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Addressing the politics of mission-oriented agricultural innovation systems

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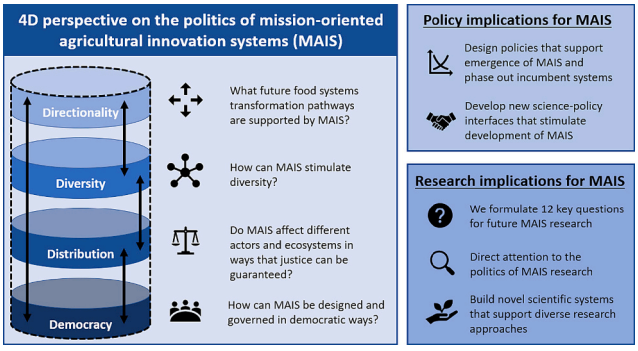
HIGHLIGHTS

- Mission-oriented agricultural innovation systems (MAIS) are emerging.
- This requires attention to the politics and governance of MAIS.
- We formulate a 4D perspective on the politics of MAIS.
- We formulate implications for research in and on MAIS.
- This helps to articulate the normative aspects of agri-food transformation.

GRAPHICAL ABSTRACT



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ABSTRACT

Mission-oriented agricultural innovation systems (MAIS) are becoming more prevalent in view of tackling the challenges of agri-food systems transformation. In this perspective, we argue that the politics of MAIS requires more comprehensive and considerable attention in the field, given the contested and deeply normative nature of the direction of innovations in agri-food systems transformation. Literature from development studies, policy sciences, and transition studies is reviewed to inform the perspective. We question the politics of MAIS structured around the dimensions of the 4D framework: directionality, diversity, distribution and democracy. Regarding directionality, MAIS should explicitly consider how power dynamics shape the direction of innovation and future agri-food systems, and to which extent these power dynamics hinder desirable directions. Considering diversity means that MAIS need to stimulate a diversity of transformation pathways; include a diversity of actors, communities and knowledge; and consider roles of both humans and non-humans in transformation. Questions regarding the distribution of resources and effects of innovations across ecosystems and communities imply that MAIS should actively advance just transitions across different scales and geographical contexts. Finally, democratization of MAIS in our view means that the ways in which knowledge and innovations are produced through MAIS should be more democratic and deliberative, though this may be challenging since missions imply strong steering. We stress that these 4D considerations also bring along important implications for the ways policies and research on and in MAIS, and agri-food system transformation more broadly, are considered. Confronting the politics of MAIS is not an easy endeavor, but critical to advance agri-food system transformation

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in directions that are not only sustainable and transformative, but also socially just and desirable. This requires for agricultural systems researchers to develop awareness on how their work feeds into the politics of MAIS, and conversely is influenced by it.

1. Introduction

Agri-food systems face severe challenges pertaining to environmental sustainability and climate change, human and planetary health, as well as socio-economic inequalities. As such, there is a need for large-scale transformations towards sustainable future agri-food systems (e.g., Willett et al., 2019; Hebinck et al., 2021; Zurek et al., 2021). In this context, there are increasing calls to gear bundled and coupled technological, social and institutional innovations to support agri-food systems transformation (Meynard et al., 2017; Barrett et al., 2020; Herrero et al., 2020). Agricultural innovation systems (AIS) has become an important perspective to understand the complex co-evolutionary networks of actors, technologies and institutions that have traditionally provided resources and conditions for such bundled and coupled agri-food innovations, such as knowledge and expertise, infrastructure, finance and policies (Annosi et al., 2022; Hall et al., 2006; Klerkx et al., 2012; Pigford et al., 2018; Touzard et al., 2015).

Numerous studies exist that assess AIS performance (see for example Lamprinopoulou et al., 2014; Menary et al., 2019; Minh, 2019) and associated interventions such as innovation platforms and innovation brokers (Klerkx et al., 2009; Schut et al., 2018; Totin et al., 2020). However, the AIS perspective has received criticism that it has been too agnostic to what purpose agri-food innovation should serve beyond economic growth and enhancing productivity, with AIS risking to reinforce unsustainable systems and unjust power dynamics (Pigford et al., 2018; Cullen et al., 2014; Hall and Dijkman, 2019). Though AIS have been concerned with enhancing sustainability, it has been shown that AIS often favor incremental innovation of production systems based on monocultures and high-external input use over more radically alternative production systems such as agroecology or biodynamic farming (Hall and Dijkman, 2019; Maye, 2016; Pigford et al., 2018; Rigolot and Quantin, 2022; Vanloqueren and Baret, 2009).

