Agricultural Systems 184 (2020) 102901

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Perspectives

Supporting food systems transformation: The what, why, who, where and how of mission-oriented agricultural innovation systems

Laurens Klerkx*, Stephanie Begemann

Knowledge, Technology and Innovation Group, Wageningen University, the Netherlands

ARTICLE INFO

Keywords:
Sustainability transitions
Food systems transformation
Mission-oriented innovation policy
Mission-oriented innovation systems
Directionality
Agricultural knowledge and innovation systems (AKIS)
Multi-sector interaction

ABSTRACT

Agricultural innovation systems has become a popular approach to understand and facilitate agricultural innovation. However, there is often no explicit reflection on the role of agricultural innovation systems in food systems transformation and how they relate to transformative concepts and visions (e.g. agroecology, digital agriculture, Agriculture 4.0, AgTech and FoodTech, vertical agriculture, protein transitions). To support such reflection we elaborate on the importance of a mission-oriented perspective on agricultural innovation systems. We review pertinent literature from innovation, transition and policy sciences, and argue that a mission-oriented agricultural innovation systems (MAIS) approach can help understand how agricultural innovation systems at different geographical scales develop to enable food systems transformation, in terms of forces, catalysts, and barriers in transformative food systems change. Focus points can be in the mapping of missions and sub-missions of MAIS within and across countries, or understanding the drivers, networks, governance, theories of change, evolution and impacts of MAIS. Future work is needed on further conceptual and empirical development of MAIS and its connections with existing food systems transformation frameworks. Also, we argue that agricultural systems scholars and practitioners need to reflect on how the technologies and concepts they work on relate to MAIS, how these represent a particular directionality in innovation, and whether these also may support exnovation.

1. Introduction

Agricultural systems transformation and more broadly the food systems transformation to which this contributes, has been the subject of debate for several decades already (Dentoni et al., 2017; El Bilali, 2019a, 2019b; Elzen et al., 2012; Weber et al., 2020; Klerkx et al., 2010; Lamine, 2011). However, recent years show a rise in concerns of how to manage future food security and sustainability without compromising food safety (Vågsholm et al., 2020). This has generated a social momentum for change regarding food systems development with studies concluding that the food system is 'broken' (Oliver et al., 2018) and needs to be made 'planet-proof' (Fraser and Campbell, 2019; Rockström et al., 2020; Willett et al., 2019), 'circular', 'regenerative' and 'inclusive' (Gosnell et al., 2019; Pouw et al., 2019; Van Zanten et al., 2019).[1] Recent events such as the COVID-19 pandemic have catalysed such reflections (Baudron and Liégeois, 2020; Blay-Palmer et al., 2020;

* Corresponding author.
E-mail address: Laurens.Klerkx@wur.nl (L. Klerkx).

[1] Obviously, agriculture is also part of other systems, such as energy systems (e.g. biofuels), construction systems (e.g. biobased materials), and clothing/fashion systems (e.g. fibres such as cotton, hemp), with which it may be highly connected, but for these similar concerns have been raised (Allwood et al., 2006; Claudio, 2007; Laibach et al., 2019).

https://doi.org/10.1016/j.agsy.2020.102901
Received 10 June 2020; Received in revised form 2 July 2020; Accepted 3 July 2020
Available online 05 August 2020
0308-521X/

Kanter and Boza, 2020; Stephens et al., 2020). As a response to these calls to transformative action, there is increasing scientific reflection on how to shape future food systems and the technologies and concepts that would underpin future food systems (Herrero et al., 2020; Kirova et al., 2019; Klerkx and Rose, 2020; Mier et al., 2018; Tittonell, 2014).[2]

In order to realize future food systems, there is a key role for agricultural innovation systems (AIS).[3] An AIS is concerned with the networks of actors from science, business, civil society, and government that co-produce the suite of technological, social, and institutional innovations that co-shape these future food systems (Gaitán-Cremaschi et al., 2019; Herrero et al., 2020; Mier et al., 2018). Many of the future food systems envision novel forms of agriculture (e.g. urban farming, vertical agriculture, cellular agriculture), which deviate substantially from the current systems which are usually land-based and in rural areas. Therefore, an AIS increasingly incorporates actors from other sectors (e.g. information technology, energy, construction) and may employ a suite of generic technologies with applications in different sectors (e.g. solar energy generation, satellite technology, robot technology, nature based and ecologically regenerative solutions) (Andersen et al., 2020; Frantzeskaki, 2019; Laibach et al., 2019; Pigford et al., 2018; Tittonell, 2020). Also, it has been argued that agricultural innovation systems, in view of them supporting particular transition pathways towards future food systems, need to become 'mission-oriented' (Klerkx and Rose, 2020; Pigford et al., 2018). These missions need to tackle grand societal and planetary challenges, such as ecosystems integrity, biodiversity, climate change mitigation and adaptation as also comprised by the Sustainable Development Goals (Mazzucato et al., 2020).

The idea of mission orientation in innovation has become increasingly popular, and this has inspired concepts such as 'challenge-led innovation' and ' mission-oriented innovation policy' (Boon and Edler, 2018; Hekkert et al., 2020; Mazzucato, 2016; Rathenau Institute, 2020). Mission-oriented innovation policy brings together elements of innovation policy, which traditionally aims to create economic growth, and transition policy, which principally aims to create change that is beneficial for society at large (Alkemade et al., 2011; Schot and Steinmueller, 2018b; Rathenau Institute, 2020). In this way, mission-oriented innovation policy serves a clear transformative purpose and aspiration in view of realizing public goods such as a clean environment, biodiversity, animal welfare, and social justice (Hall and Dijkman, 2019; Pigford et al., 2018; Schlaile et al., 2017; Timmermann, 2021). Instead of focusing on single technological fields or disciplines, mission-oriented policies are targeting a concrete problem/challenge, often cross-disciplinary, with a large impact and a well-defined time frame (Wittmann et al., 2020). Also, there is a much stronger emphasis on directionality, to articulate the role of innovation and its contribution to a societal or environmental end (Boon and Edler, 2018; Janssen et al., 2020; Pigford et al., 2018; Schlaile et al., 2017; Rathenau Institute, 2020). This requires a more active and guiding role of the state with comprehensive innovation policies to govern innovation towards this end (Hekkert et al., 2020; Mazzucato, 2016). Moreover, state involvement moves from fixing market failure to shaping markets for societally relevant innovation and fixing directionality failures (Robinson and Mazzucato, 2019). In the mission-oriented innovation policy framework, roughly four basic principles are maintained (Mazzucato, 2016)[4]:

1. Clear direction-setting from the start.
2. A portfolio of innovation projects to embrace risks, failures and uncertainties.
3. Investments across different sectors by different types of actors (public, private and third sector actors across the innovation chain).
4. Joined up policymaking and reflexivity to avoid lock-in scenarios.[5]

The ideas on mission-oriented innovation are not completely new (Robinson and Mazzucato, 2019), and have been inspired by earlier mission-oriented programs such as those from NASA. In agriculture, missions have also played a role, such as those underpinning productivity growth and modernisation in view of the Green Revolution (Spiertz and Kropff, 2011; Wright, 2012). However, these missions were often seen from an agricultural science system perspective rather than an AIS perspective.[6] Combining the idea of mission-oriented innovation policy with the innovation systems perspective Hekkert et al. (2020) introduced the concept of 'mission-oriented innovation systems', an idea alluded to earlier also for AIS by Pigford et al. (2018). A mission-oriented innovation system is defined as "the network of agents and set of institutions that contribute to the development and diffusion of innovative solutions with the aim to define, pursue and complete a societal mission" (Hekkert et al., 2020:77). Steered by a clear directionality, it can be seen as "a temporary innovation system in which policy makers and other actors aim to coordinate innovation activities, with the objective of developing a coherent set of technological, institutional and behavioural solutions" (Hekkert et al., 2020: 78).

