Literature review of methodologies for the diagnosis of Agricultural Innovation Systems (AIS)

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1 Objectives of and method for the literature review

In order to support the design of the methodology for a diagnosis of agricultural innovation systems (AIS), a rapid literature review has been undertaken, addressing three key issues:

1. What are the key features of an AIS to be considered for the design of supportive interventions?
2. What are the different types of AIS diagnoses implemented so far, their results, limitations and challenges?
3. How can a diagnostic approach support decision makers in the design and implementation of new innovation policies?

To produce a short and rapid literature review, we mobilized the database on AIS of FAO and CIRAD researchers and we complemented this data with other references using search terms such as: (diagnosis or method) AND (innovation systems OR governance of AIS OR policy innovation). Approximately 100 references were used and/or collected and analyzed, consisting of peer-reviewed scientific papers, technical reports, and policy briefs. A Dropbox was created with key references to facilitate exchanges between members of the expert team.

2 Introduction to the AIS concept

The concept of Innovation Systems (IS) has been used in the academic literature since the 1990s (Lundvall 1992) and has been influenced by evolutionary theories of innovation (Dosi et al. 1988) that have analyzed technological innovations in the industrial sector (Foray 2009). This concept is used to understand how a set of institutions, organizations, networks and individuals can interact to foster innovation in a given national, regional, or sectoral space, or in a space constructed by companies around the development of a specific technology (Carlsson et al. 2002). The literature on AKIS (Agricultural Knowledge and Information System) is the first application of the IS concept to the agricultural sector (Röling 2009).

Nowadays, it is becoming increasingly common to use an innovation-system approach to understand and spur innovation in the agricultural sector. The AIS concept has been adopted and adapted by international organizations (e.g. World Bank 2006; EU SCAR 2012; OECD 2013; Tropical Agricultural Platform 2016) to provide directions for innovation policies, and for structuring research, education and advisory services. An Agricultural Innovation System (AIS) can be defined as *"a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge"* (World Bank 2006). The TAP definition (Tropical Agricultural Platform, http://www.fao.org/in-action/tropical-agriculture-platform/commonframework/en/) is much in line with the above definition: *"a network of actors (individuals, organizations and enterprises), together with supporting institutions and policies in the agricultural and related sectors that bring existing or new products, processes, and forms of organization into social and economic use. Policies and institutions (formal and informal) shape the way that these actors interact, generate, share and use knowledge as well as jointly learn."*

However, while the AIS concept is now widely recognized and analyzed (e.g. Klerkx, Aarts, and Leeuwis 2010, Spielman, Ekboir, and Davis 2009, Hall et al. 2003, Rajalahti, Janssen, and Mekon 2008, Hounkonnou et al. 2012, Spielman et al. 2008, Francis et al. 2016), it can be used for many diverse purposes: comparing performances of countries, analyzing agricultural innovation processes with a systemic perspective, studying various components of the AIS, orienting public policies to support

innovation, etc. Moreover, in many low- and middle-income countries, policy and decision makers lack information on the state and needs of their own national AIS to guide the formulation of relevant innovation strategies and policies (Spielman, Ekboir, and Davis 2009). The purpose of an AIS diagnosis is therefore to provide them with the type of timely and usable information and, to some extent, with associated indicators they need to formulate strategies and policies to unlock the potential of agricultural innovation for sustainable food and agriculture.

Highlight 1: Different uses of the AIS concept

Touzard et al. (2015) identified four epistemic knowledge communities using the AIS concept. These communities agree globally on the main characteristics of an AIS (innovation as a process, key role of institutions and knowledge, systemic approach). These communities are distinguished by the categories of actors that compose them, by the theoretical references and uses of the IS concept, and by different terminologies and questioning of the agricultural and agrifood sectors. It is useful to present these four communities to better identify the key components of AIS to be analyzed.

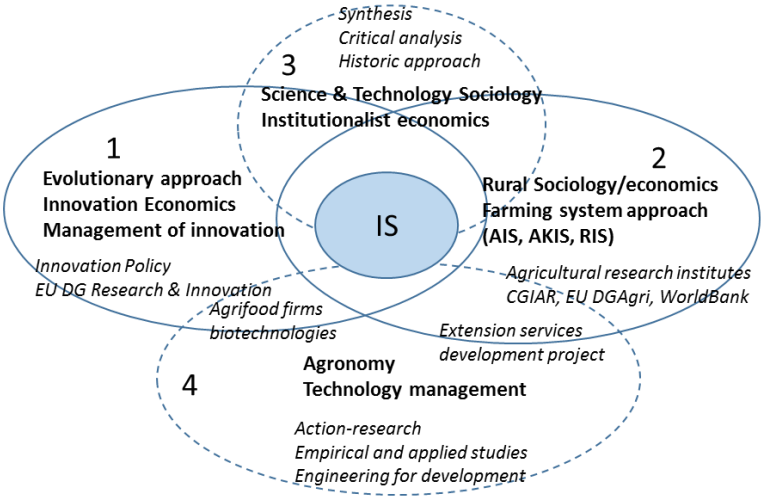

Figure 1: The four epistemic knowledge communities using AIS (Touzard et al. 2015)

The first community refers to historical macro-economic determinants of innovation systems. Innovation is promoted by key actors such as researchers, firms in or related to the biotechnology or agrifood sectors, and development agencies formulating innovation policies. This community shares a positive vision of progress and exploits the AIS concept to create an environment conducive to the dissemination of the technologies it produces. Authors use concepts such as national innovation systems, sectoral innovation systems, regional innovation systems, and clusters or models to analyze collective rules, norms and policies that allow new technology to be developed. The methodological frameworks developed by this community are not easily mobilized for agriculture in low-income countries.

The second community originates mainly from a research tradition built around agriculture development issues (work on agricultural development, analysis of systems of agronomic research, farming system approaches, etc.) and are associated with agricultural research and development institutions (CGIAR, Wageningen, Hohenheim, CIRAD, etc.). In this community, specific concepts now associated with AIS are mobilized: Agricultural Knowledge and Innovation System (AKIS), Agricultural Innovation System (AIS) (Klerkx et al. 2010), Rural Innovation System (Spielman et al. 2010), etc. Two main hypotheses shape this community. The first posits that innovation emerges from the capacity to produce knowledge, to experiment and to build collective action grounded in endogenous dynamics. The second states that innovation capacities are shaped by learning capacities (Casadella and Uzunidis 2018). Relevant support tools and specific services have to be designed in order to support such processes.

The third community consists of scientists who use the AIS concept to analyze rural transformations.

Authors refer to the evolutionist framework or to rural sociology, which testifies above all to other influences (history or sociology of science, institutional economics, theory of regulation, etc.). These are historical studies, syntheses, comparative analyses, and theoretical questions based on the transformations of agricultural and agrifood activities (e.g. Allaire and Wolf 2004, Sanchez 2008). This community's perception tends to be more critical, detached from the interests of the economic and political actors of agriculture.

The fourth community, on the other hand, is made up of scientists, engineers and actors belonging to or working in the agricultural sector who are directly involved in the implementation of innovation processes or in agricultural policy development. The concept of AIS is used to contextualize, analyze or accompany these processes and to determine its institutional conditions, without necessarily questioning the evolution or the effects of the institutions concerned.

3 Key features of an AIS to be considered for the design of supportive interventions

In this part, we review the different ways of evaluating or characterizing an AIS and the methods to collect data to assess an AIS.

3.1 Different views to analyze AIS

As a consequence of this diversity of use and interpretation of the AIS concept, several analytical approaches or views have emerged and are currently used to analyze AIS. Klerkx and al. (2012) identified an infrastructural view, a process view, and a functionalist view. This classification is still relevant for understanding how the systemic AIS concept is perceived and used by different authors. Additionally, recent work has laid more emphasis on individual and collective capacities to understand and strengthen AIS (TAP 2016). We consider four views:

- A **structural view** where AIS is seen as a structure that leads to innovation. The structural analysis of an AIS consists mainly of identifying its structural components, i.e. stakeholders and their networks. The boundaries of the system depend on the objectives of the diagnosis (for example, national innovation system, regional innovation system, sectoral innovation system). A combination of these different perspectives can be useful in designing innovation policies.
- A **functional view** where AIS is seen as performing a set of functions that is necessary to make innovation occur. Different sets of functions have been identified in the literature such as knowledge development, brokering functions, funding, etc. In this case, the AIS diagnosis may lay emphasis on one or more components of the system.
- A **process view** where AIS is seen as a complex adaptive system thanks to the dynamics of innovation processes. Different approaches of this dynamic view have been developed by scholars from the evolutionary and institutional economy (including the diffusion model) or from sociology with the multi-stakeholder approach (e.g. the "actor network theory"). In this case, the boundaries of the system will depend on the innovation process which is being analyzed. Such a view may encompass one AIS per innovation.
- An **capacity view** where AIS is seen as a system to match supply and demand of knowledge from different stakeholders and to allow capacity building. Organizational analysis aims at understanding how actors set goals and choose strategies to innovate and at helping them do so. The analysis consists of identifying the key AIS actors and their capacities, clarifying key assumptions used by actors and their vision of the problem.

3.1.1 Structural view of an AIS

The structural analysis of an AIS consists of identifying the structural components of the AIS, so that the system can be bounded, and stakeholders and their networks identified. This analysis aims at linking structures and determining how the system enables or constrains innovation. According to Knierim et al. (2015), a system is *a "collection of components that are structurally coupled by interaction patterns."* A structural analysis allows us to understand what encourages initiatives and what effect interaction patterns have on the system (Knierim et al. 2015). Structural components include not only actors, but also all aspects of the economic structure and the institutional set up affecting learning, searching and exploration processes (Kebebe et al. 2015, Wieczorek and Hekkert 2012, World Bank 2006). Agreements, contracts, explicit or implicit rules, forms of organization, institutions that orient and legitimize action are all included (Edwards 2000), as are physical facilities such as buildings, meeting rooms, roads, Internet infrastructure, and language and culture as well (Knierim et al. 2015a).

