Multilevel Innovation Platforms for Development of Smallholder Livestock Systems: How Effective are They?

Zelalem Lema[a]*, Lisa A. Lobry de Bruyn[a], Graham R. Marshall[a], Romana Roschinsky[a] and Alan J. Duncan[bc]

[a]*School of Environmental and Rural Science, University of New England, Armidale, 2351, NSW, Australia;*

[b]*International Livestock Research Institute, Addis Ababa, Ethiopia*

[c] *Global Academy of Agriculture and Food Security, The Royal (Dick) School of Veterinary Studies and The Roslin Institute, University of Edinburgh, Easter Bush Campus, Midlothian, EH25 9RG, UK*

*Correspondence: zelalemlema@gmail.com

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Abstract

There is growing recognition that sustainable development of smallholder agriculture in Sub-Saharan Africa requires a systems approach. One response to this has been the application of the agricultural innovation systems concept and the use of Innovation Platforms (IP) as tools for agricultural development. By providing social space and facilitating interactions among farmers, researchers and other stakeholders, IPs can promote collective action and foster innovation. The question is, how effective are these IPs in stimulating innovation that can be sustained beyond their lifetime, and can they be used to link issues across multiple scales? The case study reported here examined the effect of a multilevel IP structure in achieving smallholder livestock innovation outcomes in the Ethiopian Highlands. Our findings indicate that a series of IPs inter-linked across scales facilitated researcher-led technical innovations that enhanced the capacity of farmers and livestock experts around feed technologies. The multilevel IPs also improved linkages and strengthened partnerships between actors within and across levels to implement farm-level technologies effectively. However, sustained innovation requires the creation of a shared understanding among actors on the complex nature of the various value chain issues that need to be addressed to achieve meaningful change. Specifically, we found that farmers lack access to affordable services, and this requires an integration of value chain concepts within multilevel IPs at the early stages of formation to engage relevant actors across levels to stimulate multiple interventions beyond the farm-level. Changes are needed at the organizational level to facilitate reconfiguration of resources and devolution of responsibilities to support the innovation process. Similar to other studies on the utility of IPs, we found that the existence of power dynamics and an institutional context that favours the status quo are key issues that need be considered when building multilevel IPs to achieve inclusive value chain innovations.

Keywords: multilevel structure; innovation platforms; functions of innovation systems, smallholder livestock; Ethiopia.

Introduction

The productivity of smallholder agriculture in Sub-Saharan Africa (SSA) remains low relative to gains in other global regions, and the availability of food per person has remained relatively static (Pretty et al., 2011). Farm-level technological innovation, even when developed through participatory approaches, is necessary, but not sufficient for sustainable development (Hounkonnou et al., 2012). A growing body of literature recognizes that farmers lack opportunity and that creating an enabling environment through institutional changes beyond farm-level is required to link farmers to better services and value chains and achieve development outcomes (Salami et al., 2017; Hounkonnou et al., 2012).

In recent times there has been a perceptible shift from technology-focused to system-oriented approaches to innovation (Klerkx et al., 2012; Schut et al., 2016). One example is increased attention to the Agricultural Innovation Systems (AIS) concept that re-conceptualizes innovation as emerging from the interplay among many actors. An AIS is defined as "a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge" (Hall et al., 2006, p.vi-vii). This definition implies that innovation is not just about new technology, but also includes social and institutional changes.

In seeking to operationalize the AIS concept, research and development actors in SSA have increasingly experimented with Innovation Platforms (IPs) as a tool to foster innovation through providing social space for learning, experimentation and negotiation among stakeholders (Schut et al., 2016). Homann-Kee Tui et al. (2013) define an IP as 'a space for learning and change involving a group of individuals (who often represent organizations) with different backgrounds and interests: farmers, traders, food processors, researchers, and government officials. IPs act as inclusive spaces to engage diverse actors to embrace changes through facilitated iterative learning in response to changing and interconnected problems (Swaans et al., 2014; Kilelu et al., 2013). Nevertheless, the use of IPs in SSA is still evolving (Francis et al., 2016).

Various studies have shown that IPs can foster innovation in smallholder agriculture by facilitating interactions among stakeholders. These studies have focused on various elements of smallholder agriculture including livestock feed innovation (Ayele et al., 2012), improved dairy value chains (Kilelu et al., 2013), natural resource management (Lema et al., 2016), and goat value chains (Swaans et al., 2014). Various studies have pointed to weaknesses in the IP approach. For example, IPs may unwittingly reinforce pre-existing power dynamics (Cullen et al., 2014). Similarly, IPs can legitimize the power of vested interests and may, therefore, lead to less than optimal outcomes (Hounkonnou et al., 2018; Schut et al., 2016). Others have suggested that IPs have limited capacity to address structural barriers and may not be flexible enough to be guided by iterative learning processes to adapt to emerging issues (Kilelu et al., 2013; Klerkx et al., 2010). IPs' effectiveness in attaining innovation outcomes is context-dependent and influenced by the quality of facilitation, stakeholder composition and the power dynamics within IPs (Davies et al., 2018; Lamers et al., 2017; Cullen et al., 2014; Hounkonnou et al., 2012).

IPs are often established at the community level to promote farm-level innovation through participatory experimentation with farmers. These IPs tend to focus on technical change that aims to increase the technical capacity of relevant stakeholders to develop and disseminate technologies to enhance production (Davies et al., 2017; Schut et al., 2016; Swaans et al., 2014). However, sustainable development of smallholder agriculture involves more than improved technology at farm-level; institutional issues are also crucial, including access to inputs and markets for products, and the regulatory framework surrounding farm-level production. Solving these issues requires interventions beyond the farm (Hounkonnou et al., 2018; Salami et al., 2017). Failure to address institutional problems can stifle farm-level innovation that would otherwise provide opportunities for farmers to improve their livelihoods.

One option to deal with the multiple scales at which change is needed for smallholder agricultural development is to link IPs at various scales (Cullen et al., 2014). This could potentially facilitate interactions between farmers and higher-level actors and allow connections with decision-makers to address institutional barriers thereby creating a conducive environment for innovation (Cullen et al., 2014; Nederlof et al., 2011). A recent study by Lamers et al. (2017) focused on the compositional dynamics within such a multilevel IP set-up. However, the effectiveness of a multilevel structure of IPs in attaining innovation outcomes that can sustain beyond the lifetime of the IPs has not been systematically examined so far. This paper aims to fill this gap by providing an in-depth analysis on how a multilevel arrangement of IPs shaped and contributed to smallholder livestock innovation outcomes, through a case study of the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) Ethiopian

Highlands project. This study adapted the ‘Functions of Innovation Systems’ framework described in the next section.

Conceptual Framework - Functions of Innovation Systems

We used the framework proposed by Hekkert et al. (2007) which distinguishes several distinct processes as ‘functions of innovation systems’ that significantly determine the performance of a given AIS. Its emphasis is on the dynamics of innovation processes, and it suggests a process-based approach which identifies and maps key events that take place in the innovation system and contribute positively or negatively to the desired change. The framework aims to inform policy by identifying the strength of each function in a given context and the implications for innovation (Bergek et al., 2008; Hekkert et al., 2007).

To enrich our understanding of the functions proposed by Hekkert et al. (2007)within the smallholder and IP contexts, we adapted the functions of innovation systems framework by merging the intermediary functions identified by Kilelu et al. (2011) from empirical data in the context of smallholder development in SSA. In our view, the intermediary functions proposed by Kilelu lacked some essential IP functions such as resource mobilisation, and market formation, crucial for the increasingly market-driven agriculture in SSA (Ngwenya and Hagmann, 2011). We merged the knowledge development and knowledge diffusion functions following Bergek et al. (2008) that seem to overlap in the IP context. We also combined entrepreneurial activities, and market formation functions with the capacity-building function proposed by Kilelu et al. (2011) since these functions largely overlap and influence one another.

