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Diagnosis of management of bacterial wilt and late blight in potato in Ethiopia: A systems thinking perspective

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ABSTRACT

Potato is one of the most important food crops for smallholder farmers in the Ethiopian highlands. Diseases, particularly bacterial wilt (caused by *Ralstonia solanacearum*) and late blight (caused by *Phytophthora infestans*), are among the major constraints of potato production, despite continuous efforts to control them. Bacterial wilt and late blight are complex problems with multiple technical and institutional features, involving multiple actors with different perceptions and understanding, not only of the problem but also of possible solutions. Appreciating such complexity, this study adopted a systems thinking perspective. It aimed to explore actors' understanding of the complex problem situation and its implication for the management of the diseases at a collective level. Using a multi-stakeholder workshop and in-depth interviews, a qualitative study was conducted with actors that are directly or indirectly involved in the management of the two diseases. Results showed that actors essentially overlooked key systemic problems in the management of the two diseases. This is mainly reflected in actors' tendency to give event-level responses, shift responsibilities and engage in a mutual blaming to the problem of bacterial wilt and late blight. Lack of a preventive disease management culture, limited recognition of interdependencies among activities of actors, power inequalities, and top-down and linear approaches in information and knowledge sharing are identified as key structural problems that are underrated by the actors. We contend that the most appropriate way forward towards the management of both diseases is designing and implementing management strategies that, on the one hand, are preventive of disease epidemics, and, on the other hand, foster horizontal information sharing, learning and collective action among the local actors in the system. Digital platforms, particularly mobile-based technologies, can play a role in catalyzing new forms of information sharing, broader learning, and collaboration among farmers and local actors.

1. Introduction

Potato is the fastest growing food crop in Sub-Saharan Africa with a substantial increase in total production in recent years. There is a similar trend in Ethiopia: the total area of land cropped with potato has considerably expanded from about 62,000 ha to 296,000 ha resulting in an increase in total yearly production from 500,000 Mg to about 3,700,000 Mg in 10 years (CSA, 2006; CSA, 2016). As the Ethiopian population grows rapidly, potato offers opportunities as one of the main food security crops (Haverkort et al., 2012). However, despite the increasing importance of potato production in Ethiopia, its productivity remains low with an average yield around 12.3 Mg/ha, an amount very low compared to the attainable yield of up to 50 Mg/ha under improved farmer management conditions using improved varieties (CSA, 2016; Baye and Gebremedhin, 2012). A number of studies (Haverkort et al., 2012; Tsedaley, 2014; Gorfu et al., 2012; Kassa, 2012) identified disease pressure, particularly bacterial wilt and late blight,[2] as the most important production constraint and the number one priority for farmers in the management of their potato crop. Bacterial wilt has spread geographically from few potato growing areas in the lowlands

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[2] We couldn't find studies that tried to quantify total yield loss resulting from bacterial wilt or late blight disease in Ethiopia.

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and medium altitudes to almost all potato growing areas since it was first reported in Ethiopia in 1956. Bacterial wilt is categorized as seed-, soil-, and water-borne. Because host resistance to bacterial wilt is limited, it is very difficult to control (Kirk and Wharton, 2014; Burke, 2017). Late blight is known to occur throughout the major potato production areas in the country (Stewart, 1956; Gorfu et al., 2012; Mekonen et al., 2011). Late blight is primarily air-borne whereby the pathogen is carried over by wind currents or rain splashes to other plants/fields, but it is also seed-borne and soil-borne. Although there are two growing seasons (*Belg and Meher*) in most potato growing areas in the country, potato is mainly grown in the short rainy season (*Belg*) that falls between February and May. A high disease pressure in the long rainy season is the main reason why *Belg* production is dominant, despite a high yield potential of the long rainy season (Haverkort et al., 2012; Garuma et al., 2012; Bekele and Eshetu, 2008).

Cognizant of the situation, a number of previous and on-going research and development efforts have been made by different governmental and non-governmental organizations to deal with the problem of late blight. The National Potato Improvement Program within the Ethiopian Institute of Agricultural Research (EIAR), together with the International Potato Center (CIP), several regional research institutes and Ethiopian universities, has worked over the last three decades to develop potato varieties with resistance to late blight (Baye and Gebremedhin, 2012; Mekonen et al., 2011). On the other hand, bacterial wilt management has not received much attention (Gorfu et al., 2012), although there has been some research effort on areas of race characterization, and screening of cultural and biological control methods (Abdurahman et al., 2017; Kassa, 2016; Kuarabachew et al., 2007; Lemaga et al., 2005). As part of a wider government-led 'Quality Declared Seed' program, there are recent attempts to manage bacterial wilt through a combination of technical and institutional arrangements (MoANR, 2013; Thiele et al., 2011). Despite these efforts, the overall success to date has been limited and both diseases still continue to be major challenges in potato production in the country.

Previous research on potato disease management in general and management of bacterial wilt and late blight in particular is notably dominated by technical aspects of the diseases. Most technical research areas covered a range of aspects, from pathogen distribution and genetic diversity to disease management practices such as host resistance, clean seed, chemical control and agronomic practices (Tsedaley, 2014; Kassa, 2012; Mekonen et al., 2011; Bekele et al., 2012; Lemessa and Zeller, 2007; Kassa and Beyene, 2001). Only few studies tried to take a wider perspective at farmers' level (Gorfu et al., 2012; MoANR, 2013) or at system level (Tadesse et al., 2017a,b; Gildemacher et al., 2009) to assess what formal or informal institutions exist and how the institutions operate in potato disease management in general, and bacterial wilt and late blight in particular. However, there is very little attempt made to understand structural problems that give deeper insights on *why* such institutions (both formal and informal) or actors in it are operating the way they do and what that means to the management of late blight and bacterial wilt.

Plant disease results from complex interactions among biotic and abiotic factors including hosts, pathogens and environments, and farm level human activities that intentionally or unintentionally modify these interactions (Burdon et al., 2014; Franc, 1998). A good understanding of the disease cycle, including climatic and other environmental factors that influence the cycle, and cultural requirements of the host plant, are essential to design or implement an effective disease management strategy (Trabucco et al., 2013). Likewise, successful disease diagnosis or management approaches require networks of actors from the government, scientific institutions and local organizations which help to integrate surveillance and monitoring activities on the different dynamics of the disease (Mazet et al., 2014; Kelly et al., 2017). For instance, the risk of late blight can be reduced if growers communicate with relevant parties, such as neighbors, buyers, and extension workers when late blight infects their farms. Such practice can be realized when the different actors, who are supposed to have a vested interest in the management of the bacterial wilt and late blight, find a way to network and coordinate their efforts (Liao et al., 2016). This is in line with the notion of 'connective action' which is described as a new way of organizing collective action networks (Bennett and Segerberg, 2012). In this regard, various forms of ICTs (Information and Communication Technologies) may catalyze new forms of network formation, information exchange and learning that are relevant to address coordination problems (Kelly et al., 2017; Bennett and Segerberg, 2012). ICTs can play a role in facilitating real-time monitoring, cross-level and cross-scale information sharing, engagement and interaction between individuals, organizations, and agencies at multiple governance levels (Karpouzoglou et al., 2016). However, as highlighted in different strands of literature, catalyzing new forms of collective action transcends the discussion on the potential of various technology platforms and requires the articulation of the role of social, institutional or political landscapes which are crucial in formulating collective action frames (Bennett and Segerberg, 2012; Karpouzoglou et al., 2016; Chapman and Slaymaker, 2002).

In our problem context, there are different actors like farmers, researchers, government decision makers, NGOs, crop inspectors, business owners, and information providers who are expected to have different understanding or perceptions regarding the problem situation and the potential solutions to their perceived problem situation. Such different understanding and perceptions about the problem situation and the potential solutions are expected to shape the behavior of different actors towards organizing their actions in the management of the two diseases (Maloy, 2005; Leeuwis and Aarts, 2011; Jørgensen et al., 2009; Aarts and van Woerkum, 2005; Checkland, 2000). As highlighted in (Cieslik et al., 2018), collective action problems are further deepened by power imbalances and imperfect or asymmetric information. This warrants the need for a nuanced look at existing perceptions, views and practices that in one way or another play a role in shaping collective action in the management of the two diseases. A good understanding of this complexity is, therefore, a critical step to unravel whether and how ICT enabled collective action can play a role in the management of bacterial wilt and late blight.