By identifying actors belonging to the system, one can draw the boundaries of the AIS, but it remains a challenging task. Knierim et al (2015a) note that *"each system is a component in a larger system and each component of a system is a system in itself."* Actors should thus be identified according to the interaction patterns they generate with other actors and which form a systemic perspective, having a direct effect on the innovation process. Since the environment (also called *institutional landscape*) also plays a decisive role in innovation processes, scholars recommend taking into account both innovation networks and actors of the institutional environment in order *to reconstruct agency-structure interactions* (Klerkx, Aarts and Leeuwis 2010)

Based on seminal studies at the World Bank (Hall et al. 2006), common methods for performing a structural AIS analysis have been proposed. They consist first of classifying actors into different affiliation categories such as research, advisory services, private sector (including farmers, retailers, and suppliers), indirect demand (final consumers, policy makers, social interest groups) and intermediaries (education and extension services, innovation brokers) (Lamprinopoulou et al. 2014). Spielman and Kelemework (2009) consider 4 domains which aggregate several types of actors to characterize AIS at a national level: Knowledge and education domain, Bridging institutions domain (including advisory services), Business and enterprises domain (including farmers), and Enabling environment domain. This typology is also used by TAP (TAP 2017). Networks of actors and relationships between the latter are then analyzed. Interactions take different forms: collaboration (e.g. joint research activities, information sharing, facilitation of networks), competition or coopetition, as innovation networks are *the scenes of negotiation* (Klerkx, Aarts and Leeuwis 2010).

Structural analysis can be performed at a sub-system level (e.g. research and education, agricultural advisory services, private firms) to obtain an in-depth understanding of one or more sub-systems. For example, the agricultural advisory services sub-system has often been analyzed by researchers and practitioners (e.g. Sulaiman and Hall 2002, Christoplos 2010, Faure et al. 2012, Knierim et al. 2015b) with the support of international agencies (FAO, World Bank, GFRAS).

Structural analyses can be performed at different levels, according to administrative boundaries (at the country level to address the national innovation system, at the regional level to address the regional innovation system) or according to an organizational rationale (along specific value-chains to address a sectoral innovation system), or even according to a type of production (organic, fair-trade, other labelled production). Hence, defining the appropriate scale of analysis is challenging given that the AIS may take different forms (Spielman and Birner 2018): some interactions between actors may be intensive at a level and weak or invisible at another. Audouin and Gazull (2014) show that spatial patterns of agricultural innovation systems (with a spatial heterogeneity of resources, actors, infrastructures, etc.) influence the performance of an AIS with complex interactions between local, regional and national levels. A cross-analysis at different scales helps identify mechanisms such

governance modes, market access, number and types of actors in the system, rules and institutions established to regulate the system, etc. (Knierim et al. 2015b).

Different methods are used to undertake structural analyses, including analyses of (i) the level of interaction and coordination between actors (using social network tools), (ii) the weaknesses and strengths of the entire system or of each actor (using qualitative analysis and descriptive indicators), and (iii) the performances of the system. The performance analysis consists mainly of benchmarking studies based on indicators (Spielman and Kelemework 2009, OECD 2017) such as patents, R&D expenditures, numbers of researchers, and input-output or spill-over analysis of R&D investments, returns on risk capital, etc.

The literature on structural analysis highlights its limitations: (i) this type of analysis is inherently static and hence cannot account for the dynamics of the innovation landscape and processes (e.g. changes in relationship patterns between actors) and (ii) it is difficult to draw recommendations based on an AIS structure analysis because each AIS displays specific characteristics that induce a specific innovation process. Some AIS may be successful in supporting innovation and others may experience difficulties in doing so even though they may have a similar structure (Spielman et al. 2008, Bergek et al. 2008).

In addition, a group of experts underlines specific difficulties faced by system (and structural analysis) of AIS (De Roo et al. 2017):

- The system is over-analyzed, without any prioritization of information needs, which leads to a surfeit of information and unnecessary resources spent to collect and analyze data.
- The analysis is often research-oriented and is not action-oriented, thus has no impact on innovation support policies.
- Boundaries of the system are fuzzy or poorly defined because of differing stakeholder perspectives at different stages of the innovation.
- The difference in capacities between stakeholders is ignored, resulting in a weak analysis and ineffective solutions.

3.1.2 Functional view of an AIS

The functional approach to innovation systems originated from the Technological Innovation System (TIS) framework, subsequently enriched by the inclusion of key processes known as “functions”. It is assumed that the overall purpose of a TIS is to develop, disseminate and use a new technology (Bergek et al. 2008, Carlsson et al. 2002, Jacobsson and Jacobsson 2014). This approach allows different innovation systems to be compared despite the heterogeneity of their structures. It focuses on “*what is actually achieved in the system”* (Bergek et al. 2008), regardless of the structure. Functions are analyzed as processes in their general meaning of “something that is going on” (Bergek, 2012), irrespective of the direction or causalities related to the Innovation System.

The functional TIS approach is related to the system approach because “*how and how well functions are served is largely dependent on system structure”*, and because it depends on the components of the system, more precisely on the characteristics of interaction among actors, institutions and networks (Bergek 2012). Functional analysis allows system failures to be assessed and the system’s performance to be evaluated (Bergek et al. 2008, Chaminade, Intarakumnerd and Sapprasert 2008, Hekkert et al. 2007, Negro, Hekkert and Smits 2007). Mapping the functions and the interactions between them are useful to identify the drivers and constraints of innovation and to provide information to policy makers about the strengths and weaknesses of each function (Klerkx and al. 2012).

Hekkert et al. (2007), Bergek et al. (2008) and Bergek (2012) have initially proposed a set of seven functions which, through direct or indirect impacts, influence how the overall TIS operates:

1. Knowledge development and dissemination
2. Influence on the direction of research
3. Market formation
4. Resource mobilization
5. Creation of legitimization for change
6. Development of positive externalities
7. Entrepreneurial experimentation.

These seven functions can be easily adapted and applied to AIS, as Klerkx et al. (2012) have done. In a perspective focused on functions and/or services to support innovation, several authors have identified different types of generic functions/services to be fulfilled in AIS, even though the boundaries between these functions/services are not always clear. For example, Kilelu et al. (2013) identify 6 types of functions: (1) demand articulation (vision building, diagnosis, foresight), (2) institutional support (institutional change and boundary spanning), (3) knowledge brokering (connecting to knowledge and technology), (4) network brokering (matchmaking between partners), (5) capacity building (training, coaching, organizational development), and (6) innovation-process management (aligning agendas and learning). From another perspective, Heemskerk et al. (2011) identify and discuss a similar, but different, set of functions.

Based on this literature review, Mathe et al. (2016) proposed a set of services which were used to analyze 58 innovation cases studies in Europe to provide recommendations for policy makers to better support innovation in the agricultural sector: (1) Awareness and exchange of knowledge, (2) Advisory, consultancy and backstopping, (3) Demand articulation, (4) Networking, (5) Facilitation and brokering, (6) Capacity building, (7) Enhancing/supporting access to resources, and (8) Institutional support for niche innovation and stimulation of scaling mechanisms.

While some functions are well documented in the literature such as knowledge brokering (e.g. Klerkx et al. 2010) or knowledge development and dissemination (e.g. Palmeri and Rivas 2007), others, such as resource mobilization, have been investigated less. For example, Water-Bayer et al. (2005) argue for new funding mechanisms for supporting farmers and farmers' organizations to experiment on their own. This argument is also supported by the World Rural Forum (http://www.ruralforum.org/en/home).

Functional analysis can encompass a diversity of methods usually based on qualitative analysis to understand innovation processes (case studies), on social network analysis to understand one function or a group of functions, and on organizational studies to understand the roles played by actors to support key functions. Benchmarking analysis is also an option to compare countries or monitor processes.

The main limitations of the functional view is that it has only been recently – and little – used in the agricultural sector (World Bank 2008). Hence, the definition of each function remains quite fuzzy, which may make it difficult to analyze the functions since there is a risk of overlaps. The criteria used to describe the functions will have to be adapted to AIS specificities. A second limitation arises from the ongoing debate between the need to fulfill all functions in their entirety to ensure a satisfying functioning of the AIS and, in contrast, the need to guarantee a set of minimum, indispensable and sufficient functions. Such a debate shows that there is a need to adapt the diagnosis to the specific situation of each AIS. Moreover, there is still not enough evidence to understand the articulation between functions or services and the dynamics of the innovation process; some functions may be critical to a specific stage of the innovation process and not to other stages.

3.1.3 Process view of an AIS

In the process view, an AIS is perceived as a complex and adaptive system, whose innovation process has to be unravelled. Due to their dynamics and non-linear nature, innovation processes are complex and change over time, as regards the composition of the network of actors, the interaction patterns and artefacts (Klerkx, Aarts and Leeuwis 2010). Actors and their environment are linked by *mutual embeddedness* (Markard and Truffer 2008). This means that actors are conditioned by their environment while changing actively or passively. In a process view, the system's limits may depend on the innovation process which is being analyzed. Such a view can encompass one AIS per innovation. The process view highlights the need to take into account the time to understand an AIS and the balance between stability and reconfiguration of the system, depending on the changing (and usually growing) number of actors involved in the innovation process.

Various approaches of the dynamics of innovation have been developed by scholars of different disciplines (sociology, evolutionary and institutional economy, management science, etc.) and based on various perspectives such as the diffusion model from Rogers (1983), the "vortex-like" model (Akrich and al. 1998), the actor network model (Callon et al. 2006), the critical mass and tipping points concepts (Knierim et al. 2015a), and the "spiral model" (Wielinga et al. 2017).

Recently, transition studies have been used in AIS analysis to understand how changes occur and may have impacts at the system level, acknowledging the complexity of socio-technical changes. Using Geels's multi-level perspective approach, niches of innovation can be seen as an "innovation system" able to transform the dominant socio-technical regimes (Geels 2002). This approach emphasizes the role of the institutional environment in influencing rules, norms, and values that support the dominant socio-technical regime or allows the emergence of niche innovations. Geels and Schot (2007) developed a typology of four transition pathways: transformation; reconfiguration; technological substitution; and de-alignment and re-alignment.

