Towards agricultural innovation systems 4.0?

Supporting directionality, diversity, distribution and democracy in food systems transformation

Prof.dr Laurens (L.W.A.) Klerkx

Academic lecture as Personal Professor of Agrifood Innovation and Transition at Wageningen University & Research on 9 February 2023

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Esteemed Rector Magnificus, dear colleagues, students, family, and friends,

As is the case with several colleagues at WUR, though increasingly less, there is a connection to agriculture through some family tie. This also holds for me. My grandfather and my grandmother ran a mixed farm in Rijkevoort, in the province of Brabant, close to the area 'De Peel', which was being converted from a peatland area to agricultural lands in the past century. Now it is known as an area with a lot of intensive animal production, with all the problems that go with it (bad smells, nitrogen emissions, animal welfare discussions). Animal production as a specialised system, and also specialised cropping systems, ran counter to my grandparents' beliefs about the value of mixed farming. In the era of post WW2 agricultural modernisation, they were not a big fan of the scale increase that came with it, and the use of artificial fertiliser and pesticides. They believed in the mixed crop-livestock systems that are again promoted today. In a sense they were circular farmers before the term was even invented.

Though modern agriculture certainly has led to productivity increases, it has also led to environmental degradation. It does not guarantee a decent income for farmers. Producing more food has not given everyone better access to food. Some people still suffer from lack of food security and are undernourished. Others are tempted continuously to consume more and often highly processed foods, which means obesity is on the rise worldwide. Modern agriculture, and more broadly the food systems of which it is part, are a major driver of human induced change in the current 'Anthropocene', the geological era shaped by human kind (Willett et al., 2019). It has led Donna Haraway to state that we actually have created what could be called 'the Plantationocene', with all sorts of consequences such as loss of nature and biodiversity (Haraway, 2015). In The Netherlands, we now have a heated debate around the role of agriculture as regards nitrogen deposition and how that affects our nature areas which experience species loss.

These problems have led scientists to conclude that food systems (see Figure 1) are a major contributor to the exceeding of so-called planetary boundaries (Willett et al., 2019) and that food systems are 'broken'. It has been argued that food systems are in need of transformation, which entails changing the way food is produced, processed, traded, and consumed. Multiple policy plans and strategies for food systems transformation have been published worldwide in recent years, and in 2021 we had the first UN Food Systems summit. Nonetheless, despite good intentions and some concrete policy, business and citizen action, efforts for food systems transformation are often still fragmented and sometimes even contradictory. For example, in the Netherlands a plant based diet is increasingly promoted, but there is no policy action to lower the value added tax on vegetables to make these more accessible.

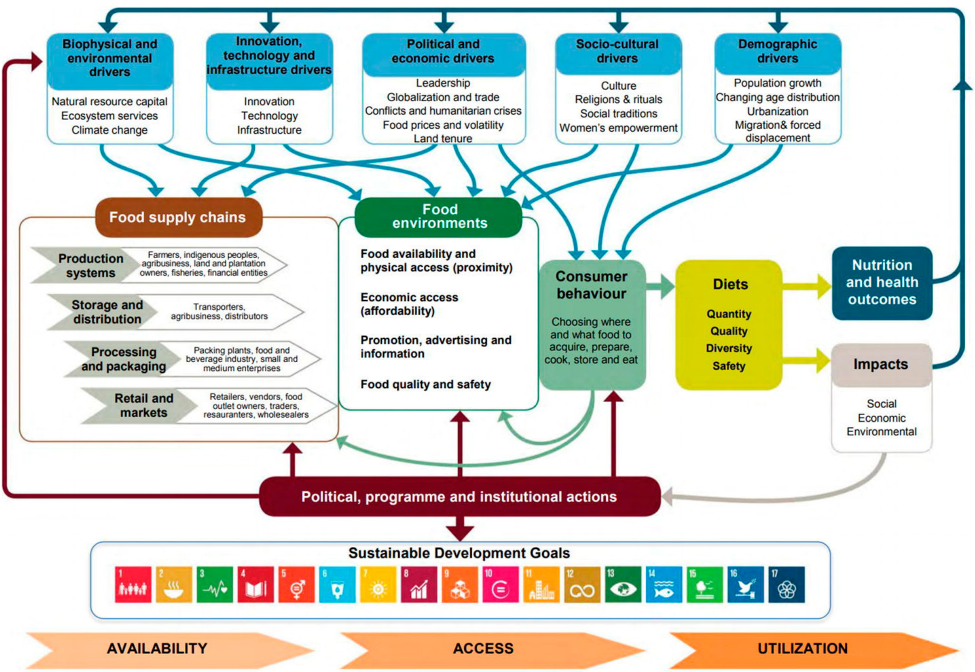

Figure 1. Food systems (source: Leach et al., 2020).

Scholars from transition studies have conceptualised transformation through the so-called X-curve (see Figure 2), which depicts how alternative systems emerge, and how existing systems decline (Hebinck et al., 2022). This is not necessarily through a process of revolution in which existing systems are fully and radically replaced by others, but it can also be through evolution, through processes of (partial) substitution and more gradual conversion of systems. So transformation can happen in big steps and through rapid changes (e.g. under influence of a major event such as the Ukraine-Russia conflict, or technological changes such as mobile broadband internet), but also incremental steps or 'small wins' (Schagen et al., 2023; Termeer and Metze, 2019).