In the context of disease management, traditional silo approaches (segmenting a complex whole) usually serve as barriers to understand underlying problems that emerge out of complex interactions (Mazet et al., 2014). In this regard, 'soft systems thinking', provides a framework for a holistic appreciation of complex problem situations by eluding fractionalization of problems into pieces. Moreover, the soft systems perspective provides enough emphasis to fluid and intangible social aspects that are known to slip under the radar of 'hard systems thinking' approach (Checkland, 2000; Senge, 2006). We posit that actors involved in the management of bacterial wilt and late blight need to have an understanding of systemic problems to be able to collectively design and implement effective management strategies. We define 'systems thinking' as actors' understanding of the systemic structure or underlying patterns of behavior in a complex problem situation of bacterial wilt and late blight management. Although there are technical and socio-ecological differences between the two diseases, at systemic level problems of both diseases share more or less similar organizational actors and institutional context. Owing to this, our study mainly takes into account differences that are believed to have influence on how the different actors understand the problem situation in the management of the two diseases. Adapting concepts from soft systems thinking, this article will answer the following three research questions: 1) To what extent and how do actors understand the systemic structure in the complex problem of management of bacterial wilt and late blight? 2) How does their understanding of the systemic structure facilitate or hinder collective action in the management of bacterial wilt and late blight? and 3) What opportunities exist for ICTs in overcoming collective action problems?

The research was conducted in Ethiopia and specifically addressed

farmers in Wolmera and Gumar districts. Data were collected in a multi-stakeholder workshop and through in-depth interviews with direct and indirect actors.[3] The interviews generated qualitative information about actors' understanding of the problem situation in relation to our area of inquiry outlined in the research questions.

The article is structured as follows. The next section presents our conceptual framework by first briefly addressing 'systems' and the prominent distinctions in 'systems thinking' at a theoretical level. The subsequent section then explains the methodology that was used to collect and analyze the data. This is followed by the results section and the discussion section. The article ends with presenting the main conclusions.

2. Conceptual framework

Unlike the hard tradition which presumes that the world contains 'systems' which can be engineered, the soft tradition assumes a 'system' to be a fluid social world, one which persists and changes (Checkland, 2000; Vickers, 2013). In this regard, systems or 'human activity systems' do not pretend to be models of the world with predefined elements but mainly a set of interlinked activities which embody a particular purpose or a specific stated way of viewing the world (Checkland, 2000; Mingers, 1980). Appreciating such system construct, Senge (Senge, 2006) defines 'systems thinking' as a mental model for seeing the structures that underlie complex situations and for selecting high from low leverage change. Thinking in systems is about reframing how people think about what they view as a problem in the first place, and what solutions might look like (Cabrera et al., 2008). Checkland (Checkland, 2000) refers this framing of a complex problem situation as a perspective of a reality or 'a world-view'.

Conceptual literature in the field of plant disease management emphasizes two key elements when discussing disease management. One is the use of systematic approaches to diagnose diseases and monitor risk levels. The second one is selection and implementation of short-term or long-term disease management strategies (Pernezny et al., 2016; Van der Plank, 2013; Apple, 1977). Taking these elements as major activities in disease management, we consider bacterial wilt and late blight management as a complex 'human activity system' that involves a range of interlinked activities. However, as highlighted in the introduction, complex problem situations involving human affairs are not straightforward and cannot be fully defined in technical terms. Understanding of the wider institutional context is equally important (Checkland, 2000; Midgley, 2003). In soft systems thinking, institutions are not just simple administrative and political organizations, but also are the rules, norms or perceptions which structure and are structured by people's practices and their areas of social endeavor (Krueger and Gibbs, 2010; Röling and Leeuwis, 2001a). These institutions, therefore, can be 'formal institutions' which are consciously designed and clearly specified as in the form of written laws, rules or regulations, within which different social entities or actors operate, or, can be 'informal institutions' such as political culture, unwritten customs, norms or perceptions which informally shape the way 'business is done' by different actors (Krueger and Gibbs, 2010; Smith, 1997). This perspective framed our approach to a complex problem situation whereby different thematic lines through the lenses of 'technical' and 'institutional' problem dimensions are used to analyze actors' understanding of systemic structure in the problem of bacterial wilt and late blight management. Our conceptualization of systems thinking that is employed to discuss the thematic lines is elaborated in the next paragraph.

In complex and dynamic human systems, Senge (Senge, 2006) positions systems thinking as a conceptual cornerstone and a fundamental discipline that frames how actors ('learning organizations' as he calls them) understand a complex problem situation and in turn respond to it. Systems thinking is about actors' understanding of systemic structure that defines a system's pattern of behavior to create the conditions for events to become likely. It entails going beyond individual mistakes, personalities, organizations or snapshots of events to see underlying patterns in the system. Seeing major interrelationships underlying a problem situation leads to new insights into what might be done to change the pattern of behavior which in turn can change events. Based on this notion, one way of investigating if people see systemic structure or underlying patterns is to look into the way situations are explained by them. In this respect, the explanation can be a reactive one based on events which usually leads to practicing superficial or symptomatic solutions ('shifting the burden' as Senge (Senge, 2006) calls it) that may only improve events temporarily but leave the underlying problem unaddressed or even worsened. The other type of explanation, not common but very powerful, is a generative one based on systemic structure or root causes to a complex problem situation which helps in identifying and applying fundamental solutions to a problem situation. Having such systemic orientation also reduces the tendency of actors to victimize or blame a particular group or organization as a cause of a problem situation (Senge, 2006). Such perspective guided our analysis of actors' understanding of systemic structure in the complex problem situation of bacterial wilt and late blight management.

To clearly discern what is and is not an evidence of "systemic structure understanding", we made an extension of the concept by defining different instances for two types of explanations and associated practices (systemic structure vs event level) discussed in the conceptual framework. This is addressed in Table 1.

3. Materials and methods

3.1. Study context and actors involved

The study was conducted based on data generated from different actors that are involved in the management of potato bacterial wilt and late blight in Ethiopia. CIP (International Potato Center) researchers and secondary literature were consulted to decide on participating actors, both in a workshop and in in-depth interviews that were employed to collect our data (Haverkort et al., 2012; Gildemacher et al., 2009; Hirpa et al., 2010). Based on this, seven categories of actors were included in the study: Government actors, Non-government actors, FBOs (Farmer-based organizations), Research and Training Institutes, Farmers, ICT-based agricultural information providers and Private sector actors. Based on the information from the workshop, the government (Ministry, Regional, Zonal, District and Kebele agriculture offices) plays an important role in agricultural policy and strategy formulation, and public extension service provision. They also work, almost single-handedly, in agricultural inputs and outputs quality control and certification, and in input and output markets through farmer cooperatives and unions. Research and training institutes are mainly involved in the development, adaptation, demonstration, and popularization of agricultural technologies and in training of subject matter specialists. They also have a role in pest/disease inspection of imported potato germplasms or samples collected from potato fields and in providing technical advice in the development of strategies in input use, disease diagnosis, and management. Actors that are involved in the provision of agricultural information use different platforms (mobile-based interactive voice response; community radio and videos) to reach out to their target communities. Only ATA (Agricultural Transformation Agency) provides information on potato agronomy and disease management through its mobile-based interactive voice response (IVR) system in pilot districts, not including our study districts. NGOs are involved in training and capacity development, agricultural inputs service, market linkages and extension services. FBOs, with strong monitoring from the government, principally work in seed

[3] Those actors with first-hand involvement in the potato disease management are labeled as direct actors. Actors who do not directly work in the sector but obliquely influence the wider context are categorized as indirect actors.

Table 1
Event-level and structural explanations and actions.

Event-level explanations and actions	Structural explanations and actions
a. If actors talk about personal, organizational or event-related problems when explaining the different aspects of the problem situation framed as technical and institutional	**a.** If actors talk about long-term patterns and interactions among different activities when explaining different aspects of the problem situation framed as technical and institutional
b. If actors explain or practice solutions that are targeted at fixing personal, organizational, event-level problems	**b.** If actors see interdependency between their activities or engage in concerted action to deal with perceived problems
c. If actors take assumption of an 'external cause' to a problem or blame others for a problem situation	**c.** If actors see their actions affect the behavior of other actors to create the problem situation they discuss
d. If actors mainly focus on their own decisions or dwell on their own judgment about 'actions to improve' a problem situation	**d.** If actors talk about the need for accommodations of different perspectives and interest of actors

Table 2
Summary of data generation method.