Furthermore, theories of change applied to development programs but more to research for development as part of AIS have gained some fame. Such studies aim at developing and testing a *complexity-aware theory of change* (Douthwaite et al. 2003, Douthwaite and Hoffecker 2017, Temple et al. 2018), linking research activities, interactions with other AIS actors and the production of impacts (Blundo Canto et al. 2018). Thus, specific AIS structures, including types of interactions between stakeholders and modes of intervention of the research community can lead to 3 different and interconnected pathways, which Douthwaite et al. (2017) call the technology development and adoption pathway, capacity development pathway, and policy influence pathway. As the impact pathway of agricultural research is a complex multi-causal phenomenon, mapping the impact of innovation processes is a challenging task (Hainzelin et al. 2016).

However, research provides only a part of the contribution to innovation and in fact does not often participate in innovation processes. A large range of services are necessary for successful innovation, including different types of agricultural services. Focusing on the dynamics of innovation and the services/functions, Faure et al. (2018) suggest that Innovation Support Services vary along the phases of the innovation process. They conclude with the need to define policy instruments by taking the dynamic process of innovation into account.

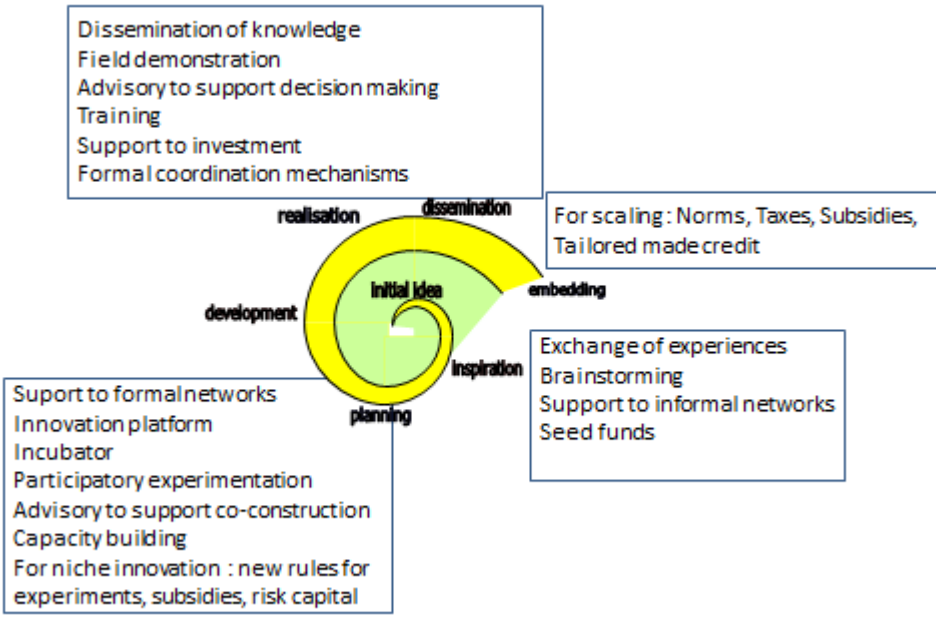

Figure 2: Main types of ISS depending on the phase of innovation (source: Faure et al. 2018)

An analysis based on the process view includes a large number of methods usually based on qualitative analysis (mainly from sociology) to understand networks and processes. In this case, benchmarking is not possible because each situation is context-specific. Indicators are sometimes used within a multi-criteria approach but not for cross-country comparison. The main limitations of approaches based on the process view are the lack of genericity (each case is context-specific) and the difficulties in assessing the outcomes and impacts with quantitative methods.

3.1.4 Capacity view of an AIS

Capacity analysis is progressively gaining frame to understand and analyze an AIS. It aims at identifying the factors that enable or hinder the performance of the AIS, by putting emphasis on the analysis of individual and collective capacities with the aim of helping actors and stakeholders set goals and choose strategies based on mutual expectations and some level of agreement on how to move forward.

Along with the emergence of innovation systems analysis, and reflecting the importance of actors' capacities to engage in innovation processes, a related concept has emerged over the past 20 years, that of "capacity to innovate" (C2I). Recent studies on capacities to innovate in AIS have evoked interest from scholars of the management sciences and in recent projects. Capacity is defined simply as "*the ability of people, organizations and society as a whole to manage their affairs successfully*" (OECD).

As a concept, capacity to innovate is significant not only in the agricultural sector (Schut et al. 2015) but also in the business world (Hult et al. 2004), and in references to national innovation systems (Wonglimpiyarat 2010). It is closely related to the concepts of adaptive capacity and capacities for social learning, and is being increasingly perceived as playing a key role in helping local-system actors respond effectively to rapidly changing external contexts. Despite this growing interest, the lack of a universally accepted definition for C2I reflects a certain "fuzziness" about its definition (Chuluunbaatar and LeGrand 2015, Hall et al. 2009).

The literature on capacity to innovate points to certain capacities and capabilities required by individuals, organizations and/or institutions which when combined create the capacity needed to innovate and sustain innovation processes over time. On the basis of a literature review, Allebone-Webb et al. (2016) classify these capacities into groups that were most alike or linked, leading to four broad capacity groups each of which may concern, or be supported by, individuals, organizations and the enabling environment, and which can be further divided into several sub-capacities:

- To envision, create and be open to new ways of doing things – to individually and/or jointly envision something new and improved; to accept or be open to new ways of doing things;
- To connect with others to access and understand new information and resources – to form new connections and to use both new and existing relationships with diverse actors (individuals and entities) in order to obtain, share and understand information and resources;
- To iteratively experiment, test, assess, and adapt – to conduct experiments involving iterative learning and improved processes and results over time; and
- To work with others to achieve action and change – to work together formally and informally in order to take effective collaborative action and achieve common objectives.

The Tropical Agricultural Platform identified 4 key capacities required for AIS to perform effectively (www.fao.org/in-action/tropical-agriculture-platform/):

- Capacity to navigate complexity,
- Capacity to collaborate,
- Capacity to reflect and learn,
- Capacity to engage in strategic and political processes (Tropical Agricultural Platform 2017).

The analysis of capacity consists of identifying the key AIS actors and their capacities, and clarifying key assumptions used by actors and their vision of the problem. The TAP and the CDAIS project provide guidance to carry out such diagnostic at local and national level. In conclusion capacity development analysis should be included in operational diagnostic of AIS.

3.1.5 The need for hybrid analytical approaches and for a mix of methods for analyzing AIS

The different views of AIS imply different hypotheses and different methods to analyze AIS. However, scholars mention that the structural view and the functional view appear to be complementary, with structural analysis having to precede functional analysis (Markard and Truffer 2008, Wieczorek and Hekkert 2012). So far, only a few studies have undertaken a combined structural and functional analysis of agricultural innovation (Kebebe et al. 2015, Lamprinopoulou et al. 2014, Turner et al. 2016).

Furthermore, there is a need to complement the diagnosis with a process view to unravel the complexity of the innovation process and to be able to identify niche innovations or best practices to support innovation. For example, dynamic analysis using the multi-level perspective (such as the PRactice-Oriented Multi-level perspective on Innovation and Scaling method: PROMIS developed by Wageningen University) takes into account the fact that substantial and complex changes concerning networks and practices happens during scaling processes (Wigboldus et al. 2016). In the same vein, a diagnosis of AIS based on the “capacities view” helps identify bottlenecks and opportunities arising from the social and human characteristics of the stakeholders, both at the local and national levels (TAP 2016).

Due to the complexity of understanding the AIS on the basis of these different views, a large number of methods have been applied and are proposed. Klerkx et al. (2012) mention methods such as (i) institutional analysis, examining the influence of institutional enablers and constraints and analyzing some types of organizations (research, extension, private sector, etc.), (ii) social network analysis to map actors and linkages, focusing on the types of ties, and analyzing their positive or negative consequences, and (iii) innovation histories to understand the process which leads from activities and events to outcomes of the innovation process. Spielman et al. (2009) also propose an overview of the methods to analyze AIS and mention the same methods plus others such as (i) comparisons between countries to demonstrate where interventions can be effective in one country based on the lessons from other countries and to illustrate the potential for cross-country spillovers, and (ii) game-theory modeling based on work in evolutionary economics, which offers insight into the value of the innovation systems framework. The literature for practitioners, such as the source book of the World Bank (2012), proposes different useful tools such as Outcomes mapping, Scoring Matrix, Problems and Solutions Trees analysis, SWOT analysis, and visioning.

To summarize, there is neither a single suitable AIS approach nor a single suitable method for AIS diagnosis or assessment. It emerges from the literature review that many approaches and methods can and are used to undertake assessments or diagnoses of AIS. A group of experts, brought together in 2016 by KIT, ICRA and Wageningen to discuss approaches and methods of AIS, acknowledged again that there is no single AIS approach, and suggested observing several common principles: clarifying the actors' objectives and expectations; balancing the breadth of the diagnosis with its depth; paying attention to power dynamics; avoiding an assumption of predictability; carefully combining quantitative and qualitative methods; and retaining a focus on informing action (De Roo et al. 2017).

3.2 Types of indicators used for AIS analysis

The various AIS diagnoses (structural view, functional view, dynamic view, organizational view) are based on different methods of collecting and analyzing data, and combine qualitative and quantitative tools. In some types of AIS diagnoses (especially ASTI as undertaken by IFPRI, OECD, FAO, World Bank), indicators are primarily used to assess the structure and performances of national agricultural innovation systems. For a more comprehensive assessment, macro-level indicators that measure static properties and performance can be complemented by indicators that capture system dynamics. For example, the "global innovation index 2017" (Grovermann et al. 2017) provides an interesting list of indicators at the national level for measuring AIS properties for different domains (research and education: 8 indicators, bridging institution: 2 indicators, business and enterprise: 5 indicators, enabling environment: 8 indicators) and for measuring AIS outcomes (6 indicators).

However, the indicators depend on the objectives of the study, on the view of the AIS, and on the method used to analyze the AIS. Table 1 lists different indicators identified in the literature.

