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RAAIS: Rapid Appraisal of Agricultural Innovation Systems (Part I). A diagnostic tool for integrated analysis of complex problems and innovation capacity

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A B S T R A C T

This paper introduces Rapid Appraisal of Agricultural Innovation Systems (RAAIS). RAAIS is a diagnostic tool that can guide the analysis of complex agricultural problems and innovation capacity of the agricultural system in which the complex agricultural problem is embedded. RAAIS focuses on the integrated analysis of different dimensions of problems (e.g. biophysical, technological, socio-cultural, economic, institutional and political), interactions across different levels (e.g. national, regional, local), and the constraints and interests of different stakeholder groups (farmers, government, researchers, etc.). Innovation capacity in the agricultural system is studied by analysing (1) constraints within the institutional, sectoral and technological subsystems of the agricultural system, and (2) the existence and performance of the agricultural innovation support system. RAAIS combines multiple qualitative and quantitative methods, and insider (stakeholders) and outsider (researchers) analyses which allow for critical triangulation and validation of the gathered data. Such an analysis can provide specific entry points for innovations to address the complex agricultural problem under study, and generic entry points for innovation related to strengthening the innovation capacity of agricultural system and the functioning of the agricultural innovation support system. The application of RAAIS to analyse parasitic weed problems in the rice sector, conducted in Tanzania and Benin, demonstrates the potential of the diagnostic tool and provides recommendations for its further development and use.

1. Introduction

The Agricultural Innovation System (AIS) approach has become increasingly popular as a framework to analyse, and explore solutions to, complex agricultural problems (e.g. Hall et al., 2003; World Bank, 2006). The AIS approach evolved from a transition from technology-oriented approaches, to more systems-oriented approaches to agricultural innovation (e.g. Klerkx et al., 2012a). Within the AIS approach, innovation is perceived as a process of combined technological (e.g. cultivars, fertilizer, agronomic practices) and non-technological (e.g. social practices such as labour organization or institutional settings such as land-tenure arrangements) changes (Hounkonnou et al., 2012; Leeuwis, 2004). Such changes occur across different levels (e.g. field, farm, region), and are shaped by interactions between stakeholders and organisations inside and outside the agricultural sector (Kilelu et al., 2013; Klerkx et al., 2010).

Adopting an AIS approach to study complex agricultural problems has important implications for research. First, it requires an analysis that acknowledges and integrates the different dimensions, levels and stakeholders' interests associated with the problem under review. Second, it necessitates a holistic understanding of the innovation capacity of the agricultural system in which the complex problem is embedded (Hall, 2005). Third, it requires insight in the structural conditions provided by the agricultural innovation support system that can enable or constrain innovation in the agricultural

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system (Klerkx et al., 2012b; World Bank, 2006). Fourth, it requires a thorough understanding of the interactions between complex agricultural problems, innovation capacity in the agricultural system and the agricultural innovation support system.

Despite the recent development and application of a variety of methods that can support AIS analyses (e.g. World Bank, 2012), the potential of the AIS approach to address complex agricultural problems remains underutilized in many fields of study (e.g. Schut et al., 2014a). Four main reasons for this were identified. First, methods used for the analysis of complex agricultural problems generally have a narrow focus, rather than a holistic view. They support the analysis of a specific dimension (e.g. the economic dimension in Beintema et al., 2012), level (e.g. the national level in Temel et al., 2003), or stakeholder group (e.g. farmers in Amankwah et al., 2012; Totin et al., 2012). Second, studies that do include analysis of multiple dimensions of problems (e.g. Singh et al., 2009), interactions across different levels (e.g. Douthwaite et al., 2003) or multi-stakeholder dynamics (e.g. Hermans et al., 2013) often have limited attention for the integrated analysis of these features of complex agricultural problems. Third, studies that integrate the analysis of multiple dimensions of problems, interactions across different levels and multi-stakeholder dynamics (e.g. Lundy et al., 2005; van Ittersum et al., 2008) have limited attention for understanding innovation capacity in the agricultural system and the functioning of the agricultural innovation support system. A fourth reason is that the majority of AIS studies are conducted *ex-post* (e.g. Basu and Leeuwis, 2012), lack a clear structure to delineate system's boundaries (Klerkx et al., 2012b), or are based on comprehensive studies which take considerable time (e.g. Jiggins, 2012). Although such studies provide a better understanding of the drivers of innovation in agricultural systems, their diagnostic ability to identify entry points for innovation to overcome complex agricultural problems is limited.

Based on the above review of the availability, scope and use of methods for AIS analyses, we have developed and tested a diagnostic tool that can support the Rapid Appraisal of Agricultural Innovation Systems (RAAIS). RAAIS fits within a tradition of 'rapid appraisal approaches' used in the field of agriculture, including the Participatory (Rapid) Rural Appraisal (Chambers, 1994), Rapid Appraisal of Agricultural Knowledge Systems (RAAKS: Engel, 1995) and the Rapid Appraisal of Potato Innovation Systems (Ortiz et al., 2013). RAAIS integrates and builds upon existing (agricultural) innovation system concepts and combines multiple methods of data collection. The objectives of RAAIS are to provide a coherent set of (1) specific entry points for innovation to address complex agricultural problems, and (2) generic entry points that can enhance innovation capacity of the agricultural system and the performance of the agricultural innovation support system. The aim of this paper is to provide a conceptual framework (Section 2) and a methodological framework (Section 3) for RAAIS. Based on its application in a study on parasitic weeds in rice production in Tanzania and Benin, we reflect on the extent to which RAAIS is able to meet its objectives, and provide recommendations for further development and use of RAAIS (Section 4), followed by the main conclusions (Section 5).

2. Conceptual framework for RAAIS

The agricultural innovation system – including both the agricultural system and its innovation capacity and the agricultural innovation support system – may be very good at tackling some complex agricultural problems, but may be incapable to deal with others (Hung and Whittington, 2011; Markard and Truffer, 2008). It underlines that understanding complex agricultural problems, innovation capacity in the agricultural system, and the functioning of the agricultural innovation support system requires integrative analysis. Despite of their interrelated character, we deem it useful for analytical purposes to first address them separately (Sections 2.1, 2.2 and 2.3), before showing their embeddedness (Section 2.4).

Table 1
Examples of stakeholder groups and diversity within stakeholder groups.

