



Governing a Collective Bad: Social Learning in the Management of Crop Diseases

Elias Damtew^{1,2}  • Barbara van Mierlo¹ • Rico Lie¹ • Paul Struik³ • Cees Leeuwis¹ • Berga Lemaga² • Christine Smart⁴

Published online: 9 January 2020
© The Author(s) 2020

Abstract

There has been strong research interest in designing and testing learning approaches for enhancing and sustaining the capacity of communities to manage collective action problems. Broadening the perspective from well-known social learning approaches in natural resource management, this study explores how social learning as a communicative process influences collective action in contagious crop disease management. A series of facilitated discussion and reflection sessions about late blight management created the social learning space for potato farmers in Ethiopia. Communicative utterances of participants in the sessions served as the units of analysis. The study demonstrates how and to what extent social learning, in the form of aligned new knowledge, relations and actions occurred and formed the basis for collective action in the management of late blight.

Keywords Crop disease · Late blight · Social learning · Collective action · Communication

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s11213-019-09518-4>) contains supplementary material, which is available to authorized users.

✉ Elias Damtew
elohan.we@gmail.com

¹ Knowledge, Technology and Innovation Group, Wageningen University, Wageningen, The Netherlands

² CGIAR Research Program on Roots, Tubers and Bananas (RTB), International Potato Center (CIP), Addis Ababa, Ethiopia

³ Center for Crop Systems Analysis, Wageningen University, Wageningen, The Netherlands

⁴ Department of Plant Pathology and Plant-Microbe Biology, Cornell University, Geneva, NY, USA

Introduction

Potato late blight disease represents a serious problem for farmers in almost all major potato-growing areas (Tsedaley 2014; Mekonen et al. 2011; Kassa and Beyene 2001). On-station studies estimate yield loss¹ in Ethiopia to range from 6% to 100% depending on the level of susceptibility of the variety (Guchi 2015; Mesfin and Woldegiorgis 2007). As late blight is air-borne and the causal agent (*Phytophthora infestans*) travels across farm boundaries, it is not just a problem of an individual farmer but a collective problem of all farmers in a geographical area (Miller et al. 2006). The propensity of late blight pathogen to traverse farm boundaries means that control efforts by any farmer confer a benefit to other nearby farmers. It also means that lack of control on any property stimulates the development of the epidemic and thus imposes costs or losses on other properties (Graham et al. 2019; Marshall et al. 2016). Miranowski and Carlson (1986), in their seminal work, stress the critical role of the mobility of diseases and pests in designing collective management responses. Accordingly, the search for solutions and management practices should take into consideration, on one hand, technical effectiveness and, on the other hand, institutional mechanisms that stimulate and facilitate collective management at the appropriate scale (Graham et al. 2019; Zamani et al. 2018; Marshall 2016). To this end, there is a well-established research effort in designing and testing approaches aimed at enhancing collective capacity in the management of agricultural pests and diseases, generally engaging farming communities in a variety of communal management practices (Hegde et al. 2017; Christmann et al. 2015; Biedenweg and Monroe 2013a).

In the broader field of socio-ecological systems, stimulating social learning is a common recommendation for developing and sustaining the capacity of managing collective action problems (Mostert et al. 2007; Pahl-Wostl and Hare 2004; Rist et al. 2003; Schusler et al. 2003; Leeuwis and Pyburn 2002; Wollenberg et al. 2001). In this body of literature, social learning is extensively examined as a conceptual and methodological approach in facilitating knowledge generation and in forging new types of social relationships among resource users that have to deal with collective action problems. Conceptual perspectives on social learning predominantly take learning as an outcome or end result. Consequently, there is limited insight into salient processes and interactions that trigger a change in individual or collective decisions and actions in the management of socio-ecological problems (Bentley et al. 2018; Beers et al. 2016; Pahl-Wostl 2007). Furthermore, there is a tendency to limit social learning outcomes to consensus or agreements (as ‘identification of adaptation options’, ‘agreement on a common purpose’ or ‘design of governance processes and arrangements’) providing little information on whether such agreements instigated action in actual practice. (e.g. Graham et al. 2019; Hegde et al. 2017; Christmann et al. 2015; Scholtz et al. 2014).

Another significant feature of this type of research is the implicit assumption that some sort of recognition of the ecological or biophysical aspect of a collective problem exists among appropriators or public good providers (Bell et al. 2016; Cárdenas et al. 2015; Brugnach et al. 2011). With this background, the focus of research is often directed towards understanding ‘how’ or ‘in what circumstances’ social learning facilitates knowledge generation and sharing among common pool resource users as well as the social relations necessary for effective collective action on an already recognized collective problem. Such framing poses a particular challenge for the management of contagious crop diseases like late blight. The collective nature of the problem can be unclear to farmers due to the poor visibility of the life cycle and mobility of the pathogen, particularly when compared to other common-pool resources (e.g.

¹ We were not able to find studies that tried to quantify yield loss at farm level

forest, fish, irrigation management) or ‘public bads’ (e.g. invasive weeds, migratory pests). As a consequence, previous research in the study area indicated most farmers do not recognize late blight as a collective problem, mainly seeing it as a private bad (Tafesse et al. 2018). Against this background, we consider that social learning approaches for disease management need to pay sufficient attention to learning about key technical aspects of diseases that are characterized by less visible dynamics in the eyes of farmers (e.g. involving oomycete, viruses, bacteria, fungi) and this could play a crucial role in redefining the nature of the problem.

By taking a process-oriented perspective to learning, this study aims to understand how collective action in late blight management develops in a social learning process. It shows how social learning emerges in an organized learning space for potato farmers in Ethiopia and how it effects collective action of these farmers. In this way, it intends to offer fresh theoretical and practical perspectives on contagious diseases such as potato late blight as a collective bad and, correspondingly, the role of social learning in crop disease management.

The paper is organized as follows. Section 2 presents a detailed synthesis of our conceptual framework on collective action and social learning setting the scene for our research questions in the same section. Section 3 provides details of the research methodology where the case study context is also described. Our research findings are presented in section 4 and then discussed in section 5, followed by conclusions in section 6.

Conceptual Framework

Collective Action in Natural Resource Management

Drawing upon Olson (1971) notion of a collective good, Marshall (1998) defines collective action as an action taken by a group, either directly or on its behalf by an organization, in pursuit of members’ perceived shared interests. Whether a particular collective action concerns a public good or a public bad is an empirical, subjective issue because resource users may either suffer from a bad or fail to benefit from a good (Hardin 2015). This perspective entails that while contagious diseases like late blight are generally presented as a public bad that needs to be prevented, collective action provisions towards their management can also be regarded as a public good. In either perception, recognition of the collective nature of the disease is important, as was stated in the introduction.

In public good governance in the realm of agriculture and natural resource management, two types of collective action are distinguished: (1) *cooperation*: bottom-up, farmer-to-farmer collective action; and (2) *coordination* that is characterized by a top-down, agency-led collective action approach (Poteete et al. 2009; Davies et al. 2004). Broader debates around the development and success of collective action focus on key performance factors and barriers to be addressed to produce benefits from collective action. Hence, successful initiatives must overcome the most common barriers to collective action (Uetake 2012; Davies et al. 2004). In this regard, a range of substantive factors can govern the performance of collective action initiatives (Poteete and Janssen 2009; Heffernan et al. 2008). Collective action is, first, highly affected by the characteristics of the natural resource (type of good) involved and on the knowledge and the predictability of the resource. The successful integration of knowledge is key to enable communities to govern their public good/bad in a sustainable way (Pahl-Wostl 2009; Pretty 2003). Second, the social dynamics of the group involved, their shared interests and voluntary actions to pursue those shared interests are also significant. In these dynamics, community members should also improve

their social relationships to overcome their collective problems (Meinzen-Dick et al. 2004; Pahl-Wostl 2000). As Ostrom (1990) highlighted, collective action is also determined by institutional arrangements, involving both locally devised, simple rules and effective monitoring and sanction systems.

In the light of the above, it can be argued that the achievement of collective action in the management of crop diseases like late blight involves significant changes in two dimensions: a change in technical knowledge about the nature of the disease and a shift in social and institutional arrangements (Deuffic and Candau 2006). As illustrated in the next sub-section, the important challenges or success factors discussed here strongly relate to the central role of social learning in the transformation of knowledge, norms and rules amongst resource users in collective action initiatives (Leeuwis and Pyburn 2002; Roling and Wagemakers 2000).