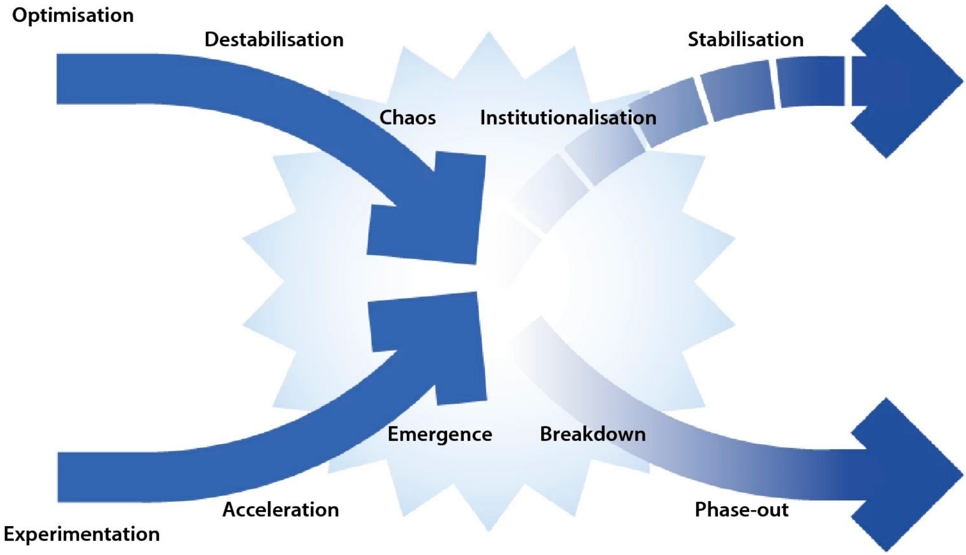

Figure 2 : The X-Curve of Transformation. (Source: Hebinck et al., 2022)

It seems that food systems transformation is moving towards the phase of emergence and chaos. Since the need for food systems change has been recognised for some time (Willett et al., 2019), there has been experimentation and acceleration of alternative ways of food production, processing, logistics , trade, and consumption. Think about organic agriculture, for example. These constitute so-called 'transition pathways' which ultimately can lead to transformation of current food systems . Current food systems are becoming destabilised due to increasing environmental and societal pressures, for example climate change and animal welfare debates, but are not yet in breakdown and phase-out.

In my work, I mainly look at the agricultural production side of such transition pathways, that means agriculture in traditional ways but also in novel ways. I will briefly characterise some of these transition pathways.

As regards 'traditional' agriculture, often related to land-based sectors, there are a host of concepts that are buzzing as regards the change from 'industrial' or 'conventional' systems to more sustainable systems, denoted with terms such as 'regenerative agriculture', 'conservation agriculture', 'ecologically intensive agriculture', 'agroecological agriculture', 'nature-inclusive agriculture', 'nature-positive agriculture', and many more terms. As WUR colleague Professor Ken Giller has pointed out together with Dr Jim Sumberg of IDS, it is often unclear what the different concepts mean, how they are different from one another, and what are the actual gains (Giller et al., 2021; Sumberg and Giller, 2022).

In terms of 'novel' forms of agriculture, it has been argued that we are now witnessing the 'fourth agricultural revolution', also denoted as Agriculture 4.0 (see Figure 3). A host of new technologies have entered the scene with the promise, expectations, or perhaps hype that they will help transform agricultural production, and food systems more widely (da Silveira et al., 2021; Herrero et al., 2020; Klerkx and Rose, 2020). These agriculture 4.0 technologies are several. Exemplary are interconnected digital technologies, such as precision agriculture technologies based on sensors and global positioning systems, novel ways of digitalised and autonomous mechanisation such as robots and drones, concepts such as vertical farming which means stacked growing of plants under ledlights, technologies such as blockchain to track supply chain transactions, and platform based apps to match demand and supply for all sorts of services.

Another example concerns novel ways to produce protein, such as cellular agriculture based on labgrown animal tissues and plant based proteins made of, for example, soybeans, field beans, or algae. Agriculture 4.0 is also increasingly about intersections with other sectors and non rural areas, such as the energy sector through concepts such as bioeconomy and agrovoltaics, and urban agriculture. Emerging and tentative systems of Agriculture 4.0 and more established alternatives, however, have not yet replaced dominant current systems. Some alternatives go through a phase of hype (e.g. plant-based protein, vertical agriculture), but then decline again in terms of development, investment and interest (Helliwell and Burton, 2021).

The debate on ‘future agricultures’ and on what Agriculture 4.0 should look like is thus in full swing. Sometimes there are strong oppositions and aggressive framings, between what have been called ‘prophets’ and ‘wizards’, or ‘techno-pessimists’ and ‘techno-optimists’. Such debates are inevitable and necessary, and have also been cultivated at WUR. However, strong juxtapositions are not always productive to moving ahead (Mockshell and Kamanda, 2018). Also, as we have learned from the past, moving to one dominant way of organising the food system may not be the best option. I argue that Agriculture 4.0 should incorporate the full range of concepts, both those associated with high-tech, and those related to circular, nature-inclusive, agroecological technologies, as they also often intersect and are all highly knowledge-intensive (Leeuwis, 2000).