Table 1: ***Examples of indicators depending of the AIS view/approach***

View/approach of AIS	Examples of indicators	Data sources
Structural	Research and education: *Quantitative & aggregate data*: - Public investments in agricultural research - Funding for agricultural research as a percentage of agricultural gross value added - Support for private investment in innovation (OECD) *Qualitative data*: - Quality of university education in agriculture - Quality of vocational training in agriculture - Demand-orientation of agricultural research - Research-extension collaboration (Grovermann et al. 2017)	National data, ASTI
	Bridging institutions *Quantitative data:* - Enrolments in agricultural programs - Capacity of public agricultural extension systems (human resources) - Level of collaboration between research centers and government agencies, estimated by number of co-authorships in scientific publications - Density of networks for co-operation between higher education institutes (OECD) *Qualitative data*: - Share and quality of extension services that are based on collaborations among innovation system actors - Share of extension expenditures that involve multiple stakeholders in (a) priority setting and strategic planning or (b) decision making and resource allocation - Frequency of priority setting, strategic planning, and reform exercises in extension services (Spielman and Birner 2008)	National data, ASTI Government, survey, expert, or other sources
	Business & enterprises *Quantitative data* - Inputs to agricultural production (fertilizer, land, rain, labor per ha, stocks of animals , etc) - Road network, foreign direct investments (Mekonnen et al. 2012) *Qualitative data* - Share of farmers who say that they have access to/are satisfied with agricultural inputs, financial services, transportation services, and marketing services - Quality of interactions among actors in a specific value chain in terms of product and process innovation (Spielman and Birner 2008)	Government, survey, expert, or other sources

	Enabling environment *Quantitative data* - Level of corruption - Size of land under irrigation as a share of arable land - Rural population density (Mekonnen et al. 2012) *Qualitative data* - Quality of policies on agricultural research, education, and extension/advisory services - Quality of legislation and enforcement of intellectual property rights - Quality of legislation and enforcement of biosafety and food safety regulations (Spielman and Birner 2008)	Government, survey, expert, or other sources
Functional	*Coupled functional-structural analysis for detecting "system failures":* - Capabilities failure - Policy coordination failure - Market structure failures *(monopoly or the lack of transparency in the ever-enlarging food chains, but also imperfections in the "knowledge market")* - Infrastructural failures - Directionality failure *(lack of shared vision among actors to orient the system)* - Demand articulation failure - Reflexivity failure *(insufficient ability of the system to engage actors in a self-governance process)* Lamprinopoulou et al. 2014 , Turner et al. 2016, Kebebe et al. 2015 - Lack of institutions enabling/facilitating collaboration and partnerships (Darbas et al. 2015)	Qualitative data, collected through interviews and workshops
Process	No specific indicators can be found in the literature. Each study defines its own indicators for analyzing, for example: • Institutional and political constraints • Embedding of constraints in different systems • Structural conditions that can cause constraints to innovation • Value chain segments • Integration levels (international; national; regional; district; ward; village; household) Dimensions of complex agricultural problems (biophysical; technological; socio-cultural; economic; institutional; political), (RAAIS Toolkit 2016)	
Capacity	**Improved (systems) capacity to navigate complexity**: - Level of cost reductions and revenue gain of AIS organizational actors. - Increase in number of co-innovations (between individuals and among organizational actors). **Improved (systems) capacity to collaborate**: - Inclusive decision-making processes about xyz in place. - AIS actors view themselves as part of an aligned interlinked system. - Perceived level of trust and commitment by AIS actors. **Improved (systems) capacity to engage in strategic and political processes**. - Resources (time, budget) dedicated for engaging in joint activities with other AIS (organizational) actors with the objective of advancing the functioning of AIS (e.g. joint publication). - Progress made in advocating for reforms. **Improved (systems) capacity to reflect and learn** - "Developmental evaluation tools" are being effectively implemented (on a scale from 1-5). (CDAIS, TAP Framework)	

Spielman and Birner (2008) explain the current lack of progress in developing comprehensive innovation indicators for developing-country agriculture by the fact that the construction of innovation indicators is subject to a range of epistemological and methodological debates. The epistemological debate refers to the question of whether quantitative measurements are able to adequately explain a system that is highly complex, context-specific, and endogenous. The methodological debate refers to how indicators are selected, constructed, and interpreted. These issues suggest that researchers need to be explicit about the potential and limitations of the indicators they construct. Moreover, researchers must be cognizant of the fact that policy makers and other stakeholders will make their own judgments on how useful innovation indicators are to informing policy choices.

Based on our literature review (e.g. Spielman et al. 2009, Grovermann et al. 2017), we can draw the preliminary conclusions that indicators are useful to:

- Provide evidence based on hypotheses developed by experts;
- Compare AIS performances between countries (benchmarking);
- Monitor the evolution of performances of national AIS over the years.

However, the following key challenges pertaining to the use of indicators still remain:

- Transparent selection of the indicators;
- Data unavailability; if data are available, they are scarce, fragmented, not reliable or of poor quality at sub-national levels for key indicators;
- Obsolete infrastructure for data collection and poor coordination among stakeholders in data collection and analysis;
- Unavailability of resources (human and financial) to collect data regularly;
- Usefulness for policy recommendations because there is no direct relationship between indicators and actions. There is a need to translate indicators into information useful for policy makers.

In conclusion, indicators can be useful to analyze AIS and to provide evidence for policy makers but they are dependent on the problems to be addressed. A set of indicators is not sufficient to understand AIS complexity and should form part of a mix of methods to analyze AIS.

4 Overview of existing operational methodologies for AIS diagnosis

In the previous section, we showed that several approaches have been developed to research AIS. They have proven their value as comprehensive frameworks for analyzing strengths and weaknesses of AIS in different contexts, from different scientific perspectives. There have been few attempts in using these frameworks as operational approaches to help AIS stakeholders in the design of policy interventions and targeted interventions. In this section, we present different types of operational diagnoses and we discuss their limitations and benefits.

4.1 Criteria for the typology of methodologies for operational AIS diagnoses

An operational diagnosis means an action-oriented diagnosis, embedded in the perspective of AIS actors in order to help them evolve or change their practices, strategies or knowledge. In general, there exists a social transformation perspective which implies the participation of the stakeholders in the diagnosis, at different stages and in various forms (more or less collaborative and with more or less standardized tools). Most often, such a diagnosis consists of four broad steps (see figure below):

- S1: Stocktaking
- S2: Identification of issues
- S3: Formulation of strategies
- S4: Action design

At the end of the diagnosis, actions are subject to validation and adoption by the beneficiaries of the diagnosis, which then leads to planning and implementation.

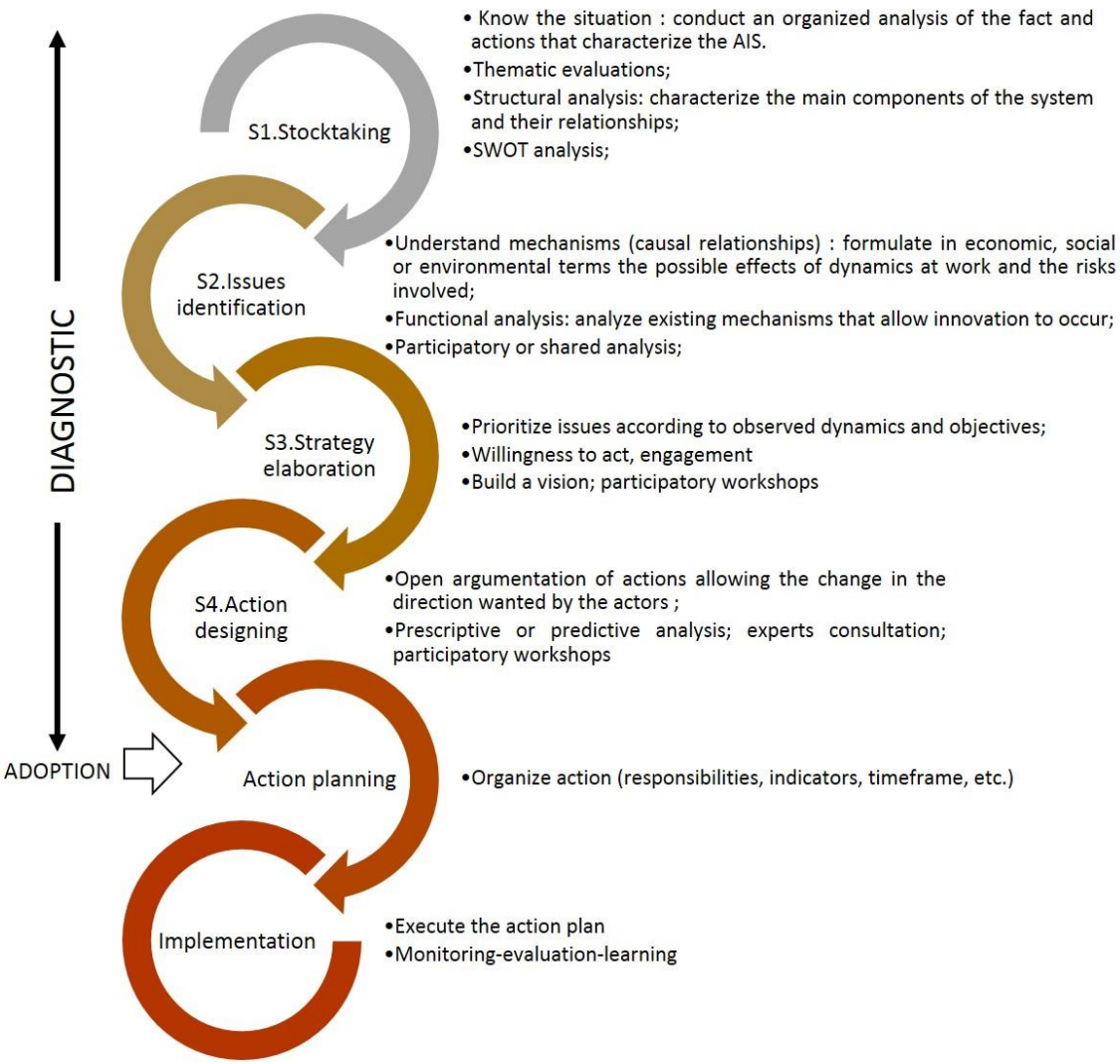

Figure 3: Case 1: Common steps in an action-oriented diagnosis

Operational diagnosis methodologies may span one or several steps of an action-oriented diagnosis, depending on the available resources, skills of the diagnosis team and time issues. At each step, different domains of the AIS (bridging institutions, extension services, private firms, enabling environment, and research and education) can be subjected to an analytical focus, according to the core questions raised by the AIS stakeholders. Then a best-fit combination between structural, dynamic, functional and capacity views can be used to obtain suitable answers. At the very least, the willingness or ability to undertake changes in a given context determines the degree of combination between an external assessment made by evaluators and internal assessments carried out by the stakeholders and actors themselves. The more stakeholders are engaged in the diagnosis, the more the assessment model relies on a dynamic view of the AIS to provide methods and frameworks for collaborative analysis of complex innovation challenges.

