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Systems Analysis in AIS: potentials and pitfalls

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Agricultural innovation systems are complex, multi-layered, and can be difficult to define and analyse. In this paper, we provide examples of 'systems analysis': describing the context, what was done, and how the outcomes informed broader research and development activities.

The five cases describe analyses of: i) agricultural systems in North-West Vietnam; ii) household food security in Central Vietnam; iii) agricultural innovation systems in Central Africa; iv) wheat commodity systems in Sub-Saharan Africa, and v) the national agricultural research system in Papua New Guinea.

These cases show that while there is no single best method to conduct systems analysis within a broader AIS approach, 'good' systems analysis demonstrates several common characteristics. Suggestions for system analysis in practice include: clarifying objectives and expectations; balancing breadth and depth; paying attention to power dynamics; avoiding an assumption of predictability; careful mixing of quantitative and qualitative methods; and a keeping a focus on informing action.

Photo: ILRI

Wheat harvest in Nigeria

Introduction

Over the past decades an evolution in the focus of agriculture and development approaches has taken place, from a more narrow technology-based focus to an increasingly broad and more complex view, involving social and institutional aspects. The Agricultural Innovation Systems approach is now seen as a framework to analyse, intervene and influence development at farm and community, and even national levels, through triggering changes in organizational and institutional (policy, cultural), as well as technology, domains.

With this evolution, changes have occurred in ways of thinking about systems, the nature of the 'system of interest' and, hence, the focus of systems analysis. 'Systems analysis' and 'systems analysis tools' can help us to understand a subset of systems components and interactions, at specific points in time. Since agricultural innovation systems are inherently fuzzy, complex and difficult to capture, there seems to be a great level of confusion among practitioners on what systems analysis could, or should, entail and what type of systems analysis is most appropriate in each context. Therefore, in this paper we attempt to:

- Provide an overview of the different uses of systems analysis;
- Show what systems analysis can achieve;
- Identify some of the main limitations to systems analysis in broader AIS approaches; and
- Provide guidance to practitioners in terms of which type(s) of systems analysis is most appropriate in different situations.

The use of systems in agricultural development approaches

The Transfer of Technology (TT) approach reflected the idea that researchers develop knowledge and technologies which are then transferred from the 'top-down' by extensionists to farmers, or other end-users (Rogers, 1962). Though not commonly regarded as a 'systems approach,' it can be argued that the focus of attention here was on the crop or animal systems, these systems being defined in terms of productivity. While successful in these terms, a growing awareness of the weaknesses of such technology-oriented approaches – principally, the lack of adoption due to resource constraints (e.g. credit, inputs, labour, market access) and the limited attention given to negative effects (e.g. public health, environment) – has initiated thinking about broader systems (e.g. Richards et al., 1987; Ying and Williams, 1999).

The Farming Systems Research (FSR) approach evolved to take into consideration the interaction between available resources (land, labour), different on-farm and off-farm activities, and how these factors influence technological performance at field and farm level. The 'system of interest' therefore shifted from the field level to the farm or household level (e.g. Shaner et al., 1982; FAO, 1995, Collinson, 2000). While this approach led to a significant improvement in understanding of rural households and small holder agriculture, it was often difficult to scale up pockets of success to have a widespread impact at scale.

Agenda 21, an international plan of action developed in 1992, promoted 'sustainable livelihoods for all'. With the concept of a 'sustainable livelihoods approach,' the focus again shifted from crop and livestock systems to people and how their 'livelihood systems' are determined by both ecological and socioeconomic factors (e.g. DFID, n.d; Ashley and Carney, 1999; Krantz, 2001).

Coming into the 21st Century, an increasing concern of many governments and development practitioners that previous approaches had not led to widespread economic development in subsistence agriculture, led to renewed emphasis on linking farmers to markets and value chain approaches (VCA). These approaches view the farm as part of a system which delivers a given product to a given market. Interventions typically focus on grouping farmers in cooperatives or producer groups, linking them to markets, and supporting local processing and value addition in order to increase benefits for farmers and reduce transaction costs (e.g. Kaplinsky and Morris, 2003; Humphrey, 2005; Vermeulen et al., 2008; Maatman et al., 2011; DCED, 2016). The 'system of interest' here is on the product value chain or 'commodity system' (Sumberg, 2013).

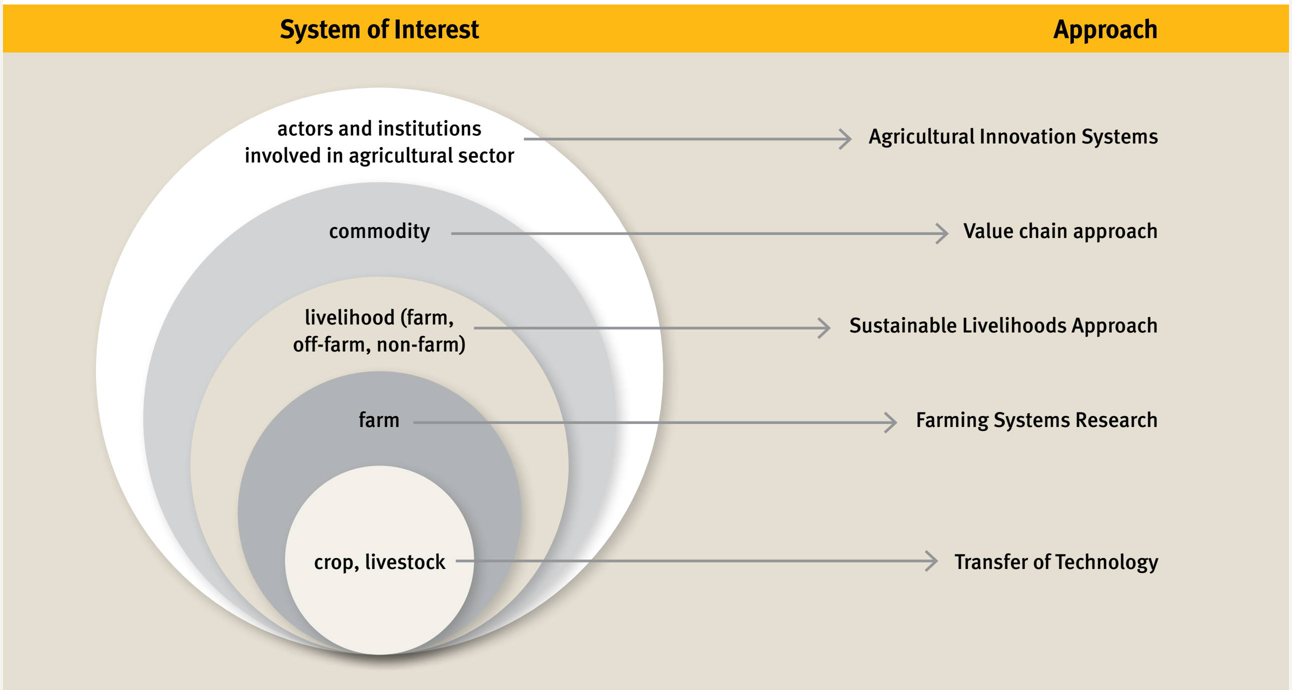
The Agricultural Innovations Systems (AIS) approach builds on the approaches above, broadening the focus to incorporate organizational, institutional and political systems. This includes paying attention to the interactions between actors and institutions, both inside and outside of the agricultural sector. The approach also builds on the concept of 'Agricultural Knowledge and Information Systems' (e.g. Roling et al., 1991; Engel and Salomon, 1997; Speilman, 2005; Hall et al., 2006; World Bank, 2012, Tropical Agriculture Platform, 2016). Where the TT and FSR approaches saw institutional and political aspects as externalities, the AIS approach actually views these aspects as part of the 'system of interest'. Intervening simultaneously in many or all of these areas is seen as necessary to have a significant impact at the scale desired (e.g. Leeuwis, 2004; Hawkins et al., 2009; Birch et al., 2011; Savary et al., 2012).