The concept of mission-oriented innovation systems can be used to critically reflect upon how mission-oriented policies are nationally and supra-nationally embedded and how this loops back on the process of

[2] Also, it is the subject of debate of policy initiatives and think tanks such as the Transforming Food Systems Under a Changing Climate initiative led by CCAFS (https://www.transformingfoodsystems.com/), the Global Alliance for the Future of Food (https://futureoffood.org/), the Food Systems Dialogues (https://foodsystemsdialogues.org/), the Commission on Sustainable Agriculture Intensification (https://wle.cgiar.org/cosai/), the International Panel of Experts on Sustainable Food Systems (IPES-Food- http://www.ipes-food.org/) and Food Tank (https://foodtank.com/), part of policy strategies such as the EU Farm2Fork strategy as part of the European Union's Green Deal (EuropeanUnion, 2020), the focus of technology events, incubators and accelerators such as Evoke Ag, Food & Farm 4.0, F&A Next, and Thought for Food (https://www.farm-and-food.com/en/, https://www.fanext.com/, https://evokeag.com/, https://thoughtforfood.org/), high level events such as the UN Food Systems Summit 2021 (https://www.un.org/sustainabledevelopment/food-systems-summit-2021/), and steering the agenda of science organizations such as the Australian Future Foods CRC (https://www.futurefoodsystems.com.au/), Oxford University (https://www.oxfordmartin.ox.ac.uk/food/) in The United Kingdom, and Utrecht University (https://www.uu.nl/en/research/sustainability/research/future-food-utrecht) and Wageningen University and Research (https://www.wur.nl/en/About-Wageningen/Strategic-Plan.htm) in The Netherlands.

[3] For an extensive explanation of emergence of the AIS concept see (Hall et al., 2006). AIS have been variedly conceptualised and studied at a national or regional, sectoral (e.g. dairy, horticulture), and technology level (e.g. pest management, water harvesting) (Kebebe et al., 2015; Kruger, 2017; Minh, 2019; Sixt et al., 2018; Turner et al., 2016). See (Klerkx et al., 2012) for an explanation how the different boundaries of AIS are cross-cutting (e.g. an AIS at a country level may contemplate several sectoral and technological AIS, which in turn may have global characteristics). In the European Union context, AIS are generally referred to as Agricultural Knowledge and Innovation Systems (AKIS).

[4] For a broader explanation, see also the insightful position paper of Janssen et al. (2020). See also the informative overview of key elements of mission-driven innovation policy by Rathenau Institute (2020), whose piece provided inspiration for the title of this paper, and also refers to the Dutch circular agriculture mission (see further footnote 8).

[5] Lock-in implies that a (food) system becomes inert to change in view of the interplay of established infrastructures, institutional frameworks (rules, regulations, values), and sunk investments. It has been argued that many current food systems have such a lock-in (i.e. 'food regimes') (Gaitán-Cremaschi et al., 2019; Leach et al., 2020), but it may also happen that an emerging alternative system becomes locked-in before it has fulfilled the envisioned goal.

[6] Though earlier mission-oriented programmes incorporated AIS principles such as TransForum in The Netherlands (Fischer et al., 2012), and the our Land and Water Science Challenge in New Zealand (de Jong et al., 2019; Duncan et al., 2018).

innovation and system change. We argue that studying AIS as a 'mission-oriented agricultural innovation system' (MAIS) would enable a better understanding of forces, interactions, catalysts, barriers in transformative food systems change, as so far studies on AIS have rarely engaged with issues such as directionality, power, and the diversity of food systems futures (Hall and Dijkman, 2019; Pigford et al., 2018; Mier et al., 2018). The purpose of this perspective is to get a debate and reflection started on this topic among agricultural systems and food systems scholars.

To enact research on MAIS, there are different sorts of questions to be asked, in terms of what, why, who, where and how, on which we will elaborate in section 2 (see also Table 1).

2. Mission-oriented agricultural innovation systems: What, why, who, where and how?

2.1. What missions are in a MAIS?

As Mazzucato (2016) argues, missions are about setting concrete directions and comprise a strategic portfolio of innovation projects (technological, social, institutional innovation), i.e. what Meynard et al. (2017) have called 'coupled innovations'. The scope of these portfolios may vary and be driven by different expectations, narratives, assumptions, policy rationales and theories of change (Janssen et al., 2020; Thornton et al., 2017)). They may be science and discovery based and technology-driven or may be driven by visions for broad systemic change (Polt, 2019; Rathenau Institute, 2020).[7] To achieve food systems transformation, missions may include concepts such as agroecology, circular or regenerative agriculture, digital transformation of agriculture, bioeconomy, or protein transitions (Gosnell et al., 2019; Mockshell and Kamanda, 2018; Shepherd et al., 2018; Tziva et al., 2020; Van Zanten et al., 2019; Wezel et al., 2009), or a combination of concepts (Kristensen et al., 2016; Laibach et al., 2019; Mockshell and Kamanda, 2018). Different existing and emerging agriculture and food technologies may support the former approaches (Herrero et al., 2020). These rather broad conceptual missions for food systems transformation may be underpinned by different types of 'sub-missions'. For example the broad mission of 'circular agriculture' may be achieved by sub-missions emphasizing either a place-based local model with closing cycles on farms, high in-field diversity and short supply chains, or a regional model in which different sorts of monoculture agriculture are connected within wider rural-urban interactions and material and energy flows (Garrett et al., 2020; Van Zanten et al., 2019). Hence, these sub-missions represent diversity in possible future food systems transition pathways and supporting technologies (Gaitán-Cremaschi et al., 2020).

Hence, it important to characterize what sort of mission a MAIS represents, how broad or narrow it is, how explicit it is made, and possibly what sub-missions may exist. Finally, just as MAIS may have a layering in its mission, there may also be several competing, co-existing or converging MAIS (e.g. agroecology and digital transformation), in view of the diversity argument and portfolio approach (Mazzucato, 2016).[8] A variety of competing or co-existing sub-missions has already been observed for concepts such as agroecology and Agriculture 4.0 (Plumecocq et al., 2018; Klerkx and Rose, 2020; Bellwood-Howard and Ripoll, 2020). Studying this diversity of MAIS can illuminate aligning or competing interests and infrastructures that have the potential to facilitate or constrain food systems change.

2.2. Why do MAIS emerge or are set-up?

As already alluded to in the previous point, it is important to determine where missions come from, as mission-oriented policy is a product of the system which it is supposed to change. Sometimes, a mission may involve a truly novel focus, and sometimes it is a 'reframing' or 'rebranding' of ongoing efforts (Janssen et al., 2020). Missions may arise from a supply-push (e.g. by policy, science, or business), or rather from a demand-pull (raised by social movements and worried citizens and consumers) or a combination of these forces. They may arise 'pro-actively' in view of horizon scanning and scenario building exercises of future food systems (CSIROFutures, 2017; De Wilde, 2016; Hebinck et al., 2018; Manners et al., 2020; Rutter, 2012; van der Weele et al., 2019; WorldBank, 2019), or rather 'reactively' when sectors or countries are faced with intractable problems such as intensifying droughts. In terms of the mission set up, it is important to consider if the missions provide strong steering and close down innovation options or consider a wide range of solutions that allow to be tinkered with, as this will result in different operationalization strategies of the missions (Janssen et al., 2020).

