Governing agricultural innovation: a comprehensive framework to underpin sustainable transitions

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Author contributions

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Highlights

- Agricultural innovation processes are inherently normative, political undertakings
- Sustainable governance of agricultural innovation requires a comprehensive understanding of all components that interact during innovation processes across societal scales
- Key components that need to be considered are: macro context, governance system, immediate context, innovative and adaptive capacity, psychosocial factors, and the innovation process itself

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Abstract

Innovations have the potential to help us address and overcome many of the challenges that agriculture is facing today. Yet, at the same time, they have the potential to create new, sometimes even more challenging, problems, especially when they are not governed in a sustainable way. Governing agricultural innovation sustainably requires understanding of all components that influence, and are influenced by, innovation processes, interactions across societal levels, and the normative and power dynamics that come together to shape the direction and outcomes of innovation processes. Hitherto, approaches to (agricultural) innovation and transition tend to specialize on a specific societal scale or sub-aspect of innovation or transition processes. In this article we aim to bring the strengths of some of the main approaches (Multi-Level Perspective, Agricultural Innovation Systems, Responsible Innovation, Innovation Management, Theory of Planned Behaviour) and insights from environmental governance literature together into a comprehensive framework. The framework describes seven key components and their interactions: macro context, governance system, immediate context, innovative and adaptive capacity of the actors, psychosocial factors, and the innovation process itself. Based on these, we present a subset of guiding questions that can be used diagnostically or for design purposes to support the sustainable governance of agricultural innovation processes.

Keywords: Sustainable governance, agricultural innovation, sustainability, legitimacy, social justice, reflexivity

1. Introduction

The world is facing many large scale challenges such as climate change, demographic change, biodiversity loss, and land degradation that act as drivers of socio-ecological change (Burkett et al., 2014; IPBES, 2019). Among other things, they challenge the current ways of practising agriculture and change the dominant requirements that society asks agriculture to fulfil. In order to address these challenges there is a need for a transition[1] toward more sustainable forms of agriculture (El Bilali, 2020; Martin et al. 2018). Both in scientific

[1] We are speaking of transition rather than transformation because the focus here is on one societal sub-system (i.e. agriculture) rather than on society as a whole. For a discussion on the difference between these two concepts see Hölscher et al., 2018.

literature, media, and new agricultural policies, innovation is highlighted as the mean to achieve this (Herrero et al., 2020; Lubberink et al., 2017). Yet at the same time, the call for more careful reflection on the potential (social) consequences of especially technological innovations in the agricultural sector is becoming louder (Eastwood et al., 2017; Klerkx & Rose, 2020; Stilgoe et al., 2013). However, socio-ecological systems such as agriculture are highly complex and unpredictable due to non-linear interactions and feedback loops that cross temporal and spatial scales (Thompson et al., 2007). Potential consequences are therefore often difficult to anticipate and arduous to counteract once an innovation is implemented (Klerkx and Rose, 2020; Sveiby et al., 2009). This is especially problematic because innovations have the potential capacity to create large scale, systemic changes beyond their intended reach (Loorbach et al., 2017; Voss & Bornemann, 2011).

Even when potential consequences can be foreseen, multiple pathways of change to address the above challenges toward a subset of alternative futures are possible (Blok & Lemmens, 2015; Foran et al., 2014). Each of these will have the potential to either contribute to sustainability or to undermine socio-ecological systems and consequently peoples' wellbeing. However, different people experience and value these pathways differently. What is perceived as a positive pathway for one might mean a loss of livelihood for another (Leach et al., 2007). The desirability of a certain innovation or transition pathway is therefore a value based, normative judgement.

Acknowledging the normativity underlying potential innovations and strived-for-futures as well as being aware that potential consequences of innovations will likely be distributed unevenly across society and might result in systemic change (Leach et al., 2007) moves innovations and their development out of a 'neutral, a-political sphere' where discussions

evolve around technical aspects of innovation development and the (challenges to) uptake. Instead, innovation processes become political, contested arenas where differing interests compete over influence on the direction and manner in which the agricultural sector develops (Turner et al., 2020). With political, we refer here to processes of power contestation and the impact of uneven power distribution on how resources, life chances, and well-being are distributed in society (Stoker & Marsh, 2010). Whereas power broadly refers to "the capacity to effect outcomes" (Morriss, [1987] 2002, 299). This can include both having *power over* and having *power to* and can manifest itself in the form of *domination* or *empowerment* (Haugaard, 2012).

In order to create sustainable, socially just, and legitimate innovation processes and outcomes there is thus an urgent need to govern innovation in a way that takes account of these normative and political dynamics and the interconnectedness between individual innovation processes and societal processes and vice versa. This need has received recognition in international agreements and declarations that strive toward a more sustainable world, including the Paris Agreement (2015), the Solidarity and Just Transition Silesia Declaration (2018), the 2030 Agenda (United Nations, 2015), and the European Green Deal (European Commission, 2019). Yet, how exactly this needs to be brought about is still unclear.

Hitherto, approaches to (agricultural) innovation and transition tend to specialize on a specific societal scale or sub-aspect of innovation or transition processes (Foran et al., 2014; Poole & van de Ven, 1989; see also Table 1) or one type of innovation, i.e. technological innovation. Individually, these approaches give valuable insights into their respective focus area but they do not provide the comprehensive understanding of innovation processes that

is required to govern agricultural innovation sustainably. To enable this kind of governance in the complex socio-ecological system of agriculture, we need to connect our understanding of all societal levels related to innovation processes. We therefore need to combine theoretical developments from multiple disciplines related to 1) the micro level: individual human behaviour and individual innovation processes, 2) the meso level: interactions between innovation processes and the contextual factors that impact upon them, 3) the macro level: the broader system within which the innovation processes take place, and 4) the way in which 1, 2, and to a certain extend 3 are shaped through governance whilst simultaneously feeding back into the governance process themselves (Folke et al., 2010; Leach et al., 2007; Ostrom, 2009; Poole & van de Ven, 1989; Poteete et al., 2010, p. 215). With governance we mean the practices and procedures of how decisions related to public affairs are made and implemented and how responsibilities are exercised (Baker, 2009; Lockwood et al., 2010). The objective of this paper is therefore to bring the strengths of multiple theoretical approaches together in a comprehensive framework that can give insights into how to govern agricultural innovation processes in a more holistic, sustainable way. Throughout this paper, when we use the term 'sustainability' we mean both its environmental, economic, and social aspects, as we argue that an agricultural innovation cannot truly be sustainable unless it takes each of these aspects into account. However, as the social component of sustainability is least developed in the agricultural innovation literature, this aspect has our main focus.

The research questions that are guiding the development of the framework is '*What components need to be considered in the governance of agricultural innovation processes, how do these components interact, and what lessons can be drawn from this to help guide the governance of agricultural innovation processes?*'. This paper thereby provides a first

step on the way of developing a generic comprehensive framework for the sustainable governance of agricultural innovation and we hope to inspire other researchers to further add on to this framework over time.

Underlying the framework is a broad definition of innovation, i.e. innovation is taken to mean a change from a previous state of doing things through the application of new or existing knowledge in novel ways (McKenzie, 2013; Spielman et al., 2008). This can include anything from the use of new technology or other objects and (management) practices, to policy instruments, market mechanisms, products, etc. (Saint Ville et al., 2016) and always entails a change in behaviour (Duru et al., 2015). Innovation can be of technological, social, economic, or institutional nature (Klerkx et al., 2012; Schut et al., 2018). Furthermore, an innovation does not have to be completely novel in order to be considered innovative, it is sufficient if it is new for the person, community, or sector who is applying it, and is therefore not always synonymous with invention (McKenzie, 2013; van der Veen, 2010). Generally, innovations are a reaction to a change in needs and/or a change in the external context (Rodima-Taylor et al., 2012).