In addition, food systems transformation is not just about changing technologies and practices for agricultural production. It is for example also about the way we organise markets, ranging from globalised value chains to local food systems, and values embedded in food culture. Here different concepts such as degrowth, food as commons, buen vivir, donut economy, and circular economy come in (Bodirsky et al., 2022; Gibson-Graham et al., 2020). In this regard, some people already go beyond using the term of Agriculture 4.0, and have coined ‘Agriculture 5.0’ in which environmental care and societal wellbeing are emphasised (Fraser and Campbell, 2019).

As the X-curve indicates, as I mentioned earlier, food systems transformation is not only about building alternative systems, it also requires undoing current agrifood systems, either through phase-out or conversion. However, this is far from easy and from finished because of many historically shaped practices, infrastructures, markets, rules and regulations, which maintain a certain balance or lock-in (Conti et al., 2021). There are many economic and political interests to maintain current agriculture and food systems. As colleagues like Dr Jeroen Candel point out, while policy discourse may talk transformation, political action and policy may nonetheless continue to support business as usual, and industry may engage in greenwashing.

Hence, transformation is in many ways about shifting power balances, which will benefit some, but will also hurt others. Transformation will have relative winners and losers, it has equity and inclusion effects, hence it has been argued lately that justice in transitions is an important consideration (Tribaldos and Kortetmäki, 2022).

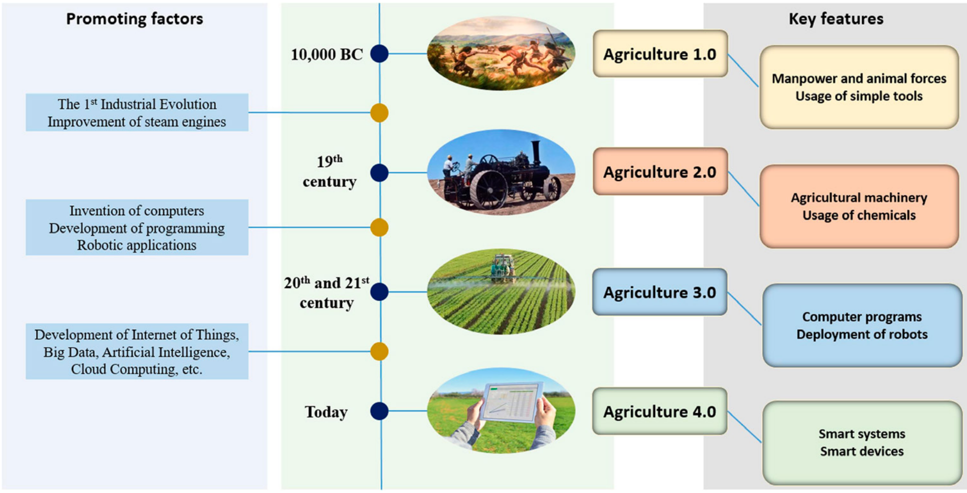

Figure 3 : evolution towards Agriculture 4.0 (Source: Zhai et al., 2020)

The role of innovation systems in food systems transformation

It is clear that the development of alternative and novel agricultural system concepts and technologies requires innovation to take place, and these are not just product or process innovations. They are comprehensive 'system innovations', for which several connected technological, social, and institutional innovations need to take place. This has been called co-evolution of innovation (Kilelu et al., 2013), or more recently 'innovation bundles' (Barrett et al., 2020). For example, for novel proteins new technologies need to be developed such as cellular meat production to create optimal textures of meat fibres, consumers need to get used to the idea their steak comes from a lab, and food safety regulations need to be adjusted. Furthermore, next to innovation, also processes of so-called 'exnovation' have to take place in which current systems are phased-out, by discontinuing certain practices of making them less attractive. In the case of food systems, this can be done for example by sugar, fat or meat taxes.

In my work, I look at how innovation and exnovation processes are organised and supported by all sorts of actors. These actors include farmers, processors, input suppliers, and consumers as part of agrifood value chains, but also dedicated innovation support actors such as applied researchers and advisors. In the scientific field I'm in we use the concept of 'agricultural innovation systems' to understand such networks of actors whose interactions produce innovation, supported by infrastructures such as research facilities, and by institutional arrangements such as innovation policies, for example through research and innovation funding.

We can devise several generations of thinking on agricultural innovation systems, or AIS[1], the study of which has a long trajectory in my chairgroup, Knowledge, Technology and Innovation. In analogy with the Agriculture 4.0 concept, I denote these in this lecture as AIS 1.0 to AIS 4.0 (see Figure 4).

Principally, the thinking on the support of agricultural innovations are started as a linear or technology transfer model in which the idea was that innovation are transferred from the outside (from research, or large agribusiness) to be adopted by farmers, so AIS 1.0 in fact only captured part of the system. In this model, the role of extension services which transferred knowledge and supported adoption was a key factor. A predecessor of KTI, Extension Science, was founded by Professor Anne van den Ban to study this process.