It is also important to contemplate whether MAIS can be considered as an 'alternative' AIS or emerge from within the dominant AIS of a country or sector. It has for example been argued that an AIS in a country may on the one hand still be focused on improving 'business-as-usual', while on the other hand may have the characteristics of a MAIS with highly transformative ambitions (Pigford et al., 2018). This would require what has been referred to as 'ambidexterity' (Turner et al., 2017; Rathenau Institute, 2020), i.e. the capacity of an AIS to simultaneously manage existing networks and policies to support (incremental) innovation in current food systems, and create new networks and policies to overcome lock-in and support radical innovation and food systems transformation. Perhaps paradoxically, food systems transformation thus also implies deconstruction of existing AIS systems or 'exnovation', by for example phasing out research investments in a non-sustainable technology or practice (David and Gross, 2019; Kivimaa and Kern, 2016; Krüger and Pellicer-Sifres, 2020). Beyond questioning environmental sustainability of production systems and supply chain set-up, exnovation may also include questioning prevalent economic paradigms (e.g. neoliberal capitalism, economic growth) (Feola, 2020; Ghisellini et al., 2016; Mier et al., 2018; Giuliani, 2018). This requires scrutinizing prevalent policy frames, goals, and policy instruments (Candel and Biesbroek, 2016; Galli et al., 2020; Janssen et al., 2020). Understanding the dynamics of MAIS emergence and its set up may as such shed light on particular policy framings, directionalities, and prevailing lock-in scenario's that influence the innovation and exnovation capacity of MAIS.[9]

[7] Polt defines 4 types of missions: science missions (e.g. US Cancer Moonshot - fundamental/basic research with high uncertainty), technological missions (e.g. Concorde, Apollo mission - specific goal with a strong focus on technological/scientific solutions), transformative missions (e.g. German Energiewende - aiming at systemic change), umbrella missions (e.g. German High Tech Strategy - comprehensive long-term policy frame). As an elaboration on this, Wittmann et al. (2020) distinguish accelerator and transformer missions, the former more science or technology based, and the latter more broadly based on societal changes and economic and system infrastructure change.

[8] For example, the policy agenda from the Dutch Ministry of Agriculture emphasizes circular agriculture (Ministry of Agriculture, 2019), which according to Ploegmakers et al. (2020) can already be divided in four narratives (which may possibly underpin different sub-missions). The knowledge and innovation agenda of the Dutch topsector approach for agri-food harbours six missions (https://kia-landbouwwatervoedsel.nl/).

(footnote continued)

[9] Innovation capacity is built through the practices, routines or processes used to mobilise, create and reconfigure arrangements of resources and capabilities in order to innovate (Turner et al., 2017). Exnovation as a concept has had limited application in agriculture and food systems, but there is ongoing work, see e.g. the project of Laura van Oers (https://www.uu.nl/staff/lmvanoers/Research).

2.3. Who (or what) drives MAIS?

To drive missions, Mazzucato (2016) emphasizes direction setting by policymakers and highlights the role of the public sector. Borrás and Edler (2020) have refined these ideas and show that states can combine roles as observer, warner, mitigator, opportunist, facilitator, lead-user, enabler of societal engagement, gatekeeper, promoter, moderator, initiator, guarantor and watchdog. As we argued in the previous sections and following Hekkert et al. (2020), missions may also arise from and be shaped by different actors beyond the state. While it can already be challenging to get 'conventional' AIS actors to co-innovate (Meynard et al., 2017), MAIS may include food economy actors previously not considered to a large degree in agricultural transition and AIS studies (Weber et al., 2020), such as Agtech and FoodTech start-ups, Think Tanks, and social enterprises. Given this diversity of actors and values, there are processes of negotiation and contestation in MAIS. The greater complexity or 'wickedness' of the grand challenge, the greater the negotiation and contestation generally is (Janssen et al., 2020; Wanzenböck et al., 2019).[10]

Therefore it is important who is included in a MAIS, and who is excluded (Herrero et al., 2020; Leach et al., 2020; Pigford et al., 2018) (see 2.1). And also, whether those excluded in one MAIS may be served by another MAIS which enacts transformative missions in a different way, thus accommodating a diversity of farmers and food system actors in terms of for example farm size, farming style, value chain model (Klerkx and Rose, 2020; Stringer et al., 2020). Furthermore, the question is not only 'who' drives MAIS, but also 'what'. It is increasingly argued that also nature itself and biological and ecological agents (e.g. plants, animals, ecosystems) need to be seen as drivers in innovation systems in view of ideas on ecological feedback loops and biomimicry and the 'more-than-human' debate in rural sociology, as well as technologies such as robotics, digital twins and artificial intelligence (Andersen and Wicken, 2020; Darnhofer, 2020; Klerkx et al., 2019; Pigford et al., 2018; van der Jagt et al., 2020).

2.4. Where do MAIS play out?

Many proposed food systems transformation concepts transcend national, sectoral and technological boundaries. They are developed in many countries simultaneously, and are connected to supra-national or even global transformative policy narratives, and flows of technologies and capital (Wanzenböck and Frenken, 2020). Also, the spaces where missions are defined (see footnote 2) are highly globalized since they consider actors from different countries, or are shaped in virtual spaces (e.g. social media). Hence, a MAIS may have the traits of a global innovation system (Binz and Truffer, 2017) and at the same time may be connected to specific national or even sector contexts. Hence, the geographical boundaries of a MAIS are fluid (Hekkert et al., 2020; Janssen et al., 2020; Pigford et al., 2018). Missions may 'travel' geographically and a MAIS may have a different pace of development in different countries. This is due to differences in state governance, and between cultural and regulatory contexts (e.g. the Common Agricultural Policy and Novel Food Legislation of the European Union) that for example may determine consumer attitude (Bekker et al., 2017; Gupta et al., 2013). Such travel may be through multinational companies who introduce products in different countries (e.g. plant based protein products), through large international innovation programs and efforts from countries to 'export' missions (Minkman and van Buuren, 2019), or through social movements (e.g. agroecology) (Mier et al., 2018; Wezel et al., 2018).

To understand MAIS, it is this important to unravel global linkages in enacting missions. Also, one can compare MAIS development between countries, in terms of what missions are espoused by a country, the stage of development of missions and whether technologies and practices have reached certain stages of readiness to go to scale (Herrero et al., 2020; Sartas et al., 2020).