According to Hekkert et al. (2007), AIS functions influence one another and are interdependent. Thus, multiple interactions between functions are expected to affect the overall functioning of the innovation system (Hekkert et al., 2007). Many possible interactions among the functions are possible, but we present a simple set of functions in Table 1 along with a description of associated processes.

Table 1. Description of activities associated with the functions of innovation systems (adapted from Hekkert et al. (2007) and Kilelu et al. (2011))

Functions adapted for the present research	Description of activities
Demand articulation (F1)	Activities that identify and prioritize the needs and interest of actors concerning their (further) support of the innovation process (Hekkert et al., 2007). The needs could include access to information, technologies, finance or could highlight institutional gaps (Kilelu et al., 2011),
Knowledge development and diffusion (F2)	Learning is central to a successful innovation system and involves learning about technologies, production, markets and other elements. Learning comes in different forms (experiments and searches), is facilitated from multiple sources, and leads to knowledge diffusion through networks (Hekkert et al., 2007).
Institutional support (F3)	Facilitation and lobbying for institutional change (e.g., policy change, new business models and stimulating new actor relationships), working on attitudes and practices (Kilelu et al., 2011); creating legitimacy for technology (Hekkert et al., 2007).
Resource mobilisation (F4)	Allocation of human, financial, and material capital that is necessary and fundamental to make knowledge production, diffusion and leveraging of change possible; it is intimately linked to stakeholders' shared vision (Hekkert et al., 2007)
Agribusiness development (F5)	Activities that strengthen farmers' and other stakeholders' marketing and business innovation capacity and incubate new service organisations (Kilelu et al., 2011); development of new rules or regulations that positively affect market opportunities (Hekkert et al., 2007).

Case Study Description and Research Methods

Case Study Background

In common with similar studies on agricultural innovation processes (Cullen et al., 2014; Kilelu et al., 2013), a single case study research design was used in the present research. Yin (2013) described such a design as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context". The case selected was Phase 1 of the Africa RISING Ethiopian Highlands project which was implemented from 2011-2016, and which will henceforth be referred to as Africa RISING. Africa RISING aimed to identify and validate solutions to problems experienced by smallholder crop-livestock farmers in the Ethiopian Highlands. Africa RISING used a multilevel structure to facilitate interactions from the farmer- to national-level through interlinked IPs established at four administrative levels.

The case provided a five-year time horizon, allowing mapping and analysis of the innovation process over the medium term. There were eight Africa RISING research kebeles (the lowest administrative unit in Ethiopia) in four regional states[1]. In each region, the focus was on one woreda (district) and two research kebeles in each woreda. The multilevel structure included a national level annual review and planning meeting, which we refer to as a 'national IP', 4-woreda IPs, 8-kebele IPs, and 60 Farmer Research Groups (FRGs). The FRG approach was used to engage volunteer farmers to test one or more technologies through on-farm trials and was a distinctive characteristic of the Africa RISING IP system. The stakeholder types involved, and the roles of each IP in Africa RISING are presented in Table 2.

Table 2. A summary of stakeholder types involved and the role of IPs at each level.

Level of IP	**Stakeholders involved**	**Purposes of the IP**
National IP	- Researchers from nine CGIAR centres, and Ethiopian Institute of Agricultural Research - Government representatives (Ministry of Agriculture and Agricultural Transformation Agency). - NGOs and other development partners - Stakeholders representing Woreda IP	Strategic role. Aligning research agenda with national priorities; enhancing actors' capacity to exchange knowledge and address institutional barriers, organizing annual review and planning meeting and learning events, training, exchange visits for farmers and IP members; and disseminating findings.
Woreda IP	- Woreda Offices of Agriculture, Livestock, Water, Cooperatives, Finance etc. - Regional universities and research centres - NGOs and private sector actors - Farmers and Development Agents (DAs)[2] representing kebele IPs	Strategic role. Provide technical support and facilitate learning between kebele IPs, institutional support for farmers and the facilitation of interaction between national and kebele IPs through regular learning events and support scaling out.
Kebele IP	- DAs - Sector experts and administrators - Elders	Operational role. Facilitate farmer selection; provide technical support and advisory services to farmers; organize IP meetings, and

[1] The Federal Democratic Republic of Ethiopia is composed of 9 national regional states. Africa RISING was implemented in four of them: Amhara, Oromia, Southern Nations Nationalities and Peoples' Region (SNNPR) and Tigray.

[2] Development Agents are agricultural experts employed by the woreda agricultural and natural resource offices to provide advisory and training services to farmers.

	- Men and women farmers representing FRGs	field days and promote scaling out within the kebele.
FRG	- A group of volunteer farmers involved in testing specific technologies through on-farm trials.	Managing on-farm trials. Experimentation with, adaptation and demonstration of a particular technology

The Multilevel IP Structure and Study Sites Selected

To identify two woredas as a study site for this research project, documents were reviewed, and the Africa RISING coordination team was consulted. Our study focused on livestock feed issues for reasons outlined later. Although most of the livestock interventions were implemented similarly across the four woredas, some criteria such as the presence of a unique pilot intervention on irrigated fodder for sheep fattening were used to select two representative woredas. Accordingly, Basona Worana and Lemo woredas and their respective kebeles were chosen to provide a comprehensive picture of the multilevel IPs' activities in respect of livestock innovations. The multilevel structure of the IPs in the two study woredas, comprising the national IP, two woreda IPs, four kebele IPs and 33 FRGs, is illustrated in Figure 1.

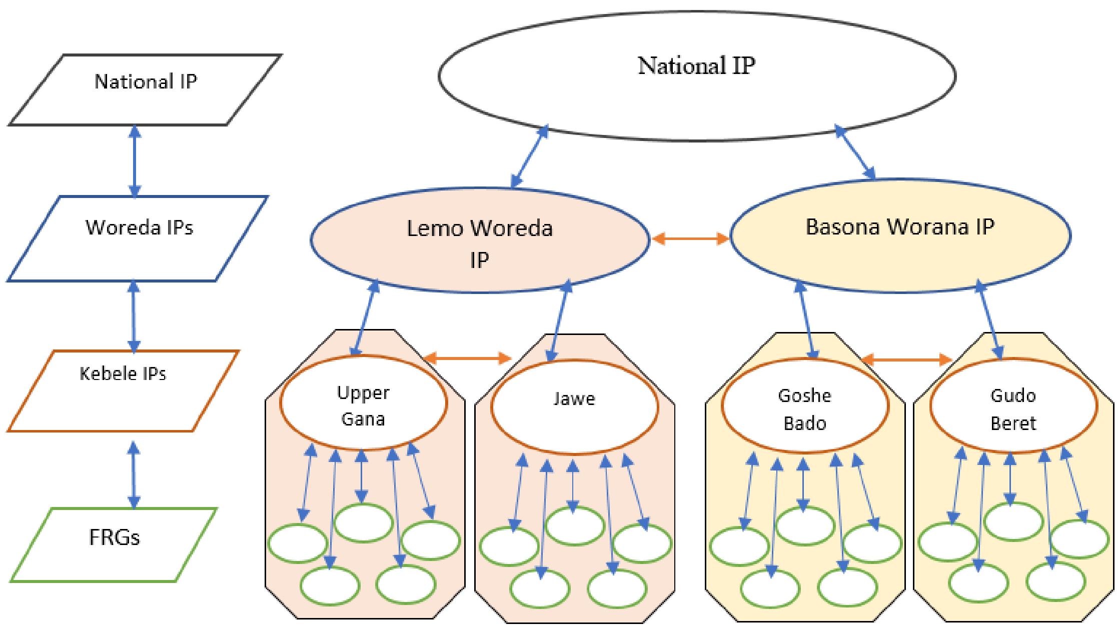

Figure 1. Schematic presentation of the multilevel structure of the IPs illustrating vertical and horizontal linkages and information flows between and across levels as indicated by the arrows.

