Chapter 20

Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions

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Abstract *Over the years, there has been an evolution of systemic thinking in agricultural innovation studies, culminating in the agricultural innovation systems perspective. In an attempt to synthesize and organize the existing literature, this chapter reviews the literature on agricultural innovation, with the threefold goal of (1) sketching the evolution of systemic approaches to agricultural innovation and unravelling the different interpretations; (2) assessing key factors for innovation system performance and demonstrating the use of system thinking in the facilitation of processes of agricultural innovation by means of innovation brokers and reflexive process monitoring; and (3) formulating an agenda for future research. The main conclusion is that the agricultural innovation systems perspective provides a comprehensive view on actors and factors that co-determine innovation, and in this sense allows understanding the complexity of agricultural innovation. However, its holism is also a pitfall as it allows for many interpretations, which complicates a clear focus of this research field and the building of cumulative evidence. Hence, more work needs to be done conceptually and empirically.*

Introduction

This chapter reviews the literature on agricultural innovation, with the threefold goal of (1) sketching the evolution of systemic approaches to agricultural innovation and unravelling the different interpretations; (2) assessing key factors for innovation

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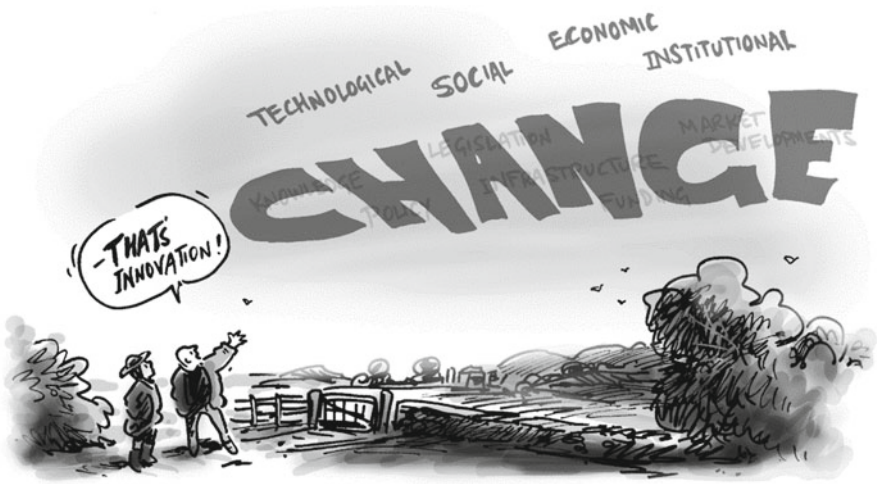

Fig. 20.1 Innovation is not just technology, but is rather a comprehensive vision of what the future should look like and which requires changes in many ambits. Innovation is driven by people's needs, ambitions and dreams, and requires that people at different positions in society change the way they work and live

system performance and demonstrating the use of system thinking in the facilitation of processes of agricultural innovation; and (3) formulating an agenda for future research.

Agricultural innovation for the purpose of this chapter is seen as a co-evolutionary process, i.e. combined technological, social, economic and institutional change. Therefore, production and exchange of (technical) knowledge are not the only prerequisites for innovation. Several additional factors play a key role, such as policy, legislation, infrastructure, funding, and market developments. Agricultural innovation is hence not just about adopting new technologies (Fig. 20.1); it also requires a balance amongst new technical practices and alternative ways of organizing. This concerns, for example, reorganizing markets, labour, land tenure and distribution of benefits (Leeuwis 2004; Röling 2009; Klerkx et al. 2010). Furthermore, agricultural innovation is not an inherently good and value free process, but normatively laden and driven by different worldviews and visions. Correspondingly, different development directions exist, each with its own winners and losers (Vanloqueren and Baret 2009; Thompson and Scoones 2009; Brooks and Loevinsohn 2011).

The above view on agricultural innovation has resulted from several in-depth studies of actual innovation processes, which discarded simplistic views on innovation as an invention (in the form of the results of scientific research, or the development of a technology) that is transferred to and adopted as such by the intended users. This broader view on agricultural innovation, seen as the result of multiple interactions between components of farming systems, supply chains and economic systems, policy environments, and societal systems, is reflected in the idea that

innovation is an outcome of '*agricultural innovation systems*' (AIS). The thinking about agricultural innovation systems can be seen as the most recent in a family of systems approaches. The perspective is still in development, and –as we will show in this chapter – tends to be approached in different ways: it is looked upon as an infrastructure or as a process, has been located at different geographical scale levels, and includes different types of research, analysis and intervention (Pant and Hambly-Odame 2009; Spielman et al. 2009; Hall and Clark 2010; Brooks and Loevinsohn 2011). This chapter intends to shed more light on the development in thinking about the role of systems in agricultural innovation.

The chapter first gives a brief historical overview of approaches to agricultural innovation that have preceded and implicitly or explicitly contributed to the AIS concept. Then, different interpretations of AIS thinking are presented, followed by enablers and disablers of AIS functioning. After displaying research methodological approaches to AIS, implications of AIS thinking for the support of innovation processes are given, displaying some emergent approaches. The chapter concludes with an outlook on emergent research questions.

Evolution in thinking on systems approaches

Differences and similarities in subsequent perspectives to agricultural innovation

A wide range of approaches to agricultural innovation has emerged over the past 40 years (see Leeuwis 2004; Leeuwis and Aarts 2011). Some well-known examples are the Transfer of Technology approach (Jarrett 1985), Induced Innovation (Ruttan and Hayami 1984), Training and Visit System (Hulme 1992), Participatory Research and Participatory Technology Development (Farrington and Martin 1988; Neef and Neubert 2011), Farmer First (Chambers et al. 1989), and Agricultural Knowledge and Information Systems (AKIS) (Röling 2009). While agricultural innovation studies appear to have developed in relative isolation of 'generic' innovation studies which focus on industrial innovation, there has always been a degree of cross-fertilization. Generic systems studies have influenced systemic thinking in agricultural innovation studies, and vice versa. For example, the works of Checkland (1981) and Kline and Rosenberg (1986) have influenced AKIS thinking. Four main theoretical traditions with a cumulative degree of systemic thinking can be distinguished. Table 20.1 provides an overview based on several authors who have reviewed the major conceptual, organizational, and institutional features connected to these approaches.