The remainder of this paper is structured as follows. First, we present the methods that we used to develop the framework and give a brief overview of the theoretical approaches that we build on. This overview focusses on the main strengths and weaknesses of these approaches in relation to the aim of this paper. Second, we present the various components of the framework. Whilst we have to draw distinct lines between the components for analytical clarity, it is important to keep in mind that they are closely intertwined and influence each other in a multi-directional way. Third, we describe how looking at the components of the framework through the parameters of legitimacy, social justice, and

sustainability enables us to create a set of guiding questions that can highlight the normative and power dynamics of the agricultural innovation process. We propose that this set of guiding questions can support the sustainable governance of agricultural innovation. We end the paper with a discussion and conclusion on the potential uses of this framework and opportunities for further research.

2. Methods

In order to identify key system components that have been acknowledged as relevant to agricultural innovation across societal levels, we began with a literature review of research articles with a focus on the governance or management of agricultural innovation. The search terms (see Annex A) were generated with this aim in mind, based on an initial scanning of literature on agricultural innovation processes and the governance of socio-ecological systems, and adapted based on several trial searches. Web of Science's (WoS) core collection database was used as the backbone of this review. We used the broadest timespan possible in WoS (1945-2020, with March 10th 2020 being the cut-off date). The returned results (N=742) were narrowed down to filter out non-relevant articles through a manual assessment of the titles and abstracts and in a second round through screening of the full-texts. This was done based on the criteria that an article would need to have its central focus on agricultural innovation processes and their management or governance or the capacity to undertake such processes. This resulted in the inclusion of 284 articles. A further 35 articles were added through snowballing (based on the reference lists of articles that were included) and expert (i.e. university based researchers specializing on agricultural innovation) feedback on the initial list, resulting in a total of 319 articles being included in this study. These consisted of both peer-reviewed papers, contributions to conferences, and

academic book chapters. Through the analysis of these articles we identified that we reached data saturation and therefore did not extend the review to other databases.

The selected articles were coded according to their main topic and theoretical approach in order to identify research gaps. In an iterative process of reading and re-reading the material, discussions between the authors, and through feedback on conference- and departmental presentations, we identified 5 key components: the adaptive and innovative capacity of the actors (i.e. any kind of entity that can take active part in an innovation process, e.g. an individual farmer, a group, an organisation, a company, etc.), the context within which the innovation process takes place, the innovation process itself, and the governance system. To develop the theoretical understanding of these components and potentially identify additional components, their role and their connection to each other we combined the insights from the more empirically oriented articles in the literature review with various theoretical approaches that have specialised on these individual components or the connection between some of them: Multi-Level Perspective, Agricultural Innovation Systems, Innovation Management, Responsible Innovation, and Theory of Planned Behaviour. The choice of using these approaches was based on their strengths in relation to the identified components and complementarity to each other's weaknesses as is shown in Table 1 as well as their dominance in the literature that was included in our review. We acknowledge that this is not an exhaustive list of theories that elaborate on the components included in this framework. This is a limitation of this study, but one that had to be made given the scope of this article. We therefore encourage future research to further build on and expand this framework. Potential literatures that could be drawn on for this purpose include but are not limited to political economy, political ecology, literature on the diffusion of innovations, philosophical approaches to (ethics in) innovation, and psychology of

Characteristics of the approach	Type of approach Multi-Level Perspective	Agricultural Innovation Systems	Responsible Innovation	Innovation Management	Theory of Planned Behaviour
Main focus	Macro & Meso level[2]: dynamics between niche-innovations, regimes (currently dominant & institutionalised way of delivering societal functions), & the landscape (macro level societal & environmental processes)	Meso level: networks of actors & the (institutional) structures that influence how these actors interact with the aim of optimizing the system for the specific innovation that is under study	Meso & Micro level: social and ethical aspects of innovation with the underlying aim to improve the societal uptake of innovations (Asveld et al., 2015)	Micro level: Individual innovation processes with specific attention toward the different stages that comprise an innovation process	Micro level: Individual actors' behavioural intent and behaviour (Maye & Chan 2020)
Strengths (in relation to the aim of this study)	systemic scale, generalizability, & understanding of interaction of processes across levels (Geels, 2019; Geels & Schot, 2007; Smith et al., 2010)	systemic scale, capacity to identify how the network configuration of actors & their socio-institutional context either hampers or supports the innovation under study (Klerkx et al. 2010; Klerkx et al., 2012; Rajalahti et al., 2008), & specialized to agricultural innovation processes	thematizing the need for anticipation of consequences, inclusion of stakeholders, reflexivity, & responsiveness (Eastwood et al., 2017; Rose & Chilvers, 2018), & raising the issue of normativity (Bronson, 2019; Klerkx & Rose, 2020; Regan, 2019)	breaking down the innovation process, concretizing the steps that are required to develop an innovation, & clarifying different management needs depending on the stage of the process (Du Preez & Louw, 2008; Kline & Rosenberg, 2010; Tidd et al., 2005, p. 65-75)	Identifying factors that influence actors' behavioural intent to take part in innovation processes, highlights the importance of normative dynamics for behavioural intent (Ajzen, 1991; Ajzen & Fischbein 2005), & supports anticipation of farmers' behaviour toward innovations (Burton, 2004)
Weaknesses (in relation to the aim of this study)	limited attention to agency of actors, political & normative dynamics, & the role of governance (El Bilali, 2019a;2019b; Lachman, 2013), & lack of attention to dynamics within individual innovation processes	limited attention to political & normative dynamics (Klerkx et al., 2012; Schlaile et al., 2017), focus to optimise the specific system under study without attention to how this may affect alternative innovation pathways (Pigford et al., 2018), & lack of attention to how different socio-institutional context factors may be more or less important depending on the stage of the innovation process	lack of reflection on own underlying normative starting points (Blok & Lemmens, 2015), limited attention to political dynamics & the influence of the meso & macro level on the actions of micro level actors, & lack of clear operationalisation within the agricultural context	Risks simplification of the innovation process (Kline & Rosenberg, 2010; Kowalski et al., 2016), no detailed insights in the meso & macro level processes or how these might be affected by the individual innovation process (Micaëlli et al., 2014), & no focus on the normative & political dynamics	Gap between behavioural intent and actual behaviour (Ajzen, 2011) & does not directly address the potential consequences of that behaviour for the actors themselves, nor how the behaviour influences the meso & macro level
What the approach is used for in this paper	distinguishing between the 'macro context' & the 'immediate context' & how these influence the innovation process	gaining detailed insights on the elements that make up the immediate context & its functional role for innovation processes	developing insights on normative dynamics	clarifying the different stages of an innovation process & their function	identifying how contextual components & normative dynamics have to come together in order to enable innovation-related behaviour

Table 1. Overview of theoretical approaches used in this study.

[2] Note: the MLP literature refers to niches as being at the micro level. We argue here that they are part of the meso level, as we use the term 'micro level' to refer to an individual innovation process and individual actors.

innovation. In addition to these theoretical frameworks, we build on insights from the literature on the governance of socio-ecological systems in order to highlight and operationalize the normative and political dimension and strengthen our understanding of the role of the governance component within the framework. While this strand of literature did not come up in our review (as it is not explicitly focussed on agriculture), we argue that it makes a valuable contribution to this framework because the agricultural sector is a prime example of a socio-ecological system. To bring all the different components and their interactions together, we were inspired by the work of Emerson and Nabatchi (Emerson et al., 2012; Emerson & Nabatchi, 2015). Whilst their work is concerned with a different topic (collaborative governance regimes) and different components, it proved helpful to graphically structure the components that we have identified in relation to the governance of agricultural innovation.