The criteria that make it possible to distinguish between different types of operational diagnoses are listed in the table below.

Table 2: Selected criteria for the typology of operational AIS methodologies

	Criteria
Times for a diagnosis	• T1: Before the design of an intervention (project or program): Take stock of the problems, identify the stakeholders involved, their relationships and potential partners, begin to structure the interevention and set priorities (action-oriented diagnosis) • T2: When the portfolio of interventions is already identified/known: Check if the intervention responds to a request, a need, a lack, etc. Check if the intervention is solid and feasible or requires modifications
Entry point of the diagnosis	• Role of public policies (Enabling environment) • R&D performance • Effectiveness of advisory services • Capacity to innovate
Diagnostic stages (T1)	From stocktaking to action planning: • S1: Stocktaking: strengths and weaknesses • S2: Identifying issues (stakes/problems) • S3: Choosing/designing a strategy • S4: Identifying possible actions/interventions • S5: Designing an action plan
Types of analysis	• Descriptive analysis • Predictive analysis • Prescriptive analysis
Thematic evaluations	Evaluations of: • Bridging organization • Education and research system • Extension system • Business and enterprises system • Financing mechanisms • Enabling environment • Capacities to innovate
AIS view	• Structural view of AIS: AIS as “innovation support structures” or “pre-conditions for innovation” • Dynamic view: AIS as “complex adaptive systems” • Functional view: AIS as a set of functions that need to be fulfilled to make innovation occur
Diagnostic techniques/tools	• Desk review • Participant/non-participant observation • Focus-group with specific tools (SWOT, netmap, etc.) • Multi-stakeholders’ workshops with specific tools (SWOT, netmap, Venn diagram, etc.) • Questionnaires • Interviews • Secondary-data analysis
Ease of implementation	• Required skills • Duration
Cost	• Low, moderate, high
Strengths and weaknesses	• How is the methodology suitable to the objectives of the FAO/AIS methodology

4.2 Typology of existing methodologies for AIS diagnoses: objectives, results, limitations and challenges

4.2.1 Presentation of selected case studies

Through a literature review, we identified nine case studies representing different ways to conduct an operational AIS diagnosis according to: specific entry points, ultimate objective, nature of the diagnosis, AIS view, and nature of data.

A detailed description of each case study, following all the criteria, is provided in Annexure 1.

4.2.2 Typology of case studies according to the diagnosis steps, nature of data and degree of involvement of AIS stakeholders

We classify AIS diagnosis methodologies according to the entry points, the ultimate objective, the steps carried out, the nature of data used and the degree of the stakeholders' involvement in carrying out the diagnosis.

Four main entry points can be distinguished: enabling environment, R&D performance, effectiveness of farm advisory services, and capacity to innovate.

AIS assessment models and tools are all linked to the nature of the ultimate objectives of the diagnosis. The ultimate objectives of existing AIS diagnosis methodologies can be of three kinds:

1. To undertake cross-country comparisons at the global level for informing international development agencies;
2. To provide recommendations to policy makers on how to improve governance and performance of the national AIS;
3. To engage in collective action for transformational change.

The willingness to undertake changes determines the degree of combination between external assessments conducted by evaluators and internal assessments conducted by stakeholders and actors themselves. The more stakeholders are engaged in the diagnosis, the more the assessment model relies on a dynamic view of the AIS to provide methods and frameworks for collaborative analysis of complex innovation challenges.

Table 3: Ultimate objectives and types of diagnoses

Entry point of the diagnosis	**Example (case study)**	**Ultimate objective**	**Type of diagnosis**
Enabling environment	OECD 2013	Make recommendations for alternative policies to improve food security by enhancing agricultural productivity through the enabling environment and innovation systems	- Descriptive (S1) - Quantitative-oriented - **Structural** view of AIS
	WB-Spielman and Birner 2008	To inform policy dialogues on agricultural innovation policy and to help identify priority areas for investments, policies, and other interventions that aim at improving the innovative performance of agriculture with a view to poverty reduction and environmental sustainability.	- Descriptive (S1) - Quantitative-oriented - **Structural** view of AIS
	Mekonnen et al. 2012	To estimate the level of technical efficiency in agriculture for a panel	- Descriptive (S1) - Quantitative-oriented

		of 29 developing countries in Africa and Asia between 1994 and 2000	- **Structural and functional** view of AIS
R&D performance	CIRAD-Temple et al.	Understand how the research system is integrated into the productive activity system and who the brokers are.	- Descriptive (S1 to S2) - Mix (qualitative and quantitative) - **Structural** view of AIS
	ASTI/IFPRI-Ragasa et al. 2011	Understand the effectiveness and functioning of the R&D organizations and systems that will receive increased investment.	- Descriptive (S1 to S2) - Quantitative-oriented - **Structural** view of AIS
	CTA/KIT 2005	Understand the strengths and weaknesses of the local science, technology and innovation system in the agricultural sector.	- Descriptive (S1) - Qualitative-oriented - **Functional** view of AIS
Effectiveness of farm advisory services	PRO-AKIS 2015	Understand the current state of farm advisory services within the infrastructure of Agricultural Knowledge and Information Systems	- Action-oriented (S1 to S3) - Qualitative-oriented - **Structural and Functional** view of AKIS
Capacity to innovate	CRP-Leuwis et al. 2016	Increase systems' capacity to innovate and contribute to improved livelihoods of low-income agricultural communities through research	- Action-oriented: S1 to S4 and further (the diagnosis is part of the capacity development (CD) process) - Mix (qualitative and quantitative) - **Mixed** view of AIS
	CDAIS-TAP 2016	Identify capacity development needs to improve efficiency and effectiveness of AIS, develop action plans to respond to these needs, and implement plans	- Action-oriented: S1 to S4 and further (the diagnosis is part of the capacity development (CD) process) - Qualitative - **Mixed** view of AIS
	RAAIS-Schut et al.	Identify entry themes for innovation to support sustainable intensification of agrifood systems	- Action-oriented (S1 to S3) - Qualitative - **Dynamic** view of AIS

<u>AIS diagnosis to undertake cross-country comparisons and to provide recommendations to policy makers</u>

In this first case, mainly indicator-based diagnoses are developed. Initiatives are taken to determine and measure indicators so that they can be used as focal points for dialogue and consultations on the state of science and technology for innovation in a given country, the causes of relative degrees of success in innovation, and the interventions that might be needed to strengthen a country's innovation system. Such initiatives include:

- The African Science, Technology and Innovation Indicators project under the New Partnership for Africa's Development (NEPAD). These indicators have been developed as a tool for African countries to monitor and benchmark the state of their agricultural innovation systems and their contribution to economic and social change and sustainable development (NEPAD 2005);
- The World Bank initiative in relationship with ASTI-IFPRI for the development of indicators to be used to gauge and benchmark national performance in developing more responsive, dynamic, and innovative agricultural sectors in developing countries in order to help the design of evidence-based policies (Spielman and Birner 2008);
- The OECD initiative for the development of a framework for the analysis of the role for public services in an AIS (OECD 2013);

While the intention to provide recommendations to policy makers may be the primary focus, these diagnoses actually inform international agencies on the status of AIS in a given context and help in the undertaking of cross-country analyses.

They are expected to tackle numerous thematic evaluations by using indicators related to the four pillars of AIS. However, each case study addresses only a few components of the AIS through the selection of a limited number of indicators, chosen according to the data available. Most quoted sources are from FAOSTAT or World Bank with very few references to in-country databases. The difficulties of accessing similar data for global diagnostic across different countries are brought to the fore. These external diagnoses are mainly conducted by individuals outside the AIS (experts from international organizations) who aim at understanding the main characteristics of AIS in order to formulate policy recommendations. In some cases, an internal assessment step is developed with stakeholders in order to validate the results.

Diagnostic processes primarily consist of taking stock of a current situation. The use of indicators is not embedded into a policy dialogue process or a participatory planning approach with AIS stakeholders. Thus the potential value of the selected indicators to inform national agricultural innovation policymaking still needs to be discussed with policy makers, development practitioners, and researchers.

<u>AIS diagnoses to engage collective action for transformational changes</u>

In this second case, the AIS diagnosis intends to engage collective action in order to solve specific problems identified by the stakeholders. In general, there is a social transformation perspective which implies the participation of the stakeholders in the diagnosis, at different stages and in various forms (more or less collaborative and with more or less standardized tools). A few such initiatives have been developed, spanning four stages of an action-oriented diagnosis, from stocktaking to action designing (S1 to S4):

- The RAAIS toolkit used to identify entry themes for innovation to support sustainable intensification of agrifood systems, and strategies for action.
- The CDAIS project which aims at identifying capacity development needs to improve efficiency and effectiveness of AIS, develop action plans to respond to these needs, and implement plans.
- The CRP initiative: The three system CGIAR research programs on Integrated Systems for the Humid Tropics, Dryland Systems and Aquatic Agricultural Systems which aim at developing research capacities to innovate.

In most cases, diagnosis is part of the capacity development (CD) process and, as such, is based on triangulation of data collection and validation with different groups of stakeholders (e.g. farmers, NGOs/civil society, the private sector, government and researchers). Participatory methods are used for data collection, data analysis, results validation, and prospective exercises. Consultative approaches (RAAIS, PRO-AKIS) are mainly used in the early stages for data interpretation and sense making. Collaborative approaches (CDAIS) are used at later stages for fostering conducive interactions between AIS actors and policy makers in order to operate changes in the AIS.

Action-oriented diagnoses are long and complex because of the multiple interactions needed with AIS stakeholders in order to organize the work of assessment. In general, time is insufficient to properly cover both quantitative and qualitative analyses needed for the understanding of on-going dynamics and also for informing the participatory decision-making process. This explains why action-oriented diagnoses are mainly qualitative, based on internal assessments conducted by the stakeholders themselves.