Data generation method	Objective	Administrative level	Actor categories and number of participants							
			Farmers	Govt. actors	Research and Training Institutes	NGOs	Agricultural Information providers	Private sector	FBOs	Total
Multi-stakeholder workshop	Participatory analysis of systemic constraints in potato bacterial wilt and late blight management	National	–	1	2	2	3	–	–	**21**
		Regional	–	1	1	–	–	1	0	
		District	–	1	–	–	–	–	2	
		Kebele	4	–	–	–	–	–	3	
In-depth interview	Generate information on actors' views of bacterial wilt and late blight problem situation	National	–	2	3	2	3	–	–	**30**
		Regional	–	2	3	–	–	1	–	
		District	–	4	–	–	–	–	2	
		Kebele	6	2	–	–	–	–	–	

potato production and agricultural input-output markets. The co-operatives have management committees, which are usually composed of model farmers, to monitor potato disease problems among others. Due to the active involvement of the government in input and output markets mainly through farmer cooperatives, the private sector was found to have quite limited engagement, at least in relation to activities relevant to the management of the two diseases. This is evident in Table 2 where it shows that it was only possible to include a single private sector actor both in the workshop and interviews. Administratively, the actors are distributed from the national (federal) level to 'Kebele' level, the smallest formal administrative unit, and are situated in the capital and regional cities and in zonal and district towns in different parts of the country.

As one actor category, individual farmers were included from Wolmera and Gumer districts which are among the major potato growing districts in the country. Wolmera is located in the Oromia region, at about 40 km west of Addis Ababa while Gumer is in the Gurage zone of the SNNP region at 220 km southwest of the capital city. Both districts are in the cool highlands with potato being one of the most important crops grown in a predominantly smallholder farming system.

3.2. Data generation methods

3.2.1. Multi-stakeholder workshop

In early November 2016, a one-day multi-stakeholder workshop was organized with 21 participants representing the above-stated actor categories. The workshop was organized with the objective of joint identification of systemic constraints and entry points for intervention in the management of late blight and bacterial wilt. A methodology from the Rapid Appraisal of Agricultural Innovation System (RAAIS) was adopted to systematically engage participants in a series of sessions to generate preliminary information on perceived constraints and opportunities in the management of the two diseases. Based on experience from RAAIS studies in different African countries the workshops provided a fast-track approach to have a generic understanding of the system that was subsequently validated and explored in more detail using the in-depth interviews (Schut et al., 2015). More generic but key findings emerged from the workshop session (e.g. *linear thinking, limited recognition of interdependency* and *shifting responsibilities*). Findings of the workshop were also instrumental in shaping the conceptual and methodological direction of the research. The workshop sessions were facilitated by the researchers and all workshop session presentations were audio-taped and transcribed.

3.2.2. In-depth interviews

Informed by the operational definitions outlined in the conceptual framework, a set of discussion points were developed. Between April and June 2017, in-depth interviews were conducted in a dialogue-based style with 30 individuals from the different actor categories out of whom 27 interviewees consented and were audio recorded. The decision on the optimal number of interviews was based on the concept of 'saturation' or the point at which no new information or themes were observed in the interview data (Guest et al., 2006).

All the interviews were conducted by the researchers with each interview taking one and half hours on average. During farmer interviews, district experts and extension workers were used as facilitators and, in some cases, as translators. As much as the formal interviews, informal conversations were instrumental in capturing information on issues that are perceived as socially or politically sensitive by the informants. Transect walks in farmers' potato fields and visits to agricultural offices, cooperative unions, input market dealers, seed quality inspection laboratories and research facilities of research centers were helpful in getting a picture of the situation on the ground. Field notes and photographs were also taken during the visits. Secondary literature was reviewed to identify some relevant teams under formal and informal institutions (Seed quality control, Research and extension, and Information sharing culture) that were found to be relevant in our problem context (Haverkort et al., 2012; Gildemacher et al., 2009; Trabucco et al., 2013; Liao et al., 2016; Guest et al., 2006). Table 2 presents an overview of the data generation methods used with the various actors at the different administrative levels.

3.3. Data analysis

The discussion points used for the interviews were loosely organized to allow actors to share their views and practices on a range of technical and institutional thematic lines that emanated from our conceptual framework (Disease monitoring and risk assessment, Disease management strategy and Politics and power relations) and that were identified from secondary literature (Seed quality control, Research and extension, and Information sharing culture). Discussion topics mainly focused on:

- Actors' perception of their roles in relation to potato disease management; their views about major problems in potato disease management; the solution they propose or the actions they take to deal with the perceived problems; the challenges they face in the process of implementing the solutions
- Actors' views about the roles of other actors, the nature of their interactions and the challenges they encounter when working with other actors; their views on how to deal with such challenges
- Actors' planning and implementation processes of different activities they execute; if and how they involve other actors in this process; their views and encounters on conflicting interests and the way they are handled

Based on our conceptualization of actors' understanding of complex problem situations (second element of conceptual framework), views and practices of actors that were captured in the discussion were coded and categorized into the different technical and institutional thematic lines. Inferences were then taken from their utterances in light of the operational definitions given on what constitutes and does not constitute a systemic understanding. Secondary data analysis was used to support our expert interpretation of the results and to put it in the context of current knowledge.

4. Results

The Results section is presented along the following three problem dimensions: Technical issues, Formal institutions and Informal institutions. As indicated in the Conceptual framework and Methodology sections, different themes are used to discuss the findings under each problem dimension. Themes discussed under the technical dimension are 'Disease diagnosis and risk monitoring' and 'Disease management strategies'. Under formal institutions 'Seed quality control' and 'Research and extension' are two thematic lines discussed. 'Political culture and power relations' and 'Information sharing culture' are themes discussed under informal institutions. Each section specifically addresses actors' understanding of the dimensions.

4.1. Actors' understanding of the technical problem aspects of management of bacterial wilt and late blight

4.1.1. Disease diagnosis and risk monitoring

High-level experts in the government, research centers and NGOs felt that disease diagnosis or risk assessment on the incidence or epidemics of bacterial wilt or late blight should be principally done by government extension workers and farmers themselves. In this regard, most informant actors, particularly government experts and researchers, strongly believed that apart from resource constraints to effectively respond to the diseases, limited knowledge of extension workers and farmers on the symptoms, favoring conditions and dispersion mechanisms of the two diseases is the key problem for existing gaps in diagnosis and monitoring of the two diseases. When it comes to technical advice on late blight and bacterial wilt management farmers seem to prefer to rely on their own judgment. Although extension workers thought that farmers have limited knowledge on detecting the diseases, most interviewed farmers believed that it is not necessary to seek advice on detecting the two diseases. Detecting late blight was perceived as an easier task for the farmers that can be done without a help from the extension workers. A farmer said: *"When you see a disease symptom on your field, you just buy chemical and apply"*. Farmers also seemed to be reluctant to seek advice on bacterial wilt[4] monitoring. A farmer stated: "*There is not much the extension workers could do for you, there is no remedy for the disease*".