The above approaches and their 'systems of interest' are not mutually exclusive, and can be viewed as embedded within each other (Figure 1). Depending on the context, the purpose, and the system(s) being considered, each approach can be useful, or play a role within a broader programme. No one approach is the 'correct' one for any situation, and each has strengths and weaknesses associated with the scope and complexity (see Table 1).

Table 1: Overview of the evolution in approaches to agricultural innovation (based on: Klerkx et al., 2012; Schut et al., 2014; World Bank, 2006)

Development Approach	Transfer of Technology (TT)	Farming Systems Research (FSR)	Sustainable Livelihoods Analysis (SLA)	Value Chain Approaches (VCA)	Agricultural Innovation Systems (AIS)
Time scale	**1950s – onwards**	**1980s – onwards**	**1990s – onwards**	**1990s – onwards**	**2000s – onwards**
Assumed purpose	Increase productivity	Increase resource use efficiency	Improve livelihood outcomes	Increase competitiveness	Increase capacity for innovation
Unit of analysis and intervention	Field/crop system	Farm/livelihood system	Household livelihoods	Farm to consumer commodity system	Local/regional social systems, incl. farmers, knowledge organizations and the private sector
System elements analysed	Variety, fertilizers, and pest control's effect on production	Labour and financial resources limiting adoption	Asset classes, vulnerability/risk, policies, structures and processes	Market demands and costs/returns of chain activities	Interactions between actors, organizations and institutions
Type of analysis tools used	Quantitative tools, such as farm level surveys and regression models	Quantitative tools, such as NUANCE-FARMSIM	Qualitative PRA tools and soft systems analysis tools	Mostly quantitative tools, such as value chain analysis and chain actor level surveys; some qualitative tools, such as focus group discussion	Quantitative and qualitative network analysis tools, policy analysis tools, and Participatory Rural Appraisal (PRA) tools
Interventions	Generate and disseminate technology	Adapt technology to constraints of resource-poor farmers	Adapt national and regional policies to livelihood realities	Match demand and supply, and link farmers to markets	Promote joint knowledge production, learning and adaptation
Behavioural change sought in	Farmers	Farmers and researchers	Rural people, researchers, policy makers and institutions	Farmer groups and private sector agri-businesses	Farmer groups, public (R&D) and private sector organizations, and (policy) institutions
Successes achieved	Increased production in favourable environments	Improved targeting and relevance of research and development	Better understanding of poverty	Increased economic activity	Improvements in organizational and institutional efficiency
Challenges faced	Limited impact in resource-poor environments and unintended consequences	Limited impact on poverty and economic development	Complexity of factors considered and identifying key intervention areas	Financing, business support services, trust between actors, and inclusion of poorer farmers	Fuzzy boundaries, managing multiple interests and scales, and generating impact within project time scales

Figure 1: Differences in the 'systems of interest' of the Transfer of Technology (TT), Farming Systems Research (FSR), Sustainable Livelihoods Approach (SLA), Value Chain Approach (VCA) and Agricultural Innovation Systems (AIS) approach



The approaches to agricultural development described above have involved changing ways of thinking about systems and the focus of systems analysis.

The transfer of technology approach and, to a large extent, the farming systems research paradigm, focused on technology as a means of maximising agricultural production – seen as the purpose of the systems being considered. The 'system' in these cases was considered as a 'hard' or objective system, and the purpose of systems analysis was to find ways of maximising the systems' efficiency.

Livelihoods approaches, and especially, innovation systems thinking, recognised that agriculture is first and foremost a human activity and determined by the interaction between different actors, each of whom have their own knowledge, ideas, beliefs and concerns. 'Systems' are no longer seen as objective ('hard'), but subjective ('soft'), as different actors perceive the system differently – or see different systems with different desirable outcomes and purposes. 'Soft' systems analysis is, therefore, less about maximising efficiency, and more about determining what should be improved (Checkland and Scholes, 1990).

Expanding the boundaries of the 'system of interest' (i.e. zooming out from a crop/animal and technology focus to broader social, systems-oriented, approaches to innovation) also changed the assumptions about what one is able to change or influence within the scope of a project or initiative. Intervention areas, such as inputs, credit, policies, institutions and markets etc., were previously considered to be part of the 'external environment,' outside the boundaries of our 'system of interest,' which projects did not attempt to influence (i.e. these factors were included in the assumptions column of a project log-frame, rather than the objectives column).

Broader 'innovation systems' approaches now increasingly seek to intervene and influence development at farm, community and even national levels, through organizational and institutional (policy, cultural) change, as well as through technology.