5 Review of diagnostic tools to inform policy makers

Agricultural innovations are context specific, which is why there is no simple recipe for supporting their emergence and upscaling. Locally embedded agricultural innovation is best supported by conducive framework conditions that enable the emergence of local innovation projects/niches/partnerships. The upscaling and dissemination of innovations can also benefit from more targeted measures to facilitate knowledge exchanges, mutual learning, professionalization and (timely) institutionalization. A long-term policy approach is needed to develop differentiated approaches to fostering agricultural innovation systems in a network of public, private and civil actors and stakeholders.

5.1 Innovation policies and their instruments

The term "innovation policy" became popular from the mid-1990s onwards. However, it does not mean that before 1990 no policy was designed to enhance innovation. An innovation policy consists of a range of different policies (and policy instruments) that have been introduced with different motivations and with different labels such as industrial policy, science policy, research policy, or technology policy (Edler and Fagerberg, 2017). In the agricultural sector in the 1980s and 1990s, innovation policies first took the form of programs to strengthen "National Agricultural Research Systems" based on the AKIS approach of the 1990s. But a change took place at the turn of the century, with innovation policies beginning to go beyond the research-extension-farmers triangle. New innovation policies were developed in 2000 onwards based, in particular, on the AIS approach. For example, two major books were published by the World Bank (2006, 2012) to conceptualize and operationalize new innovation policies for the agricultural sector.

In the agricultural sector, the international community still asks for the creation of policies and institutional arrangements conducive to innovation (World Bank 2008, FAO now). For example, Spielman et al. (2008) provide several recommendations for innovation policies concerning funding, incentives, accountability mechanisms, and interaction patterns. To strengthen education systems in Africa, these authors have the following suggestions which are also relevant for strengthening AIS: realign visions and mandates of AIS actors; develop the human capital base by enhancing innovative capabilities through investments; facilitate the flow of information and technology; induce changes in organizational cultures, behaviors, and practices; and create a conducive and appropriate policy environment.

Still in the agricultural sector, Triomphe and Rajalathi (2013) identified several high-priority domains for promoting AIS: facilitating and strengthening interactions between research and extension; improving integration and access to markets; developing public-private partnerships; creating and strengthening multi-stakeholder innovation platforms, networks and consortiums; funding innovation through grants and novel mechanisms; and promoting technology commercialization through technology transfer offices, incubators and science parks.

However, the same authors also point out that "operationalizing an AIS approach is not an easy task." In fact, since policies are based on policy instruments – which are the levers of action for policy makers –, there is a need to align recommendations to policy instruments. Based on Edler and Fagerberg (2017), we can provide a comprehensive summary of existing innovation policy instruments for different sectors.

Innovation policy instruments	Overall orientation		Goals						
	Supply	Demand	Increase R&D	Skills	Access to expertise	Improve systemic capability, comple-mentarity	Enhance demand for inno-vation	Improve frame-work	Improve discourse
1 Fiscal incentives for R&D	●●●		●●●	●○○					
2 Direct support to firm R&D and innovation	●●●		●●●						
3 Policies for training and skills	●●●			●●●					
4 Entrepreneurship policy	●●●				●●●				
5 Technical services and advice	●●●				●●●				
6 Cluster policy	●●●					●●●			
7 Policies to support collaboration	●●●		●○○		●○○	●●●			
8 Innovation network policies	●●●					●●●			
9 Private demand for innovation		●●●					●●●		
10 Public procurement policies		●●●	●●○				●●●		
11 Pre-commercial procurement	●○○	●●●	●●○				●●●		
12 Innovation inducement prizes	●●○	●●○	●●○				●●○		
13 Standards	●●○	●●○					●○○	●●●	
14 Regulation	●●○	●●○					●○○	●●●	
15 Technology foresight	●●○	●●○							●●●

Notes: ●●● = major relevance, ●●○ = moderate relevance, and ●○○ = minor relevance to the overall orientation and stated innovation policy goals of the listed innovation policy instruments.
Source: Adapted from Edler *et al.* (2016*b*, p. 11).

Figure 4: Taxonomy of innovation policy instruments (Edler and Fagerberg 2017)

The table distinguishes between 15 instruments and a range of innovation policy goals. Many of these instruments pertain to more than one goal and several goals are addressed by more than one instrument. The first two instruments focus on the creation of new knowledge and innovation through financial support to R&D and innovation, including fiscal incentives for R&D that are already being applied in a number of countries with a wide variety of designs. At least three instruments (nos. 3 to 5), focus on the support of capabilities and skills to generate and disseminate/commercialize innovation. The next three policy instruments support various forms of interaction and learning at the national and/or regional levels. Three types of policy instruments (nos. 10 to 12) focus on influencing demand for innovation in one way or another. Regulation and

standardization (nos. 13 and 14) influence both supply of and demand for innovation. The final instrument in the list (technological foresight) is an approach to understand future technological trajectories and develop policies to support and benefit from such trends.

In conclusion, a relevant and action-oriented AIS diagnosis must align its recommendations with key policy instruments to overcome the barriers to innovate.

5.2 Innovation policies adapted to national conditions and the type of innovation

Innovation policies must be adapted to each national and possibly sub-national context. Since countries differ socially and economically, the "knowledge infrastructure" evolves differently given diverse national needs, resources, capacities and institutional contexts. Innovations policies need to be adapted to each situation and thus imbue a distinct national flavor based on these differences.

Spielman and Kelemework (2009) consider 4 domains that characterize AIS at the national level: knowledge and education domain, bridging institutions domain, business and enterprise domain, and enabling environment domain. Using a set of 41 indicators, they classified countries in 4 groups: The first type of country can be described as having a strong knowledge and education domain and a weak business and enterprise domain. The second type can be described as having a strong business and enterprise domain and a weak knowledge and education domain. The third type is characterized by relatively strong scores in both the knowledge and education domain and the business and enterprise domain. The fourth type of countries can be characterized by relatively low scores in all these domains. In each of these 4 groups, innovation policies need to address different issues.

As far as the agricultural sector is concerned, one characteristic is crucial to understand how to better support innovation: the degree of integration *vs.* fragmentation of the AKIS (Knierim et al. 2015) – and especially the Agricultural Service System (ASS), which is one part of the AKIS (Faure et al. 2018). In a few countries, we might observe an integrated agricultural advisory system with a very limited number of service providers responsible for a wide range of innovation support services. Integrated agricultural service systems usually facilitate a strong coordination between actors but may not provide services relevant for innovation. These countries also run a non-negligible risk of having fewer opportunities to obtain innovative ideas from outsiders. As a consequence of privatization and decentralization reforms, we observe in many countries a "fragmented" Agricultural Service System with a large number of service providers, each of them offering a limited number of services, and often competing with each other. Fragmented ASS with a large number of competing service providers may leave ample space for innovations to emerge if strong coordination is not needed. However, if changes in social systems are required, there is a strong need for coordination between service providers and other actors to fully support innovation.

Each country's characteristics and the specificities of national priorities mean that innovation policies have to be suitably designed for each situation. To make innovation policy more effective, policy makers may therefore have to consider designing a policy mix. A correct choice of policy instruments will require thorough understanding of the systemic bottlenecks that hinder the generation and dissemination of innovations, including inadequate skills/capabilities, lack of interaction, and uncertainty about (future) demand (Edler and Fagerberg 2017). Birner et al. (2009) describe such a situation with the expression "from best practice to best fit" when analyzing extension and advisory services in order to provide recommendations to improve them.

However, policy instruments have to be more or less adapted to support innovation. Beers and Geerling-Eiff (2014) show that some policy instruments depend on the type of innovation and the phase of innovation.

Innovation phase	System transformation/ high value diversity			System optimisation/ low value diversity		
Invention	Research funding					
Business case develop-ment		Inno-vation experi-ments	Excep-tions in legis-lation	Awards/ prizes	Know-ledge vouchers	Business subsidies Innovation coach
Adaptation / adoption by first user	Legislation					
Mass adoption	Fiscalisation					

Figure 5: Policy instruments for innovation and innovation goals and phases (Beers and Geerling-Eiff 2014)

In line with this research, Faure et al. (2018) show the diversity of Innovation Support Services that exist along the phases of the innovation process and analyze the articulation of services and the alignment of ISS. Such analyses clearly show the need to define policy instruments by taking the dynamic process of innovation into account.

5.3 The construction of innovation policies: participation, capacity strengthening, and space for negotiation

Innovation policies may be designed, implemented, assessed and coordinated by key ministries (agriculture, research, industry, etc.) at the national level or at lower administrative levels (e.g. local and regional), by specialized agencies and sometimes even by non-governmental actors. This diversity of actors highlights the need to align the various interests and initiatives. National innovation councils have been set up in some countries to address this issue. Representatives of relevant ministries, public research organizations, the business community, and NGOs come together to discuss guidelines for innovation policy (Pelkonen 2006). The idea that innovation policy may contribute to solutions for urgent societal challenges has further led to an increased involvement of non-state actors in innovation policy decisions and design, and in the co-financing and implementation of innovation policy instruments (Edler and Fagerberg 2017). Several reasons can justify the use of participatory approaches to design policies: pragmatic reasons (increase the chances of success of the assessment process and of the use of results to improve the programs being assessed), political reasons (promote democracy and strengthen the actors' participation and empowerment), and epistemological reasons (there is no single reality, multiple points of view are

essential to build an argument). From a more operational perspective, participation also can render it possible to: (ii) improve the relevance and quality of the propositions, (ii) identify or specify the positive or negative dimensions of a policy depending on the point of view of each category of actors, and (iii) develop actors' capacities to reflect on their own actions and be an actor in their own development.

Several matrices detail the degree of actor participation in an outside intervention. Baron and Monnier (2003) identify the two key dimensions to characterize such a participation. While the depth defines the participation in the conduct of the assessment (definition of issues and questions, validation of the method used and the work program, participation in directing work and data collection, contribution to the analysis and interpretation of data, participation in the formulation of recommendations), the breadth of the assessment defines the types of actors participating in the evaluation (ministries, private sector, NGOs, farmers' organizations, direct and indirect beneficiaries, citizens or their representatives). The degree of participation (depth and breadth) of actors in an assessment depends on objectives of the study/project.