Social Learning: Technical and Relational Dimensions

Social learning is a broad concept and is operationalized differently in different disciplines and contexts (Koontz 2014). In the domain of natural resource management, social learning is essentially appreciated as occurring when people are brought together to share perspectives and experiences to develop a common framework of understanding as a basis for joint action (Reed et al. 2010; Pahl-Wostl 2009; Schusler et al. 2003). The literature broadly distinguishes between technical² and relational dimensions of social learning (Phuong 2017; Koontz 2014; Scholz et al. 2014; Woodhill 2010; Pahl-Wostl et al. 2007; Bouwen and Taillieu 2004; Campilan 2002). The technical dimension concerns new knowledge or insights that relate to the natural or biophysical aspect of the problem situation. The relational aspect refers to emergent social properties, such as establishing new relations, breaking existing relations, and building trust and commitment to a group vision as groups become aware of their mutual interdependencies (Beers 2016; Koontz 2014; Reed et al. 2010). In this regard, the technical learning dimension relates to addressing the first determining factor for the success of collective action, namely knowledge about the nature of natural resource at hand. The relational aspect of social learning conforms directly with social competencies needed to deal with the second collective action performance-influencing factor. Social learning is also about creating opportunities for institutional change, relevant in the governance of collective action problems. (Gerritsen et al. 2013; Scholz et al. 2013). Correspondingly, we argue that apart from normative institutions (e.g. issues of trust, reciprocity), regulative institutions as in the form of defining or redefining of rules of engagement for collective action fall within the relational sphere of social learning.

Social Learning as a Communicative Process with Outcomes

A salient notion in the conceptualization and operationalization of social learning relates to seeing learning as a process and/or an outcome. As stated before, in the natural resource management domain, social learning is often defined in relation to a wide range of potential outcomes it may have (Biedenweg and Monroe 2013a; Scholz et al. 2014; Paul-Wostl et al. 2007). The essence of considering social learning as a process with outcomes has been highlighted in literature informed by learning theories from other fields like educational

² For what we call the technical aspect, different terms are used by social learning scholars such as content aspect, task-oriented dimension, biophysical aspect, ecological processes, environmental functions, natural environment, etc.

science and organizational learning (Beers et al. 2016; Biedenweg and Monroe 2013b; Senge 2006). Different learning processes can relate to different learning outcomes and an outcome is preceded by various framings, communicative interactions or coalition building processes (Van Der Stoep et al. 2017; Pahl-Wostl 2002; Joss and Brownlea 1999). Hence, one way of making claims about tangible outcomes of social learning is tracking communications and explaining the context in which it was observed (Rodela 2013). By examining communication among participants, it is possible to unravel how learning processes lead to tangible outcomes (Beers et al. 2016; Rist et al. 2006; Pahl-Wostl and Hare 2004; Lamerichs and Te Molder 2002). This constructivist approach regards communication not merely as a process of getting a message across, but as a phenomenon in which those involved construct meanings in interaction (Leeuwis and Aarts 2011; Aarts and van Woerkum 2008; Te Molder and Potter 2005). Communication itself is regarded as an (inter)action that has direct consequences for the social and material world (e.g. relations may be damaged, parties no longer meet, violence may emerge, etc.). From a communication perspective, collective action is, therefore, dependent on a change in communication, representations, and storylines that are mobilized by interaction (Bentley et al. 2018; Leeuwis and Aarts 2011).

Assuming that social learning takes place in communicative activities, means that it must become visible in, and can be identified in communication. As Beers (et al. 2016) highlighted the knowledge, relational and (collective) action dimensions are aspects of the content of the communication (i.e., what people talk about) and the social learning process is a communicative activity that aligns these three dimensions.

There is a distinction between (collective) action in communication, in the form of agreements, proposals or decisions and physical (collective) action (actual implementation of agreements on the ground) (Beers et al. 2016). While collective action in the form of agreements is treated in our study within the communicative aspect of social learning, the actual implementation (physical action) of the communicated agreement is regarded as an external outcome or impact of social learning. In view of our conceptual disposition, social learning is, therefore, a communicative process in which new or changed technical knowledge, social relations and suggested actions become aligned and may turn into collective agreements. As depicted in Fig. 1, these learning outcomes may further effect collective action in the management of late blight.

Informed by the literature gaps highlighted in the introduction and our conceptual framing as well as the case study to which it is geared, this study addresses the following research questions:

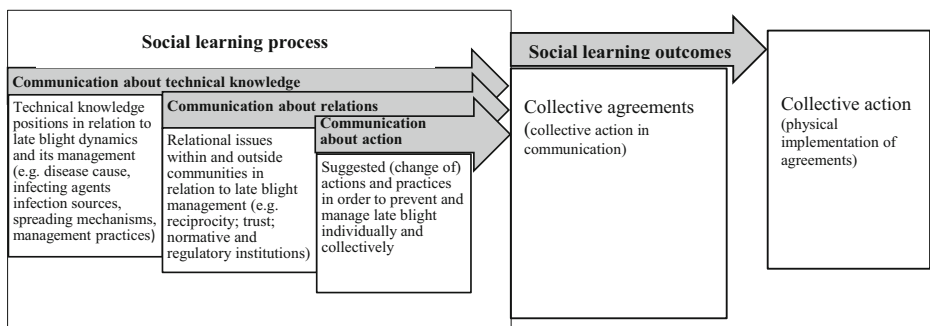


Fig. 1 Conceptual framework with perspectives from Beers et al. (2016), Bentley et al. (2018), Ostrom (1990); Scholz et al. (2013) and Rodela (2013)

Main research question: How does social learning as a communicative process influence collective action in late blight management by farmers? This main research question is subdivided into:

1. How do aligned technical knowledge, relations and suggested actions emerge in communicative utterances and relate with collective agreements?
2. To what extent and how do collective agreements translate into collective actions in the management of late blight?

Methodology

Case Study Context

The case study was conducted in a village (*Goro*) found in Wolmera district of Ethiopia's Oromia regional state. The village was selected considering issues such as production potential (it is designated as 'potato cluster' by the district), accessibility and the existence of suitable adjacent potato plots to justify collective risk situation. A total of 33 potato farmers participated in the case study. The livelihood of most farmers in the study area is primarily dependent on the cultivation of potato but also on other cereals and pulses such as wheat, barley, beans and chickpea. Most of the participant farmers are ware potato producers whereby they use a small portion of their produce for household food consumption and sell the rest in local markets as food potato. There was a seed potato producing cooperative in the area that only a few of the farmers used to participate in. The district office of agriculture was in charge of organizing the cooperatives and facilitating access to input supply and market outlets to other potato producing areas in the country. As it is further illustrated in the result section, there had been some trust issues between the farmers and the district office of agriculture, and among the farmers themselves that had consequences to the social learning process and outcomes.

Setting up a Social Learning Context

From a methodological perspective, social learning takes place in an ongoing chain of interactions, such as face-to-face meetings. These interactions offer a communication space for knowledge generation and sharing, social action and reflection (Beers et al. 2016; Leeuwis and Aarts 2011; Gee and Green 1998). The communicative interaction can be a spontaneous, self-organized natural process or something induced and guided by an external facilitator (Koontz 2014). Well-known strategies to facilitate interactions include the organization of discussion and reflection meetings. In addition, practical actions and experiments to visualize unknown biophysical processes with the help of discovery learning tools can be relevant communicative strategies for supporting social learning if they elicit communication (Leeuwis and Aarts 2011; Loorbach 2007; Leeuwis et al. 2002).

A potato scientist, with support from the community extension worker, facilitated the technical learning sessions and the first author of this paper facilitated the reflexive, follow-up meetings. Following Ford's (1999) suggestion, the design of the learning context was arranged in such a way that it provided generic themes that guided the unfolding conversations around different technical or social issues in relation to late blight management. In this regard,

the social learning context was configured through concurrent technical (conceptual and practical) sessions and reflexive meetings that were meant to inspire discussions, learning and collective action in the management of the disease. There was a total of ten such learning sessions that contained technical sessions with reflexive follow-up meetings. Each learning session took an average of two and half hours. The first two sessions were focused on disease dynamics (definition, cause, symptoms and spreading mechanisms) and opportunities for disease surveillance. The remaining eight sessions, spread across the four-month growing season of the potato crop (June–September), were designed to facilitate social learning as participants were able to exchange perspectives, negotiate, discuss success and pitfalls, and agree or disagree around different technical and relational issues in the management of the disease. As listed below, most of the learning sessions had three major parts; the first part was covered mainly in the technical sessions and the other two during reflective meetings. However, as different discussion topics were interrelated, there were apparent overlaps of the discussion agendas across the learning sessions.

- Facilitated discussion and field practical observation on the disease and its management
- Report and reflection session on activities since the previous learning session
- Deliberation on activities before the next learning session

The technical sessions provided a learning space on less visible biophysical aspects of late blight, such as signs and symptoms, causal agent and spreading mechanisms. A magnifying glass, YouTube videos and potato sizing squares were used to showcase and initiate discussion around late blight spreading mechanisms, symptoms and seed selection as management practices. Practical sessions on some relevant late blight management options took place through observation and discussion on plant growth, weather conditions and on how to implement different management options. The practical sessions were partly informed by CIP (International Potato Center) previous learning material (Cáceres et al. 2008). For the technical learning sessions, a small community-managed plot (30m² x30m²) was secured from a farmer and was planted with a third-generation potato seed provided by Holeta Agricultural Research Center.