3. Toward a comprehensive framework

The framework consists of four nested dimensions, each of which can be further broken down into smaller components: the macro context, the governance system, the foundation on which innovation processes build, and the innovation processes themselves. They are depicted as boxes within boxes in Figure 1 and elaborated on individually below. The governance system is placed between the macro context and the foundation and innovation processes because it is the mediating structure between them. Solid lines in the figure indicate the outermost structure whereas dotted lines show that there are interactions between the various dimensions. The arrows show the direction of those interactions. Together they show that the framework is characterized by 'duality of structure' or 'mutual embeddedness' (Klerkx et al., 2010; Markard & Truffer, 2008). This means that whilst the

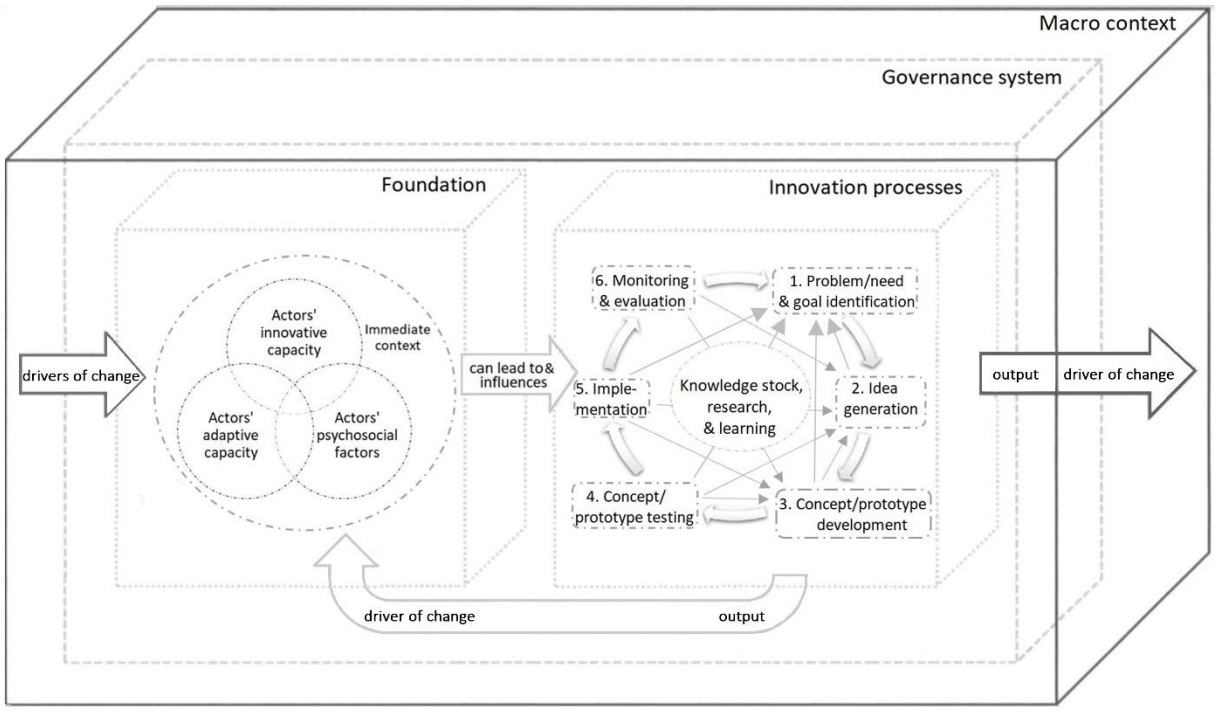

Figure 1. Comprehensive framework for the governance of agricultural innovation.
Inspired by Emerson et al., 2012, Du Preez & Louw, 2008, and Kline & Rosenberg, 2010.

structure within which the actors of innovation processes are embedded influences their actions, at the same time the structure is a result of those actions (Giddens, 1984).

3.1. Macro context as driver of change

The macro context is the setting within which the other dimensions take shape. It takes its name from its characteristics and closely relates to the landscape level in Multi-Level Perspective approaches. It consists of grand macro structures such as climate, biodiversity, demography, macro-economics, and macro-political developments. Aspirations for societal transitions are also part of the macro context dynamics; they form the background and create opportunities for individual innovation processes and require input from society at large. The macro context generally changes slowly due to natural or anthropogenic processes (Pichs-Madruga et al., 2016) but rapid, shock-like alterations also occur. The average individual actor has only very limited to no influence over the structures that make

up the macro context (Geels & Schot, 2007; Klerkx, et al., 2012). However, innovations do have the potential to influence these structures over longer time scales.

Changes in the macro context function as direct or indirect drivers (Nelson et al., 2005; Pichs-Madruga et al., 2016) of agricultural change and can therefore be regarded as key driving motivational forces behind innovation efforts. They alter either directly or indirectly the demands that society puts on agriculture (e.g. increase in population eventually leads to higher output demands on agriculture) or the natural conditions within which agriculture has to function (e.g. climate change increases variability of weather patterns and extreme weather events which alter the conditions that crops and livestock need to be able to withstand) (Hazell & Wood, 2008; van Vliet et al., 2015).

Being aware of the interactions between the macro context and innovations and vice versa is important for the sustainable governance of agricultural innovation because it can support understanding the underlying issue that is attempted to be addressed with the innovation and anticipating potential long-term consequences of the innovation. Both of these are central questions in the innovation process.

3.2. Governance system

The governance system describes how societies make and implement decisions related to public affairs, in this case agricultural innovations. It includes both structures and processes of decision making and implementation and determines how power is exercised and responsibilities are carried out (Baker, 2009; Lockwood, 2010). It comprises the patterns that result from governing activities and interactions between public and private actors who actively and purposefully aim at steering (sectors of) society into a certain direction (Jordan, 2008; Kemp et al., 2005). It is distinct from, and more encompassing than, government due

to the inclusion of non-state actors as relevant and active entities in governing processes (Lemos & Agrawal, 2006). The governance system reaches across the macro, meso, and micro level as it can operate at, and influence, each of these levels and its specific form can change over time and differ per innovation process. Because this framework is built around the question of how the governance of agricultural innovation processes can take into account the normative and political dynamics of innovation in order to create more sustainable, socially just, and legitimate processes and outcomes, we use governance in a normative sense.

We use 'legitimacy' to refer to "the acceptance and justification of authority" (Biermann & Gupta, 2011, p. 1858) and it therefore relates to the perceptions people have about the procedural characteristics and outcomes of governance processes. It addresses the perceived validity of decision-making authority and how this authority itself is established (Bernstein, 2004) and is thus one parameter through which power dynamics can be made explicit. Perceived legitimacy is important in relation to the sustainability of agricultural innovation because it increases the acceptability of, and support for, the innovation processes and outcomes (Biermann & Gupta, 2011; Lockwood et al., 2010).

With 'socially just' we point to the distribution of positive and negative consequences of the innovation process and its outcome(s) both for current and future generations (Miller, 1999, p. 6) and the consideration and respect given to the views and opinions of those who are (potentially) affected by the innovation process and its outcomes (Lockwood et al., 2010). We use it here as a parameter for both normative and power dynamics. Like with legitimacy, we highlight the importance for sustainability of how these aspects are being perceived.