In view of this mismatch in the context of agri-food systems transformation there is recognition that innovation systems need to change (Hall and Dijkman, 2019; Kok et al., 2019). To conceptualize innovation systems that aim to support transformative innovation addressing major sustainability challenges, scholars have introduced the perspective of mission-oriented innovation systems (Hekkert et al., 2020; Schot and Steinmueller, 2018; Mazzucato, 2018; Janssen et al., 2021). A mission-oriented innovation system has been 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) and later as *"a temporary semi-coherent configuration of different innovation system structures that affect the development and diffusion of solutions to a mission"* (Wesseling and Meijerhof, 2021, 2023). In comparison to earlier conceptualizations of innovation systems with boundaries at country, (sub)sector or technology level (which also hold for AIS – see Klerkx et al., 2012), a mission-oriented innovation system is typically multi-technology and cross-sectoral in nature (Klerkx and Begemann, 2020; Rosenbloom, 2020), principally determined by a so-called 'problem-solution space' or 'mission-arena' connected to the transformative challenge to be addressed (Wanzenböck et al., 2020; Janssen et al., 2023).

In the agri-food studies context, Mission-oriented Agricultural Innovation Systems (MAIS) have been conceptualized by Klerkx and Begemann (2020) in view of the increasing need to address agri-food systems transformation, and the emergence of several potentially radical and disruptive technologies under banners such as 'Agriculture 4.0' and 'Regenerative Agriculture' (see also Herrero et al., 2020). The MAIS perspective has now started to be applied to assess the mission-orientation of AIS in countries such as Aotearoa New Zealand, Australia, France and The Netherlands (Begemann and Klerkx, 2022; Fielke et al., 2023; Klerkx et al., 2023; Magrini, 2023), which have mission-oriented programs such as 'Circular Agriculture' (The Netherlands), 'Our Land and Water Science Challenge' (Aotearoa New Zealand), and the Food Agility Cooperative Research Centre's 'Mission Food for Life' (Australia). These studies note principally that in many countries this approach is still in the making, with mission-oriented innovation policies recently emerging and with scattered transformative programs. In addition, mission-orientation is increasingly recognized in the context of the EU Green Deal (such as the Farm to Fork Strategy), the 2021 UN Food Systems Summit, and the CGIAR 2030 research strategy (see also Klerkx and Begemann, 2020).

However, making MAIS work in practice is not easy. There are strong debates between and within missions; on the different future agri-food systems they might support, the technological solutions they embed, the social and market constructs they propose, and on which missions are prioritized by policy and economic actors as different visions exist on (future) food system models (Klerkx and Rose, 2020; Mockshell and Kamanda, 2018; Montenegro de Wit et al., 2021; Plumecocq et al., 2018; Gasselin and Hostiou, 2020; Sumberg and Giller, 2022). This is not surprising: food system transformation is deeply political and ideology and power dynamics strongly shape the direction of innovations (Herrero et al., 2020; Koch, 2004; Leeuwis et al., 2021; Clapp, 2021a, 2021b).[1] However, while scholars have noted the importance of addressing politics in AIS (e.g., Pigford et al., 2018; Herrero et al., 2020), and have also pointed out the political nature of developing and implementing missions (Janssen et al., 2023), it has not yet fully been explored how politics play a role in the development and dynamics of MAIS. In their earlier perspective in Agricultural Systems, Klerkx and Begemann (2020) call upon future research to *"map the networks of actors driving missions and constituting MAIS, and the governance and power dynamics within MAIS"*, but leave open what such governance and power dynamics entail. As such, there is still a need to elaborate and comprehensively articulate the political dimensions of MAIS, and this where this follow-up perspective aims to make a contribution. Importantly, we provide reflections and implications for policy makers and researchers who study, or contribute to, the development of MAIS.

In this perspective we draw on insights from studies on the politics of transformations towards sustainability. Politics is a contested concept, with many different applications in the context of sustainable transformation (see Avelino, 2017). It refers for instance to different dimensions of power (such as power to transform systems, or power to

[1] At the level of innovation projects, literature on politics of innovation has highlighted power-related challenges in food system innovation processes such as determining who is included, what solutions and sorts of knowledge are considered (e.g. experiential knowledge versus scientific knowledge), (Kok et al., 2021a; Clapp, 2021b; Turner et al., 2020) as well as the politics of scaling agricultural innovation (Woltering et al., 2019; Wigboldus et al., 2016), e.g. who gets to benefit from innovations when these scale in view of diminishing returns and environmental externalities. At the level of value chains, scholars have repeatedly stressed that corporate power concentration in large firms is a key barrier for transformation, as big corporations still strongly drive the political agenda on agri-food reform, including through shaping policy agendas, shaping market dynamics and shaping technology and innovation pathways (e.g., Clapp, 2021a, 2021b). Such power dynamics keep agri-food systems locked into their present state or leads to applying technologies without fundamentally questioning underlying economic models (Conti et al., 2021; Guerrero Lara et al., 2023).

maintain the status quo, cf. Avelino, 2017), agency (Huttunen et al., 2021) and justice (Tschersich and Kok, 2022; Jenkins et al., 2016). In this perspective, we structure our contribution by following scholars that have directed attention towards the so-called '4Ds' for conceptualizing 'food politics' (Leach et al., 2020). This 4D framework is based on a manifesto on crucial elements to be considered in transformation processes and develop awareness of different dimensions of politics and power (Stirling, 2009). It considers politics by articulating issues pertaining to (1) Directionality - regarding the future of agri-food systems that are, or should be developed; (2) Diversity - regarding diverse pathways for agri-food systems transformation that encompass different needs and wishes of human and non-human stakeholders such as nature; (3) Distribution - regarding how different transformation pathways affect different stakeholders and ecosystems, and the need to ensure just distribution of (power) resources; and (4) Democracy - regarding the ways in which agri-food systems (and their transformations) are governed and organized.