At the Ministry, and regional levels, crop protection experts understood their mandate as strategic planners and resource mobilizers in the management of different migratory and regular crop insects and diseases. There are other more economically important crop diseases that are given more attention than potato diseases. Experts gave a strong emphasis on insects and diseases of crops that are designated as strategic by the government. These are crops such as wheat, teff, maize, barley, oilseed and pulses that are produced in a larger amount, cover a wider geographic area or are essentially export commodities. Among the insects and diseases that are given high emphasis, Desert locust, Armyworm, rust, and maize lethal necrosis disease are the major ones. Owing to the focus on other crops, crop protection experts at the Ministry and regional offices said that they had little information on potato diseases in general and late blight and bacterial wilt in particular. In this regard, some opinions of district experts and extension workers at the study sites supported what is observed at the Ministry and regional levels. A district expert in Wolmera stated: *"Being one of the most important crops in our district, potato production is highly constrained by late blight and bacterial wilt but as the crop is given little attention at the regional level, it is affecting our district."*

Ministry and regional experts stressed the importance of getting their personnel and logistics ready before seasonal insect and disease outbreak comes. Once they have the resources at their disposal they can coordinate their efforts with all crop protection experts working at different levels and go out for a campaign until the disease or pest is under control. Time-bound responses are given when there is a high incidence or outbreak of diseases. But the main challenge for the high-level experts is their limited capacity to timely respond to disease outbreaks. Experts complained: "*we usually try to control outbreaks after disease or pest has already inflicted too much damage*". Farmers also seemed to follow the same routine whereby they responded after the incidence of diseases. This was highlighted by a farmer in Gumer who said: "*to reduce damage, many farmers apply chemicals when late blight is observed."* The monitoring and gathering of information on disease incidence or severity levels are mainly done by the government, an activity that is perceived as poorly organized by experts in the Ministry and regional agricultural offices. Only farmers or field level government experts do the diagnosis and share the information with high-level experts at the Ministry and regional agricultural offices. Information on high incidence of late blight is shared with regional agricultural offices who are supposed to coordinate management responses but there is no similar practice for bacterial wilt so far. The contribution of the national research institute through its crop protection research unit is marginal due to researchers' perceived logistical and human resource problems. It is worthwhile to mention that neither the extension workers nor an informant seed quality inspector operating in Gumer district were aware that the cooperative union has experts working on disease inspection, and similarly a district crop protection expert had no information on the existence of the seed quality inspection office.

4.1.2. Disease management strategies

Most farmers believed that the only available management option for late blight is fungicide application, which they usually apply after disease occurrence. Few farmers mentioned that resistant potato varieties such as Gudene and Belete are better resistant to late blight

[4] Almost all extension workers and farmers find it difficult to mention symptoms or spread mechanisms for bacterial wilt.

compared to their local varieties. But they tended to relate the importance of the resistant varieties rather to their contribution to increased productivity than to their ability to resist late blight, which was contrary to researchers' view that the primary objective of releasing the varieties is for late blight resistance. Farmers seemed to be convinced that bacterial wilt management is beyond their capacity and that the local experts have failed to 'bring them solutions'. Similarly, there was a shared view among government experts that management of late blight can be done with existing fungicides, for which they facilitate access through farmer cooperatives. Shifting potato production to the short rain season was also mentioned by workshop participants as another key strategy to deal with late blight. Interviews revealed that in Gumer about 90% of the total yearly potato production is produced in the short rain season where late blight stress is mild. Bacterial wilt management is something that is difficult for the district experts to explain. Wolmera district expert articulated: *"late blight can be controlled with fungicide but bacterial wilt is a complicated disease and is beyond our capacity, I am personally tired of being unresponsive to farmers' consistent complaint"*. The only 'curative' management option that extension agents advise farmers for bacterial wilt is 'roguing' of wilted plants, which farmers label as hardly effective.

Researchers tended to associate the problem of late blight with farmers' limited access to late blight resistant varieties that have been released by the research centers. They also listed bacterial wilt management recommendations[5] that are barely known to potato growers and extension workers participating in the study. A researcher shared his view: *"our many experimental studies have proved that using resistant varieties is key to deal with late blight"*. Researchers mentioned resistant cultivar selection process as the most important technical aspect of late blight management arguing that releasing a disease resistant variety is a lengthy and demanding process that takes as long as twelve years from acquiring germplasm[6] to screening and performance evaluation which they thought is an overwhelming task.

4.2. Actors' understanding of the institutional problem aspect of management of bacterial wilt and late blight

The existence of laws, operational guidelines and procedures in 'Seed quality control' and clearly specified approaches in 'Research and extension' services (e.g. Participatory Research and Extension, non-pluralistic extension approach etc.) form the basis for their categorization as formal institutions. However, such formal institutions were not in isolation and interplay with existing informal institutions and the different technical problem aspects of the diseases discussed in the previous section.

4.2.1. Seed quality control

For workshop participants, marginal implementation of different seed quality-related laws and regulations[7] due to government's limited enforcement capacity was taken as a major challenge in potato disease management. Seed proclamation and legal framework on variety release, registration and internal quality control (Seed Proclamation No. 782/2013), the Seed System Development Strategy (UNDP, 2011), and the Quality Declared Seed program (ESA, 2015) were considered as the major ones. As can be seen from the documents and based on the opinion of government representatives from the workshop, MoANR (Ministry of Agriculture and Natural resources) consulted and worked with different partner organizations in developing the strategies. But there seemed to be a shared view among many of the workshop participants that its implementation should have been realized by the government seed quality control and regulatory offices at regional levels. In this regard, interviewed experts at the government regulatory offices also strongly felt that such regulations or procedures have not been effectively applied. A serious shortage of inspectors and logistical constraints to cover a wide geographic area under their mandate are among the main problems mentioned affecting their inspection capacity. In the QDS (Quality Declared Seed) scheme there is, at least in principle, 'zero tolerance' for bacterial wilt for seed potato growers. The inspectors assert that when a breach of the laws and procedures is observed, they try to take timely corrective measures as stipulated in the laws. The penalty ranges from giving written warnings and banning the sale of the seed potato to revocation of licenses. Apart from the inspection that the experts do, seed-producing cooperatives have farmer committees that inspect and supervise seed potato fields of members for disease problems. In this regard, government inspectors constantly blame the committees for their poor capacity, which according to them, has pushed all the inspection burden on them. Farmers and committee members criticize back inspectors for not doing a timely inspection as it is impossible for them to sell their seed without getting the approval of the inspectors.

NGOs that have active involvement in seed potato exchange are well aware of existing gaps in seed quality control. They explain that such problem is out of their mandate and that the government should have dealt with it. When there is an appeal from the government during times of crisis, the NGOs involve in emergency seed provision programs whereby they buy seed potatoes from different seed potato producing cooperatives in the country including farmer cooperatives in the study districts. They contend that their practice is 'safe' as they are buying seed from cooperatives that are government-certified, and further argue that the government's priority in times of crisis is to curb emergency situations.

4.2.2. Research and extension

Researchers in the workshop claimed that since the introduction of a participatory research approach in the national research system, their success in transferring knowledge and promoting agricultural technologies has relatively improved. Although in principle the participatory approach is meant to be implemented in close collaboration with the public-funded extension service and other relevant actors,[8] interviewed researchers felt that joint engagement is still poor mainly due to the limited support they get from the public extension system. A researcher explained: *"Extension workers are supposed to closely follow up the research activities especially in our absence but as the local administration hardly sees the activities as their own, extension workers have limited awareness and show little interest in the research activities. In many cases, we are obliged to pay per-diems to bring the extension workers on board and hire guards to avoid theft from farmers in the experimental fields"*. Another researcher added: "*all the delicate research processes done on experimental fields are considered as a waste of time by many of the low-level experts*". District experts and extension workers acknowledged the weak collaboration with the research but held researchers' approach responsible for the situation. According to them, they usually have little information on the objectives of the research activities as the researchers do not fully involve them in the process. A district expert contended: *"It is common to see research experiments in our area that we have no knowledge of how it is initiated"*.

Limited knowledge of lower level experts on crop specific problems like bacterial wilt and late blight was among the pressing problems

[5] Keeping farm equipment clean, roguing out and burying of infected plants, sorting infected tubers, eliminating host weeds, crop rotation, using clean irrigation water are among the practices.

[6] CIP is a key partner in germplasm importation from countries like Peru, Kenya and Uganda.

[7] Although there is no specific organization responsible for quality control of seed potato, in the last few years different seed quality related laws, strategies and guidelines that apply to potato and other crops have been developed.

[8] The Research, Extension and Farmer Linkage Advisory Council (REFLAC), group of stakeholders beyond research, extension and farmers, is meant to lead the linkage between research and extension but with marginal success so far (MoANR, 2013).

mentioned by the researchers that are hampering technology adoption. Another critical challenge for researchers was a scarcity of pathologists in the research system, a similar concern that was also raised by regional seed quality inspection offices. For them, universities are not giving enough attention to the problem. Interestingly, an interviewed plant pathology professor in a university, who had no knowledge of the researchers' and the inspectors' claim, shared a different view: "*No university in the country trains students in pathology at the bachelor level, I see no need! We used to train pathologists at master's degree level but as there is no job for them, we decided to shift the program to a more generic discipline in crop protection*".