Agricultural Innovation Systems and systems analysis

Agricultural Innovation Systems (AIS) represent a dynamic web of interactions between people, organizations and institutions that enable or constrain innovation in the agricultural sector. By their nature AIS are complex; many different factors are interrelated, dynamic relationships are constantly evolving, boundaries are fuzzy, different actors have different perceptions concerning these relationships or boundaries, and different sets of actors do not always react in the same way to the same or similar interventions. AIS are therefore difficult to capture or measure.

Nevertheless, 'systems analysis' and 'systems analysis tools' can help us to understand a subset of systems components and interactions, at specific points in time. These analyses can guide the negotiation processes among various actors involved, promote exchanges between stakeholders to identify desirable development outcomes, and identify entry points for interventions that can enhance the functioning of the AIS, to achieve specific development outcomes and impact. Systems analysis can also explore the trade-offs and synergies resulting from these interventions across different systems components, levels, or actors. Furthermore, systems analysis can support ongoing monitoring and evaluation of systems interventions (i.e. what works and what does not), which provides a basis for adaptive management. In doing so, we can keep track of whether or not the interventions are successful in improving the AIS, and whether the desirable outcomes and impacts are being achieved.

The changes in the way that systems are perceived, the type and purpose of systems constructed, the boundaries defined for these systems and the different elements within them, have meant that the focus of systems analysis undertaken by projects or initiatives has also changed. This is most obvious in changes from relatively straightforward, and mostly quantitative, analysis (undertaken when systems were mostly seen as relatively simple and mechanistic) to a wider set of analyses that also take into account the perspectives of different actors, their interrelationships, multiple dimensions and multiple levels of analysis.

There are now a rich array of methods and tools that can be used to provide a wide range of empirical evidence, quantitative or qualitative, to further inform the AIS process. These 'systems analysis tools' come in various forms and can include the consideration of:

- Multiple components or dimensions – analysis of bio-physical, technological, socio-cultural, economic, institutional and political components and their interactions;
- Multiple levels – analysis of interactions between plant, field, household, community, regional and national systems;
- Multiple stakeholder perspectives – analysis of the interests, needs, assumptions and roles of different stakeholder groups, and the interactions between them, which aid or hinder collective action to overcome their interrelated constraints, or exploit joint opportunities;
- Multiple sources of knowledge – analysis of tacit and/or context-specific, applied knowledge (e.g. gained through participatory tools) and explicit or codified scientific knowledge (e.g. based on controlled experiments, modelling);
- Multiple scenarios – foresight or ex-ante analysis and modelling based on trade-offs and synergies, and how changes in specific system components or levels are likely to affect other components and the system as a whole (for better or worse);
- Multiple iterations – analysis of sequential action research cycles to continuously monitor and evaluate whether interventions align with the overall objective that the systems seek to achieve.


Photo: SW Uganda

Bean field in Central Africa

Even with these tools, however, practitioners and researchers attempting to conduct a systems analysis need to wrestle with a number of questions, including: which systems should be analysed? Where should the boundaries of these systems be set? Which components, levels or actor-networks should be included in the analysis? And which tools are most suitable? The answer to these questions depend on a number of factors, including:

- The degree of existing understanding of AIS, the outcomes desired by different stakeholders, and the extent to which these converge;
- The sources of existing knowledge (both tacit and explicit);
- The mandate and competencies of the stakeholders willing to participate in an activity, project or programme;
- The resources, in terms of budget and time available, for a defined project or programme.

Systems analyses tools differ in their complexity, data and resource intensity, qualitative/ quantitative data needs, and the possibilities for inclusion of different stakeholders as analysts and their skill requirements. For example, survey-based tools are more research-led and data-intensive, and usually aimed at developing household typologies for better targeting of development interventions (e.g. IMPACT Lite). Quantitative models, such as NUANCES–FARMSIM, can analyse and forecast nutrient flows in animal and cropping systems, combined with farmers' decisions on resource allocation, to give insight into the key processes that control farm performance (van Wijk et al., 2009; Giller et al., 2011). Many quantitative and qualitative methods for analysing agricultural systems have been published in the journal of Agricultural Systems (http://bit.ly/2nSu7Na) and tools focusing more on policy analysis are summarised at IFPRI's Food Security Portal (http://bit.ly/2othl9f).

Participatory tools, such as those described by Wageningen University Research (http://bit.ly/2027PJi), the Institute of Development Studies (http://bit.ly/1itnOCk), the International Institute for Environment and Development (http://bit.ly/2otf4uD) and many others, are designed to allow non-scientists and rural communities to analyse their own situation and to identify and develop their own interventions. The tools in the Rapid Appraisal of Agricultural Innovation Systems (http://bit.ly/2nAvf5l) also offer a more applied assessment of AIS, and provide entry points for collective action and innovation. KIT and SNV have developed a nutrition and gender sensitive systems mapping tool more aimed towards communities and NGOs, showing that such tools are not just for use by researchers (http://bit.ly/2nwjuvW).

The World Bank Innovation Sourcebook describes a number of methods for assessing, prioritizing, monitoring, and evaluating AIS (http://bit.ly/2n4bjvu). Finally, an inventory of systems analysis tools has been developed under the CGIAR Research Program on Integrated Systems for the Humid Tropics (Humidtropics) and can be accessed at: http://bit.ly/2028j24.

Current practice – Case studies on the use of situational analysis

In the section that follows we present several examples of different forms of systems analysis that have been (or in one case, could have been) applied to an AIS effort. They represent examples from the experience of the experts, academicians and practitioners present at the AIS seminar (held on September 12-14, 2016). They are not intended to reflect the existing literature of systems analysis in AIS, or to show the full range of tools available. In these examples, the systems and system boundaries vary considerably. They range from broad landscape system level analysis to analysis of individual farm-house systems. In each case we describe the objective of the situational analysis and the choice of tool, how it was conducted and by whom, and how it contributed (or failed to contribute) to the AIS process.

Situational analysis of agricultural systems in North-West Vietnam

The context

The Humidtropics CGIAR Research Program (CRP) was designed with AIS approaches at its core, and with multi-stakeholder platforms (MSPs) as a key mechanism. In part, this is due to the fact that the programme did not have any specific commodity emphasis, but instead addressed multiple crop/tree/livestock species in an integrated manner, depending on the needs and opportunities of each target system. Thus, platforms played a critical role in the joint identification of priorities, interventions and impact pathways, among other objectives.