We use the term 'sustainable' as a functional condition, meaning that it refers to "a process that can be sustained over time without eroding its own foundations" (Voss & Kemp, 2006, p. 14). The process that we are interested in sustaining is agriculture and, in extension, agricultural innovation, but we recognize that it can be contested what kind of agriculture and innovations should be able to be sustained, how this should be achieved (Leach et al., 2007), and over what time-scale. Even when there exists some agreement about desirable end goals and/or pathways, when these cannot be achieved simultaneously, value trade-offs have to be made (Voss & Kemp, 2006). This raises the questions of which values are deemed more important than others and who has the power to manifest their views on this as the standard for decision-making. In addition, the desirability of contested goals and pathways can change over time. This happens for example when cultures and broader contexts change or when more knowledge becomes available. Thus, what kind of agriculture and agricultural innovation processes the foundation needs to be able to sustain can also differ over time. Furthermore, due to the complexity and non-linearity of socio-ecological interactions and the long time-scale that needs to be considered, the governance of agricultural innovation has to take place under conditions of uncertainty (Baker, 2009; Feindt & Weiland, 2018; Vos & Kemp, 2006). It is therefore important that the processes remain flexible and adaptable to incorporate changing values and new knowledge, to address unforeseen positive and negative consequences of made decisions (Hartley et al, 2016; Stilgoe et al., 2013; Tricarico et al. 2020), and to ensure that the decisions that are made now do not unduly hamper or foreclose alternative pathways and goals for the future (Baker, 2009). Creating room for diversity through the governance system can be useful to this end as it increases the range of potential response options (Underdal, 2010).

Due to the above described characteristics and normative orientation, and in line with insights from Responsible Innovation approaches and literature on the governance of socio-ecological systems, we argue that the governance processes of agricultural innovation should be grounded in reflexive practices. Actors involved in the governing process should deliberately reflect on the potential (unintended) consequences of their decisions and on how the way that decisions are made and the values that underly these decisions reproduce the structures that can undermine sustainability and erode the foundation on which they are built (Dryzek & Pickering, 2017; Hendriks & Grin, 2007; Voss & Kemp, 2006). This includes recognizing the (potential) impacts of governance actions throughout the socio-ecological system, monitoring of past and present impacts, and anticipating future impacts (Lubberink et al., 2017; Rose & Chilvers, 2018; Stilgoe et al., 2013). In order to know what these reflections should focus on specifically we need an understanding of the components and their interactions that are relevant to agricultural innovation processes. We will therefore first continue to explore the other dimensions of this framework before we turn to how this kind of governance could practically take shape.

3.3. Foundation

The foundation stands in a bidirectional relation with the governance system and consists of components that have been identified by the articles in our literature review as either supporting and sustaining or hampering agricultural innovation processes. It includes the adaptive and innovative capacity of the actors and their psychosocial factors as well as the immediate context within which the actors are embedded. The psychosocial factors have been generally addressed as part of the adaptive or innovative capacity in the articles in our literature review, but for reasons that will be described below we treat them as a

Immediate context		**Innovative capacity**		**Adaptive capacity**		**Psychosocial factors**	
Element	*Determinant*	Element	*Determinant*	Element	*Determinant*	Element	*Determinant*
Physical infrastructure	*roads; internet; phone lines*	social capital (bridging, bonding, & linking)	*social networks; knowledge networks; network of organizations*	Social capital (bridging, bonding, & linking)	*social networks/ relationships; community services; communication networks*	willingness to adapt or innovate	*attitude to innovation; risk attitude, (social) norms & values; self-identity*
Formal institutions	*laws; regulations; company policy*	access to resources	*natural; financial*	access to resources	*natural; financial; human*		
Informal institutions	*social norms; shared societal values; implicit rules of the game*	innovative capabilities	*innovativeness*	innovative capacity	*innovativeness*		
formal organisations	*farmer organisations; NGOs; extension services*	(flexibility of) institutional context/ structure	*regulations; policies*	(flexibility of) institutional context/ structure	*regulations; policies; laws; market arrangements; political advocacy*		
Informal organisations	*non-official social networks*	Psychosocial factors	*social norms; risk attitude; culture; trust; vision; agency; attitudes; openness to new ideas & actions*	psychosocial factors	*community/ group norms; risk attitude & perception; culture; trust; social imagination; agency; will/intention; beliefs; motivation; goals; self-identity; reflexivity; values; habits & expectations; leadership*		
the market	*consumers; (international) commodity market*	knowledge/ education	*education; information flow; absorptive capabilities*	knowledge/education	*education level; access to information; local knowledge & awareness; knowledge attuned to the specific situation; learning opportunities; skills*		
direct natural environment		collaboration	*interaction between government, industry, & university*	local embeddedness	*stakeholder involvement & participatory research*		
		(space for handling) power dynamics, conflict, & negotiation		perceived adaptive capacity (self-efficacy)			
		adaptive capabilities		Ability for collective action			
		exposure to external & internal shocks		degree of diversity	*farm's diversification; livelihood diversification; flexibility in solutions*		
References: Hekkert et al., 2007; Pigford, Hickey, & Klerkx, 2018; Rajalahti et al., 2008		**References:** Aase et al., 2013; Cohen et al., 2016; Demissie & Munchie, 2014; Fielke & Bardsley, 2014; Govoeyi et al., 2019; Lowitt et al., 2015; McKenzie, 2013; Olajide-Taiwo et al., 2011; Rockenbauch et al., 2019; Röling et al., 2004; Saint Ville et al., 2016; Schut et al., 2018; Song et al., 2017; Spielman et al., 2008; Struik et al., 2014; Turner et al., 2017; Zhou & Wang, 2018		**References:** Aase et al., 2013; Akkari & Bryant, 2017; Asfaw et al., 2016; Bitterman et al., 2019; Bussey et al., 2012; Chelleri et al., 2016; Chhetri et al., 2012; Cohen et al., 2016; Darnhofer, 2010; Darnhofer et al., 2010; Dennis et al., 2016; Duru et al. 2015; Eakin, et al., 2016; Fielke & Bardley, 2014; Grundmann et al., 2012; Guido et al., 2018; Heijne et al. 2014; Knox et al., 2010; Leitgeb et al., 2014; Li et al., 2019; Lin, 2011; Lowitt et al., 2015; Lyle & Ostendorf, 2005; Makate, 2020; Mase et al., 2017; McDowell & Hess, 2012; Morton et al., 2017; Patnaik et al., 2019; Rossi et al., 2014; Saint Ville et al., 2016; Shah et al., 2019; Snyder & Cullen 2014; Turner et al., 2017; Urruty et al., 2016; Weiss & Bonvillian, 2013; Wigboldus et al., 2016; Wilk et al., 2013; Zeweld et al., 2019		**References:** Eakin et al., 2016; Morton, et al., 2017; van der Veen, 2010; Zeweld et al., 2019	

Table 2. Components of the foundation.

Note: full reference details can be found in Annex B.

component in its own right. We have brought these components together under the heading 'foundation' because together they form the foundation on which agricultural innovation processes build.

As Table 2 shows, there is considerable overlap, interaction, and dependency between the elements and determinants that make up these components. This may partially be a result of the fact that the literature on agricultural innovation uses multiple definitions of these concepts (for examples see below), uses them interchangeably (e.g. Aase et al., 2013; Rockenbauch et al., 2019), or does not define what they mean altogether (e.g. Morton et al., 2017; Röling et al., 2004). Here we make an attempt to create clearer distinctions between these components both in regard to how they are defined and what their differing functions are in relation to the innovation process. We then build on this to develop initial hypotheses of how these components come together to either enable or disenable innovation processes.

3.*3.1. Immediate context*

The immediate context comprises the structures within which the actors are embedded. Insights from the Agricultural Innovation Systems approach show that these include the physical infrastructure, formal and informal institutions, formal and informal organisations, the market, the local natural environment, and the adaptive and innovative capacity of the aforementioned components (Hekkert et al., 2007; Pigford et al., 2018; Rajalahti et al., 2008). These structures are located at the meso level but can be analysed at various scales; in the terminology of Multi-Level Perspective approaches, they can be analysed both in relation to the regime, an individual niche, or a combination of the two.