Following this 4D heuristic, in Section 2 we articulate focal points for addressing the politics of MAIS, both aimed at social science researchers within the Agricultural Systems community who reflect on and facilitate innovation and scaling processes, and natural scientists who devise technical solutions, engage in systems modeling and scenarios, as well as systems (re)design. This is neither, we stress, an exhaustive overview, nor a blueprint for future action and research. Yet, we believe that articulating the plurality of ways in which different aspects of 'politics' play a role in MAIS is crucial for further advancing our understanding, as well as the implementation of MAIS for future-proofing agri-food systems, as we will discuss in Sections 3 and 4 in which we reflect on implications for policy makers and agricultural systems researchers.[2]

2. The 4D perspective on the politics of MAIS

2.1. Directionality

What future agri-food systems transformation pathways are supported by MAIS? For agricultural systems scholars and policy makers to engage with power dynamics that shape the directionalities of innovations implies, it is essential to make explicit who drives the agenda and directions of MAIS. This implies that it is key to unravel and be aware of which technological, institutional and social innovations or concepts (e.g., sustainable intensification, Agriculture 4.0, agroecology) are pushed and advocated, by which organizations, and why (e.g., what political or financial interests and advocacy coalitions are behind it? – see e.g., Clapp, 2021a,b; Leeuwis et al., 2021). For an individual researcher or policy maker directionality may sometimes be taken for granted, and therefore needs to be reflected upon and critically questioned (Leeuwis et al., 2021), in terms of why a certain directionality driving innovation is actually pursued and how transformative it is. It is also important to articulate how different interests are (under)represented in innovation projects and what this means for innovation and transformation outcomes.

Thus, in order to effectively transform agri-food systems, there is a need to explicitly consider such politics of directionality and to reshape and restructure power-relations that hinder transformation (e.g., Rossi et al., 2019; Turner et al., 2020; Sievers-Glotzbach and Tschersich, 2019). Scholars have noted that contestation is natural and needed in such processes (Skrimizea et al., 2020; Turner et al., 2016), but contestation may however also lead to stalemates or polarization, and hence needs to be managed. This is especially relevant given that transformation of agri-food systems also requires phasing out unsustainable system elements; deliberate destabilization or *exnovation* of incumbent systems to give space to alternatives (Turnheim and Geels, 2013; Klerkx and Begemann, 2020); and the unlearning of unsustainable agricultural practices (as prevalent in particular types of highly intensive agricultural systems, and pesticide usage, see Van Oers et al., 2021). An emphasis on restructuring power relations also requires MAIS to especially include and empower women, marginalized groups, vulnerable communities and Indigenous communities (see also Section 2.2) as they can help shape directionality, but also may be strongly affected by the implementation of certain innovations (e.g., Di Prima et al., 2022; Sharma et al., 2021; Trevilla Espinal et al., 2021).

Engaging with the power dynamics underpinning the directionality of MAIS also means to acknowledge the ways in which non-humans such as ecological systems, material artefacts and (digital) technologies, act as driving forces in MAIS by shaping and constituting certain directionalities (Contesse et al., 2021; Vermunt et al., 2022; Rosin et al., 2017; Pigford et al., 2018; Klerkx and Rose, 2020; Korenhof et al., 2021). The rise of digital agriculture and Agriculture 4.0 technologies (including AI, and blockchain developments) lead to autonomous agents such as robots and AI, which upon implementation exercise an influence on directionality. Non-humans are thus not value-neutral, but shape the dynamics of design and innovation, for instance by creating 'hybrids' or 'cyborg' farmers through the use of augmented reality or immersive technology; and co-shaping robotics through recursive actions between humans, animals, plants and technologies (Klerkx et al., 2019; Finstad et al., 2021; Hupkes and Hedman, 2022; Martin et al., 2022). This calls upon agricultural system scholars to interrogate the political nature of the technologies they work on (e.g., Rose and Chilvers, 2018). Scrutinizing the politics of digital technologies might help to shape and direct MAIS to find an appropriate direction in between "AI doomsday" scenarios and naïve techno-optimism (Daum, 2021).