Data Collection

Utterances from the ten learning and reflexive meeting sessions were fully captured to particularly answer our first research question on how social learning outcomes as an alignment of changed knowledge, relations and actions were developed in participants' communicative utterances. Continuous documentation and audio recording were made on each learning session in which different learning themes about the disease and its management were covered. During these facilitated sessions, particular attention was given to participants' reflections on new insights related to the disease; the way they made sense of their existing knowledge or practice in view of new information; and how and what social or technical practices they thought had to be unchanged or modified in the management of late blight. Plenary field discussions during the technical learning sessions and follow-up, reflexive meetings (which together constituted one learning session) were important deliberative spaces for generating this information. Data for our second research question that assessed the extent to which social learning outcomes were translated into collective actions on the ground was obtained from a monitoring sheet that was filled in and presented by a monitoring committee during the reflexive, follow-up meetings with all participants. The monitoring sheet captured information

on *farmer name; type of collective practice; date of monitoring; way of communication; adherence/non-adherence; measures taken*. The researchers' field observation and participation in some of the monitoring work were additional sources of information.

Data Analysis

The study report is based on analysis of extensive meeting notes or verbatim meeting transcripts. Thus, our units of analysis are transcribed utterances of participants during the learning and reflexive meetings. Each social learning event was regarded as a particular communicative space containing various utterances of participants and hence fully transcribed verbatim. As different learning themes around the nature of the disease and the management options did not necessarily begin and end with the learning sessions and usually went beyond more than one session, all discussions from the different learning sessions that related to a particular theme (e.g. fungicide spray) were openly coded on Atlas.ti software. Accordingly, we defined five themes in the communication: *nature of the disease, fungicide use, late blight resistant and clean seed potato, killing/rouging volunteers and dehauling*.

The second stage, axial coding followed, drawing on our conceptual line of thinking on social learning as an alignment of new or changed knowledge, relationships and actions. In doing this, all quotes under the five codes were analyzed for text segments in which new or changed technical knowledge, relation and suggested management actions and practices were aligned. In nine data segments, the three dimensions had become aligned, leading to a collective agreement. These segments were taken as evidence of a process of social learning and are discussed as emergent sub-topics under the different codes. Collective agreements that followed upon such moments of alignment were regarded as the first outcomes of social learning. Finally, the analysis of the translation of collective agreements into physical collective action was based on the information from a monitoring report by the farmers' committee and the notes from follow-up discussions in the reflexive meetings.

Results

The results section consists of three major parts. The first two sections (4.1 and 4.2) present how the social learning process as a communicative interaction led to social learning outcomes across the different discussion topics entertained in the learning and reflective sessions. The third section (4.3) presents a summary of the level of translation of the social learning outcomes into collective action.

Learning about the Nature of the Disease

Discussions about the disease in relation to its cause, symptoms and spreading mechanisms sparked different kinds of relational and action-oriented discussions. As can be seen from Fig. 2, utterances about the disease shifted from regarding late blight as a weather problem to regarding it as a disease with multiple infection sources. During this initial stage of the learning sessions and particularly in the first two sessions, new insights about the cause³ and spreading

³ The causal agent (*Phytophthora Infestans*) is an oomycete but that in practice it is usually called a fungus and therefore the chemical controlling it is not called an oomycide but a fungicide.

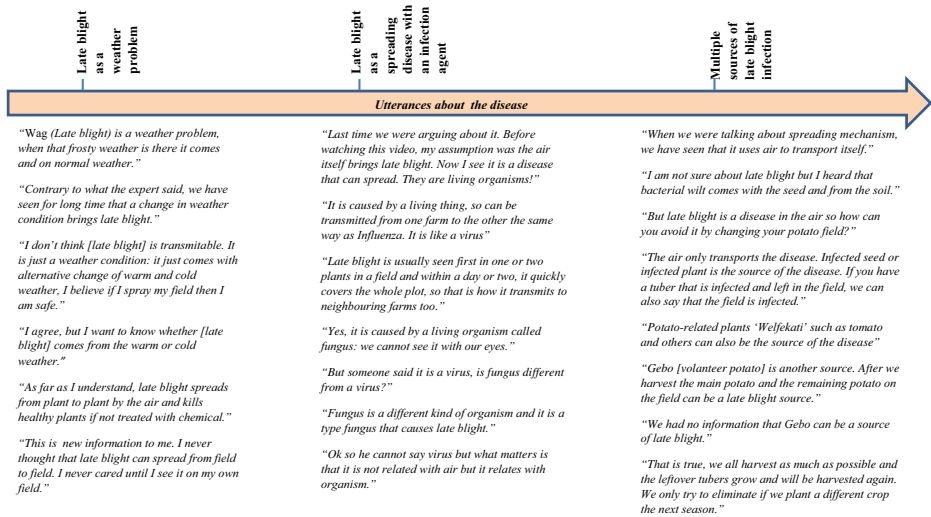


Fig. 2 Shifting conversations about the disease

mechanism brought the issue of interdependency among neighboring farmers to the center of conversations. The realization of late blight as a communal problem provided many of the participants a new lens on the way they see farmer-to-farm relationships in the management of late blight. There were marked comments on how farmers could be affected by the situation on neighboring farms and what can be done about the disease. As many stressed the importance of cooperation in managing the disease, a proposal was made by a few farmers, and endorsed by all of the other farmers present, to involve other farmers in the community that were not in the meetings. Table 1 shows how this collective agreement was related to alignment of the three dimensions of the topic in the learning process. The proposition from this group of farmers was based on articulations of their understanding of the contagious nature of the disease and their apparent practical observations of how their field had been infected directly after they had observed symptoms on adjacent fields.

An interesting proposal that followed discussions on late blight transmission and the communal risk of the disease was the importance of monitoring late blight incidence beyond their individual farms. Even though all farmers inspected their own fields to a different degree, an agreement that a group of neighboring farmers should team-up for an early morning joint

Table 1 Learning to bring on board other farmers in the community

Technical	<i>"This is new information to me. I never thought that late blight can spread from field to field. I never cared unless I see it on my own field."</i>
Relational	<i>"Just like communal livestock grazing fields and water channels management, we also affect each other with late blight."</i> <i>"Listen please; the disease can spread from his farm to my farm. What are we going to do about the other farmers who are not here?"</i> <i>"I have a neighbor, she barely looks after her field. She has never come to our meeting. We are sharing a boundary and she should be part of our concern."</i>
Action	<i>"Whether they belong here or not, they need to be told."</i> <i>"We will not persuade other farmers who are not here, but we should advise them with love to join our group."</i>

field scout was accompanied by statements about the communal risk nature of the disease and the need for adjusting existing individual-based practice in monitoring. The joint field scout was an idea that was particularly pushed by a few former seed-producing farmers who had experience of crop disease monitoring.

Conversely, some farmers argued they could control the disease on their field, irrespective of what is happening on neighboring farms. As can be observed in some of the statements below, their choice to continue working individually was mainly heralded by utterances of their previous experience of keeping the problem at bay by optimal spraying, despite their belief that late blight is a contagious disease: *“I am always well prepared with chemicals; my field is usually safe when neighboring fields are hit with Wag [late blight]”*... *“As Baysa said, if I spray enough I can protect my own field”*.... *“The owner himself can control it daily; it doesn’t cause that much problem.”* Of these five farmers, all but one eventually decided not to be part of the collective monitoring work and missed the subsequent learning and reflexive sessions.

Different statements disclosed that the farmers, in general, had experience with some sort of monitoring in their diverse social endeavors, such as community health and security matters. A fascinating relational issue that was raised and discussed before an agreement was reached on joint monitoring was how to deal with the existing traditional view that strangers entering crop fields leads to a drop in productivity. This was particularly raised by some younger farmers as a potential problem for traditional or superstitious members of the community. Although none of the farmers openly said that they did not want other farmers to enter their farm, they all generally acknowledged this as an existing belief that might pose a challenge to joint late blight monitoring. As illustrated in Table 2, the discussion around this issue was concluded with a collective agreement that all farmers should welcome a monitoring committee or a neighboring farmer in the field scout team.