During the development of the CRP, North-West Vietnam was identified as a priority region due to the relatively high levels of poverty and vulnerable agricultural systems associated with mountainous terrain. Several key national/local partners were identified as central to the work in the region, who would become participants in the region-specific MSP to be developed. In discussion with them, it was agreed that a general overview of the key elements of the agricultural systems in the region should first be conducted to inform the development of the MSP and its priorities. This was called a 'situational analysis'.

The situational analysis was regarded as the starting point for the characterization and all further analysis of an agricultural setting or landscape, and as such, had three primary objectives. The first was to characterise any broadly important system aspects that were relevant to the CRP within the target sites and, thereby, generate information to inform MSP discussions, the priority setting and all other programme activities, in order to attain the programme's intended outcomes. This implies that the programme's objectives were defined before the systems analysis took place. The second objective was to develop a common and shared understanding of the issues that needed to be addressed and


Photo: ILRI

Ladies carrying fodder, Vietnam

their potential solutions, particularly between international and national partners, allowing local and global expertise to play complementary roles. The third objective was to initiate and facilitate engagement with stakeholders and partners, through participatory information gathering and a consultation process as part of the MSP development, which was regarded as necessary for the long-term success and scalability of the programme.

What was done?

Because the types of interventions being considered by the CRP ranged from packages of technologies, to market interventions, to organizational and community innovations, the situational analysis needed to be relatively broad to capture all of the key components that could influence both the choice and success of potential interventions. The system being addressed by this form of systems analysis was therefore defined as the broad landscape level (two provinces in this case).

The situational analysis was comprised of four sections which reflected the different sub-systems being analysed. These were: a) the 'social, institutional and policy systems' of the two provinces, intended to give a development overview of the context in which rural development was occurring in the target provinces; b) 'production systems,' which described the agricultural setting, types of crop, livestock and trees, the technologies employed, and the returns to agricultural enterprises; c) 'market systems,' which not only described the agricultural market structure and practices, but also the collective enterprises and public institutions that supported agricultural development; and d) 'natural resources systems,' which described the land, water and natural resource environment.

These analyses were conducted by national agricultural research and development partners in each site with backstopping and participation by CGIAR researchers. The (qualitative and quantitative) information gathered was from different sources: a) secondary data at local/regional administrative units; b) key informant interviews and focus group discussions; c) brief, targeted household surveys; and d) market visits. These multiple sources of data allowed for the triangulation and validation of the data collected, and the participation of local and international researchers enabled the generation of additional empirical evidence to accompany existing knowledge of local stakeholders.

What was the outcome?
Draft results of the situation analysis were presented to stakeholders at the initial meeting of the North-West Vietnam MSP, comprising of government officials, research and development NGOs, community representatives, etc. Participants were asked to review and confirm, or comment on, the preliminary results of the situation analysis that were presented. In addition, stakeholders were asked to identify underlying system problems in the region and suggest possible solutions. This information was used to complement and validate the issues raised from the preliminary assessment, and was included in the final report, which was circulated to all participants and made available online. The results of the systems analysis represented joint learning, both for international participants and local experts. Informed by the analyses and having identified problems/opportunities, the research partners and stakeholders of the MSP went on to jointly develop detailed plans for locally-led research and pilot interventions (Staal et al., 2014).

Food security analysis in Central Vietnam

The context
This example of systems analysis was also conducted as part of the Humidtropics CRP, but it was focused at a very different system level: that of farm-households. The 'system' in this case was therefore the 'farm-household production, consumption and livelihood system'. Past research had led to a wide range of intervention options, ranging from those focusing on increasing the productivity of current crop and livestock activities as well as introducing new practices, to interventions beyond the farm, at other points in the value chain. AIS partners, in the targeting and prioritization of this wide array of options, wanted to quantify the potential effects that each of these interventions, if adopted, would have on the livelihoods of smallholder farmers in terms of food security.

What was done?
In this case, a new analysis framework was applied to quantify a simple food security indicator, specifically developed to analyse the livelihoods of smallholder farmers and to assess the potential impacts of proposed intervention options (Frelat et al., 2016). The analysis used data from the ImpactLITE farm household survey executed in 2014 (see http://bit.ly/2nAvmoJ for a detailed description). Members of 400 households in the Central Highlands in Central Vietnam were interviewed during a survey. Information on household composition, farm practices, the production, sales and consumption of agricultural produce and off-farm income was collected for each household.

Walking cattle, Vietnam

Photo: ILRI

This information was used to quantify a simple indicator of food security, called 'potential food availability' (Frelat et al., 2016; Hammond et al., 2016). The food availability indicator quantified the potential of a farming household to generate enough food (expressed in kcal) to feed the family through both on- and off-farm activities. Information on yearly crop production, consumption and sales; livestock production, consumption and sales; and off-farm income was combined with family size and composition, to quantify an estimate of whether the family could potentially be fed based on these activities. This indicator provided a continuous 'food-availability scale' that allowed quantification of the contribution of key determinants of food availability for individual households, within and across sites. It functioned well for sites in which food insecurity was a major problem, where agricultural productivity was low, and where total production was low due to small farm sizes.

The analysis consisted of the following steps: a) a core set of interventions was identified; b) the probable effect of the intervention on productivity, market prices and land allocation was defined; and c) the consequences of the changes on the food security indicator were simulated and quantified for each farm household. The interventions evaluated in this case were identified based on a consultation with Humidtropics partners, including those represented in the local MSP, and ranged from introducing a relatively new fruit tree species in the region and improved farm management to improved market access.

What was the outcome?
The results showed that five proposed interventions would have a small positive effect on food availability across households, while two were either neutral or negative. For a more detailed analysis, farm households were divided into four groups: severely food insecure, food insecure, food secure, and comfortably food secure. The results showed that the interventions would have different effects across these four farm household groups. For example, the introduction of a local fruit (*son fra*) would likely have a positive effect on the most food insecure households, but a negative effect on the other households because its introduction on the farm would mean the farmer has to replace other crops. This works out positively for the most food insecure households because they can replace part of their low yielding and low market price food crop, but for the more food secure households, with higher crop yields and more intensive market oriented systems, fruit production does not improve the performance of the existing crops. Another intervention, integrated pest management, would increase food security across all households.