Stakeholder groups	Diversity within stakeholder group
1. Farmers	Smallholder farmers, agro-industrial farmers
2. Non-governmental organisations (NGO) and civil society organisations	(Inter)national agricultural networks and associations, cooperatives, development organisations, donors
3. Private sector	Input and service providers (e.g. seed and agro-dealers, private extension services), agricultural entrepreneurs (e.g. processors, traders, retailers, transport companies)
4. Government	Politicians, policymakers, extension and crop protection officers
5. Research and training	National agricultural research institutes, agricultural education and training institutes, universities, international research institutes

2.1. Complex agricultural problems

Complex agricultural problems are defined as problems (1) that have multiple dimensions (Schut et al., 2014b), (2) that are embedded in interactions across different levels (Giller et al., 2008), and (3) where a multiplicity of actors and stakeholders are involved (Funtowicz and Ravetz, 1993). Regarding the first, complex agricultural problems are an interplay of biophysical, technological, social-cultural, economic, institutional and political dimensions. To exemplify this, we use a case by Sims et al. (2012), who analyse constraints for the upscaling of conservation agriculture in sub-Saharan Africa. They demonstrate how import taxes on steel, but not on imported agricultural machinery (institutional dimension), disadvantage manufacturers in developing locally adapted agricultural equipment such as no till planters (technological dimension) for effective soil conservation for sustainable crop management (biophysical dimension). Concerning the second, the dimensions of complex agricultural problems often have different implications across different levels. Mitigating the impact of agro-industrial biofuel production on food security, for instance, will require different strategies when approached at the national level (e.g. policies avoiding agro-industrial biofuel production in regions where pressure on agricultural land is already high) or at the farm household level (e.g. balancing the allocation of household labour to on-farm crop production and off-farm plantation work) (Schut and Florin, under review). Nevertheless, the different levels are interrelated, and consequently, coherent multi-level strategies are required. Regarding the third, complex agricultural problems are characterised by the involvement of a multitude of actors, stakeholders and the organisations they represent (Hounkonnou et al., 2012; Ortiz et al., 2013) (Table 1). Actors include about anyone that can be related directly or indirectly to a problem, or the potential solution. Stakeholders are those actors or actor groups with a vested interest in addressing the problem (McNie, 2007) and their participation in exploring solutions to complex agricultural problems is perceived as a critical success factor (e.g. Giller et al., 2011). Stakeholder participation can provide enhanced insights in the different dimensions of the problem, and the types of solutions that are both technically feasible, and socio-culturally and economically acceptable (Faysse, 2006). However, stakeholder groups are no homogeneous entities and often focus on their own, rather than a common, interest (Leeuwis, 2000).

2.2. Innovation capacity in the agricultural system

The agricultural system is defined as the "operational unit of agriculture" including all actors and organisations at local, regional and national levels involved in the production, processing and commercialization of agricultural commodities (Spedding, 1988). Consequently, innovation capacity in the agricultural system is defined as the ability of these actors and organisations to develop new and mobilise existing competences (including knowledge, skills and experiences) to continuously identify and prioritise constraints and opportunities for innovation in a dynamic systems context (Leeuwis et al., 2014).

Following the typical system boundaries used in generic (i.e. non-agricultural) studies of innovation systems (Carlsson et al., 2002; Papaioannou et al., 2009; Wieczorek and Hekkert, 2012), we conceptualise the agricultural system as a combination of interrelated institutional, sectoral and technological subsystems. The institutional subsystem comprises different types of institutions, which are the formal and informal rules and structures that shape perspectives and practices (Leeuwis, 2004). In this paper we examine six types of institutions; policy, research, education and training, extension, markets and politics across different aggregation levels (e.g. national, regional or district) (e.g. Cooke et al., 1997; Freeman, 1988, 1995). The sectoral subsystem is defined around a commodity or segments of a value chain (e.g. rice or cocoa) (e.g. Blay-Palmer, 2005; Gildemacher et al., 2009). The analysis of the sectoral subsystem seeks to understand interactions between, for instance, access to credit, inputs and services, agricultural production, post-harvest activities, trade, marketing and consumption related to the functioning of that value chain (e.g. Thitinunsomboon et al., 2008). Within the agricultural system, different sectoral subsystems can exist and interact. Technological subsystems are defined around an existing or novel technology (e.g. irrigation, mechanised weeding) or field of knowledge (e.g. integrated pest management) to address a particular problem that may well cut across different sectoral subsystems (Carlsson and Stankiewicz, 1991; Chung, 2012; Hekkert et al., 2007).

2.3. The agricultural innovation support system

The agricultural innovation support system provides the structural conditions that can enable (when present) or constrain (when absent or malfunctioning) innovation within the agricultural system and its subsystems (Klein Woolthuis et al., 2005; van Mierlo et al., 2010; Wieczorek and Hekkert, 2012) (Table 2). Structural conditions include (1) adequate knowledge infrastructure in the form of research, education and extension, physical infrastructure and assets such as roads and vehicles, and functional communication and finance structures, (2) institutions comprise clear regulatory frameworks and their proper implementation and enforcement, (3) interaction and collaboration between multiple stakeholders in the agricultural system, and (4) stakeholder capacities (e.g. literacy and entrepreneurship) and adequate human and financial resources (e.g. number of extension officers and funds for their backstopping). The analysis of the presence and functioning of these structural conditions contributes to a better understanding of what constraints or enables innovation capacity in the agricultural system (e.g. limited multi-stakeholder collaboration), as well as how the structural conditions provided by the agricultural innovation support system stimulate or hamper this (e.g. incentive structures for different stakeholder groups to collaborate).

Table 2
Structural conditions that enable or constrain innovation in systems (based on Klein Woolthuis et al., 2005; van Mierlo et al., 2010; Wieczorek and Hekkert, 2012).

Structural conditions for innovation	Description
Infrastructure and assets	Knowledge, research and development infrastructure; physical infrastructure including roads, irrigation schemes and agricultural inputs distribution; communication and financial infrastructure.
Institutions	Formal institutions including agricultural policies; laws; regulations; (food) quality standards; agricultural subsidies; Monitoring and Evaluation (M&E) structures; organisational mandates; market (access) and trade agreements; informal institutions such as social-cultural norms and values.
Interaction and collaboration	Multi-stakeholder interaction for learning and problem-solving; development and sharing of knowledge and information; public-private partnerships; networks; representative bodies (e.g. farmers association); power-dynamics.
Capabilities and resources	Agricultural entrepreneurship; labour qualifications; human resources (quality and quantity); education and literacy rates; financial resources.