2.5. How do MAIS evolve and how do we study this process?

It has been argued that transformative change in agriculture is generally a process in which innovative processes in several 'innovation niches' gradually change incumbent systems or 'regimes' (El Bilali, 2019a; Geels et al., 2016; Geels and Schot, 2007; Leach et al., 2012; Olsson et al., 2014; Pigford et al., 2018), though it is increasingly recognized it may also come from within incumbent agricultural systems (Gaitán-Cremaschi et al., 2019; Runhaar et al., 2020). Transformation is then the outcome of many 'small wins' instead of a sudden radical change (Termeer and Dewulf, 2019; Termeer and Metze, 2019). Equally, a MAIS does not establish overnight, but the network of actors connected to the MAIS, their interactions and the funding and innovation policies that support the MAIS will emerge gradually (Eastwood et al., 2017). Though the mission-oriented innovation approach presupposes a degree of steering, some parts of a MAIS (being a complex adaptive system) will be self-organized without the support of central steering mechanisms. Given the geographical fluidity of a MAIS, system complexity and degree of self-organization, the analytical boundaries of a MAIS not easy to establish. This affects MAIS characterization, as well as the accomplishment of a mission by a MAIS (or for that matter- several co-existing or competing MAIS).

Janssen et al. (2020) have indicated some relevant points for the analysis of MAIS (which connect to what has been discussed in section 2.1 to 2.4):

1. Complexity and 'wickedness' of the challenge, and how the challenges/solutions are understood and prioritized in the MAIS.
2. Mission design including theory of change, in geographical and temporal terms, and focus and emphasis.
3. MAIS governance, such as decision making and participation processes, accountability and learning.
4. Development of MAIS in time and space, in view of their theory of change.

MAIS analysts, drawing on generic innovation system theories, can utilize some of the existing innovation system analysis frameworks such as functional-structural analysis, innovation policy mix analysis, or social network analysis to analyse MAIS (Hermans et al., 2019; Lamprinopoulou et al., 2014; Spielman et al., 2011; Wieczorek and Hekkert, 2012; Schut et al., 2015). This can be combined with agricultural and food systems assessment and modelling approaches focusing for example on resilience (Meuwissen et al., 2019; Tittonell, 2020), and drawing on recent frameworks to analyse different aspects of food systems transformation (Gaitán-Cremaschi et al., 2019; Hebinck et al., 2018; Kanter et al., 2015; Termeer et al., 2018; Zurek et al., 2018). Such analysis may make use of data science or citizen science driven approaches bringing together large datasets of biophysical and socioeconomic data to track mission evolution (Beza et al., 2017; Fielke et al., 2020; Guo et al., 2020; Klerkx et al., 2019; Sauermann et al., 2020). Since MAIS are often global with national or regional 'branches',

[10] A relevant consideration is where the boundaries of MAIS lie: from a food systems perspective, consumers are for example highly important in view of food preference and dietary change as well as food choice environments (retail and domestic environments) and food waste prevention and recycling (Vermeulen et al., 2019; Willett et al., 2019). New AgTech and FoodTech inspired food systems (e.g. urban agriculture, vertical agriculture) also bring new players into AIS (Pigford et al., 2018). Also, food systems may have a 'blue' component, based on food captured or cultivated in water bodies (Belton et al., 2020; Tezzo et al., 2020) so can aquaculture also be considered a form of agriculture and are 'aquaculture innovation systems' (Joffre et al., 2018) also part of MAIS? One can even question whether MAIS is the correct term, if the mission is food systems transformation. For example, the concept of a 'food innovation system' (Leach et al., 2020) may be then perhaps more appropriate.

Table 1
Questions and possible actions to further conceptual development and analysis of MAIS.

Question	Possible actions
What missions are in a MAIS?	Map the diversity of food systems transformation missions, and the sub- missions that underpin them, including the contribution of different sorts of science (e.g., biophysical science, engineering, social and policy science) and the role of trans-disciplinarity
Why do MAIS emerge or are set-up?	Identify the (policy) drivers for missions and their emergence and evolution
Who (or what) drives MAIS?	Map the networks of actors driving missions and constituting MAIS, and the governance and power dynamics within MAIS
Where do MAIS play out?	Map MAIS at a (sub) country level, how they are linked supranationally, and what are the connections with other sectors
How do MAIS evolve and how do we study this process?	Further develop methodologies to capture MAIS and connect them to ongoing agricultural innovation and food systems analysis

initiatives like the Food Systems Dashboard (Fanzo et al., 2020), the CGIAR Platform for Big Data in Agriculture, the Agricultural Science and Technology Indicators network (ASTI), and Capacity Development for Agricultural Innovation Systems project (CDAIS) could play roles in enabling or hosting 'MAIS mapping'.[11]

3. Conclusion and future outlook

In this perspective paper, we have elaborated on the emerging concept of MAIS. We think its relevance lies in better understanding what drives transformative change, and create insights for policy makers and other AIS actors on innovation system directionality and innovation policy mixes for enhancing food systems transformation. This may spur reflection on subnational, national and supranational innovation activities and the adequacy of MAIS for supporting transformative change (Wanzenböck and Frenken, 2020). Table 1 summarizes some of the possible actions that may be undertaken to investigate MAIS and do MAIS mapping.

Besides introducing a MAIS perspective to understand food systems transformation, this paper aims to stimulate agricultural systems scholars and field level practitioners to critically reflect upon their own positionality within a MAIS.[12] This includes asking questions on what mission or sub-missions they contribute to and what type of contribution they make, e.g. systems (re)-design, modelling and scenario building to support mission formulation, or monitoring and analysing effects of technologies and interventions in missions.[13] Furthermore, in view of the need to create coupled innovations (Meynard et al., 2017) as well as exnovation, it requires scrutiny of the actor networks and institutional structures they are part of and whether and how these align with a MAIS. This also includes asking questions with whom they need to engage to support the formulation and development of missions and what kind of incentive systems are needed to support these interactions.

We conclude this paper by inviting the Agricultural Systems community as well as other natural and social scientists to progress the analysis of MAIS and develop it further as a concept and approach to understand and support agricultural innovation in relation to food systems transformation.

[11] See https://cdais.net/home/, https://www.asti.cgiar.org/, https://bigdata.cgiar.org/. Furthermore, generic observatories and programs on transformative innovation policy could be connected to, such as the Mission-oriented Innovation Policy Observatory https://www.uu.nl/en/research/copernicus-institute-of-sustainable-development/mission-oriented-innovation-policy-observatory (Janssen et al., 2020) and the Transformative Innovation Policy Consortium http://www.tipconsortium.net/ (Schot and Steinmueller, 2018a).

[12] It has been argued that food systems transformation also has implications for advisory systems (Klerkx, 2020). But many scholars by being engaged in trans-disciplinary research and co-innovation are also field-level practitioners.

[13] This also requires scrutiny of agricultural systems scholar on how instrumental or non-instrumental their knowledge is in view of missions and what perspective they take, e.g. knowledge as a private good or common good (Basu et al., 2017a, 2017b), and in what way they engage with transition processes (Schut et al., 2014; Wittmayer and Schäpke, 2014).

Declaration of Competing Interest

The authors declare that there are no conflicts of interest related to this paper.

Acknowledgements

The authors wish to thank the postdoc programme of the Department of Social Sciences at Wageningen University, which enabled the contribution of Stephanie Begemann to this paper. Interactions with Xianping Jia (Research Institute of Agricultural Economics at Northwest A & F University, China), Jos van den Broek, Isabelle van Elzakker and Laurens Hessels (Rathenau Institute, The Netherlands), Marko Hekkert, Wouter Boon, Matthijs Janssen, Simona Negro, Joeri Wesseling, and Giuseppe Feola (Innovation Studies group, Utrecht University, The Netherlands), and Barbara van Mierlo (Knowledge, Technology and Innovation group, Wageningen University, The Netherlands) were helpful in shaping the thinking which led to this paper. Constructive comments by the reviewers and editor Guillaume Martin were very useful in finetuning the paper.