Table 2 Learning about team field scouting and collective monitoring of late blight incidence

Technical	<i>“The disease can jump from another field to my field that is a problem!”</i> <i>“Some farmers only check their field every three days and some, like Negash, check every morning; this is a problem.”</i>
Relational	<i>“We can see each other’s field. If Adugna doesn’t see his farm, I have to see it as I don’t want the disease to be transmitted to my farm.”</i> <i>“We can have a group of two or three farmers next to each other to check all the farms together or when others are not available.”</i> <i>“We usually have committees; we even used to have a committee for monitoring Gind ateweleg (bacterial wilt) as seed producers.”</i> <i>“One thing that we need to talk openly here is that some of us would have an issue of letting other people into our farm.”</i> <i>“It is from a cultural view; you will be fearful to visit others farm from the culture”</i> <i>“Yes, we shouldn’t cover this up, we may agree here but when we go for implementing that would be a challenge.”</i> <i>“It might not be a problem of all farmers but all of us should be willing to check upon one another.”</i> <i>“We are working together here, so we should do the late blight detection together and let the monitoring committee into our farm to verify activities.”</i>
Action	<i>“As we have a collective job, we should organize a committee. It is a must to organize a committee to perform this work.”</i> <i>“I think it is good to elect the committee in a similar way as before, Shambel and Terecha usually represent us.”</i> <i>“Tamru also used to work in the seed cooperative committee, he can continue.”</i> <i>“We will visit the farm in our area in groups and, if we see the disease, everyone will be alerted”</i>

The idea of what to do with non-compliance was initially brought to the attention of farmers by the facilitator after farmers had decided to introduce team monitoring of late blight incidence. The majority of the farmers were not enthusiastic about sanctions in response to non-compliance, saying everyone should monitor late blight and that sanctions might create friction. Some farmers were less optimistic about compliance and argued that rules were needed: “*we can’t be 100% sure that he [a specified farmer] will keep his promises. That is why we need a committee and also the rules.*” Another farmer added, “*Any kind of job which will be done in a group must have a ground-rule. If you are a problem for me, we need a common agreement that will prevent you from becoming a problem.*” On the contrary, most farmers agreed with the views of two farmers who stressed “*We now know the disease risk, and everyone will do it for their own benefit*” ... “*if there are people who don’t participate in the monitoring, it is better to advise them with love than force them.*”

As illustrated here, discussions about the disease and its infectious nature led to two social learning outcomes. First, new technical knowledge about the cause and spread of the disease, reflection on their individual monitoring practices and a new way of seeing farmer-to-farm relationships in managing late blight facilitated the agreement to bring other non-participant farmers into their joint work. Second, a shift from seeing late blight as a private problem to a collective problem (new insights on the risk of late blight spread) steered discussion around cooperation and how to deal with an existing belief (bad luck) that led to a proposal for a joint field scout and establishment of a monitoring committee.

Learning about Late Blight Management

In subsequent learning sessions, deliberations on late blight management opened new windows for further reflection on the long-practiced management technique (spraying) and other late blight management options. Analysis of the different statements revealed how communications unfolded to give rise to a range of social learning outcomes.

Fungicide Use

Fungicide use for controlling late blight is a well-known practice by all the farmers and its importance was not a point of earnest discussion. Many participants reiterated the view shared by a farmer, namely that: “*chemical has always been our savior.*” But as late blight is now recognized as an infectious disease, a new interest surfaced among farmers in knowing if everyone is indeed spraying and if the monitoring committee can check spraying when they receive a report on late blight incidence. The five committee members agreed to share responsibility and individually check spraying on potato fields that are closer to their field. However, during a reflexive meeting after the first monitoring work on spraying, many farmers expressed their dismay that the committee⁴ members did not monitor the spraying after they were given reports on late blight incidence from the joint scouting team. This led to a debate on whether the usual representatives are the right people for the work and on the possibility of considering other committed farmers as committee members. This led to an agreement to replace four of the five committee members as shown in Table 3.

⁴ The selected committee members were those who had links or worked with external actors such as the local government administration, cooperative unions or rural financial institutions. These members of the community appeared to be perceived as default representatives of the community.

Table 3 Learning to replace members of the monitoring committee

Technical	<p><i>“The rain has been intense, and we are seeing late blight in different fields.”</i></p> <p><i>“While we were checking our field yesterday morning, there was late blight on Doro’s field. I and Leggesse sprayed in the afternoon before it spreads to our field.”</i></p>
Relational	<p><i>“The committee did not come and check our field after we reported that there was Wag [late blight].”</i></p> <p><i>“That is true, I [a committee member] had been busy at the Kebele.”</i></p> <p><i>“Two of the committee members are not even here [at this meeting].”</i></p> <p><i>“We shouldn’t elect/or should not be represented by people who have a lot of responsibility.”</i></p> <p><i>“This is our work and we should not be afraid of anyone.”</i></p> <p><i>“Terecha is not active for the work, he is becoming careless. He is my brother but, I am not supporting him.”</i></p>
Action	<p><i>“So, it is better if we change the members of the committee.”</i></p> <p><i>“Worku has no workload, he can work for us.”</i></p>

A new notion to most participants was the existence of different types of chemical fungicides with distinct modes of action in late blight control. While some of the farmers shared their knowledge that there are two types of fungicides (Ridomil and Mancozeb), all farmers confirmed that they only used Ridomil (a systemic fungicide) which has market dominance. During discussions, farmers learned that the two fungicides types have different modes of action. Experts considered that continuous use of Ridomil might lead to metalaxyl resistance from the pathogen while farmers questioned whether resistance might be responsible for their increased frequency of Ridomil spray over the years. Most farmers wanted to stop the continuous use of Ridomil and to alternate with Mancozeb which needs application before symptoms are observed. A few farmers, who already bought and saved enough Ridomil for the growing season, rejected the idea of alternating with Mancozeb. After the new committee reported that seven of the 25 farmers who had agreed to spray Mancozeb did not report their spraying schedule for the committee to check, the idea of enforcing rules became again a point of discussion. A consensus was reached (Table 4) that a fine should be proposed at the next meeting when everyone is present to avoid confrontation from absentees. At the next reflexive meeting, an agreement was reached to fine 100 Birr (Ethiopian currency) for those who either missed the joint team scout or failed to inform the committee on the status of late blight and

Table 4 Learning about sanctioning systems on non-compliance

Technical	<p><i>“One spray of Ridomil used to be effective, now even three times does not work for many of us.”</i></p> <p><i>“I am not effective with Ridomil anymore, maybe, the disease has already adapted with Ridomil.”</i></p> <p><i>“Ok, many of us want to try Mancozeb and see the effect in this season.”</i></p>
Relational	<p><i>“We [committee] were able to check eighteen fields and all sprayed Mancozeb as agreed. Seven people did not call us, so we do not know if they did.”</i></p> <p><i>“This is a fundamental thing - we need to be careful. Something has to be done to those who are not reporting.”</i></p> <p><i>“Unless we handle this or bypass without doing anything, the committee can’t do anything on their own.”</i></p> <p><i>“What I think is that instead of punishing a person, it is better to advise them.”</i></p> <p><i>“For example, when we meet next time if I say; oh, even if I didn’t report to the committee, I did spray, what do you do?”</i></p>
Action	<p><i>“So, this doesn’t need any further discussion, the strict rules must exist and be defined.”</i></p> <p><i>“Let the committee propose some kind of punishment. They should implement fair punishment based on their observation but not to cause harm to the person.”</i></p> <p><i>“The rules should be set by all of us and it should be the committee who will take measures.”</i></p> <p><i>“Today we become strong so that those who didn’t report know the consequences.”</i></p>

follow-up of the implementation. A further 50 Birr was agreed as the fine for being absent from reflexive meetings.

After the third monitoring on spraying, farmers realized that putting a system of sanctions in place could still not guarantee full compliance. Two farmers who had failed to report on spraying said that they could not spray because they did not have money to buy fungicide. While some farmers tried to protect these two farmers from possible fines, others argued for financial support for these farmers because all farmers are at risk if two farmers are unable to spray. In this regard, the practice of mutual aid that they do in other aspects of their social life is exerted to late blight management giving a new dimension to community reciprocity in managing contagious crop diseases. Table 5 illustrates how the proposal for mutual aid was modified at the same meeting with a scheme to use the money from fines to buy fungicides for the farmers.

Analysis of communications around fungicide use as a late blight management option featured three different social learning outcomes. First, knowing late blight as a disease that spreads, as opposed to the predominant assumption that it is a weather problem, alerted farmers to bring the monitoring aspect not only to spraying but also to assess the performance of the existing monitoring committee and replace the members. Second, a new keenness to experiment with Mancozeb to avoid the potential metalaxyl resistance, encouraged the farmers to reconsider their stance on dealing with non-compliance and to propose and forge sanctioning mechanisms. Third, the practical insight that punishment could not guarantee compliance led to a decision to financially support farmers who had not complied. As can be seen from the quotes in Table 5, this decision was made because of the perceived late blight risk from unsprayed fields.

Using Late-Blight Resistant Varieties and Clean Seed Potato

Learning on the multiple sources of late blight infection in general and infected potato tuber as an inoculum source, in particular, steered discussions around the use of healthy seed from resistant varieties to deal with late blight. New insight was made into the distinction between clean/disease-free seed and late-blight resistance varieties. Many farmers initially assumed that disease-resistant varieties would remain resistant to late blight. From some of the statements, this is partly attributed to the original framing of late blight as a weather problem. The realization that their widely grown varieties, such as *Gudene* and *Jalene* once released as late blight resistant,⁵ are no longer free from potato disease, led farmers to stress the importance of keeping their own seed clean from late blight. In this regard, proposals were made to undertake seed selection for the coming growing season, using a third-generation (G3) resistant variety (*Gudene*) for a positive selection.⁶ Seed selection would be made with the help of an extensionist and a researcher from the Holeta Agricultural Research Center which would also provide the G3 seed.