It needs to be noted that the different approaches displayed in Table 20.1 are not necessarily mutually exclusive. Some approaches consecutively fed into each other. Others emerged in parallel: the AKIS and AIS approaches. Furthermore, different approaches co-exist: besides the emergent AIS thinking, there is still great adherence

Table 20.1 Shifts in theoretical perspectives on agricultural innovation (Adapted from Sanginga et al. 2009 and integrated with Hall et al. 2006; Vellema 2008; Pant and Hambly-Odame 2009). The theoretical perspectives on agricultural innovation have broadened over time in terms of the diversity of relevant actors; the recognition of innovation as a co-development process; innovation as being both technical, social, economic and institutional change; and as a complex, non-linear process

	Type of perspective			
Characteristics of the perspective	Diffusion of innovations/ transfer of technology	Early Farming Systems Research	Agricultural knowledge and information systems	Agricultural innovation systems
Era	Central since 1960s	Starting in 1970s and 1980s	From 1990s	2000s
Mental model and activities	Supply technologies through pipeline	Learn farmers' constraints through surveys	Collaborate in research (participatory research) and extension	Co-develop innovation involving multi-actor processes and partnerships
Knowledge and disciplines	Single disciple driven (breeding)	Multidisciplinary (agronomy plus agricultural economics)	Interdisciplinary (plus sociology and farmer experts)	Transdisciplinary, holistic systems perspective
Scope	Productivity increase	Efficiency gains (input-output relationships)	Farm-based livelihoods	Value chains, institutional change
Core elements	Technology packages	Modified packages to overcome constraints	Joint production of knowledge and technologies	Shared learning and change, politics of demand, social networks of innovators
Drivers	Supply-push from research	Diagnose farmers' constraints and needs	Demand-pull from farmers	Responsiveness to changing contexts, patterns of interaction
Relation with policy and institutional environment	Science and technology are relatively independent of political and other social partners –institutional factors as external conditioners of the adoption process.	Science and technology are relatively independent of political and other social partners – institutional factors as external conditioners of the adoption process. Agro-ecological and farm-economic context is considered in integrated way	Science and technology develop and are embedded within a historically defined social, political, economic and agro-ecological context	Science and technology develop and are embedded within in a historically defined social, political, economic and agro-climatic context. Institutional change is considered a 'sine-qua-non' for innovation

Innovators	Scientists	Scientists and extensionists	Farmers, scientists and extensionists together	Multiple actors, innovation platforms
Role of farmers	Adopters or laggards	Sources of information	Experimenters	Partners, entrepreneurs, innovators exerting demands
Role of scientists	Innovators	Experts	Collaborators	Partners, one of many responding to demands
Key changes sought	Farmer's behaviour change	Removing farmers' constraints	Empowering farmers	Institutional change, innovation capacity
Intended outcomes	Technology adoption and uptake	Farming system fit	Co-evolved technologies better fit to livelihood systems	Capacities to innovate, learn and change

to transfer of technology thinking and practice as well as farming system thinking, disconnected from the broader systemic views on innovation (Röling 2009).

The system concepts behind the different perspectives on agricultural innovation

The main difference in the system concepts appear to lie in how they consider the broader institutional and policy environment, and changes in these, as relevant to agricultural innovation, i.e. where they draw the system boundaries. The different system concepts are as follows:

- The system concept in *adoption and diffusion theories*, linked to perspectives such as Transfer of Technology and National Agricultural Research Systems, is entirely social. Innovations are said to spread via communication through social systems which are networks of close friends, relatives and neighbours. Mass media play a role in later stages of the diffusion process when large groups are motivated to adopt a new technology or product (Rogers 1995). The institutional and policy context is seen as an external factor that influences adoption by individual farmers.
- *Farming Systems Research* (FSR) emerged in response to the limitations and undesirable effects of the linear technology transfer approaches. From the start, a main principle of Farming Systems Research has been the need for partnerships between farmers and technical and social scientists to involve farmers in the design of technological solutions (Norman 2002; Pant and Hambly-Odame 2009). More recently, other stakeholders, such as extensionists and policy actors, are expected to participate in a collective design process as well. Over the years, the aim of Farming Systems Research has broadened from improving the yield of specific crops to sustainable livelihoods, i.e. improved productivity integrated with social equity and protection of natural resources. The units of analysis in Farming Systems Research are primarily farms and farmer groups within their direct biophysical and socioeconomic context: "The 'farming system' is understood as including all members of the farming family and all the biotechnical processes involved in farming." (Dedieu et al. 2009: 109)
- The concept of *Agricultural Knowledge and Information Systems* (AKIS) also emerged as a critique towards linear models of innovation, but again draws broader boundaries. In an early definition AKIS is defined as "a set of agricultural organizations and/or persons, and the links and interactions between them, engaged in such processes as the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilization of knowledge and information, with the purpose of working synergistically to support decision making, problem solving and innovation in a given country's agriculture or domain thereof" (Röling 1990: 1). As can be noted in this definition, AKIS were initially seen as having a clear (national or sectoral) boundary and a common purpose. This raised the critique

(see e.g. Leeuwis et al. 1990) that the perspective still adopted a mechanistic 'hard systems' view whereby it was assumed systems exist independently from the observer, and can be analysed, understood and 'engineered' towards an unambiguous goal – a view also recognizable in adoption-diffusion studies and some farming systems studies. Later on, Röling and others more consistently adopted a soft systems thinking (Checkland 1981) perspective, emphasizing that a system and its boundaries will be understood by actors in diverging ways given their different objectives and life worlds. Thus, the AKIS approach came to focus on the coordination among actors with different perspectives of who are part of a 'human activity system' (Röling 1992) with arbitrary boundaries. Here the systems concept became used merely as a strategy to make people think of themselves as being part of a system, with the view of enhancing coordination (see e.g. Engel 1995). However, organisations like FAO have continued to use concepts of AKIS that emphasize clearer boundaries and goals (Rivera et al. 2005).