Some literature suggests that evidence use is inherently and unavoidably political (Punton 2016). Policy makers don't use evidence to inform decisions in a rational, linear way: research is just one part of the mix of considerations within what we call the "policy process". The BCURE project analyzed the agricultural policy process in 6 developing countries (Punton 2016) and made recommendations to support the policy decision making process: (i) looking beyond superficial expressions of "need", (ii) locating an entry point in a sector or government institution where there is existing interest in evidence, clear political (and financial) incentives for reform, and a mandate for promoting evidence use, (iii) taking advantage of a window of opportunity for reform, iv) building on existing institutional credibility and relationships of trust, (v) nurturing relationships with individual champions who could act as internal sponsors for the program, and (vi) since building capacities for evidence use is really about introducing institutional reforms, taking a wider systems view of how evidence is used.

5.4 How can a global diagnosis be conducive to the process of supporting policy makers and AIS transformations?

We identified the following methodological principles which we consider factors that are critical for a successful diagnosis:

- To combine an "external" with an "internal" assessment – an external assessment provides inputs for the process of internal assessment (external means individual not involved in the AIS; internal means AIS stakeholders);
- To make policy makers explicitly state their expectations in order to trigger improvements in the policy making process;
- To focus on the identification of factors that enable or hinder an improved performance of the AIS, with the aim of helping both policy makers and AIS stakeholders set goals and choose strategies, on the basis of mutual expectations and some level of agreement on how to move forward;
- To make *motivated* and *engaged* AIS stakeholders participate in the identification of problems/solutions in order to improve the AIS and inform policy makers;
- To use collaborative approaches instead of consultative ones for encouraging conducive interactions between AIS actors and policy makers;

- To impart sense to the evaluation;
- To strengthen the capacities of policy makers to participate in diagnostic activities and policy design.

6 Conclusion

6.1 The diversity of views of and methods for AIS assessment

This literature review shows the diversity of points of view in characterizing AIS (structural view, functional view, process-based view, capacity-based view). These different views of AIS are based on different hypotheses and encompass different methods of analyzing AIS. However, scholars do mention that these views appear to be complementary and useful for an operational AIS diagnosis. The expert consultation highlights two main domains to be carefully analyzed among others: the enabling environment, and the bridging organizations.

Due to this multiplicity of analytical views, a large number of methods have been proposed by scholars (e.g. social network analysis, institutional analysis, innovation histories, cross-country comparisons). These methods combine the use of qualitative and quantitative tools. In some cases of AIS diagnosis, indicators are used to assess the structure and performances of national AIS. In the "Global Innovation Index 2017", a list of macro-level indicators is proposed. They are useful for certain purposes (e.g. cross-country comparisons) but less so for others (e.g. identifying key actions to strengthen bridging organizations).

The different methods to analyse AIS have been combined in various assessment models that have been developed and are being used by the international community to carry out operational AIS diagnoses (e.g. World Bank, RAAIS, PRO-AKIS, ASTI, CDAIS). As the literature review illustrates, these methods have been developed based on different hypotheses and for different objectives. Nevertheless, they provide a rich basis for developing a methodology for a diagnosis of AIS that would be useful for policy makers.

In fact, AIS assessment models, methods and tools are all tied to the nature of the ultimate objectives of the AIS diagnosis. The literature review suggests three kinds of objectives (the expert respondents of the on-line survey emphasize objectives 2 and 3):

4. To make cross-country comparisons at the global level for informing international development agencies on support needs;
5. To provide recommendations to policy makers on how to improve governance and performance of their AIS;
6. To undertake collective action with AIS stakeholders for incremental or transformational changes in a given context.

6.2 Three different situations encompassing different types of diagnoses

According to the on-line survey, most experts acknowledge the need for adjusting the **diagnosis process** to a diversity of situations, given that the diagnosis should respond to the requests from policy makers and/or be commensurate with the level of development of the AIS. On the basis of the diversity of proposals made by experts, we distinguished three **baseline situations** (a situation may apply to a country, a sub-national region, or a value chain):

1. The challenge of strengthening AIS consists of improving the performance of AIS incrementally, in its actual working. The request from policy makers is to determine how to do more of the same. Entry points can be identified easily and the diagnosis may possibly be limited to the assessment of a few targeted AIS domains. The diagnosis has to be based on an "inside-out" process. AIS stakeholders collaborate with external actors by asking them to support the development of their innovation strategies.
2. The challenge of strengthening AIS consists of changing the way parts of the system interact. The request from policy makers concerns rules, incentives, and collaborative mechanisms that could be created to overcome functional bottlenecks. The assessment of bridging institutions is key. The diagnosis may be based on an "outside-in" process. Policy makers may call for external expertise in order to help them identify new innovation strategies
3. AIS is not operational, i.e., there exists no agricultural innovation policy framework. The challenge is to establish an AIS or to make the AIS visible. The assessment of capacity building mechanisms is key. The diagnosis may be based on an "extractive and exploratory" process, including scenario development. It is expected to be conducive to transformational changes, including learning as a critical outcome of the diagnosis itself through documentation, analysis of case studies (best-practices, lessons learnt, sharing of results).

Depending on this classification, the methods and tools to carry out an AIS diagnosis are different and adapted to each situation.

6.3 The articulation between an AIS diagnosis and innovation policy

The literature review and the on-line survey clearly identify the need to adapt the innovation policies to the national context by taking into account not only the characteristics and history of the country but also the characteristics of the AIS. The diagnosis should effectively help policy makers improve their innovation policies and propose actions regarding policy instruments. The literature review indicates a range of policy instruments that can be mobilized for policy innovation such as supporting the creation of new knowledge and innovation through financial support to R&D and innovation, strengthening the capabilities and skills to generate and disseminate/commercialize innovations, supporting various forms of interaction and learning at the national and/or regional levels, promoting regulation and standardization to influence both supply of and demand for innovation, and stimulating technological foresight. To make innovation policy more effective, policy makers may have to consider relying on a policy mix.

However, the literature review indicates that the operationalization of an AIS approach is not an easy task. There is a need to help policy makers strengthen their capacities to make use of the AIS diagnosis.

6.4 The process to carry out the diagnosis is as important as the methods to be used

The literature review suggests a need to involve AIS stakeholders in the diagnosis. Several reasons can justify the use of a participatory approach to design policies: pragmatic reasons (increase the chances of success of the assessment process and of the use of results), political reasons (promote democracy and strengthen actor participation and empowerment), and epistemological reasons (there is no single reality, multiple points of view are essential to construct an argument).

The willingness to undertake changes within a country through diagnosis call for combining external assessments made by evaluators and internal assessments made by AIS actors themselves. For internal evaluations, there is a need to define participatory methods. The balance between external and internal assessments and the level of participation may depend on the three baseline situations we identified. Furthermore, providing support to the process of policy decision making means addressing various challenges such as identifying champions to support reforms, looking for windows of opportunity for reform, and building capacities of policy makers so that they can participate in AIS diagnoses and design innovation policies.

However, action-oriented diagnoses are tricky and time-consuming because of the multiple interactions needed between AIS stakeholders in order to organize the assessment process and also to support learning.

6.5 Which possible propositions based on what we have learnt?

On the basis of the literature review and the on-line survey, we suggest key recommendations to design and implement an action-oriented AIS diagnosis:

- Clarifying objectives and expectations of the actors with the actors;
- Adapting the diagnosis to the situation of the country;
- Involving policy makers in the assessment by balancing internal and external evaluations;
- Involving key AIS stakeholders to ensure a fair participation while taking power dynamics into account;
- Combining quantitative and qualitative methods.

On the basis of these principles, three blocks regarding the method may appear to be key:

- Block 1: Rapid appraisal of AIS for (i) clarifying the situation of the country regarding the level of efficiency of the AIS (strengths and weaknesses), (ii) informing macro-level indicators concerning AIS for cross-country benchmarking purposes, (iii) identifying the needs of policy makers and their priorities for the AIS diagnosis, (ii) fine-tuning the strategy to carry out the diagnosis.
- Block 2: Analyzing AIS domains such as Knowledge and education domain, Bridging institutions domain, Business and enterprises domain, Enabling environment domain (with a specific focus on Bridging institutions and Enabling environment).
    - The type of analysis depends on the core questions to be addressed (rapid analysis *vs*. in-depth analysis, adapt mechanisms *vs*. raise awareness).
    - Specific assessment by combining qualitative and quantitative data, partially based on a participatory process, could be used in order to understand on-going dynamics. A tool box needs to be offered based on what already exists (e.g. mapping, SWOT, innovation histories).
- Block 3: On the basis of constraints and opportunities identified in block 2, identifying the levers of action and the relevant policy instruments.
    - Elaboration of scenarios and recommendations;
    - Policy design with articulation of policy instruments;
    - Setting up a monitoring and evaluation system to help policy makers learn and adapt.

There is a need to define the assessment process depending on the country's situation, with particular attention to:

- The balance between external and internal evaluations;
- The degree and mechanisms of participation of both policy makers and other actors (to orient and monitor the diagnosis, to collect and analyze data, to design recommendations and set up policy priorities);
- The need to strengthen capacity to enable policy makers to participate efficiently in the diagnosis.

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Annexure 1: Description of case studies

We present a detailed description of applied diagnosis methodologies (Table 4).