Basona Worana woreda is located in the highlands of North Shewa Zone of Amhara region, 130 km north of Addis Ababa (Figure 2). It comprises 28 rural and two urban kebeles. According to CSA (2013), the total population of Basona Worana woreda for 2017 was 140,386, of which 98.5% live in rural areas. The town of Debre Berhan is the administration centre for North Shewa Zone and Basona Worana woreda, where key IP member organizations including Debre Berhan University and Debre Berhan Agricultural Research Centre are located. The two Africa RISING kebeles included in the study were Goshe Bado and Gudo Beret. In 2007 the number of households was 1872 in Goshe Bado and 1502 in Gudo Beret; around 40% were headed by females.

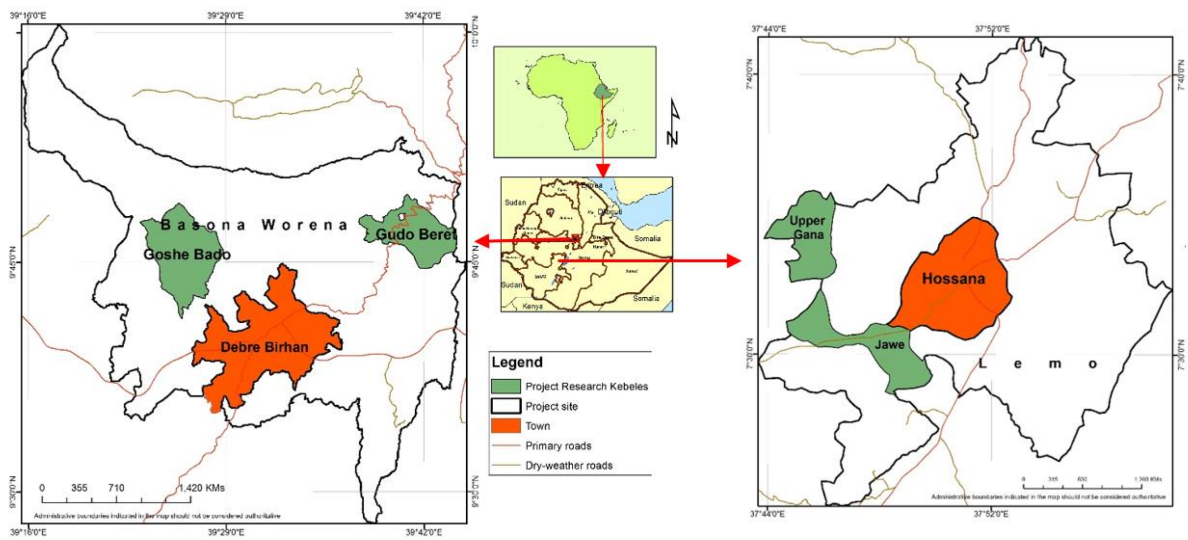

Figure 2: Location of Basona Worana and Lemo woredas and their respective research kebeles (Source: Africa RISING undated)

Lemo woreda is in Hadiya Zone in Southern Nations, Nationalities, and Peoples' Region (SNNPR), and is located about 230 km south-west of Addis Ababa. It consists of 35 kebeles, of which 33 are rural, and two are urban. The estimated total population of Lemo woreda for 2017 was 143,091, of which 97% live in rural areas (CSA, 2013). The administration centre for Hadiya Zone and Lemo woreda is Hosanna town, where key IP member organizations, including Wachamo University, are based. Jawe and Upper Gana were the two Africa RISING kebeles included in our case study. In 2007 the number of households was 914 in Jawe and 796 in Upper Gana; 22% and 12% of these were female-headed, respectively.

Farmers in both woredas practise crop-livestock farming systems. The main crops they produce include wheat, faba beans and potatoes. Livestock types include local breeds of cattle, sheep, poultry and donkeys. Farmers in these locations typically rely on grazing and crop residues to feed their livestock. Livestock is a highly valued asset that provides multiple benefits; livestock production is mainly for subsistence purposes, and opportunities for commercial livestock production are relatively limited.

The Livestock Interventions

The present research explicitly focused on livestock-related interventions that were introduced within the multilevel IPs (Table 3), although the broad emphasis of Africa RISING was on crop-livestock systems. The focus was narrowed to livestock interventions to make the study more manageable and enable an analysis of multilevel processes of technological change and innovation in greater depth than would otherwise have been feasible.

Table 3. Livestock feed technologies introduced by Africa RISING at woreda-level (ILRI, 2014)

Strategies to address livestock feed scarcity	Livestock feed technology projects	Number of participating farmers	
		Lemo	Basona Worana
1. Reduce feed losses of available feed resources	Improved livestock feed storage shed	10	14
	Improved cattle feed trough	6	9
	Manual fodder choppers[a]	-	-
2. Increase feed availability through cultivated forages	Oat-vetch mixture (rain-fed)	35	42
	Tree Lucerne	60	56
	Sweet lupin and fodder beet	12	8
	Faba bean-forage intercrop	64	20
	Oat-vetch mixture (irrigated) for sheep fattening[b]	7	_

Note:

[a]Manual choppers were demonstrated at kebele level and farmers tested and selected their preferences, but farmers showed limited interest to buy without support from Africa RISING;

[b]Only implemented in Lemo woreda

Research Methods

Human research ethics approval was granted by the University of New England (HE18-220) and by the International Livestock Research Institute (ILRI-IREC2018-19) for this research. The case study approach involves multiple evidence sources using a range of methods (Yin, 2013). For this research, two main techniques, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs), were used to collect mostly qualitative data on the innovation processes within the multilevel IPs. The data were collected between September-December 2018, two years after the IPs ended. To understand the decisions made within each IP, we conducted one in-depth FGD with members of each woreda- and kebele-level IP, and KIIs with a range of individuals across the four levels, as summarised in Table 4.

Table 4. Semi-structured interview schedules were used to conduct the KIIs and FGDs to allow follow-up queries and gain insight into the innovation processes at play.

Participants for both data collection techniques were recruited in the multilevel IPs. We sought to ensure adequate representation of women relative to their presence in various IPs by reviewing secondary data sources that documented membership and attendance records. At FRG level women accounted for 20% of the membership, and at the woreda level, the average participation rate for women was 9% for all IP events. We recruited participants based on three other criteria – (1) the level of IP in which they were involved (FRG, kebele, woreda or national), (2) the type of stakeholder they represented (farmers, researchers, government and NGOs), and (3) the need for a high degree of engagement of actors in livestock-related IP activities and the need to focus on farmers in FRGs who had tested and experienced two or more of the livestock technologies listed in Table 3. We sampled a higher proportion of women (30%) than were normally recorded as FRG members (20%) to ensure their perspectives were captured (Table 4.

Table 4). The gender balance of other stakeholders interviewed in the multilevel IPs reflected the Ethiopian institutional context where formal meetings are traditionally dominated by men (Table 4.

Table 4**).** FGDs with kebele IPs involved four farmers and two DAs while FGDs with woreda IP involved 6-8 IP members representing the four types of stakeholders. The interviews and transcription of audio-records were jointly carried out by the first author and a female research associate who specifically assisted in interviewing women farmers to align with cultural sensitivities around gender. A FGD of 1-2 hours per IP was conducted with IP members, while each KII took around 1.5 hours to complete. A summary of the data collected, and the type of participants involved are presented in Table 4.

Table 4. Overview of data collected through focus group discussions and key informant interviews at different levels of the IP system.