Researchers largely see their roles as technology or knowledge generators. A researcher affirmed: "*we have a clear mandate in the system which is generating appropriate technology*". Informant researchers considered the public extension[9] as the weak link between their technologies and farmers. There are research departments with names like "Technology Transfer and Commercialization Directorate", "Technology Transfer Coordination Unit", and they have research positions as "Technology transfer research officer". For the researchers 'the extension research' wing in the national research system has been playing an important role in facilitating conditions for technology adoption by demonstrating, promoting and popularizing different technologies generated in the research centers. However, to their dismay, a recent BPR (Business Process Reengineering) reform[10] in SARI (South Agricultural Research Institute) disbanded the extension research department with a narrative that the existing role of the department is something that can be covered by the technology developers themselves.

4.3. Actors' understanding of informal institutional problem aspect of management of bacterial wilt and late blight

4.3.1. Political culture and power relations

The government actors, particularly at the Ministry and regional level, expressed the belief that they played a key role and had a wide range of activities from policy and strategy formulation to resource mobilization and implementation of strategic plans. The Ministry of Agriculture and Natural Resources was considered by many of the actors as a focal office at the top of the structure with the highest authorized decision-making body. Country-wide strategic and annual plans have been developed by different departments at the Ministry and regional levels to go down until it reaches the lowest administrative unit (Kebele).[11] Decision makers and experts at the Ministry and regional levels argued that doing strategic planning and monitoring at the high level is instrumental to coordinate countrywide agricultural development activities. Some district experts also claimed that the centralized planning process facilitates effective communication with farmers. Experts at the study districts mainly talked about the benefit potato farmers would get if they strictly follow experts' advice whether in the management of bacterial wilt or late blight or in other agricultural activities. Although many of the lower level experts reflected this view when it came to their downward relationship with farmers, they were also found to have reservations on their upward relationship with high-level experts and decision makers at the regional and ministry level. A seed quality inspector uttered: "*the regional office sends us the number of hectares of seed potato field that we are supposed to inspect in a year. We can only send feedback if it is not workable. Sometimes they send us numbers that are much higher or lower than what is planted in a season*".

Researchers distinguished the Ministry as a powerhouse that decides on the fate of agriculture in which researchers have little voice. A metaphoric description of the situation by a researcher was: "*Our research institute is a teeth-less lion, there is not much we can do about the problem of bacterial wilt and late blight*". The NGOs and the agricultural information providers also stressed the importance of having development projects that are in line, or at least not in contradiction, with government interests to be able to sustain in the system. An NGO expert illustrated a situation: "*Our new project approach on organic potato farming and biological disease control has been an issue for the government. If we implement our project, it means that about five hundred seed potato producing farmers that will participate in our project are not going to use inorganic fertilizers, chemicals or other inputs that are government recommendations. This became a huge concern for the government people. You know, one has to be cautious in matters like this as the government views us (NGOs) only as 'gap fillers' and can tell us to go away at any time*".

Almost all actors from the workshop or the interviews acknowledged that farmers are their key partners. However, many experts from the different actor categories, particularly government experts at the lower level, held the view that despite their efforts, farmers' 'lack of knowledge' was a major challenge for the sustained problem of bacterial wilt and late blight. Likewise, NGO experts and agro-input suppliers also complained how 'limited awareness of farmers' and 'resistance to change' have compromised the success of their interventions or services. Although many of the interviewed experts believed that trainings can eventually change farmers' situation, they also mentioned that farmers usually show little interest to 'attend' or 'learn' from the trainings they organize. Among all the actors, the potato farmers are the most reluctant to share their views and mostly shy away from discussing matters that they perceive as political or will offend other actors. Very common utterances from farmers when they talked about their engagement with other actors included: "*…the district and CIP works for us….*"; "*based on the directive given to us….*"; "*…just like they told us….*"; "*if they bring us a solution…*"

Box 1 portrays a picture of the government power structure through which different agriculture-related plans are channeled. In such arrangement, farmers are expected, at least in principle, to comply with a plan that emanates from the government's strategic development agenda.

4.3.2. Information sharing culture

Lower level government experts at the districts mainly use the social organization, discussed in the 'Politics and Power relations' section, to share different types of information with farmers. They said that through the structure, they can easily share information with farmers on different development agendas including agriculture. In such communication, mobile phone plays an important role according to a district agriculture office head in Gumer. He illustrated: "*These days, communicating with farmers has become easy. All we have to do is call leaders of each 'Farmer Development Groups' and pass our message and the leaders will then call and tell each 'one-to-five' leader under them. The 'one-to-five' leaders can easily reach out the rest of the four farmers in their group who usually are their neighbors*". In such a way model farmers (group leaders), assisted by the extension workers, are expected to play a key role in facilitating information sharing with farmers. The experts labeled the model farmers as fast adopters and innovators who can play an important role in influencing other farmers that are perceived to be slow in taking up technologies. A district expert explained: "*We have model, middle and laggard farmers. We focus on model farmers who are only about ten percent of the farmers*". Government initiated trainings are organized separately to the model farmers and then together with the rest of the farmers to help the models play their catalytic role effectively. However, some of the informant farmers seemed to have their reservations on the approach stating that model farmers are usually

[9] Researchers claim that apart from knowledge gaps of extension workers in crop protection, spending their time in other activities, such as distribution of agricultural inputs, and collection of input credits and taxes from farmers, is negatively affecting their role as technology promotors.

[10] After recognizing the gap in 'bridging' research and extension, the extension research department is now back in the structure again.

[11] The plan can cascade down to the level of individual farm households as is the case in one of the study districts, Gumer. The 'politics and power relation' section provides a more detailed illustration of the planning process.

BOX 1
Organizational structure of channeling agricultural development plans

Based on countrywide strategic plans such as GTP (Growth and Transformation Plan), AGP (Agricultural Growth Program), SLM (Sustainable Land Management), short-term plans are developed by high-level experts in the different departments of the Federal Ministry or regional agricultural offices. Plans developed at this level will be shared with each zonal agricultural office within the regions. Based on those figures, the zonal offices disaggregate the information to each district under the zone and the district follows the same procedure to distribute it to the 'Kebeles' which are the lowest formal government administrative levels in the country. In such a cascade of plans, the role of the offices at immediate lower level is more of providing feedback on invalid assumptions. Although it is not formally part of the government administrative structure, a 'Kebele' also called 'Peasant Association' in rural Ethiopia, is divided into clusters that contain quite a few groups of farmers that are labeled as 'Farmer Development Groups'; the number of farmers in each group ranges from twenty-five to forty. In an ideal situation, three extension workers are distributed to closely work with such groups. Each development group has leaders appointed as chairman, vice chairman and secretary who, in most cases, are 'model farmers' and have a strong link with the local administration. To be able to get to individual farmers, 'Farmer Development Groups' are divided into a group of five farmers which is locally known as 'and le ammist', meaning 'One-to-Five'. In this final social grouping, as its name indicates, one (Model) farmer leads a team of five farmers. Using this structure, which has been in place for a decade or so, the government tries to structure its power and communicates its development agenda until it gets to a farm household level. The 'Kebeles' have a standardized form that will be filled by each household which in aggregate will fit into its Kebele-wide plan.

reluctant to share the information they access and are only benefiting themselves.

Organizations that are engaged in providing agriculture-related information to farmers and other actors through the use of different ICT platforms mainly see the problem of bacterial wilt and late blight and other crop diseases in relation to having access to reliable or timely information on existing scientific management techniques. It is a widely held view that limited awareness among governmental and non-governmental actors on the role ICT can play in crop disease management and in the wider agriculture sector is a challenge. There are different perceptions on best-bet information delivery tools ranging from 'mobile-based voice response' to 'participatory radio programs' and 'educational videos'. Providing scientific and evidence-based information is a critical factor for the interviewed experts. They argued that if scientifically proven technologies and practices are shared with farmers through available ICTs, farmers are more likely to adopt it as they will see the benefit. For this reason, information contents are mainly developed by subject matter experts within or outside the organizations. They stressed the need for developing a content that is not in contradiction with the government's extension advisory service. The information content in the ATA IVR (Interactive Voice Response) system, the first of its kind in the country, mainly adapted 'improved technology packages' used by the government extension service whereby government experts from ATA, Ministry, and national research centers participated in repackaging the content to fit to the IVR system. An expert in the organization explained if there is a need to update the content by ATA, it has to be approved by the Ministry of Agriculture and Natural Resources for its conformity with governments' recommended practices.