The set-up of the agricultural innovation support system may be good at supporting incremental 'system optimisation' that reproduce the current state of affairs, but less good at supporting 'system transformation' that can lead to radical innovations. For example, the presence of an effective top-down, technology-oriented agricultural extension system can enable the dissemination of crop protection solutions through a technology transfer approach. However, the existence of this system can form a constraint for the promotion of agro-ecological approaches through participatory, farmer-led experiments. Consequently, to achieve system transformation, both the agricultural system and the agricultural innovation support system should undergo continuous adaptation (Hall et al., 2004; Spielman, 2005).

2.4. Interactions between complex agricultural problems, innovation capacity in the agricultural system and the agricultural innovation support system

The integrated analysis of complex agricultural problems, innovation capacity of the agricultural system and the performance of the agricultural innovation support system can provide a coherent set of specific and generic entry points for innovation (Fig. 1). Specific entry points for innovations relate to those innovations that directly contribute to addressing the complex agricultural problem under study. Generic entry points for innovation related to strengthening the innovation capacity of agricultural system and the functioning of the agricultural innovation support system. For example, to reduce fruit waste in developing countries, existing technologies for conserving fruits can be adapted to fit the local context (specific entry point for innovation of the technological subsystem). This may trigger access to export markets (specific entry point for innovation of the sectoral subsystem) and require certification policies to supply such fruit export markets (specific entry point for innovation of the institutional subsystem). To support the development, implementation and enforcement of certification policies, the establishment of a national agricultural certification bureau may be required (generic entry point for innovation). The existence of such a bureau can provide an incentive for investing in the export of other agricultural products, for instance, vegetables, that, in turn, can trigger the development or adaptation of conservation technologies to reduce vegetable waste. The above example shows how structural adaptations of the agricultural innovation support system can enhance innovation capacity to addressing the complex agricultural problem under review (fruit waste), but can also have a spill-over effect on addressing other complex agricultural problems (vegetable waste). Furthermore, the agricultural innovation support system can provide conditions that support innovation in the agricultural sector more generally, for instance through innovation

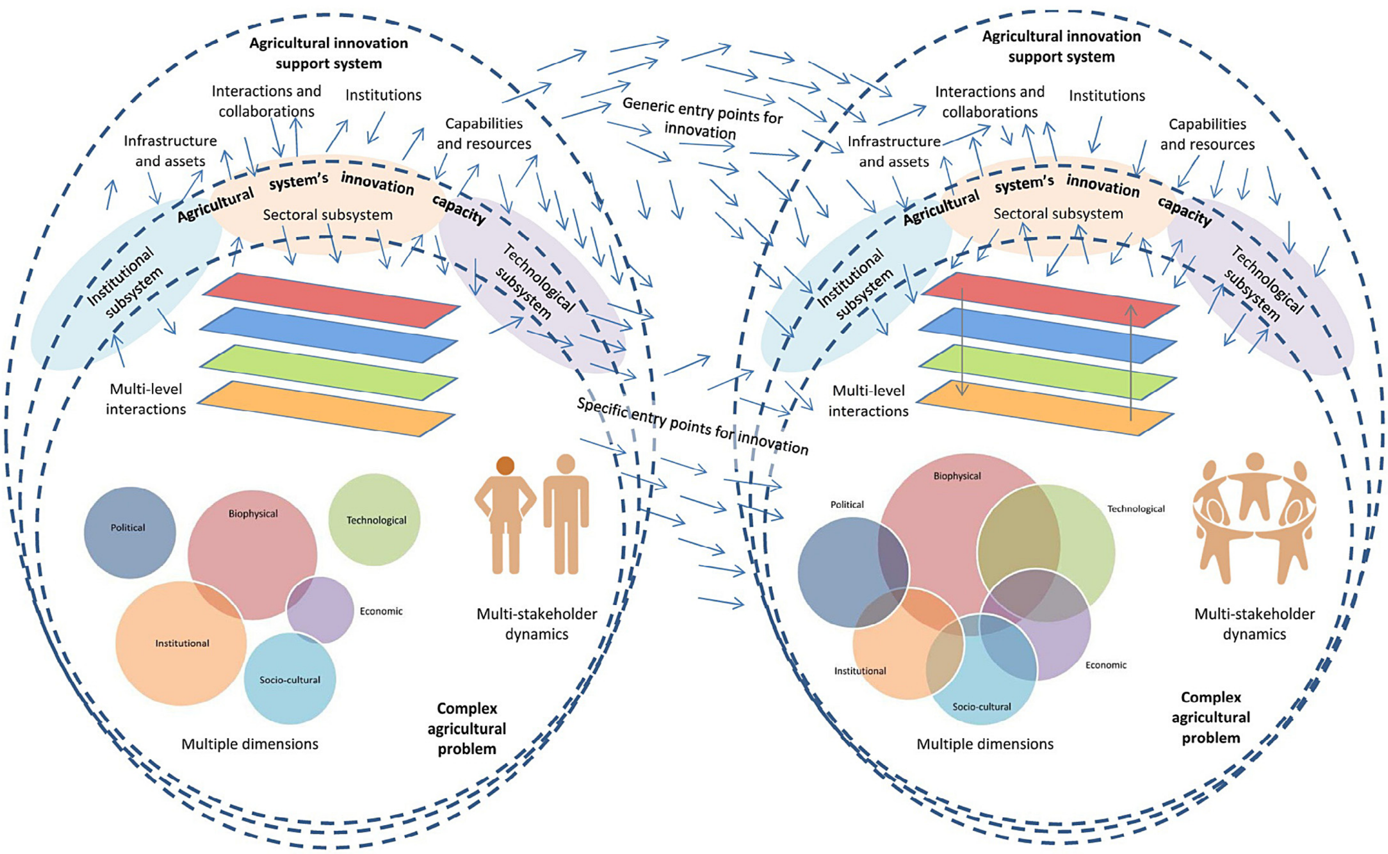

Fig. 1. Schematic representation of the dynamic interactions between complex agricultural problems (multiple dimensions, multi-level interactions and multi-stakeholder dynamics), innovation capacity of the agricultural system (including its institutional, sectoral and technological subsystems), and the structural conditions within the agricultural innovation support system that can enable or constrain innovation capacity in the agricultural system (infrastructure and assets, institutions, interaction and collaboration, and capabilities and resources). RAAIS provides insight into the current state of the system (on the left). RAAIS provides specific and generic entry points for innovation that can guide a transition towards the desirable state of the system (on the right) in which the complex agricultural problem is addressed, and the innovation capacity in the agricultural system has increased. Generic entry points for innovation can have a spill-over effect in terms of addressing other complex agricultural problems than the one under review.

policy or funding schemes that affect multiple institutional, sectoral and technological subsystems.