- *Agricultural Innovation Systems* (AIS) thinking emerged parallel to AKIS (Assefa et al. 2009; Pant and Hambly-Odame 2009), influenced by ideas on 'national systems of innovation' as developed by Lundvall (1992) and pioneered by Andy Hall and colleagues (e.g. Hall et al. 2001, 2006) in the agricultural domain. AIS are defined as "a network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge" (Hall et al. 2006: vi–vii).

The similarities between AKIS and AIS, according to Rivera et al. (2006: 587), can be explained by the fact that "AIS did not evolve as a further development of the AKIS framework, but rather as a parallel development which did not build upon the insights of the AKIS literature and the practical experience in applying this framework. One reason for this parallel rather than consecutive development may be due to the fact that, considering the background of the leading authors, AKIS evolved from the extension perspective, while AIS was developed from a research perspective." While the definitions of AIS and AKS bear a clear resemblance,[1] according to Hall et al. (2006) the main difference between AIS and AKIS lies in the greater and more explicit focus of AIS on the influence of institutions (seen as organisations like companies, public research institutes and governmental entities) and infrastructures on learning and innovation, and its explicit focus to include all relevant organizations beyond agricultural research and extension systems. Hall et al. (2006: 25), for example, see it as a weakness of AKIS that "the focus is restricted to actors and processes in the rural environment and the framework pays limited attention to the role of markets (especially input and output markets), the private sector, the enabling

[1] Recently, especially in context of European Union policy and research programs, the two concepts have more or less 'merged', because the acronym AKIS has been reinterpreted as 'Agricultural Knowledge and Innovation Systems' (Dockès et al. 2011).

policy environment, and other disciplines and sectors. The AKIS framework recognizes the importance of transferring information from farmers to research systems, but tends to suggest that most technologies will be transferred from researchers down to farmers."

The main achievement of the AIS approach thus appears to be that it has further broadened the scope of analysts and interventionists on the complex interactions between a multitude of players and sub-systems that characterize innovation. For major societal challenges like the lack of food security, the increasing impoverishment of small farmers, the effects of global warming, animal diseases, depletion and pollution of natural resources, the increase in the level of systemic thinking can be considered a necessity (Röling 2009; Brooks and Loevinsohn 2011 – see also Elzen et al. 2012, this volume). A weakness when compared to the AKIS perspective (at least the soft systems variant) is that many AIS definitions still suggest that there is somehow a common goal or focus, which is related to enhancing innovation. Hence there tends to be little recognition that the goals, interests and perspectives of interdependent actors are likely to diverge and be conflictive.

Differences in conceptualization and operationalization of AIS

As becomes clear from its definition and as shows from Table 20.1, AIS are essentially about multi-actor interactions and structures (infrastructures, policies, institutions) that may serve to enhance innovation, with an understanding that innovation goes beyond technology development, but also often requires an improvement of parts of the innovation system itself to enable co-ordination of the relevant subsystems. While there appears to be a shared understanding on elements within AIS conducive to innovation, different variants and strands of thinking continue to exist. As we will see below, these are associated with how the concept of a system is interpreted.

An infrastructural view of AIS

In a number of studies and analysis AIS tends to be approached as an 'innovation support infrastructure', sometimes biased towards the public sector (Vellema 2008). This goes along with studies that make a predominantly *static analysis* of the presence and interaction of actors (e.g. research institutes, financing organizations), and the infrastructures that govern the behaviour of actors in innovation processes (rules and regulation and physical infrastructures like transportation systems) and which exercise direct influence on innovation outcomes (e.g. intellectual property laws) present in countries. The main question is to what extent this system supports, or does not support and even constrain, agricultural innovation (e.g. Sorensen 2011). These system perspectives thus see innovation systems in terms of creating 'fertile

soil' for innovation to grow. Such studies interpret AIS both as a national innovation system (Temel 2004; Leitgeb et al. 2011; Sorensen 2011) and as a (sub-) sectoral innovation system (Blay-Palmer 2005; Gildemacher et al. 2009). This perspective on AIS correlates with a fairly static view on networks, in which embeddedness of an actor in the structure of a network, the existence of structural holes and weak ties in networks, co-determine the potential for innovation, as they give information on the available resource configurations (knowledge, finance, materials) and the potential for creative recombination of knowledge, technologies and practices (Spielman et al. 2009; Klerkx and Leeuwis 2009a). With its emphasis on clear boundaries and pre-assumed goals (i.e. the system exists to support innovation) the infrastructural view still has affinity with hard systems thinking.

A process view of AIS

Other authors tend to highlight the process side of AIS. This often results in a more *dynamic analysis* to assess the co-evolutionary process of interactive development of technology, practices, markets and institutions. This implies seeing innovation systems as self-organizing growing networks of actors connected to the development of a certain novelty, emerging from a dominant incumbent production system (characterized by certain technologies, practices) or value chain configuration and moving towards an alternative to the incumbent system or even replacing it (Ekboir 2003; Hall and Clark 2010; Klerkx et al. 2010). This implies seeing AIS as 'systems in the making'. According to this view, there is a central focus on how an agency of innovators is embedded within and supported by a broader socio-institutional and technological environment, or conversely, the efforts of innovators to change their socio-institutional and technological environment. This way of looking at systems has affinity with complex adaptive systems thinking which emphasizes processes of self-organization, coincidence and non-linear dynamics (i.e. sudden shifts) (Ekboir 2003; Leeuwis and Aarts 2011). This view on agricultural innovation systems as self-organizing entities with increasingly systemic properties bears some resemblance to work which does not explicitly use an innovation systems approach, but rather a system innovation approach to study (radical) agricultural innovation (Roep et al. 2003; Knickel et al. 2009; Elzen et al. 2011; Lamine 2011; Elzen et al. 2012, this volume)

Niches in which newcomers experiment with a novelty in practice are seen as potential starting points for changing dominant, incumbent socio-technical systems that have adverse societal effects. The central dynamic is considered to be niche branching: a process in which niches arise and grow, while a specific new technology is applied in an increasing number of market segments. It is a co-evolutionary process in which changes in the knowledge of actors, preferences of users, informal rules, regulation and infrastructure occur together with consistent changes in technology. This happens if the niches align with, and are strengthened by, instability in the dominant system that is induced by pressure from external developments at

what is called the landscape level (such as an economic crisis, a natural disaster, or demographic change) (Geels and Schot 2007; Kemp et al. 1998; Elzen et al. 2012, this volume). This focus of innovation as a competition between novelties and incumbent rules and systems connects to socio-political and political economy studies on inequalities emerging from agricultural innovation (Thompson and Scoones 2009; Vanloqueren and Baret 2009). Niches may also compete among each other to become the new dominant technology or practice.