5. DISCUSSION: a systems thinking perspective

5.1. Diagnosis and risk monitoring

The problems mentioned in relation to the limited capacity of extension workers and farmers on diagnosing and monitoring bacterial wilt and late blight, or the resource constraints are more likely manifestations of a more structural problem that appears to be overlooked by many of the actors. Failure to adequately manage a disease can often be traced back to a failure to correctly diagnose or monitor risk levels of the problem (Palmateer et al., 2016). In the management of bacterial wilt and late blight, a preventative attitude is very important as attempting to rescue a field after disease infestation does not give satisfactory results, especially with bacterial wilt. In this regard, disease management practices of the government and those of farmers are by and large campaign-based and reactive rather than being preventive. Practically, preventive approaches for bacterial wilt can range from a containment strategy and strict quarantine measures to practices that are targeted on the reduction of inoculum sources (Yuliar and Toyota, 2015; Miller et al., 2006). In this regard, existing response-based conception and practice of disease management have intrinsically made timely or accurate bacterial wilt or late blight diagnosis and monitoring 'less relevant' in the eyes of decision makers leading to limited effort or investment to improve the technical skills of farmers and extension workers or to allocate the resources required for the work. A recent government strategy document on 'Pest and Disease Management' also proclaimed the government's growing recognition that the provision of crop disease management support service has been done only whenever there is an infestation of outbreak proportions reported by farmers (MoANR, 2016). Similarly, the focus on other more important crop insects and diseases by high-level experts and decision makers could be strategically right, but this would also mean that existing reactive disease management culture would even be more pronounced and less organized for bacterial wilt and late blight problems. The absence of accredited national plant protection laboratories along the ministry structure for diagnosing crop diseases, including potato diseases, and lack of monitoring or forecast systems for late blight and quarantine measures for bacterial wilt (Haverkort et al., 2012; Gorfu et al., 2012; MoANR, 2016) are other manifestations of the structural problems that are considerably affecting proper late blight and bacterial wilt diagnosis and monitoring.

The perception by many of the actors, including the government, that disease diagnosis or risk assessment is an activity of the government has important implication from a systems perspective. Successful disease diagnosis or risk assessment approaches require networks of actors from the government, research institutions and local organizations which help to integrate risk assessment and monitoring activities on diseases (Mazet et al., 2014; Kelly et al., 2017). There seems to be a high tendency, both by the government and other actors, to see disease monitoring and risk assessment as the government's task. The tendency to underemphasize the role of other actors, which we consider as a structural problem, is limiting actors' capacity to collectively act in diagnosis and monitoring of the disease.

5.2. Management strategies

Disease diagnosis and monitoring, and implementing management options are related activities. As highlighted before, most disease control measures should aim at preventing or protecting crops from the disease rather than 'curing' the crop after it is diseased (Yuliar and Toyota, 2015; Miller et al., 2006). In systems thinking terms, the underemphasis in bacterial wilt and late blight diagnosis and monitoring,

which is argued to come as a result of the reactive disease management culture, will have a negative feedback in pushing actors to stick to the existing dominant reactive management approach (Senge, 2006; Kim and Anderson, 1998). Owing to this, the predominant management practices, roguing for bacterial wilt and fungicide application for late blight are done after the incidence of the diseases. Such reactive responses might seem logical at the time of bacterial wilt or late blight prevalence and can indeed suppress the problem at that particular point in time but it has little long-term effect in curbing the recurrence or the fast spread of the diseases. The government has just recently acknowledged that bacterial wilt of potato which used to be a problem in few places has now turned into a national problem due to the existing management responses that are tactical rather than strategic (MoANR, 2016). A recent study by a national research center associated the problem with existing neglect for bacterial wilt suggesting the need for recognizing the potential danger of the disease to potato growers in the country (Gorfu et al., 2012).

An interesting reactive response mentioned by workshop participants that is also criticised by a previous study is the shift in potato production in many parts of the country from the long rain season (*Meher*) to the short rain (*Belg*) production, despite the high yield potential in the long rain season (Bekele and Eshetu, 2008). Promoting preventive late blight management options without sacrifying yield as a result of shifting to the short rain season could have been a more systemic response. This is with the rationale that the overall objective of late blight disease management is taken to be improving potato productivity or reducing the associated yield loss (Kirk and Wharton, 2014; Burke, 2017). Application of fungicide is the most widely used late blight management practice by potato farmers in the country (Mekonen et al., 2011; Kassa and Beyene, 2001). However, uncontrolled application of fungicide is recognized for its contribution to the development of chemical resistance in the country (MoANR, 2016). The same practice, if supported with a monitoring and information sharing mechanism on when and how to apply chemicals before late blight incidence, could have been a preventive option for the disease (Pernezny et al., 2016). Such 'event' level responses could not fundamentally prevent the disease epidemics from recurring season after season or could not significantly reduce initial sources of infections.

Another notable finding from actors' views in relation to the management of the two diseases is the tendency to look at the problem situation from one's own organizational mandate or area of involvement. This is evident from the diverging views of actors on the appropriate management options for the diseases. Successful implementation of preventive management options is affected by existing perceptions towards the need for coordinating efforts. Addressing complex challenges like bacterial wilt and late blight requires that interdependent actors navigate the complexity with the help of continuous monitoring and learning, and translate progressive insight into effective coordinative capacity and collective action (Maloy, 2005). Actors' behavior to collaborate or collectively engage is highly influenced by how the different actors see their roles and scope of influence in the disease management system (Senge, 2006; Kim and Anderson, 1998). However, due to a strong emphasis on one's own organizational mandate or limited recognition of interdependencies of activities, which the different aspects of it will be discussed in the subsequent sections of this paper, successful joint engagement could not be materialized. The existing firefighting mode does not particularly work for the management of bacterial wilt, which usually demands combinations of management options that can best be implemented collectively by farmers in a village or a district (Bekele and Eshetu, 2008).

5.3. Seed quality control

Through a systems thinking lens, one can clearly observe a fixation on responding to a short-term situation in relation to the different problem aspects of seed quality control. Apparently, emergency seed potato provision, in a poor disease management culture, will not only advance the spread of the diseases, it can also contribute to other emergency situations when one takes into account the economic importance of the two diseases for potato growers (Gorfu et al., 2012; Kassa, 2012). As can be witnessed from the utterances of the inspectors, whenever potato seed quality control issues were raised, the inspectors mainly talked about event-level interventions like doing a timely inspection, giving instructions, warnings or revocation of license. The 'quick fix' solutions and a focus on their own activities have gravitated the actors to blame others for the problem without acknowledging that their own action is affecting the behavior of other actors thus creating the very problem that they blame others for (Senge, 2006). Similarly, the seed potato producing farmers in the cooperatives or the NGOs could have a chance to proactively work to change their own practices in the production or distribution of disease-free seeds but instead, they are more inclined to superficially react to the regulatory and procedural demands of the inspectors who primarily see strict enforcement as their main course of action. There is no doubt that enforcement of the regulations is necessary. However, a more systemic response could have been facilitating conditions for joint learning to improve the knowledge and technical capacities of potato growers and experts on the diagnosis, monitoring, and management of the two diseases (Maloy, 2005). This does not only help growers to produce disease-free potato seeds that different actors buy and distribute to different areas, it can also lessen the burden on the inspectors who are stretching their limited capacity to casually address bacterial wilt and late blight problems through enforcement of laws and procedures.

5.4. Research and extension

As stated by the researchers, over the years, limited adoption of agricultural technologies by farmers through the conventional research and extension approach has indeed brought a shift of emphasis towards participatory research and extension approach in the country (Bedane and Kuma, 2002). It was envisaged that the new approach will bring together the knowledge capacities of local communities with that of scientific institutions and other stakeholders in processes of technology development and use (Bedane and Kuma, 2002; Tesfaye et al., 2002). However, despite the claim to this shift, it is observable that the traditional technology transfer model is still a dominant thinking. Researchers' statements seem to implicitly authorize scientists or research institutes as the only or major suppliers of knowledge products. Existing names of the different research departments are also good imprints of a linear thinking mode. Without working towards a shift from this thinking, the 'participatory approach' cannot facilitate interactive learning processes in the direction of joint creation of knowledge and collective action (Röling and Leeuwis, 2001b). Contrary to this, a striking event-level response or a simple-fix from the researchers to the problem of not getting the required support from extension workers or farmers is paying per-diems or hiring guards. Such responses would likely have a negative long-term effect on the very participatory approach by reinforcing existing attitudes of the extension workers and probably farmers[12] in seeing the research experiments as solely researchers' business.