3. Methodological framework for RAAIS

3.1. Selection criteria for methods

RAAIS is a diagnostic tool that combines multiple methods of data collection. Building on existing experiences with rapid appraisal approaches and (participatory) innovation systems analysis, five criteria for the selection of methods have been identified.

1. Methods should be diverse, rigorous, and be able to generate both qualitative and quantitative data. This enhances the credibility and strength of the analysis (Spielman, 2005). Qualitative data provide the basis for the identification and analysis of the different dimensions of complex agricultural problems, and structural conditions enabling or constraining the innovation capacity. Such data may also provide narratives regarding the underlying causes and historical evolution of constraints. Quantitative data analysis can build on this by providing (descriptive) statistics and trends on, for instance, the distribution of constraints across different levels, stakeholder groups or study sites.
2. Methods should facilitate both 'insider' and 'outsider' analysis. Insider analysis implies data analysis by stakeholders who can provide highly detailed explanations of specific phenomena based on their knowledge and experiences. However, insiders such as farmers or policymakers often have an incomplete or insufficient critical view of the broader agricultural system or the agricultural innovation support system. Consequently, it is important to complement insider analysis by outsider analysis of data by researchers (van Mierlo et al., 2010). By combining insider and outsider analysis, the delineation of the systems boundaries is done in a participatory way, by stakeholders and researchers.
3. Methods should be able to target different stakeholder groups across different levels. When studying complex agricultural problems, it is essential to include different groups of stakeholders, their perceptions on what constitutes the problem, and what are perceived feasible or desirable solutions (Faysse, 2006; Ortiz et al., 2013).
4. Methods should be able to target stakeholders individually, in homogeneous groups and in heterogeneous groups so as to capture individual, group and multi-stakeholder perceptions on problems and solutions. Discussion and debate in both homogeneous and heterogeneous stakeholder groups generally provide a rich analysis of complex problems and potential solutions. Furthermore, multi-stakeholder interaction may reveal asymmetric power-relationships that are necessary to understand innovation capacity in the agricultural system. On the other hand, power-relationships, group pressure, or mutual dependencies between stakeholders may result in situations where sensitive

questions are avoided, or receive socially desirable responses. Methods that target stakeholders individually are more likely to provide insights in such questions (International Institute for Sustainable Development, 2014).

5. Methods together should provide sufficient detail on the complex agricultural problem under review, the innovation capacity in the agricultural system, and the functioning of the agricultural innovation support system (World Bank, 2012).

Combining different types of methods and data collection techniques provides an opportunity to triangulate and validate data. Depending on the nature of the agricultural problem under review and the available resources and time, different types of data collection methods can be used for RAAIS, taking into account the above criteria for method selection.

3.2. Methods of data collection

Based on the five criteria, four complementary methods for data collection were selected to be part of RAAIS (Table 3).

3.2.1. Multi-stakeholder workshops

Multi-stakeholder workshops mainly focused on the insider analyses of innovation capacity in the agricultural system and the structural conditions provided by the agricultural innovation support system. A participatory workshop methodology facilitates different groups of stakeholders to – individually and in homogeneous and heterogeneous groups – identify, categorise and analyse constraints for innovation in the agricultural system. Depending on the type of problem, workshops can be organised with stakeholders representing national, regional and/or district levels or, for instance, across different study sites where a specific problem is eminent. To keep the workshops manageable, and to stimulate interaction and debate, the participation of a maximum of 25 participants per workshop is proposed; for instance consisting of five representatives of the five different stakeholder groups in Table 1. As much as possible, each group should be a representative sample with respect to, for instance, gender, age, income, or ethnic groups. The workshops should be held in the language that all participants speak, and be facilitated by someone who is familiar with the cultural norms, has affinity with the problem, and understands the realities of the different stakeholder groups. The proposed workshop methodology consists of 13 Sessions subdivided into three categories, with each their own focus: (1) identifying constraints, (2) categorising constraints, and (3) exploring specific and generic entry points for innovation. Figure 2 and Table 4 provide an overview of the 13 Sessions, their sequence and relations, and their specific objective in RAAIS.

Workshops are designed to take approximately 1 day. Besides the facilitator, a note-taker documents the outcome of the different sessions and captures discussions among participants. Workshop facilitation and note-taking protocols ensure that the workshop organisation, facilitation and documentation is standardized, which is essential for comparing or aggregating the outcomes, for instance, across different study sites.

A crucial element in the workshops is the use of coloured cards. At the start of the workshop (Session 1), each of the stakeholder groups is assigned a different colour. During Session 2, each participant individually lists five constraints or challenges they face in their work and writes them down on their coloured cards. If five stakeholder groups are equally represented, this results in 125 cards. During Session 3, the participants discuss within their stakeholder groups the listed constraints, explore overlapping issues and jointly develop a stakeholder group top-5. If necessary, constraints can be reformulated based on discussions within the group. Each of the stakeholder groups use their top-5 throughout the rest of the

Table 3
Methodological framework indicating how different methods for data collection correspond with the selection criteria for methods.