Some researchers link the two approaches (innovation systems and system innovation) (Markard and Truffer 2008; van Mierlo et al. 2010a). In this combined approach, niches are seen as '*technological innovation systems'*, i.e. as specific projects or as sets of projects connected to a similar novel technology or practice that may well cut across countries or sectors (Hekkert et al. 2007). Although the term suggests a narrow technology focus, technological innovation systems thinking does comprise accompanying social and institutional change. While the term technological innovation system is not actually used, this type of technology or practice focus has been applied frequently in the study of agricultural innovation using the AIS concept (see e.g. Hall and Clark 2010; Brooks and Loevinsohn 2011).

A functionalist view of AIS

Functionalist approaches to innovation systems (Hekkert et al. 2007) tend to focus on whether or not specific functions are fulfilled. In essence this kind of systems thinking draws upon a biological metaphor, whereby the whole (the organism) cannot function well if sub- and aspect-systems (e.g. organs and transport) are lacking or do not interact harmoniously. The functions of the innovation systems approach is linked to co-evolutionary approaches (equalling technological innovation systems to niches) as it intends to systematically map technological innovation system activities, providing insights into "the interaction of forces that determine the slow and difficult change of a merely locked-in system towards a new equilibrium" (Hekkert et al. 2007: 418). Seven functions have been identified, which should be present in well-functioning technological innovation systems, consecutively or simultaneously: (1) entrepreneurial activities, (2) knowledge development, (3) knowledge diffusion in networks, (4) guidance of the search, (5) market formation, (6) resource mobilization, (7) creation of legitimacy/overcoming resistance to change. Mapping the functions, and the interaction between them, are expected to inform policy by identifying 'motors of innovation', i.e. sets of functions that reinforce each other and accelerate developments, as well as lacking functions which hinder innovation. This approach has rarely been applied to the analysis of AIS, but has been mentioned as an interesting avenue for exploration (World Bank 2008).

As we can see above, there remain different academic strands of thinking about (agricultural) innovation systems. There continue to exist different views regarding boundaries (along geographical lines or along technology lines) and on what the

system is (the support infrastructure of what is to change). Moreover, we see different implicit assumptions and conceptions about how change in systems comes about (through competition in a selection environment, through the provision of functionalities, through coincidence and self-organisation, etc.) and different orientations towards using the term system (as a descriptive or normative concept). Perhaps not all viewpoints are mutually exclusive, but there is certainly enough space for confusion and misunderstanding.

Performance of AIS: key enablers and disablers

In the previous sections we have seen that various views on agricultural innovation systems co-exist. It is interesting to note that most AIS perspectives use the term system in a normative rather than as a descriptive term. Innovation systems thinkers tend to be concerned primarily about how agricultural innovation systems should work (namely as systems that produce innovation) and with explaining why actors involved in networks do *not* collaborate, perform functions and/or work towards concerted action and do *not* show the system-like property of innovation. In fact, from a descriptive point of view one could argue that the use of the term system is a bit odd (see Leeuwis et al. 1990). Given these normative overtones in the AIS community it is not surprising that much has been written already on what are key enablers and disablers of innovation systems functioning. As demonstrated below, ideas and insights on this tend to coincide with the different conceptual viewpoints on AIS presented in the previous section.

Key enablers for innovation systems performance

Depending on the perspective of AIS that is used, different ideas exist as regards what is needed to enhance its performance. Taking the view on AIS as innovation support systems or as providing a fertile soil for innovation, it is often about the set of factors that determine networking for innovation and the formation of what have been called variously multi-stakeholder platforms (Röling 1994), innovation configurations (Engel 1995), innovation networks (Klerkx et al. 2010) or as public-private partnerships (PPPs) (Spielman and von Grebmer 2006). To enhance such 'networking for innovation', the AIS literature emphasises the need to arrive at shared visions, well-established linkages and information flows amongst different public and private actors, conducive incentives that enhance cooperation, adequate market, legislative and policy environments, and well-developed human capital (Hall et al. 2001; Spielman et al. 2008; Brooks and Loevinsohn 2011). While much of this AIS work has been carried out in developing countries, similar criteria for well-functioning have also been suggested for industrialized countries

(e.g., Knickel et al. 2009; Klerkx and Leeuwis 2009a; Sorensen 2011). A well-functioning AIS is then characterised by (Spielman et al. 2008):

- Learning within and between firms and organisations in order to innovate
- Strengthening individual and collective capabilities to innovate
- Demand and supply-driven science and technology
- Innovation agents focusing on complex and dynamic interactions
- Network-based knowledge dissemination
- Both embedded and dis-embedded knowledge dissemination: in both tacit and codified forms
- Decentralized management of innovation processes

Taking the view on AIS as complex adaptive systems or as niches that interact with regimes to establish change, approaches such as strategic niche management (Kemp et al. 1998) advocate combinations of measures to stimulate niche development and protect and nurture niches from incumbent (regime) players. Central elements in this approach are: (1) The articulation of expectations and visions. Expectations are considered crucial for niche development because they provide direction to learning processes, attract attention, and legitimate (continuing) protection and nurturing; (2) The building of social networks. This process is important to create a constituency behind the new technology, facilitate interactions between relevant stakeholders, and provide the necessary resources (money, people, expertise); (3) Learning processes of multiple dimensions: (a) technical aspects and design specifications, (b) market and user preferences, (c) cultural and symbolic meaning, (d) infrastructure and maintenance networks, (e) industry and production networks, (f) regulations and government policy, (g) societal and environmental effects. This approach has been applied in methods like interactive reflexive design (Bos et al. 2009; Elzen et al. 2012, this volume).