Moreover, the extension research wing in the national research system is preoccupied with 'technology demonstration' and 'popularization' activities. This limits its research engagement on wider systemic issues or in knowledge brokering which could have contributed to institutional innovation and transformation of the enabling environment for technology development and use (Turner et al., 2016; Turnhout et al., 2013). However, as to what seems to be a total disregard to this structural problem, the decision made by SARI is to

[12] We could not capture farmers' opinion as none of the farmers approached for the study said they had experience in participatory research.

dissolve the 'Extension Research' department. A shift from a linear knowledge/technology transfer culture could have been a generative response to improve the effectiveness of the participatory research and extension approach and its contribution to co-creation of knowledge and technologies that are more relevant to the management of bacterial wilt and late blight.

From the utterances of the different actors, one can observe similar defensive routines by the different actors while explaining the different aspects of the problem situation. Such propensity of shifting responsibilities is also reflected in the Ministry's strategy document whereby its linkage with the national crop protection research has remained a very loose owing to the research institute's low focus on plant protection technology generation (MoANR, 2016). From a systems thinking perspective, the tendency to engage in a blame-game or to see themselves in isolation have led them to look for an external cause to the problem situation (Senge, 2006).

5.5. Politics and power relations

As people have a particular way of viewing the world, judgments to be made or 'actions to improve' a problem situation should seek accommodation or deliberation among different views and interests of actors. So politics is taken to be a power-related activity concerned with managing relations between different views and interests (Checkland, 2000). Bearing the mantle of leadership in 'smallholder-based sustainable agricultural growth and development' (Chanyalew et al., 2010), the government is playing a very dominant role in planning and agenda setting in a hierarchical and top-down fashion. By the virtue of emphasizing on the expediency of this approach, some of the decision makers and experts in the government showed little regard for any power asymmetry that could arise from the top-down decision-making process. Even though the government's approach might have emanated from pure ambition and an assumed leadership role, a vision that does not appreciate interests and aspirations of the farmers or other actors can fail to inspire genuine enthusiasm. Decision-making processes can be transformed if all concerned actors become more able to surface and discuss productively their different interests and aspirations (Senge, 2006).

Strong dominance of the government ministry and its downward structure also seem to affect perceived capacity of other actors to instigate change in the system. This is clearly visible in the opinions of researchers and NGO experts on their perceived limited ability to change the problem situation and on the importance of aligning their activities with the agenda set by the government. In systems thinking terms, such attitude and associated behavior create a difficult condition for all the actors to fully realize or unleash their potential for coordinated action (Senge, 2006). Although meaningful change can best be realized when powerful actors like the government see the importance of accommodating different interests, the belief of the other actors that change has to come from outside (the government) is characteristic of non-systems thinking. It is when actors see themselves as part of the systemic structure that they realize they have the power to alter the structure of the system (Mazet et al., 2014; Kim and Anderson, 1998).

Farmers, who usually are claimed to be 'key partners' by the different actors, find themselves even in a more difficult situation to express their interests. Some of the common utterances from farmers clearly reveal their perceived position in existing power relations. A previous study on participatory natural resource management intervention in the country also supports our assessment that a restrictive political context and widely held negative attitudes towards farmers have undermined self-confidence among farmers, many of whom seem to have internalized the perception that experts and decision makers have towards them (Cullen et al., 2014). The perception that lack of knowledge of farmers is a key problem has shifted the focus of actors towards training and capacity building activities. However, different literature on power relations has already underscored that such interventions can potentially mask or exacerbate the more structural problem of power inequalities if existing power dynamics and the need for accommodation of different interests are not taken into account (Cullen et al., 2014; Aarts and Leeuwis, 2010 1).

5.6. Information sharing culture

As interactions are quite centralized and hierarchical, information sharing is practiced in the same mode. As part of an attempt to come up with a different approach, there have been some experiments on participatory information sharing and learning platforms by different international research-for-development organizations, particularly CGIAR institutes working in the country (Lema et al., 2015; Swaans et al., 2013; Abate et al., 2011). Although so far there is very limited local scientific evidence on the impact of such platforms in fostering interactive information and knowledge sharing or learning, a key insight from one empirical study in the country is of particular importance to our research topic. The study amplified that a failure to take into account power imbalances and political realities in and around learning platforms did not only gave the illusion of increased participation and learning but it also compromised the capacity of the platforms in catalyzing social change (Cullen et al., 2014).

Organizations that are engaged in the delivery of agricultural information through different ICT tools appear to have a shared 'technology-oriented' approach to information sharing which assumes that farmers will act in accordance with the implemented technology (Pilerot and Limberg, 2011). The experts mainly talk about how the information delivery tools can facilitate or improve farmers' or other actors' access to information, giving little emphasis to the existing top-down culture and power relations which are indicated to influence how actors access, interpret, share or use information. (Banjade et al., 2006; Leeuwis, 2004). Due to existing perception of information sharing as a technical rather than a social phenomenon (Checkland, 2000), the development of the information content that is delivered through the different ICT technologies is essentially expert-driven. The ATA approach can be a case in point whereby without changing the logic of content development or information sharing culture, their practice might have even increased the power of the ministry through its control on the information. Using ICTs to enable participatory and interactive information sharing is in stark contrast with classical, expert-centered approaches where ICTs are used primarily to support the dissemination of research-based information and advice (Cieslik et al., 2018; Leeuwis, 2004). On the other hand, if ICT-based interventions are context specific and build on local needs and capacities, it may enable the generation of new forms of locally relevant information and can catalyze new forms of network formation, information sharing and learning (Cieslik et al., 2018; Chapman and Slaymaker, 2002).

5.7. Opportunities for ICTs in overcoming collective action problems

Finally, our systemic analysis envisages to look for opportunities forleverages or small but well-focused interventions that have the potential of producing significant and enduring improvements to the problem situation (Senge, 2006). As it is discussed under the technical aspect of the problem situation, actors' limited recognition of interdependency and existing marginal collaboration poses a challenge to effectively monitor and manage the problem of bacterial wilt and late blight. The collective engagement problem becomes even more pronounced when the aim of disease management is geared towards disease prevention rather than disease control (Mazet et al., 2014). This is with the rationale that timely monitoring and risk information sharing, which are vital elements of a preventive disease management strategy, require a network of actors that should work towards reducing reoccurring risks of the diseases at the collective level (Liao et al., 2016). In this regard, different ICT platforms have been implicated to play a

meaningful role in overcoming connectivity problems or in complementing traditional collective action networks that aim to address complex challenges such as potato disease management (Karpouzoglou et al., 2016; Chapman and Slaymaker, 2002; Cieslik et al., 2018).

However, as highlighted in the introduction, the potential of ICTs to address coordination problems should be seen within the wider social, political and cultural context in which they are supposed to be used (Bennett and Segerberg, 2012; Chapman and Slaymaker, 2002). The amplifying function of digital technologies can, in fact, serve to perpetuate existing inequalities instead of eradicating them (Cieslik et al., 2018). If ICTs have to realize their full potential in contexts with limited horizontal and democratic information flow, active participation of actors at the periphery in the design, experimentation, and use of the digital platforms is crucial (Chapman and Slaymaker, 2002). In our problem context, farmers and low level (district) actors, who seem to be prime victims of existing power asymmetries and top-down information sharing, could be potential target groups for any ICT-supported collective disease management intervention. In doing so, the platforms will have the possibility to structurally alter the existing top-down flow of information and power inequalities by decentralizing information flow, devolving ownership over information and knowledge, decreasing dependency and providing a framework for shared learning (Karpouzoglou et al., 2016; Chapman and Slaymaker, 2002). Moreover, designing ICT supported collective disease management interventions that target high-level actors at national or regional levels can potentially fail to bring genuine enthusiasm due to the prevailing focus on the management of other insects and diseases of strategic crops. Although bacterial wilt and late blight management are still weak at the district level owing to the overall reactive disease management culture, the disease problem appears to be more recognized or felt by actors operating at the local level.