The importance of keeping their own seed source free from late blight instigated reflections around the previous and potential future role of the district government agricultural office in seed quality checking. A few farmers, previously members of a seed-producing cooperative, had

⁵ *Gudene* and *Jalene* are among the many late blight resistant varieties released by Holeta Agricultural Research Center over the years

⁶ Positive selection entails selecting healthy-looking, vigorous mother plants to obtain seed tubers for the next seasons' crop in a situation where there is a problem of availability of affordable disease free seed potatoes or resistant varieties (Schulte-Geldermann et al. 2012)

Table 5 Learning to share fungicide cost of ‘risk-causing’ farmers

Technical	<p><i>“If all of us are not spraying on time as promised, we are spreading the disease.”</i></p> <p><i>“My small field is at my backyard and far away from yours; do not worry about the disease.”</i></p> <p><i>“Ababo, it was said the disease travels long distance even as far as Geba Robi (another village).”</i></p>
Relational	<p><i>“We cannot punish Ababo and Beyecha, they couldn’t even save their potato, let alone pay the fine.”</i></p> <p><i>“We should have discussed this when we set the rules.”</i></p> <p><i>“But I suggested supporting each other or contributing money if anyone is in a problem.”</i></p>
Action	<p><i>“Why don’t we use the money that Gash (Mr) Negash is keeping?”</i></p> <p><i>“Good idea, let’s use that money to buy Ridomil for both.”</i></p>

experience of working with the regional regulatory office and the district agricultural office in potato disease (Bacterial wilt) monitoring and seed potato marketing. They considered that this had been an unfair arrangement because only a few farmers with ‘good relations’ with the offices enjoyed the market benefits. Some of the other farmers seemed to know and embrace the stories and others appeared to be new to the details. Existing negative views about district offices and regulators were amplified by stories shared by former seed producers. The discussion led to a more restrictive proposal for a potential role for the district office in seed quality monitoring.

Communications around seed quality elicited two social learning outcomes. New insights on the distinction between healthy/clean and resistant variety and the contribution of farmers handling of seed to late blight prevalence opened new avenues for farmers to adjust their opinions about researchers from someone who failed to continually provide ‘quality’ seed to someone who can also assist in keeping farmers seed clean from the disease. This led to an agreement (Table 6) to seek researchers’ support in seed selection and handling. The other learning outcome (Table 7) aligned discussions about the importance of seed quality checking with previous relation and collaborative practices with government district offices. Farmers advocated for a principally farmer-controlled seed monitoring approach, dismissing a potential role for the district agricultural office in seed quality monitoring.

Removing Volunteers

Social learning in relation to removing volunteers as a late blight management method is stimulated by awareness of how volunteers (*Gebbo*, namely potatoes growing after being left in the soil from the previous harvest) can be another source of late blight infection. Some farmers

Table 6 Learning towards collaboration with researchers on seed selection

Technical	<p><i>“My assumption was any seed that survived the weather problem is safe and I can use it as seed.”</i></p> <p><i>“Yes, what we saved from the last harvest and planted this season may have late blight and other potato diseases.”</i></p> <p><i>“Even if we use chemical, if we bring spoiled seed for next year, it is useless.”</i></p>
Relational	<p><i>“We have to look for other clean seed sources.”</i></p> <p><i>“We know that Holeta [research center] has quality seed but we don’t get it here.”</i></p> <p><i>“If we get clean seed from you, we will work to keep our seed clean. Our seed is infected with the disease now.”</i></p> <p><i>“The problem is how can we check for a disease if the experts do not support us.”</i></p>
Action	<p><i>“We can use the new seed from our learning plot but Lema [Holeta researcher] should teach and support us on the seed selection.”</i></p> <p><i>“We will also practically learn how to do that from the researcher on the field.”</i></p> <p><i>“Yes, once I [extensionist] get a good lesson, I am close to the farmers to continue supporting in seed selection and exchange.”</i></p>

Table 7 Learning towards a restrictive role for district government offices in seed quality monitoring

Technical	<i>“Once we get disease-free seed, we will work to keep the seed free from late blight.”</i> <i>“It is a similar work like Gind Atewelig (Bacterial wilt), few years ago district experts used to check the plant and the seed for Gind Atewelig.”</i>
Relational	<i>“We [seed producers] were having such kind of [monitoring] experience. They used to plan and then visit the farms to check for the existence of Bacterial Wilt. But it was a bad experience.”</i> <i>“The previous one and this one should not be the same. The reason is not the same; now the people gathered together, discuss and learn from one another but, at that time only few people used to come and tell us what to do.”</i> <i>“The process was not transparent, and some farmers wanted to commit suicide from total rejection of their seed.”</i>
Action	<i>“If it is going to be the same, I am not sure if I want to continue.”</i> <i>“Let us use our own committee, we can monitor the disease on our own but you (facilitator) help us bring the experts to technically support us”</i>

removed volunteers only when they wanted to plant another crop in a subsequent growing season but not because volunteers are an inoculum source for the pathogen. When another crop is not being planted, most farmers let the volunteers grow for a second-round harvest. Having realized the role of volunteers in pathogen spread, the issue of land contractual arrangements was raised by farmers who grow potato on a leased plot in a neighboring village. In the usual contractual agreement, the leasing farmers only harvest one time and must leave behind the volunteers for harvest by the property owners. Given the role of volunteers in pathogen spread, farmers proposed (Table 8) changing their contractual agreements to reduce volunteers. Table 9 also shows how the majority of farmers agreed to collectively implement the practice of removing volunteers from their own plot, irrespective of what they cultivate after potato.

There were two social learning outcomes related to this late blight management practice. The first one relates with knowing volunteers as pathogen inoculum source that made farmers re-define existing practices and relationships in land contractual agreements. Second learning evidence is an agreement reached by more than half of the farmers to remove volunteers and to collectively monitor this practice. This time not because they see volunteers as a weed to another crop but because it can serve as inoculum source for the late blight pathogen.

Dehauling

During the session, farmers learned that late blight can travel down from the plant (through the transfer of fungal spores) to the tuber when the haulm, comprising the aerial part of the plant, is not cut on time. However, this new insight did not lead to a learning outcome or any form of collective action in communication. Few farmers stated they had previously removed the haulm, believing it is good for tuber size and skin setting. However, they contended that the

Table 8 Learning to include the issue of control over volunteer plants in land contractual agreements

Technical	<i>“We don’t remove Gebo if we plant potato as we wanted the tubers produced from the Gebo.”</i> <i>“I think if we have to avoid the disease risk in our area, we should kill the Gebo.”</i>
Relational	<i>“You can do that on your own plot but what about me who also work on rented land?”</i> <i>“That is right, we have to leave the produce from the Gebo to the landowner.”</i> <i>“Why don’t you teach them what you learned about the disease? They may agree.”</i> <i>“It is not easy, I wish they could be here.”</i>
Action	<i>“Let’s try to discuss with the owners if they agree but they only care for their benefits.”</i> <i>“It could be difficult for this season, but we should negotiate in the Belg [coming] season”</i>

Table 9 Learning about joint monitoring of volunteer removal as a late blight management practice

Technical	<p><i>“When we plow the field, we only remove Gebo, so it will not remain there as a weed for the next crop.”</i></p> <p><i>“But getting the disease is a higher risk.”</i></p> <p><i>“Some of us still have Gebo or the tubers on our field and some just plowed and planted on it.”</i></p>
Relational	<p><i>“We cannot do much about those who recently planted.”</i></p> <p><i>“But most of us didn’t plant yet and the committee should check as it is a disease problem.”</i></p>
Action	<p><i>“This should be another activity for the committee to check before our next meeting.”</i></p> <p><i>“Just call and let us [the Committee] know before you do it and we will check and report at the next meeting.”</i></p>

practice exposed their black soil (*Koticha*) which easily cracks and the tuber to direct sunlight, turning the tuber green. Given that some farmers considered that green tuber was a major reason for rejection at the market, the farmers decided not to introduce dehauling as a management option unless there was a mechanism to avoid the change in tuber color. However, two farmers, who had no previous knowledge of the practice, said that they wanted to experiment with it on a small portion of their potato field to evaluate any effect on late blight infection or tuber color.

Linking Social Learning Outcomes with Collective Action

Analysis of the discussion around different learning themes on late blight disease and its management revealed a total of nine social learning outcomes in the form of collective agreements related to an alignment of new communicated knowledge, discussed relations and suggested actions. Table 10 illustrates the extent to which the various agreements implicated in the discussions were implemented on the ground. From a process perspective, it can be observed that there is not a one-way relationship between a collective agreement and a collective action or that collective action comes necessarily after collective agreements. For instance, agreements to change the monitoring committee, to develop sanctioning systems or to share fungicide costs are informed by reflections from practical actions. In this sense, there was an iterative learning cycle whereby farmers contentiously modified or adapted their collective action by reflecting on their collective agreements and vice versa.