References

Alkemade, F., Hekkert, M.P., Negro, S.O., 2011. Transition policy and innovation policy: friends or foes? Environ. Innov. and Societal Transitions 1, 125–129.
Allwood, J.M., Laursen, S.E., Malvido de Rodriguez, C., Bocken, N.M.P.W.D., 2006. The Present and Future Sustainability of Clothing and Textiles in the United Kingdom. University of Cambridge Institute for Manufacturing. Cambridge, UK.
Andersen, A.D., Wicken, O., 2020. Making sense of how the natural environment shapes innovation, industry dynamics, and sustainability challenges. Innovation and Development. https://doi.org/10.1080/2157930X.2020.1770975. In press.
Andersen, A.D., Steen, M., Mäkitie, T., Hanson, J., Thune, T.M., Soppe, B., 2020. The role of inter-sectoral dynamics in sustainability transitions: a comment on the transitions research agenda. Environ. Innov. and Societal Transitions 34, 348–351.
Basu, S., Jongerden, J., Ruivenkamp, G., 2017a. Beyond the dichotomy of instrumentality and non-instrumentality of knowledge production: the case of generation challenge programme. Sci. Public Policy 44, 583–597.
Basu, S., Jongerden, J., Ruivenkamp, G., 2017b. The emergence of a hybrid mode of knowledge production in the generation challenge Programme Rice research network (GCP-RRN) in India: exploring the concept of commons-based peer production (CBPP). Geoforum 84, 107–116.
Baudron, F., Liégeois, F., 2020. Fixing our global agricultural system to prevent the next COVID-19. Outlook on Agriculture 49 (2), 111–118.
Bekker, G.A., Tobi, H., Fischer, A.R.H., 2017. Meet meat: an explorative study on meat and cultured meat as seen by Chinese, Ethiopians and Dutch. Appetite 114, 82–92.
Bellwood-Howard, I., Ripoll, S., 2020. Divergent understandings of agroecology in the era of the African Green Revolution. Outlook on. Agriculture 49, 103–110.
Belton, B., Reardon, T., Zilberman, D., 2020. Sustainable commoditization of seafood. Nat. Sustainability. https://doi.org/10.1038/s41893-020-0540-7. In press.
Beza, E., Steinke, J., van Etten, J., Reidsma, P., Fadda, C., Mittra, S., Mathur, P., Kooistra, L., 2017. What are the prospects for citizen science in agriculture? Evidence from three continents on motivation and mobile telephone use of resource-poor farmers. PLoS One 12, e0175700.
Binz, C., Truffer, B., 2017. Global innovation systems—a conceptual framework for innovation dynamics in transnational contexts. Res. Policy 46, 1284–1298.
Blay-Palmer, A., Carey, R., Valette, E., Sanderson, M.R., 2020. Post COVID 19 and food pathways to sustainable transformation. Agriculture and Human Values. https://doi.org/10.1007/s10460-020-10051-7. In press.
Boon, W., Edler, J., 2018. Demand, challenges, and innovation. Making sense of new trends in innovation policy. Sci. Public Policy 45, 435–447.
Candel, J.J.L., Biesbroek, R., 2016. Toward a processual understanding of policy integration. Pol. Sci. 49, 211–231.
Claudio, L., 2007. Waste couture: environmental impact of the clothing industry. Environ.