Methods - information gathered	**Number of FGDs/KIIs (participants)**	**Participants representing**			
		FRGs (farmers)	Kebele IPs	Woreda IPs	National IP
FGDs - Collective view on individual IP processes, links with other IPs, livestock feed issues and opportunities, the role of stakeholders and their relationships, outcomes they expected and obtained and lessons they learnt.	6 FGDs (6-8 people per FGD, with a total of 39 (8 women farmers)).	n/a	4	2	n/a
KIIs - individual stakeholder's views and experiences with IPs, participation in IP events and on-farm activities, interaction within and across levels, their role in on-farm activities, incentives, and challenges faced and outcomes attained.	45 KIIs (9 with women and 36 with men), comprised of 23 farmers (7 women), 5 DAs (1 woman), 2 Universities (0 women), 3 NGOs (0 women), 5 researchers (1 woman), 7 Government (0 women).	23	5	13	4
KIIs – coordinators views on IP management: initiation, facilitation, challenges, linking and role of different IPs, feed interventions, the role of stakeholders, outcomes obtained, and lessons learnt.	3 KIIs (Africa RISING coordinators) (0 women).	n/a	n/a	2	1

NA – not applicable

Additional data sources included direct observation of farmers using the feed technologies after their interviews, and visits to facilities of selected IP member organizations such as kebele nursery sites, private dairy processors, and farmers' dairy cooperatives. Secondary data sources (project documents and IP meeting reports) provided additional information to identify and map important events and their outcomes over the 5-year timeline.

KIIs and FGDs were audio-recorded and transcribed verbatim. Steps followed for the thematic analysis (Braun and Clarke, 2006) started with familiarisation with the data during field works, through (re)reading the transcripts and listening to audio recordings and reviewing secondary sources. Using a qualitative software package, NVivo v.12, the transcripts were examined by word frequency and text search query with stemmed words to identify key phrases in the data. Data were visualised through word trees and word clouds. Trends in our data were refined through coding while taking notes relevant to answer the research questions using memos in NVivo. The data were coded to the five functions of innovation systems identified in our adapted framework for thematic analysis (Table 1).

Results

A timeline was developed to map key activities occurring within the multilevel IPs over the five-year horizon of the research. We categorized the activities into two phases, as illustrated in Figure 3. The first two-year period was classified as the 'inception phase', and the remaining three-year period as the 'implementation phase'.

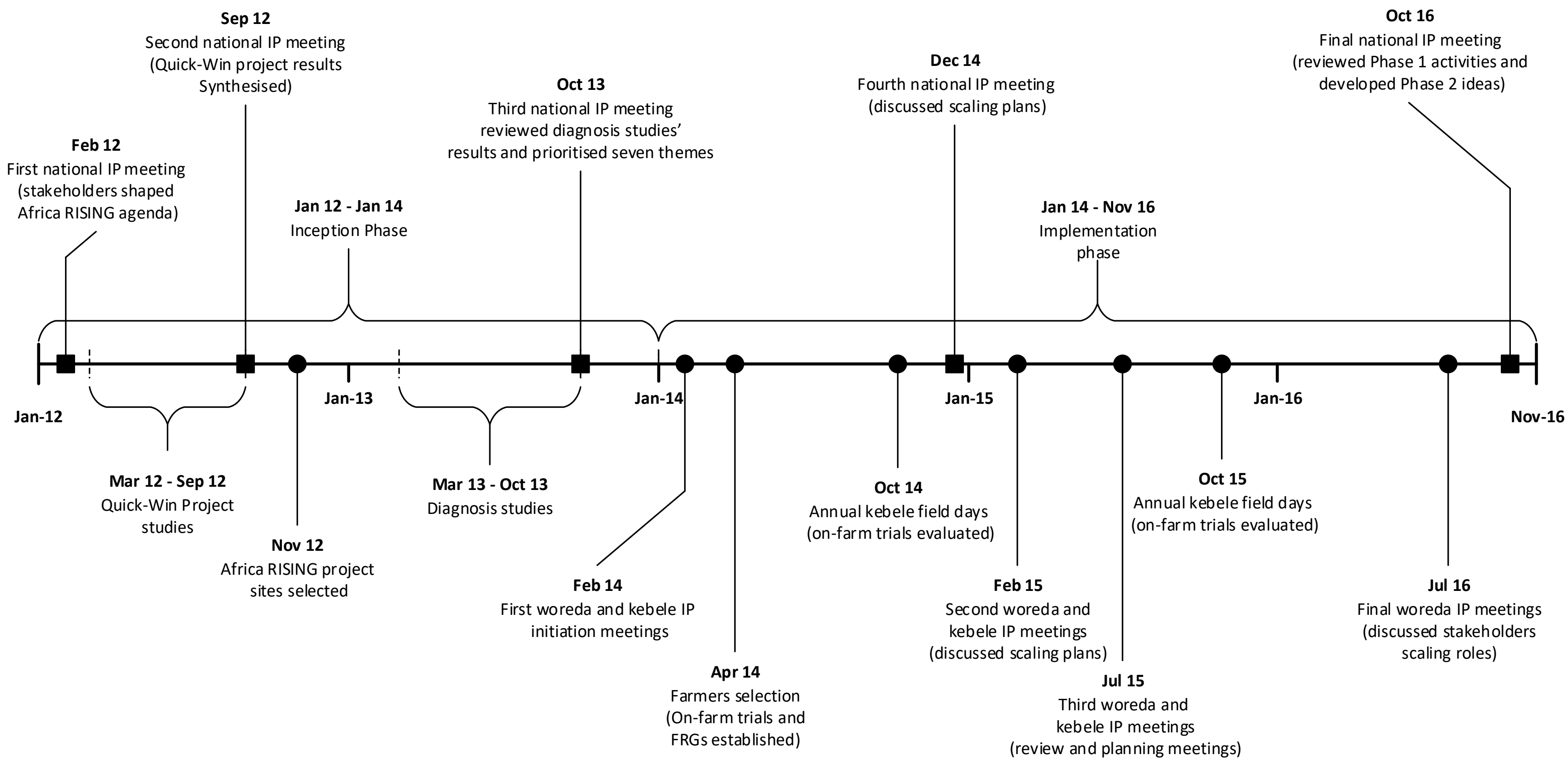

Figure 3: Timeline of Africa RISING multilevel IPs key activities. Note: ■ - Denotes the national-level IP meetings; ● - Denotes woreda-, kebele- and FRG-level activities; Month-Year.

In the following sub-sections, we present our findings on how the key activities identified in the timeline (Figure 3) affected the fulfilment of our five functions of innovation systems (Table 1).

Demand Articulation (F1)

Successful demand articulation (F1) is a process whereby the AIS reflects the needs, interests and expectations of actors, securing their support of the innovation process (Table 1). Africa RISING activity commenced with the 'first national IP meeting' (Figure 3), which focused on introducing the broad goals and approaches of the project and inviting participants to tailor its agenda to national priorities. At this meeting, stakeholders jointly listed and reviewed 70 completed and on-going projects relevant to the project's broader agenda on sustainable intensification of crop-livestock systems. Ideas for early participatory diagnosis studies – 'Quick-Win projects' (Figure 3) - were proposed at this meeting.

Quick-Win projects were designed to establish partnerships among the Africa RISING implementing partners early in the project cycle. Seven CGIAR centres along with regional universities and research centres implemented five Quick-Win projects in various locations and generated evidence to inform the Africa RISING stakeholders' subsequent decisions. The so-called Quick-Feed project (See details in Duncan and Stür, 2012) was one of these projects and focused on livestock systems. It identified production and marketing challenges and opportunities to develop dairy and sheep value chains. During the 'second national IP meeting' (Figure 3), stakeholders synthesized the Quick-Win project outputs, and this helped to inform the selection of Africa RISING sites and identify topics for further diagnostic studies.