As can be seen in Table 10, two of the nine collective agreements could not be fully translated to collective action. For example, only about half of the field scout team did a regular joint visit to their farms. A possible explanation for this might be the problem of free-riding that is common in collective action problem situations. The free riding tendency by some farmers eventually led to a modification of the agreement around sanctioning mechanisms. The fact that farmers from nearby villages were not part of the collective agreement on amending land contractual arrangements for removing volunteers had influenced the translation of the agreement into action.

Discussion

The study unraveled how social learning as a communication process in which new knowledge, relations and actions become aligned leads to collective agreements (first research question) and collective action (second research question) in the management of late blight. In answering the first research question, we discerned several communicatively agreed lines of action that were attended by communication regarding new knowledge, relations and actions. In this regard,

Table 10 Translation of collective agreements (social learning outcomes) into collective action

Learning themes	Collective agreements	Collective actions
Late blight as a contagious disease	<ol style="list-style-type: none"> <li data-bbox="232 971 275 1425">1. Agreement to bring on board other farmers that were not in the intervention <li data-bbox="303 1024 350 1425">2. Agreement for team field scout and collective monitoring of late blight incidence 	<p>Farmers brought new fellow farmers in the community and the number of participating farmers grew from 21 to 33 during the time of the learning intervention. This is without the three farmers who departed after the second learning session.</p> <p>Farmers formed 11 field scout groups (3 neighboring farmers in a group) but the groups had different levels of success. About 6 of the groups scouted regularly while the others demonstrate different levels of irregularity. The irregularly made some groups cover for each other but pushed others to only scout their own field. Farmers also formed a monitoring committee composed of five people to interact with the scouting teams.</p>
Fungicide use	<ol style="list-style-type: none"> <li data-bbox="428 1012 470 1425">3. Decision to replace members of the monitoring committee 	<p>As the committee failed to do proper monitoring after the reporting of disease incidence and the first round of spraying, farmers replaced four of the five initially selected committee members. The re-elected committee was active in collecting and sharing reports on late blight incidence and on-field monitoring of collectively agreed practices and reporting of results on reflexive meetings. Although all farmers agreed to practice seed selection and exchange, this activity was postponed to the next growing season as it needed access to clean seed from their own sources or a late blight resistant variety. A G3 seed of resistant variety (<i>Giudene</i>) was obtained from the Holeta Agricultural Research Center and planted to be used for this purpose.</p>
Using healthy seed and resistant varieties	<ol style="list-style-type: none"> <li data-bbox="627 1086 670 1425">4. Agreement for sanctioning systems on non-compliance <li data-bbox="820 971 840 1425">5. Agreement to share fungicide costs of 'risky' farmers <li data-bbox="898 980 938 1425">6. Agreement to seek for researchers' support on seed selection 	<p>Farmers developed and implemented a sanctioning system (money fines). They applied a fine of 100 Birr for a missing team field scout, 100 Birr (per scout team) for not reporting to the committee on prevalence of late blight; 50 Birr for missing learning and reflexive meetings. There were arguments between defectors and the committee on the first fines, the defectors finally skipped fines by making a public apology arguing it was the first time and that they would comply afterward. A total of eight people were fined at different times, totaling an amount of 650 Birr. Seven farmers skipped fines for bringing convincing social reasons (in the eyes of the committee) for not scouting and reporting.</p> <p>A fungicide (Ridomil) was bought for two farmers (a female and an old farmer) after late blight symptoms were detected on their field. It was not financed from shared money but from fines for non-compliance.</p> <p>This was an activity planned for the next growing season as farmers had already prepared and some had even planted around the time of discussion on seed selection. However, seed selection with technical support from a Holeta researcher was made on the harvested G3 potato seed from the practical learning plot and distributed among the farmers to be positively selected and used as planting material for the next growing season.</p>

Table 10 (continued)

Learning themes	Collective agreements	Collective actions
Killing volunteer plants	<p>7. Decision to dismiss potential role for district government offices in seed quality monitoring</p> <p>8. Agreement to include the issue of control over volunteer plants in land contractual agreements</p> <p>9. Agreement on joint monitoring of removing volunteer plants as a late blight management practice</p>	<p>Farmers continued with a monitoring committee that was only composed of community members whereby trust issues played a major role in limiting options for potential collaboration in seed quality monitoring.</p> <p>Due to a relative land shortage in the area, seven farmers leased land for potato cultivation in a neighboring village. All the farmers that were growing potato on a rented plot had already made their contracts for 2–5 years during the growing season in which our learning intervention took place. However, three of these farmers discussed with their landowners the possibility of removing volunteers but the landowners rejected the idea.</p> <p>The practice was monitored and 21 farmers out of 33 removed volunteer plants or collected remaining tubers in the soil before planting. While seven of them could not do this because of their contractual agreement, five farmers did not do it, saying hand removing the tuber is a laborious task.</p>

new knowledge in relation to the threat posed by late blight as a contagious disease was instrumental in instigating discussions about relations and potential collective actions, thereby leading to several social learning outcomes. Although our review failed to find previous studies with a grounded perspective on late blight as a collective action problem, empirical studies of pest and invasive weed management highlighted that collective responses were effective when communities appreciate that the problem crosses farm boundaries and where benefits might arise from cooperation (Graham et al. 2019). A change in the framing of late blight by the community from a weather problem to a contagious disease involving pathogens fundamentally shifted awareness of late blight disease from a private bad to a collective bad. This, in turn, instigated social learning as new knowledge on the mobility and the contagious nature of late blight, linked to new perspectives on interdependency and proposals for collective action to manage the disease. The empirical study thus confirmed our assumption that disease management has particular features compared to the collective action problems generally studied in social learning literature. It differs from dominant social learning literature on collective action problems in natural resource management, migratory pests and invasive weeds which implicitly assume some sort of understanding of the collective nature of the problem, hence picks the role of social learning from there (Zamani et al. 2018; Marshall 2016; Brugnach et al. 2011; Toleubayev et al. 2007). The key role of technical knowledge in determining social learning outcomes is also demonstrated in a situation where farmers did not agree to implement dehauling as a potential management practice, owing to their technical knowledge of the impact of direct sun on tuber quality.⁷ We contend that attempts to develop and sustain collective action around diseases that are characterized by less visible dynamics should be supported with a strong learning element around the delicate life cycle and spreading mechanisms, demonstrating the interdependency of farmers. In addition, the contribution of social learning can be amplified if it takes a step back and firmly integrates such learning in a situation where there is ambiguity on the very collective nature of the problem.

However, a better understanding of the mobile nature of the disease was not sufficient reason for some of the farmers to cooperate in disease monitoring or to reach agreements on the collective implementation of management practices. Their main argument was that they could individually control the late blight if they spray optimally, irrespective of the disease situation in the area. This finding is consistent with a case study on community-based resistant weed management whereby, despite knowledge of weed mobility, some community members perceived weed control as an individual problem by taking into account the economic costs (e.g. finance, labor) of managing resistance over time (Ervin and Frisvold 2016). Similarly, lessons from situational studies on banana wilt and potato late blight in Central Africa and Ethiopia demonstrated that the public good features of a disease management strategy depend not only on specific agro-ecological properties of the disease but also on the available technological options and other community-specific social conditions and resources (Damtew et al. 2018; Leeuwis et al. 2018; McCampbell et al. 2018). This has an important implication for the framing of contagious crop diseases, such as late blight, as public bad mainly based on its mobility. We hope that this study triggers more in-depth scholarly discussions on what other biophysical, social or economic attributes, together with disease mobility, could be integrated to advance current theoretical perspectives that present contagious crop diseases as a public bad.

⁷ This change in tuber colour and quality is a well-known phenomenon in scientific literature as a production of a group of chemicals called glycoalkaloids that are toxic when consumed.