In this way, the analysis gave a first indication of the potential of different interventions, the effect these might have on food security, and how they might affect different farm groups within the overall population. However, the results emerged as the Humidtropics were coming to an end, so were not formally included in the AIS process with the MSP in Central Vietnam. The case nevertheless shows how analysis of the farm-household system can provide evidence into AIS development.

Understanding and improving livelihood systems in Central Africa

The context
The Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA – www.cialca.org) was initiated in 2006 as a technology-oriented research-for-development (R4D) partnership, operating in Burundi, Democratic Republic of the Congo and Rwanda. The main focus was on-farm testing of improved banana, cassava and bean varieties, and enhancing farm productivity through integrated soil fertility management and good agricultural practices.

Over the years the project became more systems-oriented in terms of scope and practices. Increased agricultural productivity generated questions related to natural resource management, value-addition and marketing. Consequently, multi-stakeholder partnerships, network strengthening, and gender and nutrition questions became more prominent. As a result, this broader range of themes and system components, again generated questions around trade-offs and synergies, in terms of how interventions in (farming) systems would affect the return on labour, land and other resource investments for different types of farmers.

What was done?
When initiating a new phase of CIALCA in 2014, a Rapid Appraisal of Agricultural Innovation Systems (RAAIS) was used (Schut et al., 2015a; 2015b). The objective of RAAIS was to conduct rapid analysis of a specific agricultural problem (e.g. soil fertility) from an AIS perspective, while also capturing market and policy constraints. From this analysis, a coherent set of entry points were identified for innovation across different dimensions (e.g. technological and institutional), levels (e.g. farm, community and provincial), and stakeholder needs and interests (e.g. of the farmers, private sector and government). One of the outcomes of the RAAIS was the poor collaboration between different stakeholder groups, which sparked the initiation of a number of multi-stakeholder platforms at both local and national levels, in each of the countries.

An additional situational analysis provided insights into the market, labour, gender and nutrition situation at farm/household level, which provided a basis for trade-off and synergy analysis and the implementation of experiments with farmers.

What was the outcome?
The RAAIS processes guided different partners in identifying the key constraints for improved crop-livestock integration, mapping them against different system dimensions and levels, as well as identifying relations between their constraints and those faced by other stakeholder groups. Based on this

Photo: SW Uganda

Landscape of Central Africa

analysis, a number of productivity, natural resource management, and policy/market constraints were prioritised, which provided the basis for the development of intervention plans. Examples included, testing different potato varieties in northern Rwanda, experiments with fodder options in Burundi, and maize-soybean intercropping in Democratic Republic of the Congo. The systems analysis enabled the stakeholders to think about trade-offs and synergies at farm level. For instance, planting fodder crops on the hilly slopes of central Burundi and northern Rwanda provided fodder for animals, but also contributed to better erosion control, water harvesting and the reduction of soil degradation. Another example is the intercropping of maize and (grain) legumes: legumes fix nitrogen in the soil, while at the same time functioning as a cover crop (reducing weeding and enhancing the water retaining capacity of the soil), and providing an important source of protein for human and animal diets.

RAAIS revealed that the majority of stakeholder constraints in the Great Lakes Region required policy/market innovation, while other constraints could be resolved with productivity and natural resource management innovations (Schut et al., 2016). In practice, CIALCA research and development partners were able to accommodate the more traditional technical research at farm level, such as variety testing, fertilizer regime experiments and livestock introduction, but were less equipped to overcome constraints that required more institutional market and policy innovations at a higher systems level (e.g. access to credit and markets, quality control of inputs). During seasonal reflection meetings, farmers and other key partners kept stressing that the majority of their institutional constraints were not being addressed under the project.

The site in northern Rwanda became an exception due to the involvement of the national agricultural research centre and a local NGO. Together, these organizations lobbied for the construction of seed storage facilities, and facilitated contracts between the local farmer group and a local credit provider. This attracted the attention of local government, who started investing in the local initiative as well.

Whilst several of the local multi-stakeholder platforms did boost collaboration between local stakeholders, the national platforms did not manage to generate the same energy and enthusiasm. One of the key reasons for this was that there was limited attention to addressing the needs and interests of the non-research partners, such as the government, private sector and development organizations. Despite the continuous demand for greater attention to linking farmers to input and credit providers and markets, limited funds were made available to overcome these more institutional challenges.

The systems analysis thus provided a good overview of the key constraints for different stakeholder groups and entry points to achieve the desired impact, in the CIALCA project. However, in reality not all of these entry points led to concrete interventions. Much of the R4D investments targeted household productivity through the use of improved technologies, which meant that institutional issues were not addressed. Reasons for this include: a) a narrow focus on agricultural innovation; b) choices based on disciplinary bias and institutional mandates; c) short project cycles that impeded work on longer-term institutional innovation; d) the fear that institutional experimentation would become political; and e) complexity in terms of expanded systems boundaries and the measuring impact (Schut et al., 2016).

State mandates, commodity systems and production systems analysis

The context
Support to Agricultural Research for Development of Strategic Crops in Africa (SARD – SC) is a multi-national initiative led by the CGIAR and funded by the African Development Bank (AfDB). Within a broader mandate for enhancing food and nutritional security, as well as reduced poverty across sub-Saharan Africa, one specific aim is to improve the productivity and profitability of four strategic commodities prioritized by a number of African states: cassava, maize, rice and wheat. Innovation systems thinking has been evident in all of the initiatives, with a specific focus on the role of innovation platforms in achieving the aims and objectives. These innovation platforms include a broad number of organizations and individuals with a commitment to knowledge discovery and participatory learning, as well as to exploring options for resolving systemic and systematic challenges. For this case study the employment of systems analysis is described as part of the wheat commodity system in three countries, namely Ethiopia, Nigeria and Sudan.

What was done?
Over the course of the ongoing initiative, 27 local innovation platforms focusing on wheat have been operationalized within 15 countries. These innovation platforms have the objective of enhancing knowledge generation and dissemination within local communities, but are linked to other innovation platforms regionally as well as nationally. Knowledge, defined here as discovery and application of technological factors (seeds, equipment, production practices), shifts towards more contemporary organizational arrangements through the adaptation of introduced land use management practices.