As noted by Cieslik et al., different forms of participatory digital platforms in combination with more conventional forms of interpersonal communication and mass media can foster new kinds of connectivity, and enable the collection, processing and exchange of information among different actors or members of a community (Cieslik et al., 2018). Mobile phone technology has rapidly been accepted in rural communities and is playing an important role in fostering interaction between farmers, extension bodies and institutions (Chapman and Slaymaker, 2002; Chou and Min, 2009). Given the absence of potato disease forecast or early warning system in the country, ICT supported decision support tools can have a potential contribution in the generation and exchange of information that serves to initiate collective risk monitoring of late blight and in curbing existing practices of fungicide spray that is being done after late blight occurrence. Sharing information on the likelyhood of late blight occurrence and on preventive spray regimes that help growers and other local actors for individual or collective decision is now becoming easier through mobile phone networks in places with low internet penetration like Ethiopia (Nakato et al., 2016). Likewise, digital platforms can play a role in the exchange of information on the different disease dynamics of bacterial wilt (e.g. prevalence, diagnosis, monitoring and control options). This can help the actors to better recognize the risks of bacterial wilt, which seems to get limited attention so far. Most importantly, information sharing and learning on the risks and management of bacterial wilt can assist potato growers to advance their unsuccessful practice (roguing) in the management of the disease. With the help of mobile phones, participatory monitoring can be performed by groups of community members which can foster joint learning on the disease dynamics and enhance awareness on the need for cooperation to effectively deal with it (Trabucco et al., 2013). By designing a more bottom-up and participatory approach to content development and technology modification to better fit into local needs, existing infrastructure such as the ATA AVR system can be leveraged to better ensure institutional

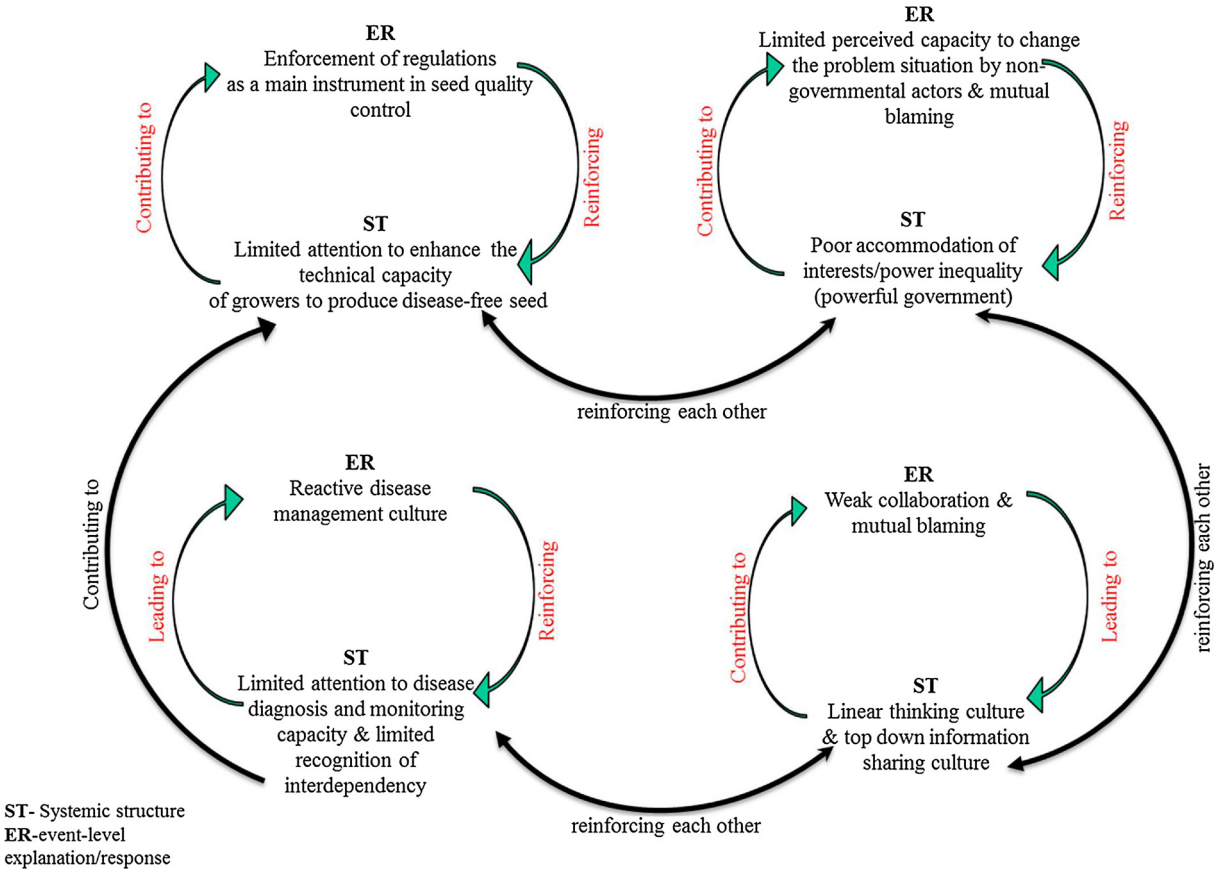

Fig. 1. Systemic structure at play in the complex problem of management of bacterial wilt and late blight.

embeddedness. To this end, further investigation on existing information and knowledge needs in relation to the diagnosis and management of each disease would help to arrive at specific recommendations on best-bet technology options and the content of information that can be used to catalyze disease monitoring, broader learning, and collective action.

6. Conclusion

This study attempted to assess actors' understanding of the problem situation in the management of bacterial wilt and late blight along multiple and interacting technical and institutional problem dimensions (Fig. 1). In so doing, it further explored its implication for management of the two diseases and the role ICT can play in overriding collective action problems. As it is demonstrated in our analysis in Section 5, actors essentially overlooked key systemic problems that are contributing to the continuation or even worsening of the disease problems. Lack of preventive management culture, limited recognition of interdependencies among activities of actors, power inequalities, top-down and linear approaches in information and knowledge sharing are among the key structural problems identified. Consequently, management responses are mainly geared towards uncoordinated short-term reactions that were found to have limited effect in catalyzing fundamental change to the systemic problems of bacterial wilt and late blight management. Fig. 1 depicts actors' key reactive responses (ERs) and the systemic structure at play (ST) across various technical and institutional aspects of the problem situation represented by the four circles with smaller arrows. It is further summarized in the figure that the systemic problems within the different problem aspects interact with one another to bring about a complex problem situation in the management of bacterial wilt and late blight.

Likewise, the existing appreciation of the problem situation has pushed many of the actors to mainly focus on their own activities and decisions with little recognition that the structural problems are results of multiple interacting factors to which they themselves, knowingly or unknowingly, have contributed their share. This is evident in actors' tendencies to shift responsibilities and engage in a blame-game when discussing the different problem aspects of the diseases. In light of our research questions, we can conclude that existing understanding of actors of the systemic structure has limited their capacity to effectively and jointly respond to the complex problem of late blight and bacterial wilt management.

As problems of bacterial wilt and late blight management have multiple technical and institutional aspects, new management interventions should also be designed in such a way that the interventions can instigate technical (preventive disease management) as well as institutional (power asymmetries and top-down information sharing) change. A bottom-up and participatory disease management approach can serve as a 'local' solution to a wider systemic problem whereby farmers, together with local level actors, can drive a positive change in the bacterial wilt and late blight management system. Local level actors such as extension workers, seed quality inspectors, researchers, and NGOs can be strategized to foster institutional embedding and broader learning.

As it is highlighted in the discussion section, a shift to a more preventive management culture warrants networking of local level actors who can collectively engage in disease monitoring and information sharing on different aspects of bacterial wilt and late blight management. Designing such interactive processes will not only help local level actors to better realize their interdependency and to have a shared understanding of the systemic structure at play, more importantly, it can facilitate collaboration and collective action to deal with their shared problem. In this respect, different forms of digital technologies or information sharing platforms can play a role in facilitating actor networking, information exchange, learning and collective action in the management of the two diseases. A promising intervention for late blight could be a mobile-based decision support tool that can be used for information sharing on disease monitoring and preventive fungicide use. Similar mobile-based digital platforms can be leveraged to enhance awareness and facilitate learning on bacterial wilt disease dynamics and management. To be able to come up with a more specific recommendation, more insight in existing ICT infrastructure, and information and knowledge needs in relation to the diagnosis and management of each disease is of paramount importance.

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