Across Africa RISING research sites, further tailored 'diagnosis studies' conducted (Figure 3), including participatory community analysis (PCA) that engaged around 300 farmers (male, female and youth) identified farmers' interests and decided on specific enterprises that would be targeted for Africa RISING interventions (See details in Lunt et al., 2018). Three top livestock enterprises in order of decreasing importance – beef, dairy and sheep were chosen with some differences across gender, whereby men tended to prioritise beef while women tended to prioritise dairy and sheep for the development of semi-commercial production through the PCA process. The PCA also informed Africa RISING on the need to establish FRGs and kebele-level IPs to bring farmers to the centre of the innovation process. For each enterprise, a value chain and market analysis identified site- and enterprise-specific challenges, opportunities and the role of value chain actors (Birachi et al., 2014). This analysis suggested a series of interventions to improve feeding, breeding and marketing for each enterprise.

The inception phase activities concluded with a third national-level IP meeting (Figure 3) where stakeholders synthesised results from diagnosis studies and prioritised feed scarcity as a major constraint to livestock development across Africa RISING sites. To address this objective, Africa RISING allocated funds for researchers who introduced the feed technologies listed in Table 3. Although the diagnosis studies stressed the importance of value chain integration targeting specific enterprise chosen by farmers, the national actors chose to focus on farm-level feed issues partly influenced by researchers' technical skills and the budget available to Africa RISING. We noted that the lower-level IPs were not established at this stage and were not part of these decisions that occurred during the inception phase, which limited their role in supporting the implementation of feed interventions identified by researchers.

At the start of the implementation phase, the woreda- and kebele-level IPs were established through 'initiation meetings' (Figure 3) during which the researchers introduced the feed technologies and invited input and cooperation to implement the interventions to address feed scarcity. As summarised in Table 2, membership of the national and woreda IPs was dominated by public organisations. The representatives were not generally decision-makers but tended to be technical experts who could contribute to the technical feed innovations. These technical IP members probably lacked the power to influence the decision-making within their organisation to mobilise resources and align their activities to complement the feed innovations.

The woreda IP assigned 5-8 people as a technical team who introduced the feed technologies to farmers and selected interested farmers during a community meeting (approximately 150-200 farmers attending) organised for each kebele. Interested farmers were invited by the kebele extension officers (DAs) who nominated themselves for participation after considering information provided to them in their local language about the benefits and resources for conducting the trials. The farmers were assessed as to whether they would be able to contribute the required resources such as shallow-wells for participating in irrigated-fodder trials. These processes are likely to have resulted in a preference towards the wealthier and male farmers who would have been better placed to contribute the resources required for participating in the trials and also tended to have better pre-existing connections with extension services with experience of technology adoption.

The technical team facilitated the distribution of inputs and delivery of training among participating farmers. As indicated in Table 3, the technologies listed were all introduced across the four kebeles except for irrigated fodder for sheep fattening which was only introduced in Lemo. Stakeholders were engaged across all levels to evaluate and tailor technologies for certain farmers or specific kebeles. Woreda and technical experts appreciated that unlike the government approach of widespread scaling before testing, these processes allowed them to adapt and select specific technologies before promoting them at scale during the final IP events (Figure 3).

The technical team in both woredas indicated the lessons they learnt on the complexity of the issues and importance of pilot testing and screening to increase the likelihood of adoption by farmers. As one Basona woreda livestock expert indicated:

> Introducing the technologies not as a package, but as individual technology provided options to suit the interests of diverse farmers with different capacity (resource). However, the farmers were not yet linked to the market to help them benefit from using feed technologies.

In summary, the national stakeholders shaped the Africa RISING agenda to fit with national priorities and identified site- and enterprise-specific livestock value chain issues, intervention areas and the role of actors. Although the livestock issues identified were interrelated and complex, the decision to prioritise on-farm feed issues seems to have been made without involving lower-level IPs or considering farmers’ needs and was influenced by research interests and the resources available to Africa RISING. This decision limited the scope of actions and the expected potential of other higher-level actors in addressing institutional and market issues above farm-level. During the implementation phase, lower-level IPs were established, and the multilevel structure facilitated an iterative learning process that allowed stakeholders to screen and adapt feed technologies to suit the interests of individual farmers. However, farmers had limited capacity to organise themselves in order to address value chain issues that constrained their opportunities to derive economic benefits from using the feed technologies.

Knowledge Development and Diffusion (F2)

The multilevel structure facilitated various forms of learning events through linking stakeholders vertically and horizontally to interact, learn and exchange knowledge. During the inception phase, researchers drove the prioritisation and selection of feed technologies. During the implementation phase, on-farm trials allowed practical learning among researchers and other stakeholders for the successful introduction of feed technologies. Researchers found the FRGs they formed to be the most critical learning structure for them to test their research ideas on the ground and receive feedback from stakeholders for technology adaptation.

Most importantly, the on-farm trials challenged the status-quo of farmers' practices and attitudes around livestock systems in three ways. First, most farmers started allocating part of their arable land and cultivating improved forages for the first-time. These farmers were typical of farmers in the kebeles in keeping relatively unproductive local livestock breeds relying on grazing and crop residues as the main sources of feed who were unfamiliar with improved feeding practices. Farmers needed considerable feed resources to feed their livestock; among the 23 farmers, we interviewed the average livestock holding was 7.25 tropical livestock units. Second, the farmers were equipped with knowledge and technology (feeding troughs and feed storage sheds) to help them avoid the estimated 30-50% losses due to poor typical post-harvest handling practices. Third, farmers became more interested in commercial dairy production due to their access to quality feed resources and learning opportunities through exposure visits to advanced dairy farmers and the existence of market opportunities for dairy products.

Knowledge diffusion was facilitated primarily through IP meetings, farmer field days and exposure visits. The national review and planning meetings were mainly aimed at evaluating progress across the kebeles and also facilitated cross-site learning that enhanced the innovation capacity of woreda IPs. At woreda- and kebele-level, learning events facilitated information flow from multiple sources. As indicated in Figure 3, IP meetings and field days were used to introduce, test, evaluate and finally promote scaling of the feed technologies. Field days were important in bringing all stakeholders from across the multilevel IPs together for joint evaluation of the technologies. In each kebele, an average of over 100 stakeholders participated in the annual field days and evaluated various on-farm trials and prototypes. Participating farmers played a central role in communicating their experience about the efficacy of the technologies they tested to non-participating farmers, researchers and IP members during the field days.

Exchange visits were also organised for farmers to learn from peers within and outside their kebele. Farmers from both woredas spoke of their impressions following an exposure visit to the nationally recognised kebele of Abreha-we-Atsbeha in Tigray region where they saw interventions on zero-grazing and planting of multi-purpose trees for the rehabilitation of a degraded watershed. Within a year, the visiting farmers had implemented similar initiatives in their kebeles, including water-harvesting ponds in Lemo and watershed management in Basona Worana. Finally, they organised another cross-site exchange visit between these two woredas. Farmers in Upper Gana kebele involved in irrigated fodder also visited a neighbouring woreda to learn about small-scale irrigation from their peers. Lemo farmers also visited a farmers' dairy cooperative in another kebele to learn about feeding and milk marketing from peers. Farmers in Lemo spoke of the benefits of participating in such events which raised their interest in the dairy business. Within Jawe kebele, a model farmer in an FRG with prior engagement in a dairy business inspired other to emulate his success. But farmers needed affordable financial or breeding services, as one farmer in Jawe kebele noted:

> I have local-breed cow with a value of about USD 170, but a model farmer who has four crossbreed cows is selling his heifer for USD 1356 in addition to regular income he gets from selling dairy products, which inspired me. I wanted but could not afford to buy the heifer, but one farmer did and then constructed the feed storage and allocated his croplands partly for forage crops. Soon, he will be the second model dairy farmer in our kebele.