2.2. Diversity

How can MAIS stimulate diversity? Considerations regarding diversity and inclusion have taken a prominent position in agri-food transitions literature (e.g., Gasselin and Hostiou, 2020; Hebinck et al., 2021; Klerkx and Rose, 2020; Leeuwis et al., 2021). Diversity is a broad concept, and the diversity of MAIS could be considered on a number of different levels. We consider this to encompass at least diversity in terms of (1) transformation pathways for future agri-food systems; (2) the communities and types of knowledge involved in MAIS as well as (3) the consideration of both human and non-humans in MAIS.

For MAIS to stimulate diversity, in our view, is for MAIS to stimulate and cultivate a diversity of innovations, transformation pathways, and as such, a diverse future of agri-food systems that accommodate sustainability in a context specific and socially acceptable way (Duncan et al., 2022; Herrero et al., 2020; Wojtynia et al., 2021). A challenge here obviously is determining what 'optimal diversity' is, also given that a mission-oriented approach requires focus and targeted investment. As Klerkx et al. (2023) note, there is quite some turbulence now in a situation where it has been recognized that existing agri-food systems are not fit for purpose anymore, but there is no clarity on what should be the transformation pathways. Such diversity could be stimulated within one coordinated MAIS that is operationalized at a national level (e.g., the Dutch 'Circular Agriculture' mission is a central mission affecting different subsectors), but could also be taken up by a diverse set of more independent and co-evolving MAIS that each stimulate different transformation pathways (e.g. digital agriculture, agroecology, cultured meat). These pathways in turn may again have different 'search directions'. Here agricultural system scientists can support different transformation pathways through redesign processes, but also by qualitatively and quantitatively assessing plausibility and impact of transformation pathways,

Second, MAIS should consider diversity regarding the actors and types of knowledge involved in innovation dynamics. Here lie roles for agricultural systems scientists, but also for broader co-innovation

[2] Though these sections are specifically aimed at policy makers and researchers, given the multi-actor nature of MAIS these reflections are equally relevant for other actors in MAIS.

networks and policy makers. AIS approaches have acknowledged this diversity of actors (e.g. through concepts as co-innovation and innovation platforms), but some groups still remain excluded, or there may for example be a disconnect of new groups of actors such as agri-food tech start-ups with farmers (Melchior and Newig, 2021; Klerkx and Villalobos, 2023). As studies have repeatedly emphasized, including Indigenous communities, knowledge and values in innovation systems is crucial to better understand system dynamics, to protect ecosystems and provide social justice, for instance in innovation systems for circumpolar agriculture in Canada (Seguin et al., 2021), or in exploring the role of Indigenous and local knowledge in food system innovation in South Africa and Mexico (Pereira et al., 2019). Yet, it is also these communities and their knowledge that face structural barriers to meaningful participation in incumbent innovation systems (cf. Seguin et al., 2021; Lam et al., 2020). Relatedly, scholars of sustainable transformation have emphasized that it is crucial to include diversities of knowledge in processes of innovation and transitions (e.g., Caniglia et al., 2021; Lang et al., 2012; Lam et al., 2020). Therefore, it is important that future MAIS stimulate the inclusion of different communities and their local, ecological knowledge, and aim to deconstruct the (historically grown) barriers that prevent them from meaningful participation. It also requires engaging with debates on the decolonization of agricultural research (Gewin, 2022; Layman and Civita, 2022; Trevilla Espinal et al., 2021).

Third, we believe that addressing the politics of MAIS in terms of its diversity, also means to actively engage with the different roles that non-humans in agro-ecological systems (e.g. plants, animals, soil) can play in the politics of transformation (Kok et al., 2021b; Ahlborg et al., 2019). Increasingly, studies on the politics of transformation argue for relational perspectives on human-nature relations, beyond the classical dichotomy (West et al., 2020; Darnhofer, 2020; Figueroa-Helland et al., 2018), which also entails reconsidering the roles (or even agency) of non-humans in agri-food transitions, as also argued in Section 2.1. For example, agroecology and biodynamic agriculture pay a lot of attention to how humans and non-humans are intertwined, instead of separating humans from nature, or placing humans above nature (see for instance De Molina, 2013; Rigolot and Quantin, 2022). Additionally, agricultural system scholars have started taking this up for example by considering animal welfare and behavior into systems redesign (Romera et al., 2020). For policy makers it could mean recognizing rights of nature, for instance in Aotearoa New Zealand where Te Urewera National Park has been recognized with *"all the rights, powers, duties, and liabilities of a legal person"* (Ruru et al., 2017: 69).

2.3. Distribution

Do MAIS affect different actors and ecosystems in ways that justice can be guaranteed? Scholars have pointed out the importance of ensuring not only sustainable, but also socially just agri-food transitions. This begs attention to the different ways in which MAIS contribute, or not, to *just* transformation processes. Issues of justice in agri-food system transformation are manifold (Kaljonen et al., 2021; Hebinck et al., 2021; Tschersich and Kok, 2022; Whitfield et al., 2021). Firstly and historically, these involve questions around *distributive justice* (how are the burdens and benefits of transformation distributed across communities?).[3] Actively framing distributive justice in light of MAIS can help to further scrutinize the justice aspects of innovation processes aimed at mission-oriented transformation.