Table 4: Main characteristics of applied AIS diagnosis methodologies

Case studies	Specific objectives (as explained in the document)	Thematic evaluations	Diagnosis tools/techniques	General comments
STRUCTURAL VIEW OF AIS				
"OCDE" methodology: Gray E. 2017. Agricultural enabling environment and innovation systems in ASEAN.	1. Assess the enabling environment in ASEAN countries 2. Take stock of agricultural innovation systems (AIS) within ASEAN countries. Provide recommendations for alternative policies to improve food security by enhancing agricultural productivity through the enabling environment and innovation systems. **Assessment model:** A country's enabling environment is defined as the multifaceted settings within which the agricultural sector and, more broadly, the economy operate, comprising non-distorting and stable policies, adequate provision of public goods, good governance through laws and regulations that are conducive to private-sector economic activity while addressing market failures, and strong and effective institutions through which government measures and actions are operationalized (Diaz-Bonilla et al. 2014).	• Enabling environment • Governance of AIS: main actors; research priorities • Investments in innovation: public investment in research, support for private investment in innovation • Knowledge flows in the AIS: agricultural education & extension • Systems for cross-country research cooperation on innovation	• Using the Agricultural Growth Enabling Index (AGEI) recently developed by the OECD (Diaz-Bonilla et al. 2014): scores • Only "cold/secondary data": statistics extracted from different sources (GFRAS, WIPO, IFPRI, OCDE, ASTI, FAOSTAT, World Bank indicators)	**Policy recommendations**: Incentives for investment in the agricultural sector and improvements in the governance of research, education and extension systems for more efficiency and responsiveness. **Strengths:** A suitable approach to compare enabling environments across countries. **Weaknesses:** It's not really an AIS diagnosis but rather an **AKIS diagnosis** focused mainly on research, education and extension systems.
WB Spilman & Birner 2008	Identify the types of investment and policy interventions needed to make developing-country agriculture more responsive, dynamic, and competitive **AIS definition:** The wide range of actors and organizations from the public, private, and civil society sectors that are involved in bringing new products, processes, and forms of organization into economic use. The framework also emphasizes the role of the institutional and policy environment that affects their performance and behavior.			

	Assessment model: Use indicators to gauge and benchmark national performance in developing more responsive, dynamic, and innovative agricultural sectors in developing countries in order to help the design of evidence-based policies.			
WB Mekonnen et al. 2012	To estimate the level of technical efficiency in agriculture for a panel of 29 developing countries in Africa and Asia between 1994 and 2000. **AIS definition:** We consider an agricultural innovation system as a theoretical construct that contributes to productivity growth through four main components: knowledge and education, business and enterprise, bridging institutions, and the enabling environment **Assessment model:** A stochastic frontier analysis of production functions	• Agricultural production • Inputs to agricultural production (fertilizer, land, rain, labor per ha, stocks of animals, etc.) • Knowledge and education: number of journal article • Business and enterprise: number of telephone lines and mobile phones, foreign investments • Bridging institutions: press freedom index • Enabling environment: level of corruption	Statistics data from FAOSTAT and WB	**Policy recommendations:** None. **Strengths:** Possible cross-country analysis Review of past dynamics **Weaknesses:** Validity of indicators and statistical analyses
CIRAD Temple et al. 2017	Understand how the research system is integrated into the productive activity system and who the brokers are in Cameroon	Macro level: • Macro-institutional landscape • Stakeholders • Relationships between research organizations and the productive sector	Structural analysis: • Semi-directive interviews with research institutions, and private firms. • Bibliometric study on trends and structure of scientific outputs in Cameroon • Multi-stakeholder workshops for SWOT analysis with research institutes, brokers and private firms	**Policy Recommendations:** AIS as a "project" that could be built by aligning current research and innovation policies Improve governance; Prioritize research topics **Strengths:** Draws up links between the private sector and agricultural research **Weaknesses:** The contribution of research to innovation is under-evaluated
ASTI/IFPRI Ragasa et al. 2011	Understand the effectiveness and functioning of R&D organizations and systems that will receive increased investment. **AIS definition:** The innovation systems perspective focuses on (1) recognition of a wider, differentiated set of innovation suppliers; (2) demand	Macro level: • Enabling environment • Agricultural Research System (ARS) • Outcomes • Impacts	• Organizational performance indicators of the ARS: Research productivity; Cost-effectiveness and efficiency; Quality of linkages • Organizational diagnosis (structure, vision, mission, resources) of the ARS: interviews	**Policy recommendations**: Ghana and Nigeria need to invest much more in agriculture in general, and in agricultural R&D in particular. **Strengths:** Specific indicators reflecting capacity, peer effects, and incentive systems are examined

	responsiveness and better connectivity of agricultural research with a wider range of innovation actors beyond extension agents and farmers; and (3) an expanded definition of the innovations being developed to include both economic and social applications (World Bank 2007, 2011). **Assessment model:** Analysis of performance and of factors that influence performance, i.e. "capacity and incentive conditions" of the agricultural research system, in terms of implementation experiences, outcomes, and impacts Combination of elements of institutional theory, organizational design, public-sector motivation literature, and an innovation systems perspective to measure and explain variations in performance.		with researchers, quantitative data (IFPRI–ARCN survey, IFPRI–STEPRI survey) • Broader enabling environment: Agricultural policies and investments, science and technology policy, national development polices, and linkages to the political system and international actors	to determine which of them explain the variations in performance measures **Weaknesses:** • Work in progress requiring ongoing refinements of measurements and definitions, especially in the event that they are scaled out to other countries. • The only set of innovation actors is the research system • Inconsistencies in performance indicators • Too many limitations for the identification of entry points for intervention
STRUCTURAL AND FUNCTIONAL VIEW OF AIS				
CTA/KIT Francis J. 2005. Analyzing the Agricultural Science Technology and Innovation (ASTI) Systems in ACP Countries	To better understand the strengths and weaknesses of the local science, technology and innovation system in the agricultural sector. **Conceptual pillars:** An innovation system framework approach that takes as its point of departure the interdisciplinary nature of the system and the diversity of factors that shape the interactions among actors and how these impact on the actors' individual and collective ability to learn, adapt and innovate.	Macro-level: • Infrastructure (policy, legislation, resources) • Market/demand (set price, volume, quality) • Dissemination: information/knowledge transmitters • Enterprises • Research & training	• Reviewing the policy environment • Identifying the key actors in the ASTI System • Analyzing and assessing the habits and practices, competencies and performance of the actors in the ASTI System • Are key functions being performed at the system level? • Mapping linkages	**Policy recommendations** pertaining to the choice of policies and support structures that might need to be put in place to stimulate learning and a continuous process of innovation. The identification of problems and solutions and the channels whereby a vision for the sector could be developed might also be specified. **Strengths:** **Weaknesses:**
PRO-AKIS Knierim et al. 2014	1. Understand the current state of farm advisory services within the infrastructure of Agricultural Knowledge and Information Systems (AKIS): How and from what sources can farmers obtain reliable and relevant knowledge, orientation and support to continuously evolve, to successfully solve problems, and to respond to external expectations and development opportunities?	Macro-level: • Institutions and regulations (public policies, coordinating bodies), • Tangible and intangible investments (Research & Development expenditures, experimental stations Micro-level:	• Inventories of AKIS and advisory services (27 countries) • 4 case studies, empirical research • Network analysis • Typologies of AKIS • Stakeholder consultations	**Policy recommendations** address the level of measures, the need for evaluation, the promotion of open research practices, long-term perspectives and roles for the private sector. **Strengths:** Usefulness of the AKIS concept, particularly for the understanding and evaluation of policy-induced innovation in agriculture

	2. Assess the effectiveness of farm advisory services **AKIS definition:** **AKIS:** a system concept that links people and institutions to promote mutual learning, to generate, share, and utilize agriculture-related technology, knowledge, and information. The system integrates farmers, agricultural educators, researchers, and advisors to harness knowledge and information from various sources for improved livelihoods. **Assessment model:** An infrastructure perspective on AKIS which includes the analysis not only of institutions and regulations (public policies, coordinating bodies), but also tangible and intangible investments (Research & Development expenditures, experimental stations) supporting AKIS.	• Small-scale farmers' access to relevant and reliable knowledge • Services bridging scientific research topics and farmers' demands • Appropriate support for diverse rural actors that form networks around innovations in agriculture and rural areas		Provide an overview of the key organizations and actors in each AKIS, the main sources of funding, clients and advisory topics. **Weaknesses:** No straightforward classification Very qualitative approach
DYNAMIC VIEW OF AIS				
RAAIS Schut et al. 2015 Rapid Appraisal of AIS (RAAIS). A toolkit for integrated analysis of complex agricultural problems and innovation capacity in agrifood systems	Identify entry themes for innovation to support sustainable intensification of agrifood systems **Conceptual pillars:** (1) complex agricultural problems (2) innovation capacity in the agrifood system and (3) the agricultural innovation system	• Institutional and political constraints • Embedding of constraints in different systems • Structural conditions that can cause constraints to innovation • Value chain segments • Integration levels (international; national; regional; district; ward; village; household) • Dimensions of complex agricultural problems (biophysical; technological; socio-cultural; economic; institutional; political)	• Interviews • Multi-stakeholder workshops • Questionnaires • Secondary-data analysis	No policy recommendations **Strengths:** As a participatory diagnosis approach, RAAIS mainly allows collective action through stakeholders' awareness (self-assessment, collective reflexion), engagement and action planning. **Weaknesses:** The diagnosis is partial and has biases with shortcomings concerning some issues due to the very participatory approach in each phase, without indications on the level of expertise of participants. Low replicability (special skills are needed to organize the whole process).
CRP Leuwis et al. 2016	Increase the capacity of systems to innovate and contribute to improved livelihoods of low-income agricultural communities through		• Both quantitative and qualitative strategies for data collection and analysis	

	research		• Participatory monitoring and evaluation approaches • Monitoring and evaluation for learning (ToC approach) • Indicators that are directly linked to the capacity itself: number of networks and initiatives, number of technical and social experiments, existence and use of linkages, extent of coalition formation, conducive modes of thinking • Indicators that are linked to the outcomes generated through the system's capacity to innovate: upscaling and outscaling of innovation, changes in mindset	
MIXED VIEWS OF AIS				
CDAIS TAP Common Framework, 2016	Identify capacity development needs to improve efficiency and effectiveness of AIS, develop action plans to respond to these needs, and implement plans.	Macro-level: • Policies and regulations • Research and education • Business and enterprises Meso-level: • Bridging organizations and their capacities Micro-level: • Innovation partnerships • Innovation capacities at two levels: individual and collective (partnerships)	• Interviews • Questionnaire • Multi-stakeholder workshops • Netmap • Timelines • Focus groups • Secondary-data analysis • Monitoring & evaluation for learning system	**Policy Recommendations** address actions and interventions to be done at the national level in order to improve the emergence, the efficiency and responsiveness of "innovation partnerships" **Strengths:** Selective on the types of stakeholders to be involved in the diagnostic Multilevel and integrated perspective of all the pillars of the AIS. **Weaknesses:** Time-consuming and expensive Low replicability because special skills are needed to organize the whole process.