Given depreciating exchange rates and continued volatility in international wheat markets, particularly after the 2008 global food crisis, efforts to achieve wheat self-sufficiency have been stepped up. Interventions promoted by the innovation platforms have therefore aimed at improving productivity in order to reduce wheat imports. The systems analysis undertaken was aimed at analysing the local and national impact of introducing improved wheat varieties through the lens of an innovations systems approach. Wheat value chains were characterized and mapped within each country, together with the challenges to and opportunities for improving efficiency, participation and equity within the value chain. Analyses related to the impact (and trade-offs) of the expansion in land used for wheat production, and the implications of reducing the import burden of wheat, have not been undertaken. This is one area which, in hindsight, could have suggested a potentially more sustainable intervention aimed at enhancing food security, as opposed to wheat self-sufficiency.

What was the outcome?
In all three hub countries, the conventional wisdom that national wheat production is not profitable has been overturned. This has led to significant interest, on the part of national governments, in investing in innovation platforms as vehicles for enhancing national wheat production. In Nigeria, experiences shared within the innovation platforms have led to wheat being included in the list of state strategic crops and the introduction of a minimum guaranteed price for wheat (and wheat seed). In Sudan, learning within the innovation platforms led to a government policy aimed at subsidizing and supporting state directed production, marketing and milling of wheat. In Ethiopia, the innovation platforms were instrumental in cementing a national desire for self-sufficiency in wheat production and the opening up of new lands to irrigation for the production of wheat. Despite having different understandings of the role of an innovation platform, national policy outcomes, which were specifically focussed on supporting wheat production (and self-sufficiency in wheat production), were clearly influenced by systems (value chain) analysis.

Would the interventions promoted have been different if the wheat focused initiative had taken a different point of departure? Farmers produce a variety of crops, many in a rotation with wheat. A broader analysis of production systems, as

Photo: ILRI

Nigerien women winnowing wheat

Photo: SW Uganda

Fruit market in Central Africa

opposed to a single wheat commodity system, may have been better able to address questions related to: (i) how national production of wheat might respond to shifting exchange rate regimes and the liberalization of import policies; (ii) whether there are optimal crop choices which could lead to improvements in incomes and nutritional security, while reducing the financial burden of food imports; (iii) the environmental, economic and social costs of a desire to achieve self-sufficiency in wheat production; and (iv) whether improvements in the efficiency of flour milling could release land from wheat production to other crops, thereby reducing both grain and flour imports and improving the diversity of crops produced nationally, as well as regionally.

One lesson learned is that the scope of systems analyses needs to be clearly articulated at inception and in line with the broader objectives for project or programme initiatives. For SARD-SC, one overarching objective was food and nutritional security. Yet, the systems analysis undertaken, with a specific focus on wheat value chains, led to an intervention aimed towards the development of approaches for enhancing wheat self-sufficiency. Whether or not wheat self-sufficiency leads to food and nutritional security is not entirely clear. A broader analysis of wheat, as part of a larger production and marketing system, may have assisted in understanding the limits and potential for wheat self-sufficiency to positively contribute to food and nutritional security. This would have enhanced understanding of the nature of trade-offs within production, marketing and economic systems and the inherent linkages therein. Stronger research and development linkages with interventions in other commodity value chains (cassava, maize, rice) may have uncovered a wider choice in sets of interventions and assessments of trade-offs – across commodities and sectors – and thereby generated a wider set of public, private and environmental outcomes, than the single commodity system analysis described in this case.

Analysis of the National Agricultural Research System in PNG

The context

Commodity-based research and development organizations in Papua New Guinea (PNG) were created to support plantations, but gradually shifted their services towards smallholders. These organizations perform research, extension and, in some cases, regulatory functions. However, the research and extension organizations worked independently of each other and had a limited tradition of working with non-traditional partners. Links with policy-makers were tenuous at best, and sector policies failed to target smallholder agriculture.

The Agricultural Research and Development Support Facility (ARDSF) Project, funded by AusAID and implemented from 2007-2012, involved the institutional development of six organizations and wider stakeholders of the National Agricultural Research System (NARS). It was established to enable selected national agricultural research and development organizations to deliver improved services to their rural stakeholders, thereby contributing to increased opportunities for rural smallholders in PNG to generate income and maintain food security.

What was done?
The ARDSF followed 4 main phases: a reconnaissance survey to identify problems in the NARS; a facilitated needs assessment phase to identify core capacities needed in the system; a broader stakeholder consultation which included results based on strategic planning, identification of impact-oriented projects, improved management systems, as well as an M&E system; and finally, competitive grants were used to refocus the system from technology transfer to improved innovation through improved processes.

The reconnaissance survey was undertaken on the key features of the NARS organizations and the challenges they faced, against the backdrop of a low level of services to smallholder farmers, and the apparent disconnect between national development policies and agricultural commodity sub-sectors. Key issues identified in the survey and following the needs assessment included:

- Successful projects and programmes, but failing organizations. The individually successful projects did not collectively deliver strategic development ambitions, nor fulfil organizational mandates articulated in terms of livelihood changes among smallholders.
- Organizations were only accountable at the project level for resource use, but not for impact.
- The need for new skills sets in NARS organizations to strengthen their capacity to provide relevant services to the smallholders.
- Governance problems were pervasive within NARS, despite periodic reforms and restructuring.
- The lack of a holistic approach to broader cross cutting issues, such as health and gender, despite the significant contributions of women in PNG agriculture.

Following the reconnaissance survey, a framework was introduced to help NARS organizations re-envisage and systematically assess the capacities needed to orient research to development needs. Following this self-assessment, each NARS organization used the Organizational Capacity Assessment Tool (OCAT) to identify core capacity development needs. These included: enhancing responsiveness to client needs; institutionalising planning, monitoring and evaluation; enhancing institutional leadership and governance; mainstreaming gender and HIV/AIDS in agricultural research; building networks and partnerships for effective collective action; improving communication within NARS; and enhancing technical services.

Building on the reconnaissance survey and OCAT, the ARDSF organized a series of workshops and consultation platforms, involving a wide range of stakeholders from researchers to farmers to policy-makers. These activities led to improved results-based procedures and systems, including: strategic programme planning, project development, organization and management, monitoring and evaluation, and gender and HIV/AIDS mainstreaming.