Health Perspect. 115, A448–A454.
CSIROFutures, 2017. Food and Agribusiness a Roadmap for Unlocking Value-Adding Growth Opportunities for Australia. (CSIRO Brisbane).
Darnhofer, I., 2020. Farming from a process-relational perspective: making openings for change visible. Sociol. Rural. 60, 505–528.
David, M., Gross, M., 2019. Futurizing politics and the sustainability of real-world experiments: what role for innovation and exnovation in the German energy transition? Sustain. Sci. 14, 991–1000.
De Wilde, S., 2016. The Future of Technology in Agriculture. STT Netherlands Study Centre for Technology Trends. The Netherlands, The Hague.
Dentoni, D., Waddell, S., Waddock, S., 2017. Pathways of transformation in global food and agricultural systems: implications from a large systems change theory perspective. Current Opinion in Environmental Sustainability 29, 8–13.
Duncan, R., Robson-Williams, M., Nicholas, G., Turner, J.A., Smith, R., Diprose, D., 2018. Transformation is 'experienced, not delivered': insights from grounding the discourse in practice to inform policy and theory. Sustainability 10, 3177.
Eastwood, C., Klerkx, L., Nettle, R., 2017. Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion: case studies of the implementation and adaptation of precision farming technologies. J. Rural. Stud. 49, 1–12.
El Bilali, H., 2019a. The multi-level perspective in research on sustainability transitions in agriculture and food systems: a systematic review. Agriculture (Switzerland) 9, 74.
El Bilali, H., 2019b. Research on agro-food sustainability transitions: a systematic review of research themes and an analysis of research gaps. J. Clean. Prod. 221, 353–364.
Elzen, B., Barbier, M., Cerf, M., Grin, J., 2012. Stimulating transitions towards sustainable farming systems. In: Darnhofer, I., Gibbon, D., Dedieu, B. (Eds.), Farming Systems Research into the 21st century: the new dynamic. Springer, Netherlands, pp. 431–455.
EuropeanUnion, 2020. Farm to fork strategy. In: For a Fair, Healthy and Environmentally-Friendly Food System. Brussels, European Union.
Fanzo, J., Haddad, L., McLaren, R., Marshall, Q., Davis, C., Herforth, A., Jones, A., Beal, T., Tschirley, D., Bellows, A., Miachon, L., Gu, Y., Bloem, M., Kapuria, A., 2020. The food systems dashboard is a new tool to inform better food policy. Nature Food 1, 243–246.
Feola, G., 2020. Capitalism in sustainability transitions research: time for a critical turn? Environ. Innov. and Societal Transitions 35, 241–250.
Fielke, S., Taylor, B., Jakku, E., 2020. Digitalisation of agricultural knowledge and advice networks: a state-of-the-art review. Agric. Syst. 180, 102763.
Fischer, A.R.H., Beers, P.J., Latesteijn, H.V., Andeweg, K., Jacobsen, E., Mommaas, H., Van Trijp, H.C.M., Veldkamp, A., 2012. Transforum system innovation towards sustainable food. A review. Agronomy for Sustainable Development 32, 595–608.
Frantzeskaki, N., 2019. Seven lessons for planning nature-based solutions in cities. Environ. Sci. Pol. 93, 101–111.
Fraser, E.D.G., Campbell, M., 2019. Agriculture 5.0: reconciling production with planetary health. One Earth 1, 278–280.
Gaitán-Cremaschi, D., Klerkx, L., Duncan, J., Trienekens, J.H., Huenchuleo, C., Dogliotti, S., Contesse, M.E., Rossing, W.A.H., 2019. Characterizing diversity of food systems in view of sustainability transitions. A review. Agronomy for Sustainable Development 39, 1.
Gaitán-Cremaschi, D., Klerkx, L., Duncan, J., Trienekens, J.H., Huenchuleo, C., Dogliotti, S., Contesse, M.E., Benitez-Altuna, F.J., Rossing, W.A.H., 2020. Sustainability transition pathways through ecological intensification: an assessment of vegetable food systems in Chile. Int. J. Agric. Sustain. 18, 131–150.
Garrett, R.D., Ryschawy, J., Bell, L.W., Cortner, O., Ferreira, J., Garik, A.V.N., Gil, J.D.B., Klerkx, L., Moraine, M., Peterson, C.A., Dos Reis, J.C., Valentim, J.F., 2020. Drivers of decoupling and recoupling of crop and livestock systems at farm and territorial scales. Ecol. Soc. 25, 24.
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36, 399–417.
Geels, F.W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., Wassermann, S., 2016. The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990-2014). Res. Policy 45, 896–913.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32.
Giuliani, E., 2018. Regulating global capitalism amid rampant corporate wrongdoing—reply to "three frames for innovation policy". Res. Policy 47, 1577–1582.
Gosnell, H., Gill, N., Voyer, M., 2019. Transformational adaptation on the farm: processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. Glob. Environ. Chang. 59, 101965.
Guo, H., Nativi, S., Liang, D., Craglia, M., Wang, L., Schade, S., Corban, C., He, G., Pesaresi, M., Li, J., Shirazi, Z., Liu, J., Annoni, A., 2020. Big earth data science: an information framework for a sustainable planet. Int. J. Digital Earth 13, 743–767.
Gupta, N., Fischer, A.R.H., George, S., Frewer, L.J., 2013. Expert views on societal responses to different applications of nanotechnology: a comparative analysis of experts in countries with different economic and regulatory environments. J. Nanopart. Res. 15, 1838.
Hall, A., Dijkman, J., 2019. Public Agricultural Research and Development in an Era of Transformation Independent Science Council of the CGIAR and Commonwealth Scientific and Industrial Research Organisation.
Hall, A., Janssen, W., Pehu, E., Rajalahti, R., 2006. Enhancing Agricultural Innovation: How to Go beyond the Strenghthening of Research Systems. World Bank, Washington.
Hebinck, A., Vervoort, J.M., Hebinck, P., Rutting, L., Galli, F., 2018. Imagining transformative futures: participatory foresight for food systems change. Ecol. Soc. 23, 16.
Hekkert, M.P., Janssen, M.J., Wesseling, J.H., Negro, S.O., 2020. Mission-oriented innovation systems. Environ. Innov. and Societal Transitions 34, 76–79.
Hermans, F., Geerling-Eiff, F., Potters, J., Klerkx, L., 2019. Public-private partnerships as systemic agricultural innovation policy instruments – assessing their contribution to innovation system function dynamics. NJAS - Wageningen Journal of Life Sciences 88, 76–95.
Herrero, M., Thornton, P.K., Mason-D'Croz, D., Palmer, J., Benton, T.G., Bodirsky, B.L., Bogard, J.R., Hall, A., Lee, B., Nyborg, K., Pradhan, P., Bonnett, G.D., Bryan, B.A., Campbell, B.M., Christensen, S., Clark, M., Cook, M.T., de Boer, I.J.M., Downs, C., Dizyee, K., Folberth, C., Godde, C.M., Gerber, J.S., Grundy, M., Havlik, P., Jarvis, A., King, R., Loboguerrero, A.M., Lopes, M.A., McIntyre, C.L., Naylor, R., Navarro, J., Obersteiner, M., Parodi, A., Peoples, M.B., Pikaar, I., Popp, A., Rockström, J., Robertson, M.J., Smith, P., Stehfest, E., Swain, S.M., Valin, H., van Wijk, M., van Zanten, H.H.E., Vermeulen, S., Vervoort, J., West, P.C., 2020. Innovation can accelerate the transition towards a sustainable food system. Nature Food 1, 266–272.
van der Jagt, A.P.N., Raven, R., Dorst, H., Runhaar, H., 2020. Nature-based innovation systems. Environ. Innov. and Societal Transitions 35, 202–216.
Janssen, M.J., Ladeia Torrens, J.C., Wesseling, J., Wanzenböck, I., Patterson, J., 2020. Position Paper 'Mission-Oriented Innovation Policy Observatory'. Retrievable through. https://www.uu.nl/sites/default/files/MIPO%20position%20paper%20-%20v21-05-2020.pdf.
Joffre, O.M., Klerkx, L., Khoa, T.N.D., 2018. Aquaculture innovation system analysis of transition to sustainable intensification in shrimp farming. Agron. Sustain. Dev. 38, 34.
de Jong, K., Daellenbach, U., Davenport, S., Haar, J., Leitch, S., 2019. Giving science innovation systems a 'Nudge'. Technol. Innov. Manag. Rev. 9, 51–61.
Kanter, R., Boza, S., 2020. Strengthening local food Systems in Times of concomitant global crises: reflections from Chile. Am. J. Public Health e1–e3.
Kanter, R., Walls, H.L., Tak, M., Roberts, F., Waage, J., 2015. A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health. Food Security 7, 767–777.
Kebebe, E., Duncan, A.J., Klerkx, L., de Boer, I.J.M., Oosting, S.J., 2015. Understanding socio-economic and policy constraints to dairy development in Ethiopia: a coupled functional-structural innovation systems analysis. Agric. Syst. 141, 69–78.
Kirova, M., Montanari, F., Ferreira, I., Pesce, J., Albuquerque, D., Montfort, C., Neirynck, R., Moroni, J., 2019. Research for AGRI committee - megatrends in the Agri-food sector: Global overview and possible policy response from an EU perspective. In: European Parliament. Structural and Cohesion Policies, Brussels, Policy Department for.
Kivimaa, P., Kern, F., 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Res. Policy 45, 205–217.
Klerkx, L., 2020. Advisory services and transformation, plurality and disruption of agriculture and food systems: towards a new research agenda for agricultural education and extension studies. J. Agric. Educ. Ext. 26, 131–140.
Klerkx, L., Rose, D., 2020. Dealing with the game-changing technologies of agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? Global. Food Security 24, 100347.
Klerkx, L., Aarts, N., Leeuwis, C., 2010. Adaptive management in agricultural innovation systems: the interactions between innovation networks and their environment. Agric. Syst. 103, 390–400.
Klerkx, L., Mierlo, B., Leeuwis, C., 2012. Evolution of systems approaches to agricultural innovation: Concepts, analysis and interventions. In: Darnhofer, I., Gibbon, D., Dedieu, B. (Eds.), Farming Systems Research into the 21st Century: The New Dynamic. Springer Netherlands, Dordrecht, pp. 457–483.
Klerkx, L., Jakku, E., Labarthe, P., 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda. NJAS - Wageningen Journal of Life Sciences 90–91, 100315.
Kristensen, D.K., Kjeldsen, C., Thorsøe, M.H., 2016. Enabling sustainable agro-food futures: exploring fault lines and synergies between the integrated territorial paradigm, rural eco-economy and circular economy. J. Agric. Environ. Ethics 29, 749–765.
Kruger, H., 2017. Creating an enabling environment for industry-driven pest suppression: the case of suppressing Queensland fruit fly through area-wide management. Agric. Syst. 156, 139–148.
Krüger, T., Pellicer-Sifres, V., 2020. From innovations to exnovations. Conflicts, (De-)politicization processes, and power relations are key in analysing the ecological crisis. Innovation 33, 115–123.
Laibach, N., Börner, J., Bröring, S., 2019. Exploring the future of the bioeconomy: an expert-based scoping study examining key enabling technology fields with potential to foster the transition toward a bio-based economy. Technol. Soc. 58, 101118.
Lamine, C., 2011. Transition pathways towards a robust ecologization of agriculture and the need for system redesign. Cases from organic farming and IPM. Journal of Rural Studies 27, 209–219.
Lamprinopoulou, C., Renwick, A., Klerkx, L., Hermans, F., Roep, D., 2014. Application of an integrated systemic framework for analysing agricultural innovation systems and informing innovation policies: comparing the Dutch and Scottish agrifood sectors. Agric. Syst. 129, 40–54.
Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., Olsson, P., 2012. Transforming innovation

