement of societal stakeholders such as citizens, civil society organisations (CSOs), farmers, teachers, and consumers (FEC, 2015), who co-constitute the Quadruple Helix (Carayannis & Campbell, 2010), is rare and is often given low priority (EC 2030 Expert Group, 2018). Given these actors' central role in food systems and the importance of understanding the different values and perceptions within these systems, it is important to actively engage them in food system R&I (SCAR, 2018). This raises the need for a better understanding of how to organise and stimulate stakeholder interactions during the research process and how to interpret the outcomes of these interactions (FEC, 2018).

5. Connecting Food Research and Policy

Given the above-mentioned limitations, we need strategies that will trigger a *double* transformation – of the food systems *and* of their R&I systems (Kok et al., 2019). Seizing the opportunities to transform R&I systems, we argue, has implications for research practice (how research is done) and requires specific governance interventions.

5.1 Research Practices and Competence Building

As mentioned earlier, transdisciplinary R&I approaches to food system transformation are fundamentally different from linear and disciplinary approaches, and this raises the need for a different type of R&I organisation (Boström et al., 2018; Luederitz et al., 2017). In practice, knowledge integration and engaged stakeholder collaboration are challenging; what knowledge is actually needed and legitimate, which stakeholders need to be involved at what stages of the research process, and which methodologies or strategies would be most effective to stimulate knowledge co-production and transformative learning (Abson et al., 2017) are issues that cannot be properly addressed without a thorough rethinking of the role of researchers and the role of science more generally. Examples of roles other than that of 'traditional scientist' include 'change agent' (actual normative participation of researchers to stimulate change in practice), 'knowledge broker' (intermediation between different epistemics), and 'reflexive process facilitator' (the facilitation of transformative learning) (Fazey et al., 2018; Wittmayer & Schäpke, 2014) – these are all roles that can be interpreted differently when applied in practice and can entail different (and even conflicting) expectations. The fact that such roles require specific organisational and inter-personal competences in terms of attitude, knowledge, and skills (Mauser et al., 2013), especially for practitioners managing innovative R&I and governance experiments, adds to the difficulty of adopting them in real-world situations (Nevens et al., 2012).

Recently, several projects have been developed that aim to contribute to competence building. For example, the IFSTAL project (Innovative Food Systems Training and Learning) has been training postgraduate students in 'food systems thinking' since 2015 in a cross-disciplinary multi-university program in the United Kingdom (Ingram et al., 2020). Another example is the Horizon2020 FIT4FOOD2030 project, that has established 14 City and Food Labs in European cities and regions. In these Labs, food system stakeholders have co-created and tested educational modules for different audiences (citizens,

professionals, students, school children), which aim to contribute to competence development in food system thinking and transdisciplinary research (Kok et al., 2019).

To be able to stimulate researchers to adopt such new roles and engage in novel R&I approaches to food system transformation, there is a need for a paradigm shift within the research and education communities (O'Brien et al., 2013) but also within the policy community and wider society. A first vital step towards this is competence building for researchers, policymakers, and society in general.

5.2 Research Programmes and Funding

Several governance intervention strategies can be utilised to reorientate R&I systems towards food system transformation and to create an enabling context for transdisciplinary research approaches.

1. *Fostering transdisciplinary research*. Alongside traditional R&I, there is a need to develop transdisciplinary research approaches by investing in the creation of meaningful interactions between researchers, societal actors, and policymakers, but also by stimulating different academic incentive structures. For example, to stimulate changes in food consumption practices, R&I should not only focus on individual factors but also on contextual factors (in particular the dynamics that shape food environments) and policy factors (Gill et al., 2018). Such transdisciplinary research is crucial to build an evidence base for the development of integrative food policies that embrace the entire food system and calls for strong *investment in the social sciences*. Large-scale transformations cannot be achieved exclusively through technological investment. The production of knowledge on the interplay between technological, social, economic, cultural, and political factors is vital to understand and govern complex societal systems. Furthermore, social sciences can help to articulate dilemmas and formulate policy recommendations to mitigate negative effects of trade-offs in future pathways for transformation. This also requires fostering R&I programmes and collaborations that aim to bridge the gap between 'hard' and 'soft' (or quantitative and qualitative) approaches in food systems research (Jansen, 2009). For example, systems-modelling approaches, such as agent-based modelling, are important tools for assessing the impact of policies and interventions that aim to change consumption practices and could complement traditional and transdisciplinary research approaches.