Communication about late blight as a shared risk played a key role in reaching agreement on collective action. This stimulated discussions on new types of social relationships for collective monitoring, including a committee and neighbor-to-neighbor field scouts. In this regard, the monitoring system performed two key relational functions: joint information collection and sharing on late blight incidence not only informed collective management activities but also leading to sanctions and new reciprocity as communities strove to deal with non-compliance. This mirrors the assessment by Ervin and Frisvold (2016) that when there is a shared understanding of the collective nature of the problem, interest can develop within communities in conducting monitoring and applying appropriate penalties when some operators do not comply with locally prescribed management practices. Even though farmers initially decided to implement monitoring, despite traditional superstition around letting others into their individual fields, they were not enthusiastic about sanctions. However, the fact that they eventually developed sanctioning systems and forged new ways of reciprocity through mutual aid in buying fungicides highlighted the observation by Ibuka et al. (2014) that social learning helps farmers to amend their perceptions of risks and their collective rules of engagement. In this regard, our research provided evidence that social learning can lead to the emergence of a rudimentary form of institutionalized coercion which can help to reduce overcome non-compliance in the management of contagious crop diseases, such as late blight. In a hypothetical game scenario, Zhang et al. (2014) similarly reported that ‘toy-communities’, guided by payoff considerations, started with a clear preference for the treatment without punishment but shifted to peer-punishment after a few rounds. We consider that the emergence and evolution of regulatory institutions through social learning has significant theoretical implications for the way scholars conceptualize social learning in the management of agricultural collective action problems in general and contagious crop diseases in particular. In this respect, a great majority of the reviewed literature on the subject appreciates regulatory institutions (e.g. monitoring, incentive mechanisms, graduated sanctions) from an institutional theory perspective, principally seeing it as an externally imposed system, rather than as something that can potentially emerge through social learning (e.g. Wulandari and Inoue 2018; Hegde et al. 2017; Six et al. 2015; Christmann et al. 2015; Pahl-Wostl 2009).

In relation to our second research question, our aim was to examine the influence of social learning on collective action in the management of late blight, focusing on the actual implementation of collective agreements. As can be noted from the results, while most farmers agreed that collective actions should be implemented, a few of these proposals could not be translated into action. For instance, farmers tied to property owners from a neighboring village via contracts could not translate the agreement to modify the rights to control volunteers into action. This relates to Ostrom’s (1990) thesis on the importance of delineating clear boundaries between users and non-users of a resource. Although public good boundaries often have a gradient quality or are fuzzier (especially for highly mobile resources) than implied in the traditional public good design principles (Baggio et al. 2016; Cox et al. 2010), having a clear definition of geographical and institutional boundaries appears to be an important precondition for the translation of agreements into collective action. In this regard, unclear boundary definition for late blight management represented a missed opportunity for our social learning approach to inspire better cooperation between two seemingly different communities which are institutionally interrelated through land contractual agreements in potato cultivation. Although many of the agreements were physically implemented, there was visible non-compliance from some farmers, mainly on team scouting and on reporting on disease incidence.

Contrary to a range of evidence from public good studies, non-cooperating behavior of a few farmers did not seem to stop other farmers from complying with most of the collective agreements. This appears to provide some support for the conceptual premise of Ervin and Frisvold (2016) that farmers may still have an incentive to manage invasive or contagious crop problems and benefit from the adoption of practices, even when their neighbors do not and even when acting collectively is considered the best strategy.

This study showed how social learning, through aligned knowledge, relations and actions in communications, formed the basis for collective agreements and collective action. However, we are limited in being able to explain the translation from learning to action. Multiple factors may have influenced the extent of implementation of collective actions implicated in the social learning outcomes: levels of risk perception, information sharing/communication, production objectives, group heterogeneity, and resource boundary (Graham et al. 2019; Cox et al. 2010; Ostrom 2010). In this regard, there is considerable scope for more research to explore and detail the different factors in action around the translation of collective agreements into actual practices on the ground.

Conclusion

We conclude that social learning and associated collective actions in the management of late blight are outcomes of an ongoing communication process with a range of interlinked technical, relational and action related issues. Outcomes of such a learning process can thus be made visible through the analysis of communicative processes. In this regard, the conceptualization of social learning in the management of contagious crop diseases would benefit from a broader view than what is commonly implied in the traditional social learning literature on natural resource management. This means, on the one hand, that conceptualization needs to strongly support community learning in relation to clearing ambiguities on the collective nature of the disease and, on the other, that this conceptualization needs to widen its scope for further systematic analysis of implementation of agreed collective actions. The crucial role of regulatory institutions in the management of public bads, such as late blight, also warrants social learning to embrace the emergence or evolution of such institutions in its conceptual and methodological approaches. We contend that social learning is a necessary precondition for collective action (the implementation of agreements in our case), but may not necessarily lead to it, given potentially multiple factors in operation. This interplay between social learning and collective action, specifically the role of different factors in the translation of agreements into practical action for the management of contagious diseases, requires further exploration.

Acknowledgments The research presented here is conducted under a research program of Responsible life-science innovations for development in the digital age: EVOCA that is funded by Wageningen University International Research and Education Fund (INREF). We would like to acknowledge INREF and the International Potato Center (CIP) for co-funding this research and the Ph.D. training of the first author. Additional funding was provided by the CGIAR Research Program on Roots, Tubers and Bananas (RTB) and US Agency for International Development (USAID) Federal Award no. 663-G-00-09-00420. We thank all participants for their willingness to share their views and provide valuable information for the research.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Aarts N, Van Woerkum C (2008) Strategische communicatie [strategic communication]. Van Gorcum, Assen, The Netherlands
- Baggio JA, Barnett AJ, Perez-Ibara I, Brady U, Ratajczyk E, Rollins N, Rubiños C, Shin HC, David J, Aggarwal R, Anderies JM, Janssen MJ (2016) Explaining success and failure in the commons: the configural nature of Ostrom's institutional design principles. *Int J Commons* 10(2):417–439
- Beers PJ, Van Mierlo B, Hoes AC (2016) Toward an integrative perspective on social learning in system innovation initiatives. *Ecol Soc*, 21(1)
- Bentley Brymer, A. L., Wulffhorst JD, Brunson MW (2018) Analyzing stakeholders' workshop dialogue for evidence of social learning. *Ecol Soc*, 23(1)
- Biedenweg K, Monroe M (2013a) Teasing apart the details: how social learning can affect collective action in the Bolivian Amazon. *Hum Ecol* 41(2):239–253
- Biedenweg K, Monroe M (2013b) Cognitive methods and a case study for assessing shared perspectives as a result of social learning. *Soc Nat Resour* 26(8):931–944
- Bouwen R, Taillieu T (2004) Multi-party collaboration as social learning for interdependence: developing relational knowing for sustainable natural resource management. *J Community Appl Soc Psychol* 14(3): 137–153
- Brugnach M, Dewulf A, Henriksen HJ, Van der Keur P (2011) More is not always better: coping with ambiguity in natural resources management. *J Environ Manag* 92(1):78–84
- Cáceres PA, Pumisacho M, Forbes G, Andrade Piedra, JL (2008) Learning to control potato late blight—a facilitator's guide. International Potato Center
- Campilan D (2002). Linking social and technical components of innovation through social learning. *Wheelbarrows Full of Frogs: Social Learning in Rural Resource Management*. Assen, The Netherlands, 135–146
- Cárdenas JC, Rodriguez LA, Johnson N (2015) Vertical collective action: addressing vertical asymmetries in watershed management. *Documento CEDE*, (2015-07)
- Christmann S, Aw-Hassan A, Rajabov T, Rabbimov A (2015) Collective action for common rangelands improvement: a climate change adaptation strategy in Uzbekistan. *Soc Nat Resour* 28(3):280–295
- Cox M, Arnold G, Villamayor TS (2010) A review of design principles for community-based natural resource management. *Ecol Soc* 15 (38)
- Damtew E, Tafesse S, Lie R, van Mierlo B, Lemaga B, Sharma K, Struik PC, Leeuwis C (2018) Diagnosis of management of bacterial wilt and late blight in potato in Ethiopia: a systems thinking perspective. *NJAS-Wageningen Journal of Life Sciences* 86:12–24
- Davies B, Blackstock K, Brown K, Shannon P (2004) Challenges in creating local Agri-environmental cooperation action amongst farmers and other stakeholders. The Macaulay Institute, Aberdeen
- Deuffic P, Candau J (2006) Farming and landscape management: how French farmers are coping with the ecologization of their activities. *J Agric Environ Ethics* 19(6):563–585
- Ervin DE, Frisvold GB (2016) Community-based approaches to herbicide-resistant weed management: lessons from science and practice. *Weed Science*, 64(SP1), 609–626
- Ford JD (1999) Organizational change as shifting conversations. *J Organ Chang Manag* 12(6):480–500
- Gee JP, Green JL (1998) Chapter 4: discourse analysis, learning, and social practice: a methodological study. *Rev Res Educ* 23(1):119–169
- Gerritsen AL, Stuijver M, Termeer CJ (2013) Knowledge governance: an exploration of principles, impact, and barriers. *Sci Public Policy* 40(5):604–615
- Graham S, Metcalf AL, Gill N, Niemiec R, Moreno C, Bach T, Ikutegebe V, Hallstrom L, Ma Z, Lubeck A (2019) Opportunities for better use of collective action theory in research and governance for invasive species management. *Conserv Biol* 33(2):275–287
- Guchi E (2015) Disease management practice on potato (*Solanum tuberosum* L.) in Ethiopia. *World Journal of Agricultural Research* 3(1):34–42
- Hardin R (2015) *Collective action*. Resources for the Future Press. Baltimore, MD: Johns Hopkins University Press