We posit that the extent to which the immediate context is aligned with the kind of innovation that is strived for determines the degree of innovative or adaptive capacity that the actors need to be able to initiate and bring an innovation process to a close. I.e. if the immediate context is structured in a way that is supportive to the specific innovation, the degree of innovative and adaptive capacity that is required for this specific innovation process will be lower than in the case where the immediate context is not supportive of the innovation that is strived for. While innovative and adaptive capacity are partially dependent on the immediate context, they are distinct enough (as presented in Table 2) to be able to potentially fill each other's gaps. In addition, the immediate contextual factors that influence the adaptive and innovative capacity of actors can be different than the contextual factors that support or hamper a specific innovation. Understanding this interaction between the immediate context and the innovative and adaptive capacity of the actors is important for the governance of agricultural innovation and the understanding of power dynamics because it reveals how the immediate context empowers certain actors whilst putting others out of the power to adapt or innovate.

3.3.2. Actors' innovative and adaptive capacity

Innovative capacity is defined in the agricultural innovation literature in multiple ways. For example, it is referred to as the capacity or ability to adapt to change by developing or implementing and mastering new processes, products, and services (Aase et al., 2013; Schut et al., 2018; Spielman et al., 2008), the conditions and capacity to drive change and create and implement innovations (Cohen et al., 2016), or the sum of human resources, scientific and technological services, support to research and development, business climate, capital markets, and connections and infrastructure (Weiss & Bonvillian, 2013). We take innovative

capacity to refer specifically to the ability to create or generate innovations. This encompasses both the ability to create an innovative idea and the ability to turn that idea, or someone else's idea, into something that could be implemented. It does not include the actual implementation. We posit that it is especially important in the initial stages of an innovation process.

Adaptive capacity on the other hand is referred to, for example, as the ability or capacity of an entity, to prepare for, respond, and adapt to change in the (social and/or natural) environment through a change in behaviour (Asfaw et al., 2016; Bitterman et al., 2019; Cohen et al., 2016), having the resources and ability to use those resources that are required for adaptation (McDowell & Hess, 2012), or a combination of farmers' experiences and perceptions of stressors, opportunities, environmental change, their associated risks, and the decision-making context (Eakin et al., 2016). We take adaptive capacity to be linked to the implementation of innovations, as the implementation requires adaptation to the existence of the innovation. Therefore, we define adaptive capacity as the capacity to adapt to (anticipated) change through the implementation of innovative or old practices. It includes having the relevant resources (financial and natural) and knowing how to apply them appropriately (skills and knowledge) and/or having a network through which one can access relevant resources, skills and knowledge. In addition, it includes the perception of the actor of the sufficiency of his or her (access to) relevant resources, skills, and knowledge (i.e. perceived adaptive capacity). We expect that adaptive capacity is especially important in the later stages of the innovation process.

The degree of innovative and adaptive capacity always stands in relation to what the actor is adapting to (i.e. the stressors/type of change) or what kind of innovation the actor is

striving for (Akkari & Bryant, 2017; van der Veen, 2010). The capacity to innovate or adapt in a given situation therefore depends on having (access to) the relevant kind of resources, skills, and knowledge specific to that given situation. Generic adaptive or innovative capacity then refers to the overall capacity to react to or generate any kind of change (Cohen et al., 2016).

We posit that both innovative and adaptive capacity are directly linked to power dynamics as they influence in how far an actor has the capacity to affect the innovation process and its outcomes. At the same time, making decisions during an innovation process on factors that can affect the future innovative and adaptive capacity of actors includes deciding on who will have more or less power in the future. These are thus important aspects that need to be reflected on during the governance of agricultural innovation processes.

In addition, it needs to be recognized that the innovative and adaptive capacity of individuals stand in relation to the innovative and adaptive capacity of the other societal levels. They can reciprocally influence each other both positively and negatively. For example, a farmer with high perceived technical adaptive capacity to climate change and environmental degradation might not be willing to support measures that would mitigate these challenges (Gardezi and Arbuckle, 2020), thereby potentially undermining the adaptive capacity of the community around them.

3.3.3. Actors' psychosocial factors

Because adapting or innovating always entails a change in behaviour, regardless of the type of adaptation or innovation (Duru et al., 2015), having a supporting immediate context and an adequate degree of adaptive and innovative capacity on its own is not sufficient to ensure

that an innovation process will be initiated and brought to a conclusion (Lyle & Ostendorf, 2005; Morton et al., 2017). Because of this, and in line with the Theory of Planned Behaviour, the intention or willingness to change certain behaviour, here the willingness to adapt or innovate, is regarded in this framework as a component in its own right (Ajzen, 1991; 2011). Elements that have been identified as making up this willingness include attitude to innovation (in general and to this specific issue), risk attitude, (social) norms and values, self-identity, and trust (see Table 2). We expect that depending on the type of innovation, how much the innovation deviates from current practices, and the societal level at which the innovation process takes place, some of these elements may be more or less important. Further empirical research is needed in order to clarify this.

Understanding these elements and how they take shape can give insights in the normative orientation of actors involved in, or affected by, the innovation process and is therefore important when addressing normative dynamics within agricultural innovation processes through governance.

3.3.4. Link between the components of the foundation: foundational failure or functioning

As described above, the components of the foundation interact and depend on one another. The way they fit together either enables or hampers innovation-related behaviour. We hypothesize that the immediate context and innovative and adaptive capacity together determine how much behavioural control the actors have to initiate and go through an innovation process. Likewise, we posit that they influence, together with the psychosocial factors, the perceived innovative and adaptive capacity. These in turn are expected to influence the control beliefs. The psychosocial factors are also expected to influence the behavioural and normative beliefs of the actors. Following the Theory of Planned Behaviour,

the behavioural, normative, and control beliefs shape the actors' attitudes toward a behaviour, subjective norms, and perceived behavioural control, which in turn determine behavioural intention. Behavioural intention and actual behavioural control are the determinants of behaviour (Ajzen, 2011; Armitage & Christian, 2003) (see Figure 2).

We hypothesize that when all components of the foundation work together favourably for the innovation that is strived for, i.e. when the actors have 1) sufficient (perceived) innovative capacity to develop an innovative idea and/or to make an innovative

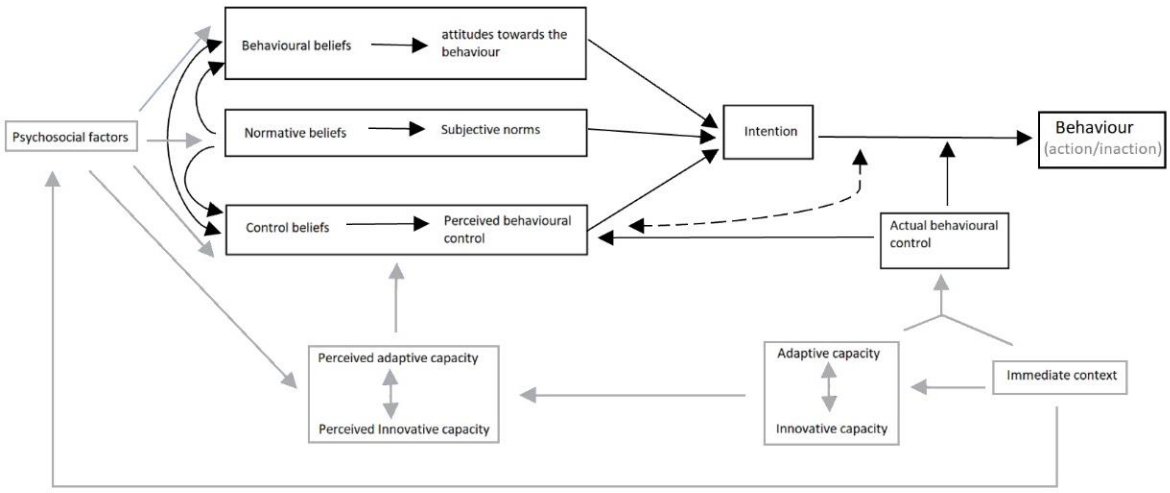

Figure 2. Interactions between the foundational components.
Adapted from Ajzen & Fischbein (2005). Aspects marked in grey are our propositions.