National-level stakeholders spoke of the lessons they learnt from their experience with the multilevel IPs. They acknowledged that the IPs had a broad research focus and tended to place a higher priority on crops, which limited the time and resources available to facilitate learning on livestock innovation. They appreciated the broader attention to intensifying crop-livestock systems but also pointed out the limitation of the multilevel IP structure to deal with the complex issues within the livestock systems. The national-level stakeholders proposed the need for more opportunity to interact with farmers and other stakeholders to be able to effectively integrate institutional innovations. Farmers and other stakeholders also suggested that instead of organising farmers as FRGs around short-term technological trials, organising them around potential livestock marketing enterprises of their choice would support their collective capacity and commercial knowledge beyond the trial period.

In summary, the multilevel structure effectively facilitated multiple avenues of learning and knowledge exchange and supported various technological innovation outcomes around feed technologies. The learning activities linked to the on-farm trials and exchange visits enhanced the technical capacity of farmers and livestock experts and resulted in significant change regarding farmers' access to improved feed technologies. Besides, the learning stimulated farmers' interest in commercial dairy production. Researchers also benefited from direct feedback from FRGs and stakeholders to adapt the technologies before wider scaling. Thus, the knowledge development and diffusion function (F2) was mostly fulfilled in respect of farm-level technical knowledge on livestock feed issues, but with limited institutional innovation outcomes by way of organising and empowering farmers to address constraints along value chains that continue to impede commercialisation of their products.

Institutional Support (F3)

The establishment of the multilevel IPs themselves represented an institutional innovation that led to some positive changes in improving linkages among actors within and across levels. Many IP members interviewed spoke positively about the strong partnership established between nine CGIAR centres and with national research organisations and universities. Researchers from across regional and national levels formed multidisciplinary teams and employed their diverse skills to co-implement several activities under a single project - Africa RISING. Researchers indicated that they had previously found it challenging to partner with technical experts because of rigid government structures and that the IP setup provided them with better opportunities for such partnerships and generated legitimacy.

At woreda-level, stakeholders appreciated the improved communication pathways established between government organisations that were formerly constrained by a highly structured administration and formalised communication procedures. The government representatives specifically appreciated the informal and interactive space created by IP events that brought stakeholders together. Such events helped stakeholders to build personal relationships with representatives from relevant higher-level government organisations.

At kebele-level, the capacity of the livestock DAs around feed innovations was enhanced and livestock extension services provided by DAs to farmers were improved. For example, Upper Gana kebele Office of Agriculture used its Farmer Training Centre's (FTC) nursery site to multiply and distribute forage seeds introduced by the IPs and by doing so the office enhanced its extension service to farmers. The livestock extension people indicated that previous government and NGO projects they were involved with tended to support crop production with little emphasis on the livestock sector that limited the sector actors' exposure to livestock innovations.

Government and NGO stakeholders highlighted the positive change in farmers' attitudes and practices demonstrated by their interest in commercial dairy farming and then following up with an allocation of land to forage crops. Government stakeholders indicated the historical difficulties they had faced in promoting feed technologies to bring about such attitudinal change and suggested that farmers' engagement in various learning activities before supporting wider scaling had been a positive influence.

The majority of farmers interviewed confirmed that their skills around feed production, management and utilisation had improved through Africa RISING, but that access to services such as loans, veterinary services, and improved breeds remained an issue. For example, farmers had expressed their preference for a breeding bull service rather than artificial insemination, as the latter was often unavailable during the critical mating time for logistical reasons. As a farmer in Gudo Beret kebele noted:

> We have been seeking support to have access to bull service to increase our milk production. There is a high demand, and milk collectors are daily coming to our doorsteps. If any partner wishes to organise and support us, we are ready to contribute a half share of the breeding bull cost and also pay around USD 30 per bull service.

Despite the limited IPs' focus on institutional innovation to guide institutional innovations around the provision of such services, the woreda stakeholders pointed to their limited power and resources to initiate such interventions and the need for support from higher-level decision-makers. One national-level CGIAR researcher also explained the difficulty of the process and the importance of engaging decision-makers:

> We must ensure the right policy people, along with their technocrats, professional people in related fields, come to important IP meetings. Alternatively, since lobbying the policy people might be beyond our mandate, we can ensure the message is conveyed to the right policymakers through policy briefs and other means.

In summary, the multilevel IPs as an institutional innovation improved partnership between CGIAR and national actors across all levels. Actors' interactions enhanced communication, minimised duplication of efforts and provided legitimacy to co-implement farm-level technical solutions. The positive changes observed in farmers' attitudes and practices were considered as a significant first step to transform their extensive and subsistence farming to a more intensive and commercial system. However, farmers and woreda actors (being experts not decision-makers) lacked the power and resources to influence decisions made within the higher-level IPs. The strong focus on farm-level livestock feed issues limited the breadth of the innovation process and potential of multilevel IPs to engage higher-level decision-makers to support farmers in gaining access to the affordable services they needed. Researchers understood the importance of lobbying decision-makers but regarded it as beyond their mandate.

Resource Mobilisation (F4)

In addition to the limited donor resources allocated through Africa RISING, the multilevel structure of IPs was expected to leverage further resources through organisations involved with the IPs. This was limited by designing the innovation process that was limited to the financial and knowledge resources allocated by Africa RISING. The operational funds were made available to researchers to identify feed innovations and implement and not directly allocated to a particular IP to foster their joint actions, diversify actions and complement the innovation process. This limited the capacity of non-researchers and the individual IPs to contribute to the innovation process. We identified one exception where Africa RISING allocated funds directly to Lemo IP due to strong demand from IP members to address the disease problem threatening one of the woreda's main feed and food crops, 'Enset'.

Government actors at national-level were less represented to support the innovation process, but woreda- and kebele-level actors made several 'in-kind' contributions in terms of human resources and facilities. The woreda IP technical team from government organisations allocated their technical staff time to assist with the implementation of on-farm trials, including in selecting farmers, providing training, organising field days and collecting data from the trials. In terms of facilities, the woreda and kebele stakeholders contributed offices and land to facilitate learning within the multilevel IPs. For example, Wachemo and Debre Berhan Universities provided office space free of charge for Africa RISING woreda coordinators while kebele-level government nursery sites were used to produce forage seedlings. Participating farmers allocated their land and other local materials (e.g., timber), and managed the on-farm trials that were the learning sites for all IPs.

Africa RISING coordinators and national researchers acknowledged that the stakeholders' contribution enabled the effective implementation of various on-farm trials. The coordinators also noted that addressing the complex livestock issues and operating the multilevel structure was resource-demanding unless supported by actions from other key stakeholders. Woreda actors believed that some IP members, such as universities, had the necessary resources to deliver critical services along the value chain that farmers were demanding to enhance the utilisation of the feed technologies. They indicated that as part of the universities' mandate to provide research and community services in the woredas, the government allocated dedicated funds for these universities, and this could have been identified early to lobby decision-makers to support and complement the activities initiated by the IPs. For example, in Basona Worena, stakeholders indicated that Debre Berhan University had provided a breeding bull through the FTC at kebele-level to help farmers access breeding services, but the relevant decision-makers were not involved in the woreda IP.

Thus, although a single Africa RISING funding model contributed a significant share to the IPs facilitation and implementation activities to address feed issues, more resources from member organisation would have been needed to address the interlinked value chain issues. The IP member organisations mobilised non-financial resources to support farm-level feed interventions, but this was not enough as there were also missed opportunities. There could have been greater linking of farmers to organisations involved in the multilevel IPs that could have provided ancillary livestock services.

Agribusiness Development (F5)

Some of the livestock issues identified during the inception phase were related to a lack of local knowledge on the efficient use of feed resources. Researchers and livestock experts provided on-farm training that equipped FRG members and livestock experts with new skills on feed production, management, and utilisation. Positive changes in farmers' attitudes and practices were observed as described under F2, and farmers gained new skills and technologies to produce and utilise quality feed. However, farmers also expressed their need to improve their marketing and business skills to maximise returns from their investments in feed innovations.