- Heffernan C, Nielsen L, Thomson K, Gunn G (2008) An exploration of the drivers to bio-security collective action among a sample of UK cattle and sheep farmers. *Preventive veterinary medicine* 87(3–4):358–372
- Hegde N, Elias M, Lamers HA, Hegde M (2017) Engaging local communities in social learning for inclusive management of native fruit trees in the Central Western Ghats, India. *Forests, Trees and Livelihoods* 26(1): 65–83
- Ibuka Y, Li M, Vietri J, Chapman GB, Galvani AP (2014) Free-riding behavior in vaccination decisions: an experimental study. *PLoS One* 9(1):e87164
- Joss S, Brownlea A (1999) Considering the concept of procedural justice for public policy-and decision-making in science and technology. *Sci Public Policy* 26(5):321–330
- Kassa B, Beyene H (2001) Efficacy and economics of fungicide spray in the control of late blight of potato in Ethiopia. *Afr Potato Sci J* 9(1):245–250
- Koontz M (2014) Social learning in collaborative watershed planning: the importance of process control and efficacy. *J Environ Plan Manag* 57(10):1572–1593
- Lamerichs J, Te Molder H (2002) The delicate discourse of support. *Wheelbarrows Full of Frogs. Social Learning in Rural Resource Management: International Research and Reflections. Assen, The Netherlands*, 301–14
- Leeuwis C, Aarts N (2011) Rethinking communication in innovation processes: creating space for change in complex systems. *Journal of agricultural education and extension* 17(1):21–36
- Leeuwis C, Pyburn, R (2002) Social learning for rural resource management. *Wheelbarrows full of frogs: social learning in rural resource management: international research and reflections*, 11–24
- Leeuwis C, Pyburn R, Boon A (2002) Concluding reflections on social learning. *Wheelbarrows Full of Frogs: Social Learning in Rural Resource Management: International Research and Reflections. Assen, The Netherlands*, 449–470
- Leeuwis C, Cieslik K, Aarts N, Dewulf A, Ludwig F, Wemers SE, Struik PC (2018) Reflections on the potential of virtual citizen science platforms to address collective action challenges: lessons and implications for future research. *NJAS-Wageningen Journal of Life Sciences* 86:146–157
- Loorbach D (2007) Transition management: new mode of governance for sustainable development. *International Books, Utrecht, The Netherlands*
- Marshall G (1998) *A dictionary of sociology*. Oxford University Press, New York
- Marshall G, Coleman MJ, Sindel BM, Reeve IJ, Berney PJ (2016) Collective action in invasive species control, and prospects for community-based governance: the case of serrated tussock (*Nassella trichotoma*) in New South Wales, Australia. *Land Use Policy* 56:100–111
- McC Campbell M, Schut M, Van den Bergh I, Van Schagen B, Vanlauwe B, Blomme G, Gaidashova SV, Njukwe E, Leeuwis C (2018) Xanthomonas wilt of Banana (BXW) in Central Africa: opportunities, challenges, and pathways for citizen science and ICT-based control and prevention strategies. *NJAS-Wageningen Journal of Life Sciences* 86:89–100
- Meinzen-Dick R, Di Gregorio M, McCarthy N (2004) Methods for studying collective action in rural development. *Agric Syst* 82(3):197–214
- Mekonen S, Alemu T, Kassa B, Forbes G (2011) Evaluation of contact fungicide spray regimes for control of late blight (*Phytophthora infestans*) in southern Ethiopia using potato cultivars with different levels of host resistance. *Tropical Plant Pathology* 36(1):21–27
- Mesfin T, Woldegiorgis G (2007) Impact of farmers' selected idm options on potato late blight control and yield. In *8th African Crop Science Society Conference, El-Minia, Egypt, 27-31 October 2007* (pp. 2091–2094). African crop science society
- Miller JS, Nolte P, Olsen N, Miller T, Bohl B, Thornton M (2006) Late blight management action plan for potatoes. University of Idaho Extension
- Miranowski JA, Carlson GA (1986) Pesticide resistance: Strategyies and Tuctics for management. National Academy Press, Washington, DC
- Mostert E, Pahl-Wostl C, Rees Y, Searle B, Tabara D, Tippet J (2007) Social learning in European River-basin management: barriers and fostering mechanisms from 10 river basins. *Ecol Soc* 12(1):19
- Olson M (1971) *The logic of collective action: public goods and the theory of groups*. Harvard University Press, Cambridge
- Ostrom E (1990) *Governing the commons – the evolution of institutions for collective action*. Cambridge University Press, New York
- Ostrom E (2010) Polycentric systems for coping with collective action and global environmental change. *Glob Environ Chang* 20:550–557
- Pahl-Wostl C (2000) Towards sustainability in the water sector: the importance of human actors and processes of social learning. *Aquat Sci* 64(4):394–411
- Pahl-Wostl C (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Glob Environ Chang* 19(3):354–365

- Pahl-Wostl C, Hare M (2004) Processes of social learning in integrated resources management. *J Community Appl Soc Psychol* 14(3):193–206
- Pahl-Wostl C, Craps M, Dewulf A, Mostert E, Tabara D, Taillieu T (2007) Social learning and water resources management. *Ecol Soc* 12(2):5
- Phuong LTH (2017) Developing adaptive capacity in times of climate change in central rural Vietnam: exploring smallholders' learning and governance (Doctoral dissertation, Wageningen University)
- Poteete A, Janssen M, Ostrom E (2009) Multiple methods in practice: collective action and the commons. *Multiple methods in practice: collective action and the commons*. Princeton University press, Princeton, New Jersey, USA
- Pretty J (2003) Social capital and the collective management of resources. *Science* 302(5652):1912–1914
- Reed M, Evely AC, Cundill G, Fazey IR, Glass J, Laing A, Newig J, Parrish B, Prell C, Raymond C, Stringer L (2010) What is social learning? *Ecol Soc* 15(4):4
- Rist S, Chiddambaranathan M, Escobar C, Wiesmann U (2006) "It was hard to come to mutual understanding..."—the multidimensionality of social learning processes concerned with sustainable natural resource use in India, Africa and Latin America. *Syst Pract Action Res* 19(3):219–237
- Rodela R (2013) The social learning discourse: trends, themes and interdisciplinary influences in current research. *Environ Sci Pol* 25:157–166
- Roling NG, Wagemakers MA (eds) (2000) Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press
- Scholz G, Dewulf A, Pahl-Wostl C (2014) An analytical framework of social learning facilitated by participatory methods. *Syst Pract Action Res* 27(6):575–591
- Schulte-Geldermann E, Gildemacher PR, Struik PC (2012) Improving seed health and seed performance by positive selection in three Kenyan potato varieties. *Am J Potato Res* 89(6):429–437
- Schusler TM, Decker DJ, Pfeffer MJ (2003) Social learning for collaborative natural resource management. *Soc Nat Resour* 16(4):309–326
- Senge P (2006) *The fifth discipline: the art and practice of the learning organization* (revised and Updated Edition). Doubleday, New York
- Six B, van Zimmeren E, Popa F, Frison C (2015) Trust and social capital in the design and evolution of institutions for collective action. *Int J Commons* 9(1):151–176
- Tafesse S, Damtew E, van Mierlo B, Lie R, Lemaga B, Sharma K, Leeuwis C, Struik PC (2018) Farmers' knowledge and practices of potato disease management in Ethiopia. *NJAS-Wageningen Journal of Life Sciences* 86:25–38
- Te Molder H, Potter J (Eds) (2005) *Conversation and cognition*. Cambridge University Press
- Toleubayev K, Jansen K, van Huis A (2007) Locus control in transition: the loss and reinvention of collective action in post-soviet Kazakhstan. *Ecol Soc* 12:38
- Tsedaley B (2014) Late blight of potato (*Phytophthora infestans*) biology, economic importance and its management approaches. *J Biol Agric Health* 25:215–226
- Uetake T (2012) Providing Agri-environmental public goods through collective action: lessons from New Zealand case studies. Paper presented at the 2012 NZARES conference, Tahuna conference Centre—Nelson, New Zealand. August 30–31
- Van Der Stoep H, Aarts N, Van Den Brink A (2017) Shifting frames: mobilizing policy attention for landscape values in a Dutch urban–rural fringe. *Journal of Environmental Policy & Planning* 19(6):697–711
- Woodhill J (2010) Sustainability, social learning and the democratic imperative: lessons from the Australian Landcare movement. In *Social learning systems and communities of practice* (pp. 57–72). Springer, London
- Wulandari C, Inoue M (2018) The importance of social learning for the development of community based Forest Management in Indonesia: the case of community forestry in Lampung Province. *Small-scale Forestry* 17(3):361–376
- Zamani N, Bazrafkan K, Minaei K (2018) Understanding grower non-participation in the collective management of carob moth in pomegranate in Iran. *NJAS-Wageningen Journal of Life Sciences* 85:42–49
- Zhang B, Li C, De Silva H, Bednarik P, Sigmund K (2014) The evolution of sanctioning institutions: an experimental approach to the social contract. *Exp Econ* 17(2):285–303

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.