for sustainability. Ecol. Soc. 17.
Leach, M., Nisbett, N., Cabral, L., Harris, J., Hossain, N., Thompson, J., 2020. Food politics and development. World Dev. 134, 105024.
Manners, R., Blanco-Gutiérrez, I., Varela-Ortega, C., Tarquis, A.M., 2020. Transitioning European protein-rich food consumption and production towards more sustainable patterns-strategies and policy suggestions. Sustainability (Switzerland) 12, 1962.
Mazzucato, M., 2016. From market fixing to market-creating: a new framework for innovation policy. Ind. Innov. 23, 140–156.
Mazzucato, M., Kattel, R., Ryan-Collins, J., 2020. Challenge-driven innovation policy: towards a new policy toolkit. J. Ind. Compet. Trade 20, 421–437.
Meuwissen, M.P.M., Feindt, P.H., Spiegel, A., Termeer, C.J.A.M., Mathijs, E., Mey, Y.d., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigani, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., Ciechomska, A., Accatino, F., Kopainsky, B., Poortvliet, P.M., Candel, J.J.L., Maye, D., Severini, S., Senni, S., Soriano, B., Lagerkvist, C.-J., Peneva, M., Gavrilescu, C., Reidsma, P., 2019. A framework to assess the resilience of farming systems. Agric. Syst. 176, 102656.
Meynard, J.-M., Jeuffroy, M.-H., Le Bail, M., Lefèvre, A., Magrini, M.-B., Michon, C., 2017. Designing coupled innovations for the sustainability transition of agrifood systems. Agric. Syst. 157, 330–339.
Mier, Y., Terán Giménez Cacho, M., Giraldo, O.F., Aldasoro, M., Morales, H., Ferguson, B.G., Rosset, P., Khadse, A., Campos, C., 2018. Bringing agroecology to scale: key drivers and emblematic cases. Agroecol. Sustain. Food Syst. 42, 637–665.
Minh, T.T., 2019. Unpacking the systemic problems and blocking mechanisms of a regional agricultural innovation system: an integrated regional-functional-structural analysis. Agric. Syst. 173, 268–280.
Minkman, E., van Buuren, A., 2019. Branding in policy translation: how the Dutch Delta approach became an international brand. Environ. Sci. Pol. 96, 114–122.
Mockshell, J., Kamanda, J., 2018. Beyond the agroecological and sustainable agricultural intensification debate: is blended sustainability the way forward? Int. J. Agric. Sustain. 16, 127–149.
Oliver, T.H., Boyd, E., Balcombe, K., Benton, T.G., Bullock, J.M., Donovan, D., Feola, G., Heard, M., Mace, G.M., Mortimer, S.R., Nunes, R.J., Pywell, R.F., Zaum, D., 2018. Overcoming undesirable resilience in the global food system. Global Sustainability 1, e9.
Olsson, P., Galaz, V., Boonstra, W.J., 2014. Sustainability transformations: a resilience perspective. Ecol. Soc. 19 (4), 1.
Pigford, A.-A.E., Hickey, G.M., Klerkx, L., 2018. Beyond agricultural innovation systems? Exploring an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. Agric. Syst. 164, 116–121.
Ploegmakers, H., Raaphorst, K., Kooij, H.J., Aarts, N., 2020. Analyse debat kringlooplandbouw. Eindrapport. Faculteit der Managementwetenschappen, Centre for Urban Research (CentUR) Geografie, Planologie en Milieu. Radboud Universiteit, Nijmegen, The Netherlands. https://repository.ubn.ru.nl/handle/2066/218997.
Plumecocq, G., Debril, T., Duru, M., Magrini, M.-B., Sarthou, J.P., Therond, O., 2018. The plurality of values in sustainable agriculture models: diverse lock-in and coevolution patterns. Ecology and Society 23 (1), 21.
Polt, W., 2019. Re-Orienting STI Policies towards Mission- Oriented Innovation Policies – Where Do we Stand? Where Are we Heading? Joint CSTP/ CIIE Workshop Session 2: Reorienting STI Policies and Funding to Tackle Societal Challenges. Joanneum Research, Paris.
Pouw, N., Bush, S., Mangnus, E., 2019. Editorial overview: towards an inclusive food systems approach for sustainable food and nutrition security. Curr. Opin. Environ. Sustain. 41, 93–96.
Rathenau Institute, 2020. Mission-driven innovation policy: what, how, why? Rathenau Institute, The Hague, The Netherlands Retrievable through. https://www.rathenau.nl/en/knowledge-ecosystems/mission-driven-innovation-policy-what-how-why.
Robinson, D.K.R., Mazzucato, M., 2019. The evolution of mission-oriented policies: exploring changing market creating policies in the US and European space sector. Res. Policy 48, 936–948.
Rockström, J., Edenhofer, O., Gaertner, J., DeClerck, F., 2020. Planet-proofing the global food system. Nature Food 1, 3–5.
Runhaar, H., Fünfschilling, L., van den Pol-Van Dasselaar, A., Moors, E.H.M., Temmink, R., Hekkert, M., 2020. Endogenous regime change: lessons from transition pathways in Dutch dairy farming. Environ. Innov. and Societal Transitions 36, 137–150.
Rutter, S.M., 2012. A 'smart' future for ruminant livestock production? Cattle Practice 20, 186–193.
Sartas, M., Schut, M., Proietti, C., Thiele, G., Leeuwis, C., 2020. Scaling readiness: science and practice of an approach to enhance impact of research for development. Agric. Syst. 183, 102874.
Sauermann, H., Vohland, K., Antoniou, V., Balázs, B., Göbel, C., Karatzas, K., Mooney, P., Perelló, J., Ponti, M., Samson, R., Winter, S., 2020. Citizen science and sustainability transitions. Res. Policy 49, 103978.
Schlaile, M., Urmetzer, S., Blok, V., Andersen, A., Timmermans, J., Mueller, M., Fagerberg, J., Pyka, A., 2017. Innovation Systems for Transformations towards sustainability? Taking the normative dimension seriously. Sustainability 9, 2253.
Schot, J., Steinmueller, W.E., 2018a. New directions for innovation studies: missions and transformations. Res. Policy 47, 1583–1584.
Schot, J., Steinmueller, W.E., 2018b. Three frames for innovation policy: R&D, systems of innovation and transformative change. Res. Policy 47, 1554–1567.
Schut, M., Klerkx, L., Rodenburg, J., Kayeke, J., Hinnou, L.C., Raboanarielina, C.M., Adegbola, P.Y., van Ast, A., Bastiaans, L., 2015. RAAIS: Rapid Appraisal of Agricultural Innovation Systems (Part I). A diagnostic tool for integrated analysis of complex problems and innovation capacity. Agricultural Systems 132, 1–11.
Schut, M., van Paassen, A., Leeuwis, C., Klerkx, L., 2014. Towards dynamic research configurations: a framework for reflection on the contribution of research to policy and innovation processes. Sci. Public Policy 41, 207–218.
Shepherd, M., Turner, J.A., Small, B., Wheeler, D., 2018. Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution. J. Sci. Food Agri. https://doi.org/10.1002/jsfa.9346. In press.
Sixt, G.N., Klerkx, L., Griffin, T.S., 2018. Transitions in water harvesting practices in Jordan's rainfed agricultural systems: systemic problems and blocking mechanisms in an emerging technological innovation system. Environ. Sci. Pol. 84, 235–249.
Spielman, D., Davis, K., Negash, M., Ayele, G., 2011. Rural innovation systems and networks: findings from a study of Ethiopian smallholders. Agric. Hum. Values 28, 195–212.
Spiertz, J.H.J., Kropff, M.J., 2011. Adaptation of knowledge systems to changes in agriculture and society: The case of the Netherlands. NJAS - Wageningen J. Life Sci. 58, 1–10.
Stephens, E.C., Martin, G., van Wijk, M., Timsina, J., Snow, V., 2020. Editorial: impacts of COVID-19 on agricultural and food systems worldwide and on progress to the sustainable development goals. Agric. Syst. 183, 102873.
Stringer, L.C., Fraser, E.D.G., Harris, D., Lyon, C., Pereira, L., Ward, C.F.M., Simelton, E., 2020. Adaptation and development pathways for different types of farmers. Environ. Sci. Pol. 104, 174–189.
Termeer, C.J.A.M., Dewulf, A., 2019. A small wins framework to overcome the evaluation paradox of governing wicked problems. Polic. Soc. 38, 298–314.
Termeer, C.J.A.M., Drimie, S., Ingram, J., Pereira, L., Whittingham, M.J., 2018. A diagnostic framework for food system governance arrangements: the case of South Africa. NJAS - Wageningen Journal of Life Sciences 84, 85–93.
Termeer, C.J.A.M., Metze, T.A.P., 2019. More than peanuts: Transformation towards a circular economy through a small-wins governance framework. Journal of Cleaner Production, 118272.
Tezzo, X., Bush, S.R., Oosterveer, P., Belton, B., 2020. Food system perspective on fisheries and aquaculture development in Asia. Agriculture and Human Values. https://doi.org/10.1007/s10460-020-10037-5. In press.
Thornton, P.K., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S., Campbell, B.M., 2017. Responding to global change: a theory of change approach to making agricultural research for development outcome-based. Agric. Syst. 152, 145–153.
Timmermann, C., 2021. Social justice and agricultural innovation. Korthals, M., Thompson, P.B. (Eds.), The International Library of Environmental, Agricultural and Food Ethics 31 Springer In press.
Tittonell, P., 2014. Ecological intensification of agriculture-sustainable by nature. Curr. Opin. Environ. Sustain. 8, 53–61.
Tittonell, P., 2020. Assessing resilience and adaptability in agroecological transitions. Agric. Syst. 184, 102862.
Turner, J.A., Klerkx, L., Rijswijk, K., Williams, T., Barnard, T., 2016. Systemic problems affecting co-innovation in the New Zealand agricultural innovation system: identification of blocking mechanisms and underlying institutional logics. NJAS - Wageningen Journal of Life Sciences 76, 99–112.
Turner, J.A., Klerkx, L., White, T., Nelson, T., Everett-Hincks, J., Mackay, A., Botha, N., 2017. Unpacking systemic innovation capacity as strategic ambidexterity: How projects dynamically configure capabilities for agricultural innovation. Land Use Policy 68, 503–523.
Tziva, M., Negro, S.O., Kalfagianni, A., Hekkert, M.P., 2020. Understanding the protein transition: the rise of plant-based meat substitutes. Environ. Innov. and Societal Transitions 35, 217–231.
Vågsholm, I., Arzoomand, N.S., Boqvist, S., 2020. Food security, safety, and sustainability—getting the trade-offs right. Front. Sustainable Food Syst. 4, 16.
Van Zanten, H.H.E., Van Ittersum, M.K., De Boer, I.J.M., 2019. The role of farm animals in a circular food system. Global Food Security 21, 18–22.
Vermeulen, S., Park, T., Khoury, C.K., Mockshell, J., Béné, C., H, T., Heard, B., Wilson, B., 2019. Changing diets and transforming food systems. CCAFS working paper no. 282. Wageningen, the Netherlands: CGIAR research program on climate change. Agriculture and Food Security (CCAFS).
Wanzenböck, I., Frenken, K., 2020. The subsidiarity principle in innovation policy for societal challenges. Global Transitions 2, 51–59.
Wanzenböck, I., Wesseling, J., Frenken, K., Hekkert, M., Weber, M., 2019. A framework for mission-oriented innovation policy: alternative pathways through the problem-solution space. SocArXiv doi:10.31235/osf.io/njahp.
Weber, H., Poeggel, K., Eakin, H., Fischer, D., Lang, D.J., von Wehrden, H., Wiek, A., 2020. What are the ingredients for food systems change towards sustainability? - insights from the literature. Environ. Res. Lett. https://doi.org/10.1088/1748-9326/ab99fd. In press.
van der Weele, C., Feindt, P., Jan van der Goot, A., van Mierlo, B., van Boekel, M., 2019. Meat alternatives: an integrative comparison. Trends Food Sci. Technol. 88, 505–512.
Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., David, C., 2009. Agroecology as a science, a movement and a practice. A review. Agronomy for Sustainable Development 29, 503–515.
Wezel, A., Goette, J., Lagneaux, E., Passuello, G., Reisman, E., Rodier, C., Turpin, G., 2018. Agroecology in Europe: research, education, collective action networks, and alternative food systems. Sustainability (Switzerland) 10, 1214.
Wieczorek, A.J., Hekkert, M.P., 2012. Systemic instruments for systemic innovation problems: a framework for policy makers and innovation scholars. Sci. Public Policy