Researchers drew lessons from their first attempt in piloting a new business model in one kebele to enable farmers to derive more profit from the use of feed technologies. For the pilot intervention researchers engaged seven farmers in Lemo woreda in irrigated fodder production for a sheep fattening operation. With support from IP members, researchers went beyond their traditional research role to identify and purchase sheep of improved breeds through their organisation, despite having limited experience. The procurement process for five sheep per participating farmer on a loan basis was protracted and raised costs for the farmer when receiving their sheep. The researchers provided water-pumping equipment and trained farmers to irrigate an oat-vetch fodder plot, to formulate feed rations and to fatten lambs within three months and linked farmers to veterinary services. Although farmers supplied fattened sheep in time for the targeted holiday market, the expected profits were not realised.

Researchers indicated their main lesson was for their research organisation regarding the level of flexibility and support they needed to allow them to take on atypical roles such as this. Farmers appreciated all the support, including financial underwriting, they received through the multilevel IPs to try the new business model. However, farmers indicated they were constrained limited access to affordable services, particularly veterinary service, to continue the business beyond the IPs independently.

Farmers wanted support to form organisations (cooperatives) they trusted to improve their access to inputs and markets for their livestock production. In Gudo Beret kebele, farmers referred to the experience they had with a recently established cooperative for food crops with support from Africa RISING and indicated how their bargaining power in input and output markets for potato was enhanced. Farmers in Jawe were also keen to establish a dairy cooperative along the lines of one they visited during an exchange visit to another kebele. We observed the input and output market opportunities made available to farmers by a private dairy processor in Lemo. The processor was collecting more than 1000 litres of milk per day from about 70 farmers and providing members with concentrate feeds on a loan basis. Farmers involved in feed interventions were not, however, producing sufficient milk from local breeds to allow them to join such schemes.

In summary, the activities of the multilevel IPs enhanced technical capacity of farmers and experts around feed innovation. Although stakeholders appreciated farmers' demand for livestock services, the IPs supported one component of the livestock enterprises, the technical feed innovations. Researchers' attempt to play new roles to address institutional barriers necessitates changes within their organisation. The primary constraints were found to exist along the value chain related to organising farmers and enhance their marketing and business skills necessary to enhance farmers' economic returns as incentives for reinvestments in feed technologies and to grow their enterprises. For this, farmers aspired to work collectively through, for example, forming cooperatives to deal with market issues.

Discussion

The Interplay between Innovation System Functions

In this study, we examined the impact of a multilevel structure of IPs implemented by Africa RISING in stimulating innovation in the smallholder livestock system in target sites in Ethiopia. The functions of innovation systems framework, which we adapted to fit our case study context, was used for this purpose. These functions are – demand articulation (F1), knowledge development and diffusion (F2), institutional support (F3), resource mobilisation (F4) and agribusiness development (F5). In our case study, we found that the success of the hierarchy of IPs in stimulating innovation depended on the performance of all functions. The national IP identified a series of interrelated and enterprise-specific value chain issues (F1), and proposed research activities to address, in particular, issues around livestock feed. The IP structure particularly supported technical knowledge development and diffusion (F2) and to some extent institutional support (F3) that improved links between various stakeholders. Such changes helped farmers to develop a vision towards a more commercial mode of livestock keeping beyond the prevailing subsistence system. However, our work emphasises that sustaining these farm-level changes requires institutional changes beyond farm-level (for F3, F4 and F5) that require a shared understanding among stakeholders of the complex nature of livestock issues and a commitment to improving value chains (F1). We had expected that the linking of IPs at various scales would have facilitated change at both farm-level and beyond, but our findings show that institutional innovations around marketing and services were not dealt with to the extent that they could have been due to lack of deliberate attention to recognise and deal with such institutional barriers. Despite the multi-level structure of IPs which was designed to link farm-level issues to the higher-level organizational issues that also need to be solved to elicit lasting change, there was a tendency for the focus to remain at farm level. This was partly related to the role played by researchers in deciding on intervention packages.

These findings indicate the interdependence between the various functions we studied and in particular, the importance of demand articulation (F1) in determining the course of events during the ensuing innovation process. Below, we discuss the complex dynamics we observed within these functions in two sub-sections. Firstly, we focus on the inception phase activities which were conducted before the IP structure had been fully established to understand the implications for demand articulation (F1). Secondly, taking the interdependency between the functions into account, we discuss the effect of demand articulation (F1) on the remaining functions and draw lessons to inform future interventions.

The Inception Phase – The Importance of Creating a Shared View on the Complexity of the Livestock Value Chain Issues

Early in the innovation development process, a standard activity is demand articulation (F1) to identify societal problems (Hekkert et al., 2007), which lay a foundation to fulfil the other functions. Within the IP context, F1 can be fulfilled through the diagnosis of issues and prioritisation, and below we discuss how engaging in diagnoses before the establishment of lower-level IPs impacted the fulfilment of F1.

Early in Africa RISING, there was a strong focus on the identification of issues and opportunities through participatory diagnosis activities guided by the value chain concept. Specifically, the livestock value-chain and market analyses identified detailed constraints and opportunities from production to marketing for dairy, sheep and beef enterprises as prioritised by men, women and youth farmers. These analyses took a holistic view and undertaken for specific livestock enterprises that incorporated the interests of a different group of farmers and other value-chain actors. Findings from earlier research show that many community-level IPs tend to focus on the diagnosis of farm-level issues and overlook the institutional landscape constraining farmers (Hounkonnou et al., 2018; Davies et al., 2017). With this in mind, the national-IP identified site- and enterprise-specific priorities and value chain actors from production up to marketing and emphasised the need for integrated interventions to achieve significant productivity improvements. Thus, the national-level IP was heavily involved in assessing demand (F1) before the IP setup had been fully established.

Despite the holistic value chain focus of early diagnostic activities, the subsequent activities mainly focused on farm-level technical feed interventions influenced by national actors. A study by Lamers et al. (2017) suggests the need for active stakeholder engagement to co-prioritise through negotiation can help to develop a shared understanding on the complexity of the issues and stimulate simultaneous actions required across the levels to address them. Thus, closer adherence to the needs identified through early diagnostic activities could have been better achieved if stakeholders and value chain actors from across levels had jointly pursued an agreed agenda through facilitating learning and constructive dialogue (Ravichandran et al., 2020). In the event, the lack of an established IP structure early on meant that on-farm activities were already in train before learning and feedback mechanisms were in place which could have altered the course of events more along the lines of the expressed needs of farmers.

The Implementation Phase – the knock-on effect between functions of innovation systems

Our evaluation of the impact of the nested IP operation during the implementation phase suggested that the structure was relatively successful for knowledge development and diffusion (F2) and institutional support (F3) around livestock feed interventions. In this case, the structure facilitated learning within, across and outside the multilevel IPs linked to the on-farm trials (F2) and improved linkages between researchers, livestock experts and farmers that were essential to the successful introduction of farm-level feed technologies. Farmers' learning between FRGs provided them with options to select appropriate feed innovations and helped them to start shifting the use of low-quality crop residues towards a more intensive and improved-quality feed resources. Thus, farmers' technical learning around feed innovations, their exposure to experienced dairy farmers through exchange visits and the existence of a market for dairy products fostered their interest. The interest of male farmers in collective actions towards commercial dairy farming was fostered in particular. Recent research has indicated that higher-level IPs play an important role in empowering community-level IPs through facilitating exchange visits for farmers and local actors to learn from peers advanced in commercial dairy farming in Indian MilkIT multilevel IP project (Ravichandran et al., 2020).