Clearly, the functionalist approach sees as performance criteria the fulfilment of the functions mentioned in the previous section. All three views on innovation systems appear to discern similar enabling factors, with the main difference that the complexity/niche-regime perspective and the functionalist perspective appear to have a more central concern with regards to power struggles and negotiation between innovators (niches) and incumbents (regime).

Key disablers of innovation systems performance

Often innovation systems do not act as systems and display imperfections or system failures that hinder learning and innovation. Creating and fostering effective linkages amongst heterogeneous sets of actors (i.e. the formation of adequate innovation configurations, coalitions, PPPs) is often hindered by different technological, social, economic and cultural divides (Pant and Hambly-Odame 2006; Oreszczyn et al. 2010). Such divides may be caused, for example, by different incentive systems for public and private actors, differences between local indigenous knowledge

Fig. 20.2 Innovation, as a result of human interaction, often fails because people do not understand each other, because they belong to different worlds which have their own languages and cultures

systems and formal scientific knowledge systems, social and cultural differences that cause exclusion of certain actors and ideological differences (Fig. 20.2).

Different categories of *innovation system failures* exist (Klein Woolthuis et al. 2005; van Mierlo et al. 2010a):

- *Infrastructural failures* concern (absence of) the physical infrastructure, such as railroads and telecom are constraints requiring major investments that cannot be made independently by the actors of the system. They also concern investments in knowledge infrastructure (R&D facilities) and financial infrastructure.
- *Hard institutional failure* refers to laws, regulations and any other formalised rules, or the lack of them, hampering innovation. For example, lack of IP regulation takes away incentives from innovators as they cannot protect their innovation. Absence of environmental regulation on radically different systems, having an institutional vacuum, may slow down certain developments.
- *Soft institutional failure* refers to unwritten rules, norms, values, culture, or 'the way business is done'. They affect how actors interact, but also relate to their (in) ability to change their norms and values in order to enable innovation to take place.
- Related to institutional failures is *strong network failure*, which refers to actors locked into their relationship, which causes myopia and blocks new ideas from

outside and prohibits other potentially fruitful collaborations. *Weak network failure* refers to a situation where actors are not well connected and fruitful cycles of learning and innovation may be prevented because there is no creative recombination of knowledge and resources. These two failures indicate an apparent paradox in networking for innovation: a quest for a balance between openness and closure, informal or formalized interaction, trust relationships or contracts (Håkansson and Ford 2002).

- *Capabilities failure* points to the lack of technical and organizational capacity of the system to adapt to and manage new technology and organizational innovations, such as a certain level of entrepreneurship, adequately educated persons, time to dedicate to innovation, and networking skills.
- Finally, *market structure failures* refer to the positions of and relations between market parties. Such as a monopoly or the lack of transparency in the ever enlarging food chains, but also imperfections in the 'knowledge market' (Klerkx and Leeuwis 2009a).

To assess the enablers and disablers of AIS functioning, a number of methods have emerged or are suggested, as not all types of analysis have yet matured. We will discuss these in the next section.

Methods for researching AIS

To analyse and assess innovation support systems (static view) and innovation systems in the making (dynamic view) a number of *innovation system analysis methods* have been applied and are proposed (see e.g. Spielman et al. 2009 for an overview):

- *Institutional analysis*, looking at the influence of institutional enablers and constraints in relation to innovation systems performance or of parts of it (Hall et al. 2001; Clark et al. 2003; Klerkx and Leeuwis 2008; Spielman et al. 2008). There are many studies that focus on such 'soft institutional failures' looking at projects and governance mechanisms such as R&D planning schemes (e.g. Hall et al. 2001; Klerkx and Leeuwis 2008). This kind of analysis can be approached from both an infrastructural and a process perspective.
- *Social network analysis* to map institutional linkages (Temel 2004; Spielman et al. 2011), visualizing relationships between actors, and assessing the position of actors within the system (in terms of centrality, number of ties, strength of ties). This type of research is generally used in a more infrastructural and static perspective.
- *Innovation histories* or *innovation journeys* (Douthwaite and Ashby 2005; Spielman et al. 2009; Klerkx et al. 2010). This is a way of recording innovation processes by means of timelines, focusing on important events and the relationships and activities which defined those events and influenced the outcome of the innovation process. Clearly, this type of research shows affinity with the process view of AIS.

- *Game-theory modelling*. According to Spielman et al. (2009) this is based on emerging work in evolutionary economics and offers insight into the value of the innovation systems framework, illustrating the spontaneous processes of social self-organization and the ways in which public policy and organizational structures can affect these processes. Again, this type of analysis tends to be process-oriented.
- *Benchmark analysis*, based on indicators such as patents, R&D expenditures, numbers of researchers, and input-output/spill-over analysis on R&D investment, returns on risk capital, etc. (Spielman et al. 2009). This type of research generally starts from an infrastructural and static perspective.
- *Innovation system analysis*, using the different categories of system failures cross-tabulated against actor groups to identify failures and underlying motives in the innovation system as well as to identify windows of opportunity, for both infrastructural (Gildemacher et al. 2009), and process-oriented analysis (Klein Woolthuis et al. 2005; van Mierlo et al. 2010a).
- *Functions of innovation systems approach*: are all functions properly performed? (Hekkert et al. 2007). This type of analysis has been mostly executed in a process-oriented fashion.

Since AIS thinking has been around for a while, the AIS approach has proved its value as a comprehensive framework for analysing strengths and weaknesses in agricultural innovation systems in different contexts. However, it has been less applied as an operational concept with policy options and targeted interventions ininnovation processes (Spielman 2006). In the next section we will discuss some emergent interventions which take a specific innovation systems perspective.