39, 74–87.
Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S.E., Srinath Reddy, K., Narain, S., Nishtar, S., Murray, C.J.L., 2019. Food in the Anthropocene: the EAT*Lancet* commission on healthy diets from sustainable food systems. Lancet 393, 447–492.
Wittmann, F., Hufnagl, M., Lindner, R., Roth, F., Edler, J., 2020. Developing a typology for mission-oriented innovation policies. In: Fraunhofer ISI Discussion Papers - Innovation Systems and Policy Analysis, No. 64. Fraunhofer ISI Karlsruhe.
Wittmayer, J.M., Schäpke, N., 2014. Action, research and participation: roles of researchers in sustainability transitions. Sustain. Sci. 9, 483–496.
WorldBank, 2019. FUTURE of FOOD Harnessing Digital Technologies to Improve Food System Outcomes. World Bank, Washington D.C.
Wright, B.D., 2012. Grand missions of agricultural innovation. Res. Pol. 41, 1716–1728.
Zurek, M., Hebinck, A., Leip, A., Vervoort, J., Kuiper, M., Garrone, M., Havlík, P., Heckelei, T., Hornborg, S., Ingram, J., Kuijsten, A., Shutes, L., Geleijnse, J.M., Terluin, I., van't Veer, P., Wijnands, J., Zimmermann, A., Achterbosch, T., 2018. Assessing sustainable food and nutrition security of the EU food system-an integrated approach. Sustainability (Switzerland) 10, 4271.