In later studies, it was recognised that innovation is actually implicitly or explicitly co-developed together with the main stakeholders through multiple feedback loops, including farmers but also other relevant players in agri-food systems. First, this was mainly focused on actors in the knowledge system and focused on interactive and participatory science, which became known as Agricultural Information Systems or Agricultural Knowledge and Information Systems[2], developed by former KTI professors Niels Röling and Paul Engel (AIS 2.0).

Later, this was broadened to capturing the complex dynamics of multi-actor innovation of all actors connected to an agricultural value chain and its support environment such as finance and policies (AIS 3.0). AIS 3.0 is seen as a complex adaptive system with multiple interactions in processes of innovation co-production or co-innovation. The AIS 3.0 perspective is now used to understand what players in a given country or sector matter for innovation and what their roles are, the broader institutional and policy frameworks that enable or disable collaboration for innovation. It can be used as a diagnostic framework to detect particular barriers or 'systemic failures' that hinder co-innovation. To deal with such barriers different multi-actor interventions to enhance co-innovation have emerged such as innovation platforms, innovation hubs, and innovation brokers (on which I did my PhD thesis). With many colleagues at KTI we have worked with this AIS 3.0 perspective over the past decade.

1 As goes for many concepts, AIS is not the only approach to look at innovation as a multi-stakeholder concept, there are similar concepts such as open innovation, or the triple or quadruple helix.

2 Now AIS 3.0 are also called AKIS in some contexts, where the acronym stands for Agricultural Research and Innovation Systems.

With its focus on innovation as a multi-actor innovation co-production process, the AIS 3.0 way of working is also well anchored within WUR, where terms have been used as ‘golden triangle’ or ‘Dutch Diamond’ to describe the collaborative work between WUR and other agrifood actors to jointly innovate. AIS of the third generation is an important concept in agrifood development worldwide, with large institutions such as World Bank and FAO promoting it.

Despite it being a useful concept for capturing the complexity of agricultural innovation, a major recent critique on AIS 3.0 is however that it is mostly focused on innovation for economic growth and less explicit about how to organise innovation and exnovation for food systems transformation. Since a wave of attention between 2005 and 2015 the AIS concept has seen limited further development. The recent technological developments of Agriculture 4.0 and a focus on transformation call for a revisiting and broadening of the concept (Hall and Dijkman, 2019; Pigford et al., 2018) (Schot and Steinmueller, 2018).

Following colleagues such as Andy Stirling, Melissa Leach and Jessica Duncan, (Stirling, 2009; Stirling, 2011; Duncan et al., 2022; Leach et al., 2020), I argue that the concept of AIS should better accommodate the so-called 4D’s for food systems transformation.

Directionality: What directions are different transition pathways headed in? What goals, values, interests, power relations are driving particular pathways?
Diversity: Is there a sufficient diversity of transition pathways? Are these diverse enough to resist powerful processes of lock-in, build resilience in the face of uncertainty, and respond to a variety of contexts and values?
Distribution: Who stands to gain or lose from current or proposed transition pathways, or alternatives? How will choosing between different pathways affect inequities of wealth, power, resource use, and opportunity – across various elements (gender, ethnicity, class, place and so on)?
Democracy: is there equity of opportunity for voice and inclusion, and processes that enable and enhance this, whether formal or informal?

In relation to these 4Ds in the current context of agriculture and food systems transformation, AIS 3.0 has some shortcomings that hinder a better understanding of how transformative innovation unfolds and needs to be supported (see also Klerkx and Begemann, 2020; Pigford et al., 2018), which would need to move to an AIS 4.0.

1 AIS 3.0 does not yet seem to comtemplate very well the diversity of new players that have come in under influence of digitalisation and other Agriculture 4.0 technologies.

2 The issue of *diversity* of *directionalities*, so what sorts of innovation and exnovation are supported, is often not well addressed in AIS 3.0. AIS are often still seen as an homogenous whole, whereas given the diversity of directionalities and connected actor networks, there is considerable heterogeneity in AIS. What does this imply for the balance of power in food systems, what is the distribution of impacts?
3 The recognition of who has agency, who is included in innovation and who not? So to what extent is there democracy in AIS? How can marginalised actors be empowered? What is the role of non-humans in this respect? Though contemplated by science and technology studies in the field of agriculture, within systems concepts on innovation the agency of non-humans and the material has not yet been well recognised.

Next I will elaborate a bit more on research lines connected to these gaps in knowledge that may help to further build the concept of AIS 4.0.

Figure 4: evolution towards AIS 4.0 (source: own elaboration)

Research agenda

1. New players in AIS 4.0
As regards the first point, new players in AIS 4.0. Within AIS 2.0 and 3.0 it has been contemplated that the sources of innovation can be multiple. The seminal work by Keith Pavitt (Pavitt, 1984) indicates agriculture is a ‘supplier dominated’ sector in terms of innovation, in which players such as large agrochemical companies, machinery producers, biotech companies push the technological frontiers. This may hold true for industrialised forms of agriculture, but the role of more decentralised local, farmer or community based, and grassroots innovation is also widely recognised. Recently, to this diversity of sources of innovation AgTech and FoodTech start-ups can be added, in view of the Agriculture 4.0 revolution. It has been shown that investment in the form of risk capital and venture capital has gone up dramatically, as agricultural technology and service development is seen as the next investment object.