For agricultural systems researchers to address the politics of MAIS, means acknowledging that development, adoption and scaling of agricultural innovations (whether high-tech or social innovations) have significant effects on the distribution of resources across societies. At the same time, the current distribution of resources in agri-food systems also strongly drives the capacities of agri-food actors (such as small-scale farmers, food businesses or consumers) to develop and adopt specific innovations, that could support their (communities') livelihoods. In light of rapid digitalization and other technologies shaping Agriculture 4.0 (Basso and Antle, 2020; Herrero et al., 2020) which may have pervasive positive as well as negative effects across spaces and scales (Herrero et al., 2021; Kloppenburg et al., 2022; Rose et al., 2021), scholars have articulated the need for innovation systems to engage with approaches such as Responsible Research and Innovation (Klerkx and Rose, 2020; Metta et al., 2022; Stilgoe et al., 2013) to mitigate inequalities and exclusion dynamics that might emerge. This requires MAIS to be sensitive to divergent distributive effects across space and scale, as well as trade-offs that emerge in transition dynamics (cf. Tribaldos and Kortetmäki, 2022; Tschersich and Kok, 2022).

Important in this regard is that MAIS should contribute to just transformation in a wide range of geographical and cultural contexts, both in the Global North and the Global South, and in high-income as well as low- and middle-income countries (see Hebinck et al., 2021). While agri-food transitions have increasingly adopted issues of justice in policy and research, work on missions and transformative innovation policies has mostly incorporated these notions under labels such as 'inclusiveness' or 'inclusive growth' (see Haddad et al., 2022). This leads to several questions: how, and in which ways, are the benefits and burdens of innovations and transformation pathways put forward by MAIS distributed[4]? How can inclusion, growth and sustainability be combined in MAIS? How can MAIS restore historical injustices regarding the damages done to ecosystems, social injustices originating in the commodification of food and seeds, and the associated colonial (market and institutional) structures of global trade and oppression that have come with the technologies and practices developed in AIS (Ferrando et al., 2021; Vivero-Pol, 2017; Figueroa-Helland et al., 2018; Boogaard, 2021)? More explicitly engaging with work regarding food democracy, food justice, food sovereignty and post-growth economics (e.g., Lang, 2005; Candel, 2022a; Gottlieb and Joshi, 2010; Guerrero Lara et al., 2023) might also help to further advance just MAIS. In summary, this requires agricultural system researchers to interrogate the different ways in which MAIS could propagate innovation dynamics that reinforce (translocal) dynamics of injustice, might disadvantage specific communities or might produce adverse effects. In turn, this might also help to design MAIS that deliver just distribution of resources, contribution to both just and sustainable innovation dynamics.

2.4. Democracy

How can MAIS be designed and governed in democratic ways? For innovation systems to contribute to just transformations, and to help in designing and implementing innovations that have societal support, scholars have indicated that democratization is crucial to consider (e.g., Duncan et al., 2022; Stilgoe et al., 2013; Smith and Stirling, 2018). Democratization of innovation and transitions has been argued to have intrinsic normative value (see Chilvers and Longhurst, 2016), could enhance legitimacy of interventions (De Geus et al., 2022), and might yield better environmental governance (Pickering et al., 2022). For

[3] In the emerging literature on just transitions (often building on Western scientific traditions), issues pertaining to justice in transitions are also considered in light of *procedural justice* (how are just transformation processes organized?); *recognition justice* (whose values and perspectives are recognized in transformation pathways?); and *restorative justice* (how can we restore historical injustices in transformations?). See for instance Jenkins et al. (2016) and Tschersich and Kok (2022).

[4] Especially important to consider are trade-offs that MAIS might bring along: what if missions pushing for high-tech Agriculture 4.0 innovations positively affect biodiversity and farmer incomes in particular geographical contexts, but lead to adverse environmental and socio-economic effects in other parts of the world?

MAIS, democratization in our view requires, i.e., (1) ensuring that knowledge, innovations and transformation pathways are produced in deliberative and democratic ways; and (2) ensuring that the broader governance of MAIS is organized democratically, pointing to the need for institutionalizing democracy in different ways and for different purposes.[5]

For the democratization of production of knowledge and innovations for agri-food systems, there lie ample opportunities for MAIS to move beyond technocratic expertise through approaches such as responsible innovation (Rose and Chilvers, 2018; Chiles et al., 2021; Van Mierlo et al., 2020), citizen science (Ebitu et al., 2021; Ryan et al., 2018), inclusive innovation (Nhantumbo et al., 2016; Hoffecker, 2021), transdisciplinary research (Den Boer et al., 2021; Francis et al., 2008), decolonizing methodologies (Smith, 2021) and co-innovation and open design (Berthet et al., 2018). These approaches open up research and innovation processes to include participation and deliberation of different societal stakeholders, such as citizens, farmers and other agri-food system actors. Embracing the richness and value of different types of knowledge in co-production approaches (Hakkarainen et al., 2022) offers opportunities for agri-food systems research to engage with what has been dubbed 'democratic directionality' (Duncan et al., 2022). For MAIS to engage with democratization thus means that MAIS should establish and support the spaces and networks that could support democratized co-production of transformative knowledge and innovations, such as multi-stakeholder platforms, innovation platforms, transition intermediaries, public-private partnerships (PPPs), and Living Labs that bring together a wide variety of societal stakeholders around issues of agri-food innovation and transition (Klerkx et al., 2009; Metta et al., 2022; Chiles et al., 2021; Kok et al., 2023).