Stimulating AIS: Interventions at different levels

Recently, some methods and toolkits for AIS interventions have been developed (World Bank 2008; van Mierlo et al. 2010b, c). Roughly two types of interventions can be discerned, which are obviously closely linked to each other:

- *Innovation support system*-level interventions aimed at making structural changes in the innovation support system (research, extension, education, funding, etc.) and the enabling policy environment to optimize AIS functioning.
- *Innovation network*-level interventions connected to stimulating the formation of innovation networks (called variously innovation projects, platforms, coalitions, public/private partnerships) which are usually below the niche level (niches consist of several networks working on similar topics) and supporting their role and functioning, e.g. in forming linkages, fostering partnership, stimulating learning, and helping them to exercise agency to bring about broader institutional change.

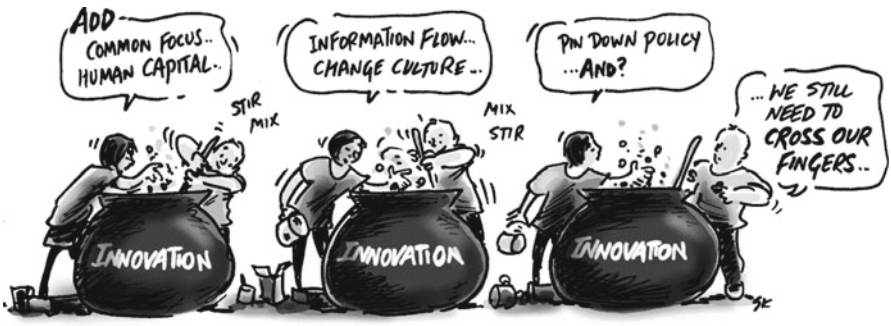

Fig. 20.3 While innovation systems thinking recognizes that there needs to be a good mix of factors for innovation, it is hard to establish the perfect mix beforehand: innovation systems and policies need to be adaptive

Support system level interventions

As regards support system-level interventions, this often deals with changing or creating policies and institutional arrangements conducive to innovation (World Bank 2008). For example, Spielman et al. (2008) generate several recommendations for this type of interventions from a structural analysis in Sub-Saharan Africa. They typically deal with overall policies affecting funding, incentives, accountability mechanisms and interaction patterns (Fig. 20.3). To strengthen the education systems the authors have the following suggestions among others:

- Realign visions and mandates: get a common focus on development objectives of all AIS players.
- Develop the human capital base by enhancing innovative capabilities: investments in training.
- Facilitate the flow of information and technology: i.e. change extension systems, develop systemic intermediaries.
- Induce change in organisational cultures, behaviours, and practices: e.g. change the orientation of research systems towards demand-driven modes of working.
- Create a conducive and appropriate policy environment: reduce the capriciousness of policies, increase influence of the sector on policies.

As existent innovation systems in terms of policies and instruments may not be optimal for supporting radically different developments but rather support incremental change and optimization of existing production systems, several authors (Bos et al. 2009; Klerkx et al. 2010; van Mierlo et al. 2010a, b), discuss the importance of structurally changing, for example, existent legislation and funding instruments, as these may favour incumbent systems but hinder innovative development. This deals, for example, with environmental regulations that do not accommodate new technologies and lack of risk capital facilities.

Innovation support system interventions are expected to create either a generic or a novelty-specific innovation enabling context in which innovation networks or partnerships develop and become productive as the chance on innovation increases. However, at the local level of these networks a conducive context is needed as well, and ideally, network level interventions and broader system level interventions feed into each other. In the next section we describe two specific, recently developed types of interventions aimed at stimulating innovation networks with a broader systemic perspective: (1) via researchers and extensionists/advisors acting as innovation brokers and (2) with the aid of reflexive monitoring.

Interventions aimed at innovation network performance: Dedicated innovation brokers as systemic intermediaries

Currently, the emergence of new organizational forms for stimulating agricultural innovation is evident, appearing under a variety of banners such as transdisciplinary research projects, network approaches, system innovation programs, and public-private partnerships. Although there are many operational differences they all somehow facilitate a collective process in which new social and technical solutions, or at least their contours, are designed, agreed, and/or acted upon. Interventions that aim at fostering innovation network thus often deal with improving communication between innovating actors. Despite the existence of a broad literature on the facilitation of interactive processes and social learning in agriculture (see e.g. Leeuwis and Pyburn 2002; Cristóvão et al. 2012, this volume), the literature on embedding this facilitation role as a specialised function in AIS is still limited. Although mentioned as a solution to innovation system fragmentation and underperformance (Spielman and von Grebmer 2006; World Bank 2008; Oreszczyn et al. 2010), the topic appears to have been less systematically investigated in the agricultural sector. Nonetheless, there is an emerging experience of actors that explicitly dedicate themselves and position themselves as a systemic intermediary and a systemic facilitator, an in-between in a many-to-many relationship (Howells 2006; Leeuwis and Aarts 2011). These systemic intermediaries act as *innovation brokers*, whose main purpose is to build linkages in AIS and facilitate multi-actor interaction in innovation (Klerkx et al. 2009; Klerkx and Leeuwis 2009a). In some countries, such as the Netherlands, these innovation brokers have emerged as specialized actors (Klerkx and Leeuwis 2009a), but in other countries several types of organizations (e.g. research organizations, NGOs) have taken up this role (Klerkx et al. 2009).

However, embedding such an innovation broker role as an additional role to, for example, 'classical' research and extension is challenging. As the World Bank (2008) argues, research organizations should focus beyond the connection with farmers (through participatory research) on the interface with private sector actors in the value chain (traders, processors) and broader civil society, and must change their governance systems towards partnerships. The latter also includes rewarding

alternative forms of research (such as action research – see Hocdé et al. 2008; Van Paassen et al. 2011; Schut et al. 2011) and cooperation of different actors, instead of focusing on publications.

However, beyond changing the incentives for the research organizations and their roles, this also requires changing perspectives. Research funding organizations need to take an innovation systems view and adapt their funding mechanisms in such a way that research agenda setting and funding processes enable this kind of multi-actor partnerships (Klerkx and Leeuwis 2009b). For example, a clear challenge is to balance long-term and short-term perspectives in research through multi-actor partnerships, to ensure all partners are satisfied in their needs and remain motivated (Klerkx and Leeuwis 2009b).