idea (of themselves or someone else) implementable regardless of the immediate context, 2) sufficient (perceived) adaptive capacity to implement the required action regardless of the immediate context, and 3) when they are willing to change their behaviour in line with the strived for innovation, the foundation forms enabling conditions that sustain the innovation process. However, if this process and its outcome marginalizes certain groups, it will reduce their innovative and adaptive capacity and can therefore not be regarded as sustainable over the long term as it erodes the foundation for future innovations.

The Agricultural Innovation Systems approach refers to multiple types of 'innovation system failure' when a certain element of the context forms a constrain on innovation efforts in a way that makes successful innovation and adaptation unlikely (Klerkx et al., 2012; van Mierlo et al., 2010). In our framework we highlight that the foundation will function as a hampering factor only when there is a mismatch between any of the components of the foundation and the innovation that is strived for. It is also important to be aware that system failures are primarily identified in relation to a specific (type of) innovation even though the foundation generally has to be able to support more than one (type of) innovation simultaneously. Attempting to intervene in the foundation through governance to make it more favourable for a certain (type of) innovation can therefore result in trade-offs for other innovations and even lock-ins (Pigford et al., 2018). This should thus only be done based on thorough reflection on the (potential) consequences of the intervention not only for the specific desired innovation but for the system at large.

3.4. Innovation processes

The innovation processes section of the framework relates to the structures and processes of agricultural innovation. Combining insights from literature on innovation processes in agriculture and literature with an Innovation Management approach reveals that each innovation process, regardless of the extend of change that is brought forward through the innovation, the type of innovation, the type of actor that is driving the process, and the societal level at which the innovation takes place goes through the same set of structural stages. How these stages are shaped, who is involved, how long they last, etc. will differ from case to case, but the underlying structure is generic to all innovation processes (Du Preez & Louw, 2008; Sutherland et al., 2012; van der Veen, 2010).

The first stage is identifying, or recognising that there is a problem that needs to be solved or a (new) need that wants to be fulfilled. These generally stem from a change in external conditions in the landscape or immediate context or a change in internal objectives of the actor(s) (Sutherland et al., 2012; van der Veen, 2010). Being clear about what exactly the problem or need is, and consequently what the goal of the innovation is, is essential because it will set the direction of, and boundaries to, the entire innovation process. It can help to address the problem or need by its roots and in some instances reframing what the problem or need is can open up or close down opportunities for innovation (Tidd et al., 2005, p. 11; Schot & Steinmueller, 2018). Thus, whoever is in a position to decide on the problem and goal formulation has considerable power over the direction of the innovation process. It is important here to acknowledge the significance of how a need or problem and goal is framed and that different actors can have differing frames around the same situation (Beland Lindahl, 2008). This is likely to be especially relevant if the innovation process is aiming to satisfy a need or solve a problem for multiple stakeholders simultaneously. The second stage is the stage of idea generation on how the problem potentially can be solved or the need fulfilled. Available options are identified, evaluated, and assessed (Pignatti et al., 2015; Sutherland et al., 2012). At the end of this stage one or several ideas are chosen for further development (Du Preez & Louw, 2008). Both the first and the second stage function to set the strategic orientation of the innovation process and are thus highly political undertakings (Lindner et al., 2016). We therefore argue that these stages should be explicitly internalized into the innovation process rather than taken for granted at the outset and be given explicit consideration in the governance process. The third stage is concerned with the development of a concept or prototype of the idea(s). Here the idea(s) are turned into

something tangible (Du Preez & Louw, 2008). We posit that stage one to three build on the innovative capacity of the actors.

The fourth stage is concerned with testing the concept/prototype in practice (Kline & Rosenberg, 2010). The fifth stage is the implementation stage. This can include marketing efforts if it is the aim that the innovation becomes (widely) dispersed (Tidd et al., 2005, p. 95) or only the actual full-scale application of the innovation in its intended context (van der Veen, 2010). The final stage, monitoring and evaluation, is not always included, but nonetheless highly important to increase learning (Tidd et al., 2005, 96). It is often integrated in all the aforementioned stages. Whilst monitoring and evaluation can seem like an objective undertaking, we want to highlight its normative underpinning. What is deemed as an important evaluation criteria, what kind of knowledge is perceived as legitimate to base evaluations on, and when set criteria are deemed to be satisfactorily met may differ from person to person. Therefore, whoever has the power to make decisions on these aspects, also has the power about what kind of lessons are drawn from such monitoring and evaluation practices. After the final stage, one can return back to stage one (Du Preez & Louw, 2008). We hypothesize that the fourth, fifth, and sixth stage rely on the adaptive capacity of the actors.

As innovation processes are generally messy, these stages should be seen as an abstract conceptualisation of the innovation process. The stages are likely to overlap and it is possible that at the end of progressing through a stage, the actor will loop back one or several stages rather than move forward to the next stage (Du Preez & Louw, 2008; Meynard & Casabianca, 2009). Because innovation is dependent on new or existing knowledge (both explicit and tacit), at the centre of the innovation process and each stage lies the existing

knowledge stock, research and learning, and processes of knowledge exchange among actors. These feed into the stages of the innovation process, but the stages can likewise feed back into the knowledge stock through new insights (Kline & Rosenberg, 2010; Tidd et al., 2005, p. 15). Figure 1 displays this.

3.5. Output and outcomes

The innovation process generally produces both outputs and outcomes. With output we refer to the actual innovation, e.g. a new technology, management practice, policy, etc. The output and the dynamics of the innovation process can function as direct and indirect drivers of change to all the components of the foundation, the governance system, and (over time) the macro context. Outcomes, on the other hand, describe how this change takes shape both over the short- and long-term; they are the combination of the intended and unintended consequences of the innovation process and its output. They can be of social, economic, natural, and/or political nature (Emerson & Nabatchi, 2015). The output and resulting outcomes of an innovation process can create lock-ins, or path dependency, i.e. they have the potential to determine the direction of, and room for, future innovation pathways (Voss & Kemp, 2006) and therefore have the potential to influence agricultural transition. Whether or not these (unintended) outcomes are positive or negative depends on the perspective from which they are being evaluated (Emerson & Nabatchi, 2015). The shape of the output and outcomes depends on the decisions that are being made at each stage of the innovation process and the way that these decisions are being made.