As such, the meaningful inclusion and deliberation of societal perspectives into MAIS, also requires more institutional embedding in science and innovation policy efforts. Importantly, this requires MAIS to warrant accountability and ensure democratic legitimacy of transformative missions and the innovation efforts these imply (cf. De Geus et al., 2022; Genus and Stirling, 2018). This includes asking questions such as: who decides on which projects, innovations and associated transformation pathways public money is spent (through subsidies, tax policies, etcetera)?; how can governments and companies account for the societal impacts that emerge (especially in light of private sector profits versus public goods and real costs)?; and what forms of science support mission-oriented innovation? Since agricultural systems researchers play roles in committees designing calls for research proposals, assessing proposals, and performing mission-oriented research, they too can influence mission-oriented science and innovation policy (see also Section 4).

3. Policy implications for the governance of MAIS

The political nature of MAIS (as well as agri-food innovation and transformation in general) begs for reflection on what this implies for how governance of MAIS can be designed, in efforts to support desired directionality, diversity, just distribution and democracy.

First, there is a need for new policy instruments that support MAIS. This requires developing coherent mixes of policy instruments that support transformative and disruptive innovations and networks, while also phasing out incumbent unsustainable practices and technologies that contribute to carbon lock-ins and other food system inertia and unjust dynamics (e.g., Janssen et al., 2021, 2023; Turnheim and Geels, 2013; Conti et al., 2021; Hebinck et al., 2022). It also requires governments to deploy and establish mixes of innovation policy instruments (e.g., R&D funding, taxes, regulations, etcetera) that support transformative and mission-oriented innovation dynamics, in ways that are coherent, consistent, complete and credible. For effective establishment of MAIS, innovation policies need to be connected to sectoral policies and the political economy of agriculture, environment, health, and other domains across multiple governance levels in order to mitigate trade-offs, ensure synergies and act upon crucial cross-sectoral leverage points. In making this change, challenges may arise on multi-level governance in agri-food systems as innovation policies are shaped in highly diverse policy contexts (from local to regional and supranational settings). In addition, both incumbent agricultural policies (e.g., the EU Common Agricultural Policy (CAP)) and emerging policy efforts that could support mission-orientation (e.g., the Farm to Fork Strategy) become highly contested (see Candel, 2022b; Trèves et al., 2022) and mission-oriented innovation policy mixes are often not yet coherent and consistent (EEA, 2022). It also begs for reflection on the performativity of policy concepts: how do dominant policy narratives shape (or hinder) particular pathways for agri-food systems innovation and transformation (Fairbairn et al., 2022; Lajoie-O'Malley et al., 2020)? Also, here the political economy of major economic models underpinning politics such as neoliberal globalized capitalism versus other economic models such as state-led economy, donut economy, solidarity economy, and degrowth and postgrowth economy plays an important role (Guerrero Lara et al., 2023; Bodirsky et al., 2022; Gibson-Graham and Dombroski, 2020).

Second, in addition to policy development, it is important to stimulate productive and inclusive science-policy interfaces on agri-food transformation and institutional arrangements that facilitate these (e.g., Hainzelin et al., 2023; Šūmane et al., 2021; Turnhout et al., 2020, 2021). There is a large number of science-policy interfaces that link (scientific) knowledge to processes of policy making in light of food system transformation, such as CGIAR, the UNFSS, the High Level Panel of Experts (HLPE) of the United Nations, IPES food, and the High Level Expert Group of the European Commission. While these have been effective in providing policy makers with robust and comprehensive scientific evidence and policy pathways for agri-food systems transformation, there is still the need to further strengthen, support and establish science-policy interfaces and institutions that foster pluralities of transformation pathways and knowledge, and provide legitimate, credible and evidence-based science (e.g., Turnhout et al., 2020, 2021), especially in light of the mission-oriented challenges in agri-food systems (Singh et al., 2023). This brings into question the way current institutions shape the relation between science and action, and how they give rise to particular directionalities in agri-food innovation, and not others (Herrero et al., 2020; Fanzo et al., 2020; Duncan et al., 2022; Dinesh et al., 2021; Turnhout et al., 2021). This latter point requires explicit attention as there is the risk of incumbent interests hijacking such multi-stakeholder science-policy interfaces. For instance, Canfield et al. (2021) describe the recent UNFSS with its promise of democratic engagement, and argue that its *"efforts to govern global food systems in the public interest has been subverted to maintain colonial and corporate forms of control"*. This impairs procedural justice in the UN-FSS (Tanzer et al., 2022).