Some of these start-ups operate within paradigms of conventional agriculture, others have more disruptive propositions. Some are highly driven by silicon valley models of fast growth, fast scale-up, fast revenues (Biltekoff and Guthman, 2022; Fairbairn et al., 2022; Reisman, 2021), whereas others are driven by social entrepreneurship and transformative ambitions (Nyamekye et al., 2021). These start-ups introduce potentially radical innovations and new ways of working, and ask for new roles of traditional players. For example, what raw materials will dairy and beef farmers provide in a context of cellular meat and dairy and precision fermentation, and what does this mean for the processing industry? How do integrative concepts such as agrovoltaics and circular agriculture foster new ways of cooperation between sectors such as energy and sanitation?

Early research done in New Zealand by former KTI PhD Dr Kelly Rijswijk showed that the emergence of new players in the context of digital agriculture had implications for the so-called organisational identity of existing actors in the AIS, in her case agricultural research and advisory organisations, both in terms of their intangible identity such as norms and values, and their tangible identity in terms of the sorts of capabilities they develop and the services they provide (Rijswijk et al., 2019). They had to grasp how digital agriculture and agtech companies affected them and reposition them in the evolving AIS.

To bring it closer to home, we also see these developments at WUR, which is an organisation which always has adapted to its environment (e.g., to phenomena such as privatisation, demand-driven science, social license) (Spiertz and Kropff, 2011). In recent years, all kinds of initiatives have developed, such as StartLife and StartHub, the Wageningen Data Competence Centre, the One Planet Centre, but a comprehensive study of what this means for how we innovate and how it has impacted WUR's role in the innovation system is still to be done. This is relevant, also in view of the fact that through new technologies such as robotics, other universities which have traditionally not been specifically focused on agriculture are developing agrifood branches, for example the Delft AgTech Institute. Additionally, large programme in the AgTech and also FoodTech space are proliferating, like Robocrops and Agrofood Robotics, and programme such as Cellular Agriculture funded by the Dutch Growthfund.

We thus need a better understanding of whether and how this changing landscape of players in the AIS affects the way agrifood innovation is done. With visiting PhD Moritz Dolinga we have started to explore this topic, analysing how actors in the Wageningen AgTech ecosystem are innovating, and what is the influence of a 'Silicon Valley style' of innovating with start-up incubators, and accelerators.

However, it is not just about 'tech' only, there are also other players who have perhaps been around for longer, that need to be contemplated well. These include grassroots movements related to agroecology, community supported agriculture, and forms of social agriculture (Anderson et al., 2019; Espelt, 2020; Hassink et al., 2013).

So this line of work aims to explore questions such as: Who is part of AIS 4.0, or do some actors innovate at the margins? Is there one AIS 4.0, or are there several? Is AIS 4.0 synergic, or does it foster unproductive antagonisms (Leeuwis et al., 2021)? Also, are the boundaries of AIS 4.0 global, national, sectoral, regional, technological, cross-cutting? Or are AIS rather led by the challenge tackled or the food system vision they aim to realise? This brings me to the next research line.

2. Missions driving AIS 4.0
It has been argued that theory on AIS so far is largely devoid from serious reflection on directionality. In other words, innovation for what aim, following what vision of future agriculture and food systems, with what bundle of technologies and social practices? AIS are often presented as technology neutral, but different values and visions on what is 'good agriculture' and 'good food systems' influence investment choices (Leeuwis, 2000; Vanloqueren and Baret, 2009). Directionality is thus an essential part of AIS. In the past clear political choices have been made, for example choices for specialised systems, monocultures, certain scales of operation, sometimes pushing for a universal model. Well-known criticisms coming from Wageningen Rural Sociology are that there is not one style of farming, and that there can be several viable options. Also, a model that works in one place, does not necessarily work in another place.

As I argued earlier, in the current context of transformation which tries to break with dominant unsustainable food system configurations, we are currently witnessing a plethora of technologies, social innovations, and value proposition, constituting different transition pathways. Some of them are more niche oriented and can be quite radical, others are reconfigurations from the incumbent system and mainly imply incremental change.

There is quite some agreement that markets only cannot drive more transformative change, and break with system lock-ins and path-dependencies (Conti et al., 2021; Klerkx and Begemann, 2020). Recently, pleas have been made that it again requires stronger public sector guidance and investment and political choices on where to go to and to regulate the market. This has been contemplated in ideas on 'mission-oriented' or 'challenge-led' innovation, which is is about gearing innovation towards solving these societal challenges and support directionality. Missions have a clear ambition and vision for what a transformed food system should look like and orchestrate a portfolio of 'bundled innovations'.

In view of what mission-orientation may mean for the study and operationalisation of AIS 4.0, following ideas by Professor Marko Hekkert and colleagues at Utrecht University (Hekkert et al., 2020), one could consider the idea of 'mission-oriented innovation systems' as a key building block of AIS 4.0 (Klerkx and Begemann, 2020; Pigford et al., 2018). In other words, AIS 4.0 is essentially a mission-oriented innovation system. These are innovation systems that form around a particular challenge and transition pathway, such as protein transition or circular agriculture. However, there are still many questions and issues on how to make mission-orientated innovation systems work.