As regards the role of extension organisations, or more broadly, advisory service providers, who as a rule have acted as intermediaries in the translation and exchange of knowledge for problem solving and innovation, the shift to such a systemic intermediary and systemic facilitator role is still challenging (Leeuwis 2004; Rivera and Sulaiman 2009).

Leeuwis and Aarts have summarized (see Table 20.2) what the changes towards such an innovation broker or systemic facilitator role imply for communication professionals such as extension and advisors, but they also apply to researchers who intend to foster partnerships, e.g. action researchers. This connects to three main functions important for fostering networks and partnerships (Klerkx et al. 2009; Leeuwis and Aarts 2011):

- Demand articulation: articulating innovation needs and visions and corresponding demands in terms of technology, knowledge, funding and policy, achieved through problem diagnosis and foresight exercises.
- Network composition: facilitation of linkages amongst relevant actors, i.e. scanning, scoping, filtering and matchmaking of possible cooperation partners.
- Innovation process management: enhancing alignment in heterogeneous networks constituted by actors with different institutional reference frames related to norms, values, incentive and reward systems. It includes a host of facilitation tasks which ensure that networks are sustained and become productive, e.g. through the building of trust, establishing working procedures, fostering learning, managing conflict and intellectual property management.

Enhancing the reflexivity of innovation networks

Innovation networks meet specific challenges like the inherent unpredictability of the outcome of their actions, the many uncertainties they need to deal with, the social ambiguity and the need to be and remain flexible and ready to embark on new paths. To support them in meeting these challenges reflexive monitoring has been developed. This type of monitoring and evaluation encourages participants of an innovation network to keep reflecting on the relationships between the key items: the long term goals of an innovation endeavour, normalized practices, plus the

Table 20.2 Roles of systemic facilitators/innovation brokers (Adapted from Leeuwis and Aarts 2011), which consist of three main roles: demand articulation, network composition and innovation process management

Demand articulation	Network composition	Innovation process management
Demonstrate and visualise interdependencies among stakeholder practices	Make an inventory of existing initiatives, complemented with stakeholder analysis	Identify and propose process facilitators who are credible and trusted by the stakeholders involved
Explore and exchange stakeholder perspectives (values, problems, aspirations, context etc.) Through discussion, role playing, dramatization, visits, filmed interviews, informality, humour, fun etc.	Build on existing initiatives for change and the networks around these	Work towards process agreements, including dealing with media, mandates etc.
Visualise invisible bio-physical processes with the help of discovery learning tools or simulation	Arrange contact between disconnected networks who may have compatible interests	Probe to explicate the interests and fears that underlie mobilised arguments and counter-arguments
Explore past and current trends and likely futures if nothing changes	Work towards 'coalitions of the willing' and exclude actors who do not feel interdependent	Steer collaborative research activities to questions relevant to less resourceful stakeholders
Use visioning tools and scenario analysis to imagine (and find common ground on) possible futures	Mobilise pressures from outside (carrots and sticks) to enhance feelings of interdependence	Make stakeholders talk in terms of proposals and counter-proposals
Discuss institutional and other influences that reinforce existing patterns/problems	Forge/broker contact between existing networks and outsiders and/or outside expertise	Ensure regular communication with constituents to take them along in the process
Organise contact with others who have encountered and managed similar problems		Translate agreed upon problems and solutions into storylines and symbols that are likely to resonate in society
Elicit uncertainties that hinder change, and design collaborative investigation and experimentation to develop common starting points		Use media and lobby tactics to influence societal agenda's and advocate solutions (with the help of storylines/symbols)
		Use practical actions and experiments as source of reflection and learning, rather than organising discussion and reflection only
		Organise regular reflection on process dynamics and satisfaction with outcomes

Table 20.3 Key characteristics of forms of monitoring and evaluation (Adapted from: van Mierlo et al. 2010c). Purposes shift from monitoring and evaluation for accountability purposes with low stakeholder participation, to monitoring and evaluation for learning purposes with high stakeholder participation

		Extent of participation	
		Low	High
Ambition to reach institutional change	Low	Result-oriented evaluation (e.g. Logical Framework)	Participatory monitoring and evaluation (e.g. most significant change)
	High	Evaluation of system developments at the system level	Reflexive monitoring

developments in the systems surrounding them, that offer not only barriers, but also opportunities for agricultural innovation.

The central aim of this type of monitoring is to increase reflexivity; this is the case when the network develops new coordinated ways of acting while the institutional context is changing too (and partly as a result of this). The latter is important, since innovation networks bring together actors who are part and parcel of problematic institutional contexts that are seen to demand innovation (van Mierlo et al. 2010a, b).

There are essential differences between reflexive monitoring and other more familiar forms of monitoring and evaluation (see Table 20.3 for a comparison of different forms of evaluation). The future simply does not develop as predicted, finances are often uncertain, there are often conflicts of interest and people have a tendency to keep plodding along the same old path. Consequently, strategies tend to be developed in an iterative fashion rather than at the start and the objectives often change during the course of an innovation trajectory. Moreover, results often only become visible after a long time. It is therefore not very realistic to have an expert collect data for subsequent evaluation using pre-defined objectives with a result-oriented approach. The Logical Framework approach is commonly used in the agricultural domain (IFAD 2006).

Participatory types of monitoring and evaluation in which the actors have their say can help ensure that participants learn, and learn together. A world famous example is fourth-generation evaluation (Guba and Lincoln 1989).[2] In agriculture the MSC method (most significant change) is a well-known example of fourth generation evaluation (Davies and Dart 2005). Reflexive monitoring takes it a step further, though. Learning is not the end in itself. It is about learning to tackle the challenges that are encountered in innovation trajectories, by developing possible solutions jointly. Participatory methods base their monitoring on the current

[2] These concern qualitative and anthropological models of evaluation, which emphasize the importance of observation, the need to retain the phenomenological quality of the evaluation context, and the value of subjective human interpretation in the evaluation process.

perspectives and the goals of the people involved, which are often at odds with the need to put the institutional preconditions up for discussion and to develop other, radically different realities. After all, it is precisely these existing perspectives that may be part of the problem.