In contrast to the MilkIT IP project that was initiated to support farmers in commercial dairy farming Africa RISING as a multilevel IP had no specific enterprise focus for the feed technologies. Also, if farmers were interested in developing an enterprise such as commercial dairying they still faced other interrelated value chain issues including access to finance, veterinary, breeding and other services. Supporting farmers' enterprise development would require integration of value chain concept from the beginning with demand articulation (F1) to guide the integration of feed and market innovations and identify and engage relevant stakeholders across different levels. This finding is also supported by previous studies (Ravichandran et al., 2020; Hounkonnou et al., 2018; Kilelu et al., 2017; Kilelu et al., 2013; Ayele et al., 2012). Value chain integration is particularly important for realising the anticipated advantages of a multilevel IP structure. It allows the organisation of farmers and enhancement of their collective actions or strategic engagement with relevant higher-level actors in order to influence and stimulate actions required to support farmers to increase productivity and make business links with market actors and service providers which was the case in India MilkIT (Ravichandran et al., 2020) than the Tanzanian MilkIT IP project experience where outcomes were relatively limited despite market and feed innovations integration (Kilelu et al., 2017; Duncan et al., 2015). For example, if Universities who are involved in a technical capacity in the multilevel IP could also contribute at other levels of decision making that align with enterprise development such as the provision of breeding bulls. Such strategic engagement and devolution of roles within the multilevel IP could fulfil institutional and market-related functions (Lamers et al., 2017). A study by Hounkonnou et al. (2018) showed that prioritising specific potential commodities and aligning IP priorities with interests of relevant actors is vital to enhancing their commitment to mobilise resources (F3) and trigger institutional changes (F4) that improved value chains and linked smallholders to reliable markets (F5).

However, successful reconfiguration of relationships between actors to enable them to play complementary roles requires sufficient understanding of the context-specific power dynamics between actors under which IPs operate (Kilelu et al., 2017) and the political context in which innovation occurs. Many have pointed out that state-driven linear agricultural development in Ethiopia reinforces the status quo, and impedes new participatory structures such as IPs from facilitating inclusive innovation (Cullen et al., 2014; Ayele et al., 2012; Spielman et al., 2011). Also, we need to recognize that the smallholder livestock sector has received less attention than the crop sector by successive governments (Asresie et al., 2015; Negassa et al., 2012), and the widely held negative attitude towards farmers and their knowledge restricting their interaction with other actors (Cullen et al., 2014) and how this plays a role in limiting transformation of the livestock sector. Furthermore, the recent food transformation agenda has tended to favour urban dairy farmers at the expense of rural poor dairy producers lacking market infrastructure (Minten et al., 2020). Thus, the starting conditions in the form of the prevailing political economy are important in shaping the effectiveness of institutional innovations such as the multilevel IPs that we studied. New structures such as multi-level IPs are not necessarily sufficient to overcome prevailing power relations. These issues need to be considered in the design of interventions aimed at empowering marginalised farmers, and more attention should be given to understanding how the prevailing institutional environment might hamper the efforts of community-level actors to negotiate with higher-level decision-makers and influence their actions (Ravichandran et al., 2020; Lamers et al., 2017).

Following the value chain concept, reorganising FRGs around a specific livestock enterprise (such as dairy cooperatives) is vital to enhance inclusion of both men and women farmers and coordination between farmers, and strengthen their negotiating power for useful institutional changes (Davies et al., 2018; Hounkonnou et al., 2012). Such reorganisation of farmers to enable marketing innovations leads to inclusive value chain innovations that open more opportunities for non-participating and disadvantaged women farmers (Ravichandran et al., 2020). Although we found that multilevel IPs enhanced horizontal learning between farmers, the focus there was more on enhancing the individual capacities of participating farmers for the trials rather than their collective capacities to engage successfully with actors along their value chains. Thus, deliberate and simultaneous efforts at local- and higher-level IPs are required to mobilise farmers while linking them with market-actors. Despite, value chain integration within the concept of multilevel IPs, the existence of power dynamics, unfavourable institutional context and evolving market dynamics need to be anticipated when building inclusive multilevel IPs (Kilelu et al., 2017; Cullen et al., 2014; Ayele et al., 2012).

Researchers faced challenges in going outside their traditional roles within individual research organisations that would allow them to address the various institutional barriers facing farmers beyond farm-level. This capacity to broaden a researcher’s role was found to be important as sustained use of the feed interventions required market-oriented interventions.

Findings from previous research have shown that when feed interventions are accompanied by improvements along the value chain, improved incomes encourage further investment in feed technologies to develop the enterprise (Ayele et al., 2012).

After the IPs were phased out, farmers in Jawe kebele were already seeking support to establish a dairy cooperative to improve their access to inputs and services. Since farmers lack negotiating power and agency, they need external support to facilitate organizational change. Although in the case of Africa RISING, the IPs were time-limited, the enhanced capacity of farmers and the improved links to higher-level actors appear to have had some lasting impact. Institutional change of this kind has been identified as necessary for overcoming systemic barriers constraining smallholder development in SSA (Hounkonnou et al., 2018; Davies et al., 2017; Ayele et al., 2012). Such sustained changes can further enhance the effectiveness and inclusiveness of the multilevel IPs if innovation processes are guided by value chain concepts to determine who to engage at what level (Kilelu et al., 2017; Ayele et al., 2012).

Overall, the multilevel IP structure achieved positive outcomes such as improved linkages between CGIAR scientists and other stakeholders that resulted in multiple benefits in terms of minimising duplication of efforts, enhancing communication between actors and improving the technical capacities of actors. The joint actions enabled the multilevel IPs to attain technological innovation outcomes that provided farmers with various options to address the feed issues. The dynamic and complex nature of smallholder agriculture, even when the focus is narrowed to livestock innovations, necessitates a flexible approach to adapt IP priorities to the interests of actors (F1). It also requires a strategic approach to engage and lobby with decision-makers (F3) and mobilise and reallocate resources (F4) to address prioritised and emerging marketing and business issues (F5). This implies the need for future multilevel IPs to recognise the functional dynamics and their interdependency to devolve roles to appropriate levels with sufficient consideration of the history of power relationships between actors and evolving market structure. Scholars have stressed the importance of a flexible and adaptive learning approach to deal with such complex processes to attain innovation outcomes that contribute to the improvement of smallholder livelihoods (Kilelu et al., 2013; Klerkx et al., 2010).

Conclusions

How might a nested hierarchy of IPs affect the usefulness of IPs in stimulating innovation across scales in a smallholder farming system? To answer this research question, we used the multilevel IPs of Africa RISING as a case study and a modified functions of innovation systems framework as a way to structure our enquiry. Through improved networks, the multilevel structure allowed the IPs to drive positive outcomes around farm-level innovations to address feed scarcity and enhanced the technical capacity of farmers and experts. Technical capacity was enabled due to the strong focus on iterative learning linked to on-farm trials (F2). Facilitation of stakeholders' interactions within and across levels strengthened actors' linkages (F3). However, the weaknesses observed in setting priorities that focused on farm-level interventions (F1) limited the engagement of other important actors to support the fulfilment of other functions related to institutional changes. Thus, the multilevel IPs were used to facilitate technological innovations, but institutional changes would be necessary to achieve significant livelihood outcomes.

We conclude that the multilevel structure of the IPs we studied enhanced interdependency and partnerships between the various actors involved. However, achieving meaningful outcomes would require more joint prioritisation of issues to guide the innovation process. This could be addressed if the value chain concept were better integrated within multilevel IPs and more attention given to understanding context-specific power dynamics to identify and engage representative farmers and other relevant actors to achieve institutional changes that open more opportunity for the wider community of farmers. It would also require changes within member organisations to facilitate reconfiguration of resources, actors' roles and their relationships to support the innovation process.

This study adapted the functions of innovation systems framework in evaluating how the activities of a mature multilevel structure of IPs affected innovation performance by studying the case 2 years after the IPs ended to allow assessment of ongoing performance. The framework was useful in mapping the various activities undertaken across the multilevel structure. Our analysis highlighted the interdependence between the functions and how a weakness observed in the demand articulation function (F1) had a knock-on effect on the other functions in smallholder livestock innovation systems.

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