Though the state is important in mission-oriented innovation systems, in view of co-innovation principles, the state cannot shape such directionality just by itself. In society there are also multiple civil society organisations, thinktanks, and NGOs co-shaping such missions. Here also lies a challenge: whereas a mission may presuppose strong top-down steering, it needs buy-in from below, and a democratic process (at least in our Western European context). Also, whereas missions may imply a strong prioritisation towards a particular direction, they also need sufficient diversity (Leach et al., 2020) to accommodate different values in pluralistic societies. So how many missions can there be in AIS 4.0, are there competing mission systems and what does this imply for transitions? For example, there have been criticisms that at international fora such as the UN Food Systems Summit (Duncan et al., 2022; Montenegro de Wit et al., 2021) high-tech transition pathways are favoured over agroecological transition pathways.

In addition, following Leach et al., there are always *distributive* impacts, of how transformative missions impact on people, the environment, etc. This means that it is also important to study issues of justice in transitions (Rijswijk et al., 2021; Tribaldos and Kortetmäki, 2022; Wigboldus et al., 2016). For example, how does a mission-oriented approach deal with issues such as responsible innovation and scaling, and to what extent is responsible innovation and scaling reconcilable with a bold 'moonshot' type mission?

Some work has already started in this research line. With postdoc Dr Stephanie Begemann we have been researching the Dutch Circular Agriculture mission, and found that existing structures for innovation policy and planning, reduce the ambition of the mission since they represent vested interests. Also, PhD candidate Maria Fernanda Rodriguez has looked at comprehensive policy mixes for transformative missions, and similarly has found that reinventing these policy mixes is not easy due to legacy policies and rebranding of existing policies. Thus, future work should analyse under what circumstances missions really become transformative and supported by balanced and responsible innovation and exnovation policy mixes.

Mapping directionalities and associated transformative missions in AIS 4.0, and what power dynamics and coalitions are connected to such missions, are thus a key aspect of future research. Here novel methods for such ‘mission mapping’ could be used based on data science looking at all sorts of indicators, such as discourse coalitions, level of investments, societal sentiments, and the number of organisations emerging in a technological field related to a mission.

Now I will go to the last research line on AIS 4.0.

3. Non-humans in AIS 4.0

The AIS concept emphasises the roles of actors (people) and institutions (rules, habits, regulations, norms, laws, policies), so AIS are essentially, driven by human structures and agency (Klerkx et al., 2010). However, increasingly also the role of non-humans and materiality in agrifood innovation has become recognised. This is quite logical in view of agrifood systems being constituted of biological and technological systems and closely interacting and being embedded within ecosystems. Modern agriculture has tended to have a control paradigm and a focus on limited diversity, and many innovation decisions from the past involved an engagement with non-humans which have led to detrimental effects (e.g. intensive animal farming, high external output use). Biodiversity crises and perspectives such as circular, regenerative and nature-positive agriculture call for a reconnection and integration with nature, and this asks for research on the interplay between humans, non-humans, and materiality in agricultural innovation systems.

Recently, the agrifood sociology literature has also called for renewed attention to human and non-human relationships in farming, through concepts such as assemblages and affordances (Comi, 2020; Darnhofer, 2020; Glover, 2022). The STS and critical agrarian studies branch of KTI, has focused for a long time already on materiality and non-human agency, for example through methods such as technography (Jansen and Vellema, 2011).

The study of non-humans and materiality in agriculture is hence not new, but agriculture innovation systems and agrifood transition studies are rather implicit about it. I argue that more explicit attention to how ecological agents such as plants and animals, but also digital agents such as artificial intelligence, interact with humans in AIS 4.0 is needed. We need to understand how this influences innovation and exnovation outcomes and ultimately food systems transformation (see also Glover, 2022; Vermunt et al., 2020)).

A better consideration is, for example, needed of how ecological processes determine a certain space of innovation options, and the sorts of feedback loops are triggered in innovation process (e.g. in scaling) and how innovation system actors anticipate on and adjust to these. Also, other forms of agency of nature start playing roles. In many countries, nature is getting legal rights (e.g., legal rights of rivers, rights for animals) and this may have implications for how agricultural innovation systems operatie. Also, as colleague Professor Bedir Tekinerdogan has also argued, the role of AI as an autonomous innovation agent and how it steers innovation processes is needed (Haefner et al., 2021). The Chilean company NotCo, for example, has become very successful by using machine learning to determine its plant based protein products.

Understanding the role of non-humans and materiality in AIS 4.0 is also important now that we are getting hybrids of systems e.g. mixes of agroecology with digitalisation such as pixel-cropping, which are becoming more prevalent (Bellon-Maurel et al., 2022; Ditzler and Driessen, 2022; Klerkx, 2020) and the increasing role of copying nature in technology through biomimicry as Professor Vincent Blok argues (Blok and Gremmen, 2016).