As with many efforts to promote organizational change, there were tensions between stakeholders. From the start of the process, therefore, it was important to create a community of champions, through technical and governance committees which drew on both members from NARS organizations and their stakeholders, to promote and defend the new visions and approaches, both within the NARS organizations and ARDSF, and beyond.

In addition to the above, the ARDSF also implemented a competitive, Agricultural Innovation Grant Scheme (AIGS), which funded 33 projects. This scheme successfully shifted funding from technology transfer to innovation in a broader sense, aimed at social and economic gain, marketing and value chain development, promoting cross-cutting linkages between agriculture, health and education, etc.

What was the outcome?
The achievements of the ARDSF were evaluated by an independent external team. They reported improvements in the NARS in terms of policy, organizational planning and practices, as well as the impact on agricultural productivity and livelihoods. The PNG NARS emerged as a more coherent set of organizations, working collectively with partners to address client-oriented priorities, set out in strategic plans that aligned with national development goals, and mainstreamed concerns such as gender and HIV/AIDS.

The AIGS projects significantly increased farm incomes and provided new livelihood opportunities, successfully targeting women, who traditionally add value through food processing. A proposed policy forum and new competitive grant scheme were expected to form elements of a new policy instrument to support smallholder innovation and development — the National Agricultural Innovation Facility (NAIF). However, the PNG NARS was not able to fully maintain the momentum established by the ARDSF, partly due to a lack of sufficient investment in programmes and projects.

Conclusions and implications

The cases described above show a variety of systems being analysed – from regional agricultural systems and household food production systems in Vietnam, to innovation systems at different levels in Central Africa, to national commodity systems in North Africa, and research and innovation systems in Papua New Guinea. The purpose of these analyses varied, from identifying research and innovation options, to an ex-ante analysis of proposed interventions, to specifically improving the general performance of research organizations within a broader innovation system.

These cases show that one type of systems analysis cannot answer all questions, or fit every circumstance. The choice of systems analysis depends on the specific needs of the AIS being addressed, the perceived knowledge and practice gaps that need to be filled, and the interests and mandates of the partners facilitating the AIS process, among other factors. In the sections below we synthesise the key lessons from the case studies into (1) an overview of what systems analysis can achieve if done properly, and (2) the limitations of systems analyses.

What can systems analysis achieve – if done properly?

While there is no 'right' way to conduct a systems analysis within a broader AIS approach, we believe that a 'good' systems analysis should show the following characteristics:

- A clearly defined 'system of interest,' including a boundary of what is perceived as part of the system to be analysed and what is not. This also includes the identification of the wider context or environment, which may have long-term consequences for outcomes in the target system, such as broader agricultural market trends or climate change scenarios.
- An analysis of the linkages between different domains. For example, the analysis of the agricultural system of Papua New Guinea showed linkages between the vegetable production sector and human health, resulting in a competitive call for specific agricultural innovation grants that linked agriculture, health and education.
- Conducted before priorities are set or programme objectives are defined for a given initiative. In an iterative process, situational analysis can and should be done several times because systems are not static, but rather dynamic. In this way, systems analysis not only informs the programme's initial objectives, but also the adaptations along the way. For instance, the example of CIALCA showed that the programme's objectives were set prior to the in-depth systems analysis. As a result, the programme was not able to incorporate interventions to address the socio-institutional bottlenecks which were discovered during the systems analysis.
- Identify the key actors and their capacities, interests and inter-relationships. Hence, stakeholder analysis is a key aspect of systems analysis. Moreover, another component of a proper systems analysis consists of creating clarity on stakeholders' assumptions about the main problems and intervention logic.
- Inclusive and participatory, meaning that formulating the questions to be answered, as well as conducting the actual analyses, should be done in collaboration with those stakeholders that are likely to have influence in, or be affected by, the programme or initiative (to be formulated). 'Inclusive' here refers to ensuring that the interests and viewpoints of different stakeholders, including more marginalised groups such as youth and women or minorities, are taken on board in defining the system, priority areas and analysis focus. This also implies that research actors can, but should not be the *only* actors involved in systems analyses. The example of the CRP programme in North-West Vietnam showed that when a systems analysis is dominated by research institutes only, it bears the risk that local stakeholders don't feel a sense of ownership during the implementation phase of the programme.
- Make use of and integrate different 'types' of knowledge (e.g. 'indigenous' knowledge gained through participatory tools, as well as 'scientific' knowledge gained through modelling), hence allowing different stakeholders to come to a common understanding and develop a plan of action around a common goal.
- Result in a thorough understanding of the root causes of the perceived problems in the 'system of interest,' as well as identify potential points of leverage (including the aspects of the system that can be controlled and those which can be influenced). This could also include an ex-ante analysis of potential trade-offs and a cost benefit analysis of potential interventions. The example of the household food security system analysis in Central Vietnam showed that the systems analysis could have informed decisions on which type of interventions would have had positive effects on food availability, had the results of the systems analysis been presented before the programme was nearing its end.

What are the challenges faced in systems analysis?

Systems analysis can also be used less effectively or efficiently, in cases where the following characteristics apply:

- The system is overanalysed. Not every aspect of a complex situation can or should be analysed. Resources (money, people, time) are always limited. There are many potential analyses that can be done, so a careful prioritization of information needs is necessary.
- Analysis is conducted for the sake of research, not development (change). Institutionalized incentive systems for researchers (publish or perish) often encourage researchers to develop new forms of analysis (tools), or further refine others, which may not lead to improved decision making by stakeholders who need to take action to improve the situation.