4. Governing for sustainable agricultural innovation

Now that we have a general understanding of the foundation and structure of agricultural innovation processes we can return to the question of how to govern these processes in a

way that creates sustainable, socially just, and legitimate processes and outcomes. We have raised the importance of reflexivity both on the decisions that have to be made and the way in which they are made and described the components that need to be taken into account in these reflections. Based on the three parameters legitimacy, social justness, and sustainability as described under section 3.2. and the insights into the key components, how they relate to each other, and their role in the innovation process, we propose a set of guiding questions (see Table 3) for reflection that can support the governance process. These questions were developed by looking at the potential disruptive, normative, and power dynamics present within each stage of the innovation process in relation to the components of the framework and by linking this to the parameters of sustainability, legitimacy, and social justice. Reflecting on these questions should help in making explicit the specific normative and political underpinnings of a certain innovation process and aid the anticipation of potential consequences. It can help to enable dialogue between stakeholders with differing opinions, create awareness of the potential broader consequences of an innovation beyond the immediate self-interests of the innovator, and help to come closer to a balance between conflicting interests and perceptions of risk. However, it is not the goal to reach consensus on these questions or on final decisions because that would disregard that some values, viewpoints, and interests simply cannot be united (Johansson et al., 2018; Voss & Bornemann, 2011). These questions do therefore not prescribe certain specific decisions that should be made. Rather, they should be used to open up room for learning, create understanding of underlying values, interests, and power relations, and form a base for the re-articulation and reconfiguration of aims, values, and practices when the reflections show that current processes are unsustainable or perceived as illegitimate or socially unjust. Ultimately, they should lead to more informed, deliberate

Stage of the innovation process	**Guiding questions**	**Methods that could be used to examine these questions (non-exhaustive), inspired by Dryzek & Pickering (2017), Eastwood et al. (2019), Muiderman et al. (2020), Reed et al. (2009), & STEPS Centre (n.d.)**
Questions that should be reflected on repeatedly at each stage	Who is (not) involved? Why? Is it a result of limited *innovative* and/or *adaptive capacity*? If stakeholders are involved, how are they involved? What is their role in this stage? Why? What types of knowledge are relied on? Why? Who has (no) decision-making power (in all aspects that are raised in the other questions)? Why? What are the structures of decision-making (e.g. consensus, voting)? Why? What are the structures for accountability for those that make decisions? Are there mechanisms in place to ensure that all relevant voices are heard and treated with respect? What are the (potential) consequences of the answers to the above and stage-specific questions in terms of perceived *social justice,* perceived *legitimacy,* and *sustainability*? Are these acceptable or is adjustment needed?	Stakeholder analysis Creation of codes of conduct Stage-gating Impact Assessment Forecasting (Participatory) scenario analysis
1. Problem/need & goal identification	What is the underlying *driver* that is causing the problem/change in needs perceived to be? Is this the same for all stakeholders or are there different views? What is the goal of the innovation? Does it aim to adapt to, mitigate, reverse, or alter the direction of change of the *driver* that is causing the problem? What *values* underly the different framings of the problem and the goal? Whose *values* are they? Who is affected by the identified problem and goal? What alternative problem and goal framings could there be? Do they open up or close down possible solutions?	Participatory workshops Stakeholder analysis Evaluation H Deliberative mapping Deliberative polling Q method Participatory impact pathway analysis (Participatory) scenario analysis
2. Idea generation	What *values* underly suggested ideas? Whose *values* are they? What kind of future would this idea contribute to creating: what could be potential short- and long-term consequences of the suggested idea(s) for *all the components and elements of the foundation and the macro context*? What would the potential consequences mean for the future *capacity of the stakeholders to innovate and adapt*? Is this similar for all stakeholders or does it put some into a more or less favourable position than others for future innovation efforts? Does this idea impact the *immediate context* in a way that gives some stakeholders more power to act than others? Does this idea close off alternative innovation pathways in the future through its potential impact on the *immediate context* and *innovative* and *adaptive capacity*? Are these potential consequences acceptable or would they require correction? From who's perspective is this assessed? What trade-offs (regarding *values, goals, use of resources, etc.*) have	Value sensitive design User-centred design Participatory workshops Focus groups Deliberative polling Deliberative mapping Deliberative valuation Evaluation H (Participatory) backcasting Citizens' juries Multi criteria mapping (Participatory) scenario analysis Forecasting Participatory impact pathway analysis Impact assessment

	to be made when this idea would be pursued? Are these acceptable? How does this idea relate to the *psychosocial factors* of the stakeholders? What alternative ideas could there be and how do they look like in terms of the above questions?	
3. Concept/ prototype development	For whom is the concept developed (i.e. for who should it work)? Why is the idea turned into this specific concept? Are there alternatives? What are the advantages and disadvantages of this (and alternative) concepts and for who? What resources and structures would be required to implement this concept? How does this relate to the current *adaptive and innovative capacity* of the stakeholders and their *immediate context*? What would this mean for the future *adaptive and innovative capacity* of the stakeholders and potential future innovations? Are these potential consequences acceptable?	User-centred design Value-sensitive design (Participatory) scenario analysis (Participatory) backcasting Participatory workshops Focus groups Deliberative Mapping Deliberative Polling Deliberative valuation Multi criteria mapping Impact Assessment Participatory impact pathway analysis
4. Concept/ prototype testing	What are the criteria used for testing? What alternative criteria could be considered? What are the underlying *values* that have guided the selection of the criteria and whose *values* are they? Do these criteria take into account the *psychosocial factors* of the stakeholders and the (potential) impact on the *immediate and macro context*? What are potential consequences of using these specific criteria rather than others? Are these acceptable?	Value-sensitive design User-centred design Participatory workshop Focus groups (Participatory) scenario analysis Impact Assessment Participatory impact pathway analysis Citizens' juries
5. Implementation	In case of marketing: what underlying *values* are targeted with marketing? How do they relate to the *values* underlying this innovation? What resources are needed for the implementation? How does this relate to the current *adaptive capacity* of the stakeholders and their *immediate context*? What would this mean for the future *adaptive capacity* of the stakeholders and potential future innovations? Are those with currently insufficient *adaptive capacity* somehow supported to still be able to benefit from the innovation? What are direct/immediate and long-term consequences of the implementation across *all components and elements of the foundation* and *macro context*? What are the trade-offs that those implementing this innovation have to make?	Value-sensitive design User-centred design (Participatory) backcasting Stakeholder analysis (Participatory) scenario analysis Forecasting Impact assessment
6. Monitoring & evaluation	What are the criteria used for monitoring and evaluation? What alternative criteria could be considered? What are the underlying *values* that have guided the selection of the criteria and whose values are they? Do these criteria take into account impacts on *all components and elements of the foundation* and *macro context*? What are potential consequences of using these specific criteria rather than others? Are there mechanisms in place to learn from the monitoring and	Participatory workshops Value-sensitive design User-centred design Deliberative valuation (Participatory) scenario analysis Innovation histories Participatory impact pathway analysis

	evaluation results? Why (not)?	Impact assessment
	Are lessons learned used to alter the innovation and innovation process? Why (not)?	

Table 3. Guiding questions for the governance of agricultural innovation.

decision making both by the stakeholders and the actor who is in charge of the innovation process (Gregory et al., 2001; Pickering, 2019). The questions in Table 3 can thus serve as a guideline or tool for anyone who is interested in making agricultural innovation processes and outcomes more sustainable.

5. Discussion

The framework that we have presented here integrates insights from multiple theoretical approaches that have their focus on sub-aspects of innovation processes into a comprehensive framework and starts to build new theory on the interactions between the components and their role and how these insights can be used to support the sustainable governance of agricultural innovation. We posit that it improves existing approaches to agricultural innovation in two main ways. First, due to its comprehensiveness, this framework can better account for the interconnectedness and interdependence of the components and the various societal levels. Through the inclusion of all the components and attention to how they interact, this framework comes closer to the real-world complexity of innovation processes than approaches that only focus on one or a few of the components and societal levels. Therefore, it can better support reflections on potential consequences of certain decisions and contributes to a more holistic, sustainable governance approach. Secondly, where other frameworks seem to take the direction of innovation as a given and give only limited attention to power dynamics, this framework enables to take a step back and reflect on the normative and political underpinnings of such processes.