Through the work of PhD candidate Maria Contesse we have already shown that non-human actors such as agricultural pests such as ‘Bagrada’ or the ‘painted bug’ are active agents that influence the choices humans make in transition processes (see Figure 5). They can also provide windows of opportunity to accelerate transitions, or conversely, counteract transitions (Contesse et al., 2021). With colleagues Dr Katherine Legun and Dr Karly Burch we have been looking at how robotisation affects human expertise in connection with the non-human expertise of the robot, and how that is intermediated by plants. With Dr Kelly Rijswijk we worked with the concepts of socio-cyber-physical systems to understand different interactions in agrifood digitalisation and what that means for organising responsible innovation.

a)

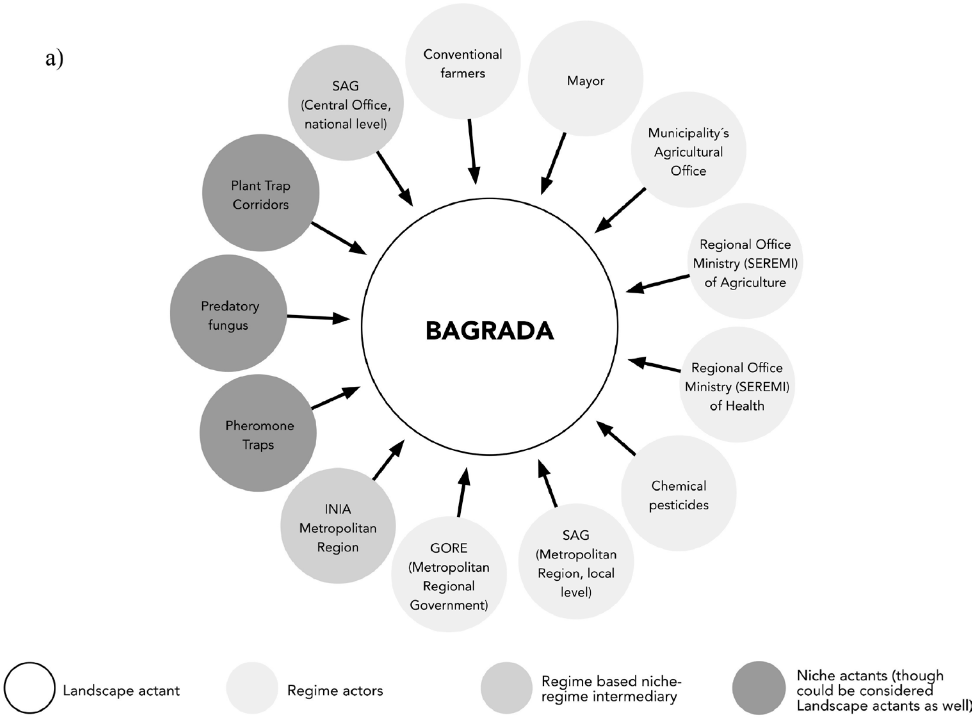

Figure 5: Bagrada a a key agent in agrifood systems transitions (Source: Contesse et al., 2021)

Based on this initial work, in this line of work I aim to further develop a whole systems understanding of how different material, human, and non-human relationships shape AIS 4.0.

Zooming in: on the role of dedicated innovation support agents in AIS 4.0

I have discussed three main lines I want to explore, but before going to some final words of thanks I want to zoom in here on innovation and perhaps also exnovation support agents. These include researchers like myself, and it has been widely argued that in current mission-oriented innovation systems for agrifood systems transformation their work should be transdisciplinary, that they should take stronger advocacy positions and perhaps be more activistic, and open up to a diversity of non-scientific and indigenous knowledge systems. KTI colleagues like Dr David Ludwig, Dr Annemarie van Paassen, Dr Barbara van Mierlo, and Professor Cees Leeuwis, to name just a few, are doing excellent work on this.

I want to particularly talk about advisors and other intermediaries. This is a longstanding interest of KTI, or actually one of its foundations. It also has been a core topic of my PhD research which still has my interest and has continuing relevance.

The advisory profession is affected by the dynamic playing field of Agriculture 4.0. For example, a disruptive force may come from Agriculture 4.0 technologies such as robotics and artificial intelligence. The advisory profession also needs to accommodate directionality, diversity, distribution, and democracy in food systems transformation. It is therefore important to better understand how advisory services connect to, and are impacted by, different transition pathways towards transformed food systems. This implies asking questions such as (Klerkx, 2020):

- How do advisory systems respond to and connect to different transition pathways, such as AgriTech or regenerative agriculture?
- How do advisory service providers adjust to digitalisation and undergo digital transformation?
- How are value dilemmas managed by advisors in terms of which type of transition pathways they espouse, both personally and at an organisational and professional level?
- How are (dis)continuities managed in the advisory profession in view of transitions in which some ways of farming may disappear?

Though some initial work has been done via the projects of Dr Kelly Rijswijk and Dr Mariette McCampbell, more empirical studies are needed in this area, these are the sorts of questions we intend to explore in the PhD projects of Satish Nagaraji and Andrea Gardeazabal from CGIAR which have recently started.

Though mainly focused on research, my research agenda will also inspire my teaching, and will offer numerous thesis topics for students. As they are the scientists, advisors, and policy makers of the future they will need to be trained and function in a fast-moving environment of food systems transformation and agriculture 4.0. Luckily, multiple programme at WUR are offering this type of thinking, such as the master in rural development and innovation, the master governance and sustainability transformation, and the data science specialisations.