- A fuzzy or poorly defined 'system of interest'. It is difficult to analyse a 'system' if it is poorly defined in terms of boundaries, the important components and their relationships, and more importantly, what is perceived as within or external to the system. At the beginning of the agricultural innovation system process, different stakeholders have different perspectives about what is important: what should be achieved, which factors influence this, what is within their power to change or influence (i.e. within the boundaries of the 'system of interest') and what external factors need to be understood and where possible mitigated (e.g. climate change). As the process develops, and the system becomes better defined by the stakeholders, analysis of that system can become better directed and more effective.
- The difference in initial capacities among stakeholders is ignored, resulting in a weak analysis and ineffective solutions. Not everyone is a system expert. Therefore, there is a need to develop the capacity of key actors involved in the analysis to minimize some of the above short comings. In PNG, efforts were made to create champions within the NARS organization from the outset by sharing the research for development principles that linked research with development outcomes. For instance, leadership training and several tailor-made learning workshops showed their value at a critical stage of the project; when the opinions of those who wanted to follow the traditional technology transfer approach and those who proposed agricultural research for development that goes beyond one type of research, were openly contracted with each other (Adiel Mbabu and Andy Hall, 2012).
- The connection between systems analysis and AIS interventions is not made. Often there seems to be a missing link between the outcomes of the systems analysis and the focus of the interventions in the AIS. For instance, in the case of CIALCA, research and development partners were able to accommodate the more traditional technical research at farm level, such as variety testing, fertilizer regime experiments and livestock introduction. However, less attention was paid to constraints that required institutional market and policy innovation at a higher systems level (e.g. access to credit, markets, and quality control of inputs). The example of the SARD-SC case, in three African countries, showed that there can be a mismatch between the focus of the system level analysis (in this case focusing on the wheat commodity only) and the local reality in which farmers integrate different crops and livestock. This type of mismatch

Maize crop in Central Africa

Photo: SW Uganda

often happens when the 'system of interest' is narrowly defined, but a wider focus and analysis could have resulted in more appropriate interventions.

Suggestions for systems analysis in practice

Based on the above, we offer the following suggestions for those using systems analysis within an AIS programme:

- **Balance breadth and depth:** Systems analysis needs to strike a balance between developing a broad understanding of the local foodscape (assuming agriculturally based interventions) and a more in-depth understanding of specific areas of intervention. In this way it is somewhat similar to the classic 'T' model, in which the assessment tries to develop a broad understanding of the complex, interconnected nature of the social, economic and environmental conditions of where we work (the top of the 'T'); while also developing a more profound knowledge of the sub-systems of particular interest (the bottom of the 'T'). Developing this type of understanding means taking into account the needs, preferences, and views of all stakeholders, including public and private actors, civil society, and the health and environmental sectors.
- **Pay attention to gender and power dynamics:** In many societies, specific groups, such as women, youth, and/or the poorest members of local communities (often landless) and traditional indigenous communities as well as migratory peoples or other minorities, have little political or social power. Often, their opinion is not sought and they are not recognized, or treated, as contributors to development interventions. Power imbalances, often stemming from economic inequalities, are a key factor in the way a system operates. Power relations at the household and community level, and particularly those formed along gender lines, can be just as crucial as economic factors in determining the way that a local food system operates, and how agricultural development is addressed.
- **Do not assume that all systems are predictable:** The dynamic nature of systems (which can become increasingly volatile through the actions of outside actors), means that they are inherently unpredictable. Our 'Theories of Change,' and other attempts to forecast outcomes, should recognize this and should influence the role that we imagine for ourselves, shifting it from architects of a system that we can control and manage to gardeners in a living, fluctuating system. There should be less of a focus on ex-ante design, specification and control, and more on continuous group interaction and iteration, as well as continual horizon scanning and reassessment of the evidence (adaptive management).
- **Do not assume that systems work is easy:** Most professionals are trained and used to working in more linear planning systems. Working with the ambiguities and complexities of systems thinking can be both new and challenging. It takes additional time and effort, and often requires capacity building, for many of the stakeholders involved. Given these constraints, we need to be realistic about what can be achieved and allow for the additional time and space that is often needed (see above regarding capacity on systems analysis).
- **Keep it simple:** A good systems analysis should be rigorous, but at the same time a relatively simple process. There is a danger of getting bogged down in the complexity of systems and spending too long mapping and analysing before moving to action. Understanding is important, but so is moving forward on what has been learned. Investment in the situational assessment process should also be proportional to the length and size of the proposed programme. For example, a multi-year, multi-million dollar agriculture project will require a much more time and energy intensive situational assessment than a relatively small, three month project.
- **Ensure you have the support of donors and other stakeholders before conducting a systems analysis:** Systems analyses typically take more time and are more resource intensive than traditional pre-project assessments, it is therefore important that relevant stakeholders are aware and supportive of this before starting. The tensions experienced in the PNG case could possibly have been avoided, or at least lessened, if the requirements of analysing the NARS had been more clearly articulated and agreed. One way to address this challenge is to include a 6-12 month inception period, where systems analysis and awareness raising among potential partners can be undertaken, to gain momentum at the stage of implementation of the agreed priorities. In addition, initiating new activities that have a high degree of consensus among multiple stakeholders and build on past experiences can also justify the time spent on an in-depth analysis.
- **Decide when both quantitative and qualitative methodologies are useful, and mix and match as necessary:** The real-world consists of both 'hard elements' that are amenable to a quantitative methodology, including rigorous modelling, and 'soft elements' that are better described using qualitative methodology. Stakeholders need to be aware of these elements when initiating partnerships and making commitments to the process.
- **Systems analysis should inform action:** The bottlenecks and potential leverage points identified in a systems analysis may be interesting from an academic point of view, but they need to lead to concrete action. The participatory and interactive nature of a good systems analysis means that if action is not taken, the synergies, trust, and stakeholder mobilization developed can instead lead to frustration and a lack of trust in future project activities. If, from the outset, it is already known that the foreseen initiative is not mandated to address institutional and policy issues, this should be made explicit. In such a case, it would be better not to conduct a broad systems analysis, but to limit analysis to those narrower systems where actors involved do have the mandate, initiative and resources to act.

Photo: SW Uganda

Roadside vegetable market in Central Africa

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During the seminar, participants dug into critical issues surrounding AIS, aiming to trigger new thinking, as well as collaboration between participants, to influence agricultural research and development policy and practice.

The seminar resulted in five Working Papers:

- Do theories of change enable agricultural innovation systems to navigate? A reality check and comparison from practice.
- Systems Analysis in AIS: potentials and pitfalls.
- Agricultural Research for Development to Intervene Effectively in Complex Systems and the implications for research organisations.
- Diversity, inclusion and Gender Dynamics in Agricultural Innovation Systems.
- The contribution of AIS approaches to achieving impact at scale: intentions, realities and outlooks.

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