We suggest that this framework can be used either diagnostically to assess past or current innovation processes or prescriptively to support the design of current and future innovation processes. When the framework is applied in practice there are several aspects that need to be considered. Because the framework presents a generic description of components that need consideration in the governance of agricultural innovation processes, when the framework is applied it will need to be adapted to the specific case. Whilst the guiding questions we propose here can be used as a basis for any kind of innovation process, additional questions that target the unique challenges of the specific innovation under consideration might be required. Another important part of adapting the framework to a specific case is deciding on the boundaries of the system that is under consideration. This decision will depend on the specific issue at hand and the time and other resources that are available. It might often not be possible to take a complete holistic perspective (Verschuren, 2001). Generally, it can be stated that the larger the scope, the more complex and time consuming the application of this framework will become. However, the smaller the scope, the more likely it is to lose sight of the complexity and interconnectedness of socio-ecological systems and thus to overlook potential interactions and consequences. We therefore argue that it is important to be explicit about the artificiality of system boundaries and the consequences this has on the claims and proposed solutions that are made based on such analyses. It is possible to focus on certain sections of the framework, but when discussing the results of such an analysis, they should be brought back into the wider context of the overarching framework. At first sight, needing to reflect on all the guiding questions and taking all the components and their respective elements into account might look as a daunting and time consuming task. However, we argue that spending additional time on these reflections during each stage of the innovation process will result in more informed

decisions and therefore likely streamline the innovation process, improve the sustainability, perceived legitimacy, and perceived social justness of both the process and its output and outcomes, which will result in time saved on having to correct consequences of less informed and less deliberate decision-making.

Besides the possibility for practical application of this framework to gain insight into and support specific empirical cases to improve their sustainability, as the framework is in the early stages of its development, it provides also numerous research opportunities for further theory development. First, the propositions that we have brought forward based on our understanding of the various theoretical approaches would benefit from empirical testing. The framework could be applied to analyse past and current agricultural innovation processes related to multiple types of innovations to examine the validity of our theory-based assumptions. This could, secondly, also help in examining if there are any additional components that we have missed. Third, further empirical research would be useful to identify the relative importance of the components and their elements. This kind of research could also examine if certain components and elements are more important for certain types of innovations or in specific kind of situations and if there are any generalizable patterns related to this. Fourth, future research could focus on operationalizing the components of the foundation by further unravelling the elements and possibly even sub-elements that constitute them. Finally, regarding the proposed guiding questions, application of the framework could help to identify which questions are especially important and whether or not there are important questions missing.

6. Conclusion

Innovations can help us address and overcome many of the challenges that agriculture is facing today. Yet at the same time, they have the potential to create new, sometimes even more challenging, problems (Voss & Kemp, 2006). In addition, perceptions on the desirability of certain innovations and the futures they might lead to are rooted in normative judgement that may differ from one person to the next. Governing agricultural innovation processes in a way that takes account of these characteristics requires a comprehensive understanding of all components that interact during innovation processes across societal scales. Hitherto, research has focussed on unravelling certain sub-aspects of agricultural innovation processes; creating in depth understanding on these sub-aspects but losing sight of the complex whole. In this paper we have strived to bring this knowledge together in a comprehensive framework. We hope that this framework will generate more critical and comprehensive debates in research on agricultural innovation and help policy makers and innovators alike to guide the design of new innovation processes, to understand and assess underlying values and power relations in current innovation processes, and support the assessment of innovation processes in terms of their sustainability, (perceived) social justice, and (perceived) legitimacy.

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Annex A. Details to the literature review.

	Search Criteria
Indexes	SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI
Timespan	1945-2020 (as the search was conducted on March 10, articles published after that date were not included)
Search string	TS=(agri* OR farm* OR horticultur*) AND (innovat* OR "socio-technical transition" OR pathway OR future OR vision*) AND TS=("reflexive governance" OR "adaptive governance" OR "transition governance" OR "deliberative governance" OR "participatory governance" OR "transformative governance" OR "reflective governance" OR "responsible governance" OR "adaptive management" OR "transition management" OR "deliberate transformation" OR "reflective deliberation" OR "responsible innovation" OR "responsible research and innovation" OR "responsible research & innovation" OR "co-innovation" OR "participatory innovation" OR "collaborative innovation" OR "inclusive innovation") OR ("adaptive capacity" OR "transformative capacity" OR "innovative capacity" OR "responsive capacity")
	Note: "sustainable governance", "governing sustainably", "sustainable management", and "managing sustainably" were not included in the final search string because trial searches showed that these terms lead primarily to literature that looks at the sustainability of specific practices rather than at the governance of innovation
Inclusion criteria	have a central focus on agricultural innovation processes and the management or governance of these processes or the capacity to undertake such processes

Table A.1. Search criteria.

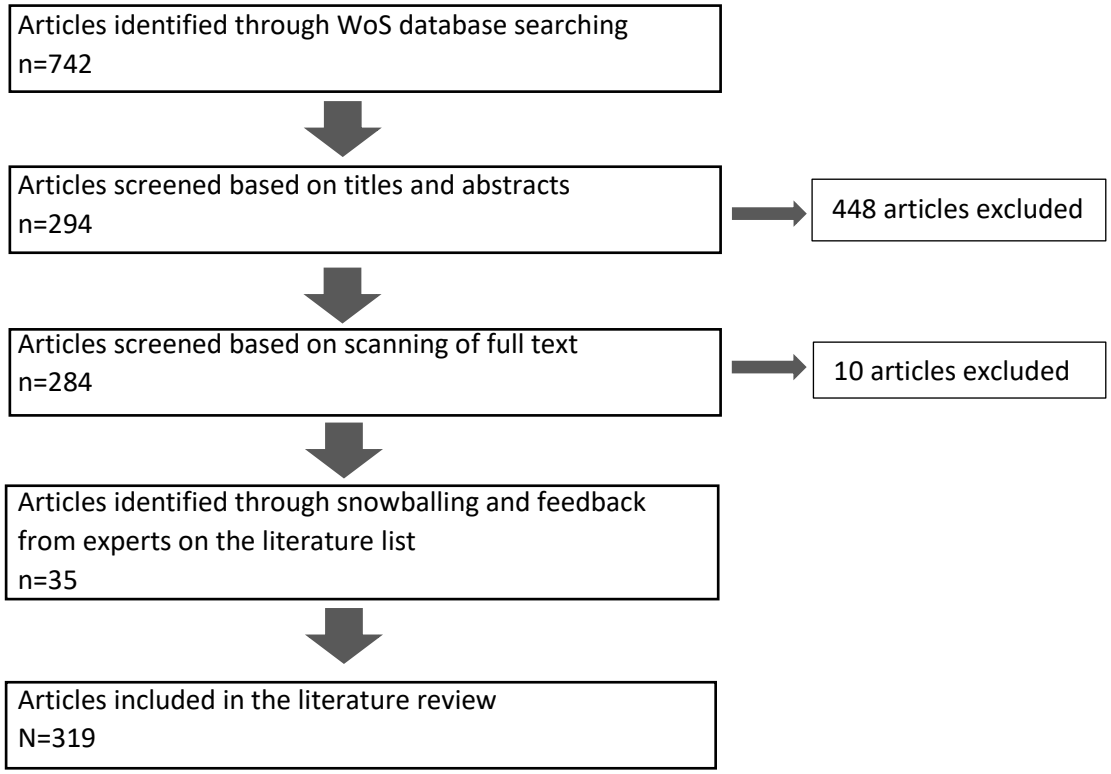

Figure A.1. Selection process of articles that were included.

Annex B. Bibliographical details for articles referred to in Table 2. Components of the foundation.

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