Selection criteria for methods / Methods for data collection	Type of data		Insider/ outsider		Stakeholder group					Stakeholder involvement			AIS analysis		
	Qualitative	Quantitative	Insider	Outsider	Farmers	NGO/ civil society	Private sector	Government	Research and training	Individual	Homogeneous groups	Heterogeneous groups	Complex agricultural problems	Innovation capacity in the agricultural system	Agricultural innovation support system
Multi-stakeholder workshops	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Semi-structured in-depth interviews	✓	✓		✓		✓	✓	✓	✓	✓			✓	✓	✓
Questionnaires		✓		✓	✓			✓		✓	✓		✓		
Secondary data analysis	✓			✓			N/a				N/a		✓	✓	✓

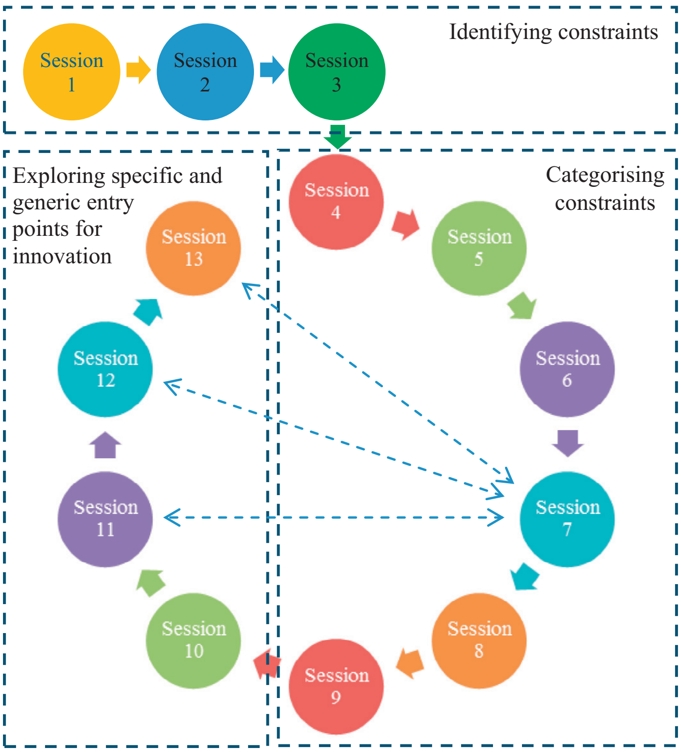

Fig. 2. The relation between the 13 Workshop Sessions and their sequence, subdivided over the three categories. The dotted arrows indicate relations between the different sessions in terms of triangulation and validation of data.

sessions during the workshop; hence 25 cards (five cards per stakeholder group) (Photo 1–4).

The use of the coloured cards facilitates the analysis of different sessions during and after the workshops. As the cards are coded and recycled throughout the successive sessions, photographs can be taken to capture the results (for example Photo 1 and 4). Such photographs can be analysed after the workshop, and can also be used to validate the note-taker's data. Furthermore, the cards provide insight into the relations between constraints identified by different stakeholder groups (Photo 2 and 3). Combining the results from different sessions can stimulate integrative analyses, for instance, combining data resulting from Sessions 5 and 6 provides insight in the structural conditions for innovation across different levels. Similarly, the outcome of Sessions 7 and 11 can be compared to triangulate the data, as both seek to identify key constraints for innovation in the agricultural system.

3.2.2. Semi-structured in-depth interviews

To guide the semi-structured interviews, a topic list is prepared and fine-tuned for each interview. Using a topic list provides a degree of flexibility to identify and to anticipate interesting storylines related to the problem under review, and allows validation of data that was gathered during previous interviews or during the workshops. Interviews should take a maximum of 1 hour, ensuring a high level of attentiveness of both the respondent as well as the interviewer. Sampling of interview respondents should follow a stratified approach, to ensure that stakeholders representing different study sites, different stakeholder groups, and different administrative levels are included. Within those strata, respondents can be selected purposive or based on snowball sampling where interview respondents make suggestions for who else should be included in the sample (Russell Bernard, 2006). The sample size can be based on the concept of "saturation," or the point at which no new information or themes are observed in the interview data (Guest et al., 2006). Interviews can be recorded and transcribed electronically. From an ethical point of view, interviewees should give permission for interviews to be recorded, and researchers should ensure confidentiality of all interview data. Recording may not always be desirable, as the voice recorder can create a barrier between the researcher and the respondent, especially when it comes to discussing politically sensitive issues. Instead of recording, detailed notes can be taken and transcribed electronically. The transcribed interviews can be coded. Ideally, interviews are conducted and coded by two researchers, which will enhance the quality of the analysis.

3.2.3. Surveys

Based on the workshops and the interviews, some of the constraints may be eligible for broader study among specific groups of stakeholders through the use of surveys. Such surveys may provide more insights in, for example, the socio-economic impacts of climate change on smallholder agriculture in specific regions, the quality of agricultural extension received by farmers in addressing complex agricultural problems, or access to agricultural inputs for male or female headed households. Surveys are not necessarily limited to farmers, but can also be conducted with any of the other stakeholder groups involved. For the data to be complementary, surveys should be completed in the same study sites as where the workshops were organised and among a representative sample of the targeted stakeholder group. To achieve that, a stratified random sampling strategy can be used to identify respondents across different study sites, levels or stakeholder groups. A (efficient) sampling method that allows for optimal allocation of resources can be used to determine the sample size (e.g. Whitley and Ball, 2002).

3.2.4. Secondary data collection

Secondary data are written data with relevance for the analysis of the complex agricultural problem, innovation capacity of the agricultural system or the functioning of the agricultural innovation support system. Examples are policy documents, project proposals and reports, laws or legal procedures, project evaluations, curricula for agricultural education and training, (agricultural) census and organisational records such as charts and budgets over a period of time. The sampling of secondary data is not clear cut. Key agricultural documents such as agricultural policies or agricultural research priorities should be included. These documents can refer to other relevant data. Furthermore, secondary data is often provided during, or following interviews. Insights from secondary data can be verified in interviews with stakeholders (e.g. the extent to which policy is implemented and enforced).

4. RAAIS' ability to provide specific and generic entry points for innovation and lessons learnt from its application

We tested RAAIS through a case study aimed at analysing constraints and opportunities for innovation to effectively address parasitic weeds in rain-fed rice production systems in Tanzania (April–October 2012) and Benin (June–August 2013). The results from RAAIS in Tanzania are elaborated in Schut et al. (2014c). Data were gathered across national, zonal, regional and district levels. Multi-stakeholder workshops (with 68 participants in Tanzania and 66 participants in Benin) were organised in three study sites (districts) in Tanzania and Benin where parasitic weeds are eminent. In-depth interviews were held with representatives of national-, zonal-, regional- and district-level representatives of farmer cooperatives and associations, NGO/ civil society, private sector, government and research and training institutes (42 in Tanzania, 65 in Benin). Across the three study sites in the countries, a

Table 4
The 13 Workshop Sessions subdivided over the three categories, and their specific activities and objectives in the RAAIS.