The emphasis of *reflexive monitoring* is on flexibility, rather than on a strictly structured methodology or a rigid sequence of steps. This type of monitoring is customized work: the challenges of the moment hindering innovation determine the monitoring activities. Hence, the monitor is not only an observer but also –primarily – a facilitator who intervenes for example if new insights are not resulting in actions. He or she encourages participants to reflect upon the relationships between the project and its context, between project activities, and between short-term objectives and long-term ambitions. This allows them to break away from the old patterns of thinking and acting, and away from the undesirable effects that were associated with them. The monitor can add impetus to this change by holding discussions with participants, asking questions about implicit assumptions, giving advice about the composition of the network or the purpose and program of a meeting, drawing attention to problems and external developments, emphasizing the progress within the project, and so forth. At times, special tools are used. One such tool is the collective system analysis in which the Innovation System framework developed by Klein Woolthuis et al. (2005). It is used to collectively analyse institutional barriers as well as windows of opportunity for an envisioned innovation that emerges in the slipstream of external developments. Hence, reflexive monitoring is expected to support the emergent design of joint directions of solutions aiming for long term ambitions.

The first experiences with reflexive monitoring show that it can help participants go a step further than making plans with no obligations, and genuinely get involved with an innovation initiative (Regeer et al. 2009; van Mierlo et al. 2010b). It has encouraged researchers to tackle questions more creatively instead of getting stuck in more of the same type of studies. Additionally, it has encouraged all kinds of actors involved to look at their networking activities from a broader perspective on institutional barriers within society, and to recalibrate those activities. The collective system analysis has been shown to support system thinking in innovation networks. It did indeed have the potential to enhance reflexivity if carried out collectively. However, regular patterns of thinking and acting within projects have been found to interfere in subtle ways with the new knowledge generated and to limit the transformation of the reflexive feedback and insights into action.

Outlook and research agenda

In this chapter we provided an overview of the different ways agricultural innovation systems have been conceptualized, operationalized, researched and how interventions have been shaped under the influence of these perspectives. The AIS perspective

provides a comprehensive view of actors and factors that co-determine innovation, and in this sense facilitates an understanding of the complexity of agricultural innovation. However, its holism is also a pitfall as it allows for many interpretations, which complicates a clear focus of this research field and the building of cumulative evidence. As a result, more work needs to be done conceptually and empirically. Some suggestions for further research are given below.

(a) More *systematic analysis of similarities and differences* between different innovation system and system innovation perspectives in a similar vein as some authors (Coenen and Díaz López 2010; Markard and Truffer 2008) did in their comparison of theoretical frameworks used for studying industrial innovation. The aim would be to explore opportunities for cross-fertilization without losing the richness of their paradigmatic differences and their respective value for research questions which cannot be studied from other paradigms. This includes linking the scientific discussions on agricultural innovation to those in industrial innovation studies, e.g. on how to prevent the inherently dynamic conceptualization of innovation systems to become static in the actual analyses of these systems.

(b) Articulate and be transparent about the *perceived system boundaries* of the AIS that is being studied (sector, country, region, technology, value chain), and the extent to which we speak about a functioning system or a network which is a 'system in the making'. It is also about recognizing diversity of subsystems within a system, and getting a clearer view of how different system boundaries cut across each other (see e.g. Hekkert et al. 2007). This is also about recognizing that actors in AIS cater for different, sometimes very divergent, development directions (e.g. a research institute supporting simultaneously both transgenic crops, organic agriculture, and multifunctional agriculture), and may both have enabling and constraining roles (e.g. government funding research and innovation , but also maintaining legislation favouring incumbents). This calls for a more careful description of the multiple identities of actors in AIS, and recognizing that innovation systems simultaneously enable and constrain innovation (Hung and Whittington 2011). This includes acknowledging that while gaining complete knowledge of a system is impossible, defining the boundaries of the innovation system to be analysed in itself a value-driven act, marginalising what lies outside the system. A systematic reflection on the choices made, e.g. as in critical system heuristics (Werner and Reynolds 2010) may help AIS researchers to welcome and deal with the different perspectives of actors involved in systems and thus to return to soft systems thinking.

(c) More systematically reflect on the *implicit and explicit theories of change* that underlie different modes of systems thinking. In the early 1990s the emergence of the AKIS perspective led to intensive debates on whether systems should be looked at from a hard systems, soft systems or critical systems perspective, and since then the array of systems perspectives has only expanded (e.g. with autopoietic systems thinking and complex systems thinking) (see Leeuwis 2004: 295–301 for overviews). Each of these perspectives goes along with different assumptions about reality, fundamental processes and theories of change. It seems

high time to pick-up that debate again, to compare systematically perspectives and to formulate a coherent conceptual perspective that can inform AIS practice.

(d) Develop a *better understanding of how actions and agency* at the level of innovation projects or specific socio-technological trajectories (niches, technological innovation systems) influence broader system change (niche, regime, structural change in national or sectoral innovation systems). Now often studies remain concentrated either on the innovation project management or technology design and development level; or take a rough, long term transition perspective, or focus mainly on a structural analysis of innovation support system conditions. In the spirit of the concept of the 'duality of structure' (Giddens 1984), concepts such as 'effective reformism' (Klerkx et al. 2010; Roep et al. 2003) 'anchoring of innovations' (Elzen et al. 2012, this volume) or 'institutional entrepreneurship' (Hung and Whittington 2011) aim to bridge this gap between different levels in innovation systems (i.e. innovation networks, niches, innovation support structure, regime) and how they link and influence each other.

(e) *Develop research methods* that – in addition to the analysis of structures and their changes and 'hard' innovation system performance criteria such as patents, numbers of researchers, monetary investments in research and innovation – allow for analysis of the many intangible effects of interventions in processes of learning and innovation. For example: network formation and synergic effects of networking, the role of visions as guiding devices in innovation, emergent and synergic effects of different separate innovation systems interventions, i.e. what have been dubbed 'soft' evaluation criteria (Oughton et al. 2002). This also includes developing research methodologies that are part and parcel of the innovation process. AIS research would then be a form of action research that stimulates not only reflection but also reflexivity and researchers would then also be innovation brokers.

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