I will now move on to my word of thanks.

Words of thanks

This is a quite special academic lecture by a Wageningen professor. Not only has it been almost 4 years ago that I was appointed as personal professor, I am now also largely working from Chile where I am affiliated to the University of Talca as a Principal Scientist. However, as 'born and raised' WUR scholar, I do not see this as my farewell lecture.

In the coming years, I will continue to execute a fair share of this agenda in collaboration with the KTI group and other colleagues at WUR. I want to thank the Rector Magnificus Professor Arthur Mol for giving me the opportunity to hold this academic lecture, SSG director Professor Jack van der Vorst and KTI chair Professor Anita Hardon for enabling ongoing connections with KTI and WUR.

As is often said, science is a team sport, and my career has been shaped by the several teams I had the pleasure to be part of. I will stop using professional titles now otherwise this lecture will become far too long!

There are many colleagues to which I am grateful and indebted, both nationally and internationally. They are so many I cannot mention them all personally. Internationally, I am grateful for the collaborations with colleagues such as Ruth Nettle from the University of Melbourne, James Turner at AgResearch, Janet Reid and Dave Grey at Massey University, David Rose at Cranfield University, Gordon Hickey at McGill University, Carlos Miguel Sierra at INIA Uruguay, Alejandra Engler at the Universidad Catolica, Guy Boisier at the Universidad Austral, Carlos Huenchuleo at the Universidad Catolica de Valparaiso, and Pablo Villalobos and all my other new colleagues at the University of Talca. I have learned a lot from all the colleagues I collaborated with in interdisciplinary projects such as Convergence of Sciences, the Parasite project, Nutritious Pond, and Horteco, 3R Kenya, and DESIRA, such as Catherine Kilelu, Olivier Joffre, Marc Schut, Jonne Rodenburg, Santiago Dogliotti, and Gianluca Brunori. I am happy to be part of the networks of colleagues within the International Farming Systems Association, the European Seminar on Extension and Education and the International Sustainability Transitions Network.

Nationally, there are many peers with whom I interact, for example those connected to other innovation studies groups, at Erasmus University, the University of Twente, University of Eindhoven, Vrije Universiteit Amsterdam and Delft University. In particular I want to thank the colleagues at the Innovation Studies group at the Copernicus Institute of Sustainable Development at Utrecht University who have always been a source of inspiration, and who hosted me for two years as a visiting professor. Many Wageningen colleagues, such as Walter Rossing, Jos Bijman, Simon Bush, Marc Verdegem, Lammert Bastiaans, Simon Oosting, Jan Brouwers, Dirk Roep, Jessica Duncan, Dirk Roep, Lenneke Vaandrager, Marijn Poortvliet, Jasper de Vries, Sjaak Wolfert, Valentina Materia, Maria Annosi and Noelle Aarts, have contributed to where I am now through the multiple interdisciplinary collaborations we've had.

I've been lucky to always have been part of a great chairgroup, first at Communication and Innovation Studies, and later at the Knowledge, Technology, and Innovation Group, embedded in the broader section Philosophy, Innovation, Communication, and Education. First as a PhD and postdoc, and later as a staff member all the way to professor. I thank all my colleagues in KTI and SPICE for the stimulating environment. That I am now a professor, is for a large part thanks to the team of 25 PhDs and 12 postdocs I've had the joy to work with over the years and from whom I've learned a lot, both in terms of gaining scientific knowledge and for becoming a better mentor. A special thanks goes to 'De Grote Leider', the person who I call my mentor, Cees Leeuwis. Cees thanks for believing in me and supporting me from 2002 onwards! I also want to thank my other mentor at KTI, Barbara van Mierlo, for all career related advice. I also could not have done this without the excellent support of our secretaries and admin staff, and a special thanks to Inge Ruisch who always has booked all my trips and is always in for a chat. Now, to conclude my words of thanks, I will switch to Dutch and Spanish.

Dat ik hier vandaag sta is mogelijk gemaakt omdat er een goede basis is gelegd in ons gezin, en in de bredere families Klerkx en De Klein, met waarden zoals eerlijkheid en oprechtheid en hard studeren en werken (soms een beetje te hard). Pas recentelijk ben ik gaan beseffen dat mijn zussen en ik allemaal eerste generatie academici zijn en dat dat best bijzonder is. Ik ben blij dat ons pap en mam hier vandaag zijn, ons Ank en Miek en aanhang, dank jullie wel voor alles. Ook dank aan alle vrienden die me gesteund hebben vanaf de middelbare school, via de universiteit, tot nu, het is fijn om zo velen van jullie hier te zien.

Ahora voy a cambiar nuevamente a otro idioma, para también dar las gracias a mi otra familia, los González Herrera, y mis amigos al otro lado del planeta en Chile. Gracias por su cariño, su apoyo, por hacerme sentir en casa en Chile. Y las últimas palabras son para las amores de mi vida. A mis hijas Ayelén y Yanara, y la mujer quien está a mi lado siempre en todo, mi Ninoska: gracias por acompañarme y apoyarme para llegar a este día tan importante y especial.

Ik heb gezegd

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