Categories	Sessions	Activities	Objective(s)
Identifying constraints	1. Opening and participant introduction	Participants (1) introduce themselves and receive information about the workshop methodology; and (2) are subdivided over different stakeholder groups (e.g. groups identified in Table 1)	• To ensure an equal representation of participants over the different stakeholder groups
	2. Individual brainstorming about constraints	Participants individually identify five constraints they face in their work	• To make an inventory of general constraints in the agricultural system faced by stakeholders
	3. Developing a top-5 of constraints in stakeholder groups	Participants (1) discuss constraints within respective stakeholder group; (2) develop an stakeholder group top-5 of constraints; (3) present the top-5 to other stakeholder groups; and (4) discuss within and between stakeholder group(s)	• To gain insights in the key constraints in the agricultural system as faced by different stakeholder groups • To create awareness and stimulate learning among stakeholders
Categorising constraints	4. Categorising constraints along different types of institutions	Participants (1) categorise top-5 constraints as policy-, research-, education and training-, extension-, markets- and/ or politics-related; (2) present results to the other groups; and (3) discuss within and between the stakeholder group(s)	• To gain insights in how key constraints relate to the different types of institutions (institutional subsystem) • To create awareness and stimulate learning between stakeholders
	5. Categorising constraints along structural conditions that can enable or constrain innovation	Participants (1) categorise top-5 constraints along the structural conditions drivers of innovation (Table 2); and (2) discuss within and between the stakeholder group(s)	• To gain insights in how the stakeholder constraints relate to structural conditions provided agricultural innovation support system and whether these enable or constrain innovation capacity • To create awareness and stimulate learning between stakeholders
	6. Categorising constraints across different (administrative) levels within the institutional subsystems	Participants (1) categorise top-5 constraints across different administrative levels (e.g. national, regional, district); (2) discuss results with other stakeholder groups; and (3) discuss within and between the stakeholder group(s)	• To gain insights in how key constraints relate to different institutional (administrative) levels • To identify and analyse interactions between different levels • To create awareness and stimulate learning between stakeholders
	7. Identifying relationships between constraints, and identifying key constraints	Participants (1) jointly discuss and identify relations between the different constraints; (2) identify constraints or challenges that are central in the analysis; and (3) discuss within and between the stakeholder group(s)	• To analyse relationships between different constraints • To identify key constraints • To create awareness and stimulate learning between stakeholders • Identify generic entry points for enhancing the innovation capacity in the agricultural system
	8. Categorising constraints along the sectoral subsystem	Participants (1) categorise stakeholder group top-5 constraints along the segments of the value chain; and (2) discuss within and between the stakeholder group(s)	• To analyse constraints along the sectoral subsystem • To create awareness and stimulate learning between stakeholders
	9. Categorising constraints along different technological subsystems	Participants (1) categorise top-5 constraints along different technological or knowledge fields; and (2) discuss within and between the stakeholder group(s)	• To analyse constraints along different technological subsystems • To create awareness and stimulate learning between stakeholders
Exploring entry points for innovation	10. Exploring constraints stakeholder groups can solve themselves versus problems that can only be solved with or by others	Participants (1) categorise top-5 constraints as: 'can be solved within the stakeholder group', or 'can only be solved in collaboration with other stakeholder groups'; and (2) discussion within and between the stakeholder group(s)	• To identify constraints that require collaboration between stakeholder groups • To create awareness and stimulate learning between stakeholders • Identify entry points for innovation in the agricultural system
	11. Exploring constraints that are easy/ difficult to solve	Participants: (1) categorise top-5 constraints as relatively 'easy' or 'difficult' to address; and (2) discuss within and between the stakeholder group(s)	• To explore which constraints require system optimisation (easy to address) and those that require system transformation (difficult to address) • To create awareness and stimulate learning between stakeholders • To triangulate data with Session 7 (are key constraints perceived to be easy/ difficult to address) • Identify entry points for enhancing the innovation capacity in the agricultural system
	12. Exploring constraints that are structural/ operational	Participants categorise top-5 constraints along a four-step gradient, ranging from 'very structural', 'structural', 'operational' and 'very operational' challenges and constraints	• To distinguish between structural constraints that require specific innovation, and more structural problems that require generic innovation. • To create awareness and stimulate learning between stakeholders • To triangulate data with Sessions 7 and 11 (relation between key constraints how these are perceived by stakeholders) • Identify generic entry points for enhancing the innovation capacity in the agricultural system
	13. Identifying priorities and solution strategies	Participants (1) jointly discuss and develop an overall top-5 of constraints; and (2) jointly identify potential strategies to address these constraints	• To explore opportunities for addressing systems constraints through multi-stakeholder collaboration • To explore similarities and differences with the key systems constraints identified in Session 7 • Identify key entry points for innovation

socio-economic farmer survey (152 in Tanzania, 182 in Benin) was held to study the impact of parasitic weeds on rain-fed rice farming (see N'cho et al., 2014 for more information). In Tanzania, a farmer-extensionist survey (120 farmers, 30 agricultural extension officers) was held to explore the effectiveness of the national agricultural extension policy across the three study sites (see Daniel, 2013 for more information). Additionally, for both countries, secondary data including crop protection, extension and general agricultural policy, national research priorities, agricultural census and agricultural training curricula were analysed. Data gathering and initial analysis took around three months for each of the countries, and involved two researchers. We first conducted the in-depth interviews, followed