In order to further stimulate the emergence of MAIS that take into the highly political innovation dynamics at play, there is thus a need to transform linked policy instruments and science-policy interfaces alike. Moving towards MAIS hence also means innovating the AIS, which could be done via smaller mission-oriented innovation experiments which then may induce more structural change of innovation systems (Turner et al., 2017; Kok et al., 2022; Markow et al., 2023).

[5] We are aware that the notion of democracy is approached and plays out differently in different socio-political contexts and governance traditions, and MAIS will need to deal with different 'innovation cultures' (Pfotenhauer and Jasanoff, 2017) and also different sorts of sustainability challenges in different countries. Nonetheless is has been shown that some of its values such as voice and participation may also enhance innovation in more centrally state-led countries (see e.g., Friederichsen et al., 2013).

4. Reflections on the role of MAIS research and researchers

In this perspective, following Leach et al. (2020), we have applied 4 focal points for assessing the politics of MAIS: directionality; diversity; distribution and democracy. This 4D perspective provides different entry points to addressing the politics of MAIS, but the different dimensions are not mutually exclusive. Rather, in empirical reality, there are strong interactions between the different dimensions. Importantly, focusing on 4Ds in MAIS will lead to trade-offs and incompatibilities within and between different dimensions, in designing and implementing missions. Based on this perspective, we present four cross-cutting reflections: two regarding research *on* MAIS, and two regarding research and researchers *in* MAIS. An overview of key research questions based on the 4D framework is outlined in Table 1, and discussed below.

First, considering research *on* MAIS, following Klerkx and Begemann (2020) there is a need to map out which food system transformation missions there are on (supra)national levels, as this remains ill-defined, despite the emerging work mentioned in Section 1 (Begemann and Klerkx, 2022; Fielke et al., 2023; Klerkx et al., 2023; Magrini, 2023). Increasingly dedicated methodologies are emerging which can help in doing so (Wanzenböck et al., 2020; Wojtynia et al., 2021; Elzinga et al., 2023; Toillier et al., 2022). Without getting more clarity how MAIS are shaped, researching the politics in them will be difficult. Relatedly, this could help to better link research to policy developments, where the emergence of considerations regarding social justice and inclusiveness in agri-food innovation is getting substantial traction (see e.g., the UN Food Systems Summit, and efforts of CGIAR), yet where transformative policies also face strong resistance of incumbent agri-food lobbies (e.g., the EU Farm to Fork Strategy, see Candel, 2022b; Schebesta and Candel, 2020). The ways in which such policies become negotiated and contested, and the ways they shape, interact with, as well as hinder or support the establishment of truly transformative MAIS, is a key direction for future research. This might also help address the gaps and contradictions between policy discourses and concrete action (see EEA, 2022).

Second, explicitly addressing the politics of MAIS might help to better understand the how and why of innovation dynamics, as well as to provide relevant governance interventions. Asking a variety of questions regarding the politics of (agri-food) transformation, might help to articulate the variety of ways in which MAIS become political. Turning the gaze to politics could also help to articulate how innovation dynamics and MAIS emerge differently in different countries, and across geographical scales and contexts, which are important considerations in the field of sustainability transitions (see e.g., Hebinck et al., 2021, Pigford et al., 2018, cf. Coenen et al., 2012). Future research on MAIS could also explore the degrees to which interactions (both synergies and trade-offs) between different dimensions of the 4D framework take shape in different geographical contexts, also considering the interactions between the Global South and North. Importantly, in light of the dominance of Western institutions, knowledge and values in scholarship on agri-food systems (e.g., Gewin, 2022; Tschersich and Kok, 2022), it could be valuable to consider whether the 4D framework itself provides enough opportunities to articulate and study the dynamics of (de)colonization (beyond the redistribution of resources and power, see Kukutai et al., 2021) that research and innovation reproduce, or whether adding a 5th D on Decolonization is needed.