2. *Fostering transformative research agendas*. Both private and public funders can support the transformative potential of food systems R&I by establishing more integrated transdisciplinary and mission-driven R&I funding programmes. Novel funding programmes need to go beyond the basic idea of funding individual transdisciplinary research projects and stimulate *portfolios of projects* that will reinforce one another over time, at different governance levels and with regard to different sectors and thematic (policy) fields. A promising example of an integrated food systems R&I approach is nutrition-sensitive agriculture (NSA), which focuses on the different pathways through which agriculture can influence the underlying determinants of nutrition

outcomes. NSA practices are characterized by the engagement of different types of actors and by a systemic perspective to account for the substantial impact of contexutual factors on the relationship between agriculture and nutrition outcomes (Ruel, Quisnumbing & Balagamwala, 2018). Fostering transformative research agendas includes expanding research on integrated food systems approaches such as NSA to create more empirical evidence with regard to processes and outcomes. This is important not just to progress research on sustainability, impact at scale and cost-effectiveness, but also to explore how these integrated approaches could stimulate effective food system governance by informing integrated food policies and funding schemes (Ruel, Quisnumbing & Balagamwala, 2018). Stimulating integrated food systems R&I approaches calls for creating more (free from conflict of interest) public–private partnerships that would provide an opportunity to better align public and private funding efforts (Townsend et al., 2018). However, since issues that attract a high level of public interest do not always attract private sector investment (Serraj & Fuglie, 2015; Heisey & Fuglie, 2018) it is of crucial importance to *build strong and independent public R&I systems* that can address market and system failures and engage with dominant and established pathways that are difficult to transform (FEC, 2018). Connecting and aligning R&I policies and experimenting with novel funding programs is happening, for instance, within the context of the EU FIT4FOOD2030 project. In experimenting, at the same time, with novel ways of funding and doing R&I for food system transformation, 'Policy Labs' are adopting co-creation methods with a wide variety of stakeholders in 11 EU member states (Kok et al., 2019).

3. *Stimulating innovative experiments*. Public institutions need to find ways to combine top-down policy pathways with bottom-up experimentation to shape conditions for systemic change. The latter can be stimulated through approaches such as strategic niche management (Schot & Geels, 2008) and transition management (Loorbach, 2007) that focus on creating space for novel innovations, enable learning between diverse multi-stakeholder groups, and explore future pathways for system transformation. The worldwide rise in food policy networks, including multi-stakeholder food policy councils, is an example of innovative experiments that need to be supported because of their potential to link bottom-up initiatives with evidence-based food policies (Sonnino, Tegoni & De Cunto, 2019). R&I has an important role to play in fostering the inclusiveness and effectiveness of innovative food system governance experiments such as food policy councils and real-world laboratories via participative monitoring and evaluation efforts. This is key to be able to scale-up learning experiences, connect local experiments with each other and with higher governance scales and inspire the collaborative design and implementation of effective multi-level interventions and integrated food policies (Sonnino et al., 2019; Gupta et al., 2018; Nevens et al., 2012.).

6. Concluding Remarks

R&I could be a catalyst for a much-needed food system transformation, especially in situations of great uncertainty, like the one generated by the COVID-19 pandemy, when exploring all possible future lies at the heart of innovative transformation. Yet, releasing its potential requires moving beyond traditional

approaches that, although valuable from a sectoral perspective, have shown substantial limitations when responding to some persistent problems that affect food systems. Against this background, in this paper we have explored issues that need to be addressed to develop more transdisciplinary and transformative R&I efforts and governance interventions that we consider necessary to support such efforts. The transformation of the food system, like the transformation of any complex system, offers an exciting opportunity for crossing the boundaries within and between science, policy, and society. A thorough rethinking of the role of R&I is a crucial step towards the development of the integrative policies that are necessary to engender systemic change – in the food system and beyond.

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