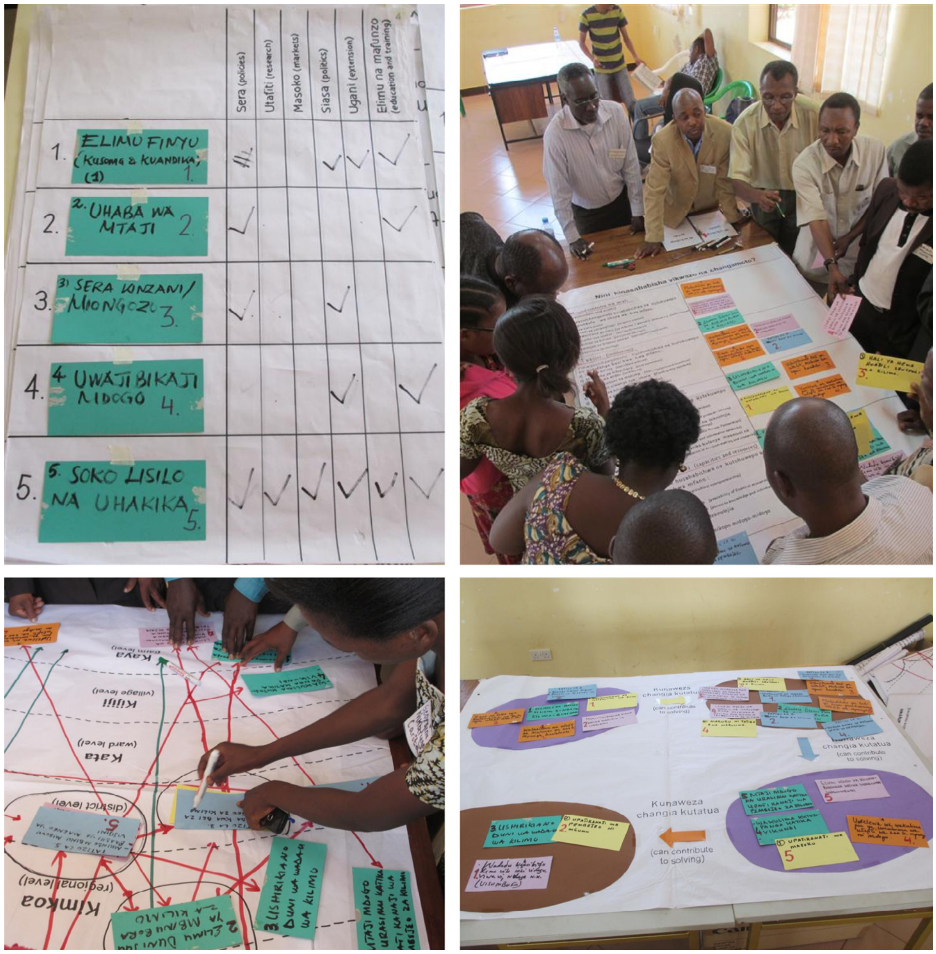

Photo 1–4. Photo 1 (top left): Top-5 of constraints of NGO/ civil society representatives and their categorisation under the different components of the institutional subsystem (Session 4). Photo 2 (top right): The categorisation of the top-5 of the different stakeholder groups along different structural conditions that can enable or constrain innovation (Session 5). Photo 3 (bottom left): The identification of relationships between different constraints (arrows), and key problem (circled cards) (Session 7). Photo 4 (bottom right): The categorisation of the top-5 of the different stakeholder groups along a four-step gradient ranging, from structural to operational constraints (Session 12). Photos were taken by M. Schut during multi-stakeholder workshops in Tanzania held in October 2012.

by the multi-stakeholder workshops. In Tanzania, both the socio-economic farmer survey and the farmer-extensionist survey were held after the interviews and workshops. In Benin, the socio-economic farmer survey was held preceding the in-depth interviews and workshops. Secondary data collection occurred throughout the fieldwork. Below, we will further reflect on the main objectives of RAAIS, as well as provide recommendations for further improvements and use of RAAIS, using our experiences from Tanzania and Benin.

4.1. RAAIS' ability to provide specific entry points for innovation to address complex agricultural problems

RAAIS contributed to an integrated understanding of different problem dimensions, multi-level interactions, and multi-stakeholder dynamics related to parasitic weed problems. With regard to the different problem dimensions, interviews demonstrated a potential relation between, for example, the preference for growing local, aromatic rice varieties (social-cultural dimension), the low capacity of farmer to purchase certified seeds (economic dimension), and the spread of parasitic weed seeds through the local rice seed system (technological dimension). Additionally, analysis of workshop data revealed how the untimely and insufficient availability of agricultural inputs provided by the government (institutional dimension) and limited interaction and collaboration among networks of key stakeholders (political dimensions) form additional bottlenecks for addressing such problems. It created awareness that describing and explaining complex agricultural problems, and exploring and designing solutions is unlikely to be successful if the different problem dimensions are analysed and treated separately (Hall and Clark, 2010; Spielman et al., 2009).

Data gathering across different levels (national, region, and district level) enabled the analysis of the interactions and (mis)matches between different levels (Cash et al., 2006). An example that emerged during the workshops and the interviews is Tanzania's national export ban, that prohibits export of agricultural produce (e.g. of rice) as long as the country has not been declared 'food secure'. This national export ban influences local market prices, and consequently, also farmers' willingness and ability to invest in, for example, purchasing agricultural inputs such as fertilizers and seeds (e.g. Poulton et al., 2010). This, in turn, provided an opportunity to identify entry points for innovation across different levels, which has been identified as a critical factor for addressing complex agricultural problems (e.g. Giller et al., 2008, 2011). As expected, and confirming previous reports (e.g. van Mierlo et al., 2010), the participatory analysis of multi-level interactions showed that stakeholders (insiders) often identify constraints at the level they represent (Schut et al., 2014c). This was complemented by our analysis as researchers (outsiders) of the multi-level interactions regarding the parasitic weed problems.

The involvement of different groups of stakeholders was essential for enhancing the credibility, validity and quality of RAAIS, as well as for delineating the boundaries of the agricultural system and the agricultural innovation support system, which is considered a key challenge when using AIS approaches to analyse complex agricultural problems (Klerkx et al., 2012b). Furthermore, stakeholder participation provided a better understanding of the feasibility and acceptability of solutions for stakeholder groups. Although we believe that the stakeholder groups included in the testing of RAAIS (Table 1) provide a good starting point, other stakeholder groups (for instance the media) may be included in the sample (e.g. Ortiz et al., 2013) depending on the type of complex agricultural problem under review. The triangulation of data resulting from the different methods enabled us to validate findings, and to verify strategic communication by stakeholders, for instance, to verify how the extension system as described by policymakers in interviews, functioned in reality according to surveyed farmers.