Third, let us consider the roles of research and researchers *in* MAIS. An explicit consideration of the politics of MAIS begs reflection on the political nature of research that enables agri-food system transformation. This is especially relevant in current times of quickly developing and potentially disruptive technologies (Herrero et al., 2020; Klerkx and Rose, 2020; Reardon et al., 2019), which many agricultural systems scientists such as agronomists, agricultural technology developers, animal and plant breeders work on. As we have stressed, such technologies and their impacts are not value-neutral, and this raises several questions. How do particular interpretations of, and values related to, concepts like agroecology, resilience, food security, biodiversity or digital agriculture find their way (or not) into research and innovation efforts such as field trials, equipment and systems design and engineering, and modeling and scenario mapping (e.g., Vanloqueren and Baret, 2009; Allen and Prosperi, 2016; Gasselin and Hostiou, 2020)[6]? How can productive interactions between transformation pathways been achieved without that these loose too much meaning, e.g. between digital agriculture and agroecology, and agroecology and regenerative agriculture (Bellon-Maurel et al., 2022; Tittonell et al., 2022; Sullivan, 2023)? Which (types of) knowledge and values do agricultural systems researchers include in their models, which metrics do they use, which scientific engagement activities, and what does that imply for the outcomes of research, as well as the resulting innovation dynamics that builds on these outcomes? Confronting such questions requires researchers to consider which agri-food actors they engage in co-developing such modeling and scenario mappings and why (cf. Karlsson et al., 2018), and which approaches they consider appropriate in light of support of agri-food system transformation. On a more fundamental level, it also points to the question of which (private and public) actors and institutions determine and influence research agendas through funding calls and other (policy and financial) instruments, which already encompasses strong directionalities for research (e.g., Reardon et al., 2019; Pimbert et al., 2010; Klerkx and Leeuwis, 2008; Lahsen and Turnhout, 2021). If MAIS research relies too much on

Table 1
Key questions regarding the politics of MAIS, based on a 4D perspective.

Dimension	Key questions for MAIS research and researchers
Directionality	What future agri-food systems transformation pathways are supported by MAIS, and how do I as a researcher relate to these? • In which ways do different (powerful) actors, institutions and structures shape the direction of MAIS? • How can MAIS contribute to redirecting power relations in the agri-food systems? • How can MAIS contribute both to building new systems, as well as phasing out incumbent systems?
Diversity	How can MAIS stimulate diversity, and how do I as a researcher deal with diversity? • How do MAIS balance diversity with directionality? • Are there 'optimal' diversities to aim for through MAIS, in terms of transformation pathways, or types of knowledge? • How do MAIS actively empower diverse groups of actors, including the most vulnerable communities?
Distribution	Do MAIS affect different actors and ecosystems in ways that justice can be guaranteed, and how do I as a researcher deal with this responsibly? • How do MAIS address distribution of benefits and burdens? • What trade-offs between different justice dimensions emerge in MAIS? • How does (the absence of) fair distribution through MAIS become manifest across geographical scales and contexts?
Democracy	How can MAIS be designed and governed in democratic ways, and how can I as a researcher organize for this? • How do MAIS acquire legitimacy and accountability of their outcomes and processes under different governance systems? • How does 'democratization' impact the directionality, diversity and distribution of MAIS? • How is democratic knowledge production in MAIS institutionalized in incumbent scientific systems?

[6] Obviously the politics of choices has always played a role in AIS, as well as its consequences, as analysed by the fields of Critical Agrarian Studies and Political Agronomy (see e.g. Scoones, 2007; Scoones and Thompson, 2011; Taylor et al., 2021) but in view of the strong normative and transformative character of MAIS may need more explicit attention.

technical knowledge, dominant values and incumbent interests, this leads to underrepresentation of important transformation pathways and social innovations (cf. Scoones et al., 2020; Pigford et al., 2018; Tschersich and Kok, 2022). In fact, it often reinforces unsustainable and unjust dynamics (see Turnhout et al., 2020).

Fourth and finally, this points to the potential of transdisciplinary research approaches for understanding and accelerating the development of MAIS and agri-food system transformation. Considering the complexity and political nature of innovation dynamics, scholars have stressed that complementing mono- and interdisciplinary research with transdisciplinary research efforts that include a plurality of societal actors, knowledge and values in research processes, might lead to more robust research outcomes, innovations better suited to tackling local challenges, more legitimacy of interventions, as well as could help illuminate promising transformation pathways (e.g., Lang et al., 2012; Fazey et al., 2018; Den Boer et al., 2021). Such interdisciplinary and transdisciplinary perspectives have already been noted as important for the Agricultural Systems community (e.g. Berthet et al., 2018; Brun et al., 2021; Rossing et al., 2021; Reardon et al., 2019), but could be strengthened further. Given the normative nature of directionalities fostered through MAIS, transdisciplinary approaches themselves are political, which requires reflection and careful attention in research processes, for otherwise such efforts might reinforce existing power dynamics and hinder transformation (Turnhout et al., 2020; Fritz and Binder, 2020). For research to support MAIS not only requires novel research approaches, but also requires changes in the way agri-food research projects are funded, organized, valued and supported by policy instruments (Rossing et al., 2021). Hence, this requires a double transformation: if research truly aims to contribute to transformative agri-food innovation, we also need different scientific systems (Kok et al., 2019; Fazey et al., 2020) that accommodate for a large diversity of research approaches.

In conclusion, confronting and engaging with the politics of MAIS is not an easy endeavor, but it is critical to advance agri-food system transformation in directions that are not only sustainable and transformative, but also socially just and desirable.

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Authors declare no competing interests.

Data availability

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