4.2. RAAIS' ability to provide generic entry points for innovation

RAAIS demonstrates interactions between complex agricultural problems, innovation capacity of the agricultural system – consisting of institutional, sectoral and technological subsystems – and the agricultural innovation support system. For example, applying fertilizer (technological subsystem) in rain-fed rice production is seen as a promising management strategy to reduce infection levels of *Rhamphicarpa*, one of the parasitic weeds involved in the study, and mitigate negative effects of the parasite on rice yields (Rodenburg et al., 2011). However, as was highlighted during the RAAIS workshops in both in Benin and in Tanzania, fertilizers are difficult to access in rural areas. In Benin, there is no well-developed private agro-dealer network and distribution infrastructure to support the supply of agricultural inputs. Furthermore, interviews showed that the public extension and input supply systems in Benin focus on the cotton sector, rather than on cereal crops (sectoral subsystems). In Tanzania, a private agro-dealer network and distribution infrastructure exists, but structures controlling the quality of fertilizers (institutional subsystem) are functioning sub-optimally according to interviewed government officials. In some areas, fake agro inputs are dominating the market, resulting in a limited trust and willingness to invest in applying fertilizer according to farmer representatives who participated in the workshops. The example shows how the absence or poor performance of fertilizer distribution infrastructure, limited farmer-extensionist interaction and lack of functional institutions for quality control (being structural conditions for innovation) constrain the innovation capacity in the agricultural systems and its technological (in this case fertilizer) and sectoral (the rice value chain) subsystems. Another example is based on secondary data analyses that demonstrated the lack of an operational strategy to address parasitic weeds in Tanzania and Benin. In both the interviews and workshops, stakeholders highlighted the general lack of interaction and collaboration between stakeholders in the agricultural sector (being a structural condition for innovation) as one of the main reasons for the absence or poor implementation of parasitic weed and other agricultural policies and strategies.

The aforementioned examples demonstrate how RAAIS can support the identification of generic entry points for innovation. Such innovations can directly contribute to addressing the complex agricultural problem under review, but can also have a spill-over effect in terms of addressing broader constraints that hamper the innovation capacity in the agricultural system. For example, the lack of stakeholder interactions and collaboration in the agricultural system can provide an entry point for the adaptation of the structural conditions in the broader agricultural innovation support system, for example through investments in innovation brokers or multi-stakeholder platforms (Kilelu et al., 2013; Klerkx et al., 2010). Such structural adjustments can facilitate multi-stakeholder collaboration in tackling parasitic weed as well as other complex agricultural problems.

4.3. Lessons learnt from applying RAAIS and recommendations for further improvement

Based on our experiences in Tanzania and Benin, we recommend conducting RAAIS in an interdisciplinary team of researchers with expertise on different dimensions of complex agricultural problems and on different data collection methods (Hulsebosch, 2001). Other suggestions include the experimentation with other combinations of methods, and on different types of complex agricultural problems. The workshop methodology could be made more interactive, in the sense of directly feeding back results of the sessions to participants to stimulate reflection and validate analyses during the workshops. Post-workshop surveys could provide additional insight into whether stakeholders felt they could freely raise and discuss their ideas and needs.

The multi-stakeholder workshops, but also the surveys, presented a rather static picture of the complex agricultural problem under review and the innovation capacity of the agricultural system in which the problem is embedded. However, initial workshops and surveys could function as a baseline, to which future workshops and surveys can be compared. Other methods such as secondary data analysis or in-depth interviews present a more dynamic image of how, for example, collaborations between stakeholders evolve over the years. Our experiences in Tanzania and Benin show that ensuring social differentiation among workshop participants, interviewees and survey respondents (e.g. of different gender of age) was challenging, as, for example, the majority of workshop participants were male. Specific Workshop Sessions could have more attention for categorisation and priority setting by different gender or age groups. The facilitation of the multi-stakeholder workshops ensured that different stakeholder groups could raise and discuss their ideas (Hulsebosch, 2001). Despite such efforts, unequal power relations and differences in the ability to debate and negotiate that inherently exist between groups may have played a role. In line with our expectations, politically sensitive issues were more freely discussed in individual interviews as compared to multi-stakeholder setting.

The combination of different methods of data collection was essential. In terms of the sequence of data collection, we recommend to first conduct and analyse the RAAIS multi-stakeholder workshops to identify constraints, and subsequently conduct the in-depth interviews and surveys that can provide more insight in the distribution and underlying root causes of these constraints. The workshops then provide a 'fast-track' approach to identifying entry points for innovation, that can subsequently be validated and explored in more detail using the in-depth interviews and stakeholder surveys. This would furthermore increase the 'rapidness' of RAAIS as a diagnostic tool.

An updated version of the RAAIS multi-stakeholder workshops has been used to identify constraints, challenges and entry points for innovations related to the 'sustainable intensification of agricultural systems' in Burundi, the Democratic Republic of Congo, Rwanda, Nigeria and Cameroon under the CGIAR Research Programme for the Humid Tropics (Humidtropics) (Schut and Hinnou, 2014). Several of the recommendations made in this paper, including the revised sequence of methods for data collection and the use of post-workshop participant questionnaires, have been implemented and tested successfully. Some of the bottlenecks identified, such as social differentiation (e.g. gender and age groups) among workshop participants remained problematic and require further attention. At the end of the Humidtropics RAAIS workshops, participants developed action plans to address the prioritised constraints (Workshop Session 13). This required an extension of the workshops of half a day. The development and implementation of the action plans forms an important element for continued stakeholder collaboration in multi-stakeholder platforms.

5. Conclusions

This paper demonstrates the potential of RAAIS as a diagnostic tool that can support and guide the integrated analysis of complex agricultural problems, innovation capacity in the agricultural system, and the performance of the agricultural innovation support system. RAAIS combines multiple qualitative and quantitative methods, and insider (stakeholders) and outsider (researchers) analyses which allow for critical triangulation and validation of the gathered data. Such an analysis can provide specific entry points for innovations to address the complex agricultural problem under study, and generic entry points for innovation related to strengthening the innovation capacity of agricultural system and the functioning of the agricultural innovation support system.

Recommendations for further improvement include using RAAIS for the analysis of other types of complex agricultural problems, using other combinations of methods of data collection, and providing directly feedback to workshop participants to stimulate reflection and validate workshop outcomes. An adapted sequence of data collection methods in which workshops provide a 'fast-track' approach to identifying entry points for innovation, followed up by more in-depth interviews and stakeholder surveys would increase the RAAIS' diagnostic capacity. The participatory development of concrete action plans based on RAAIS can provide a basis for continued multi-stakeholder collaboration to operationalise and implement specific and generic entry points for innovation.

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