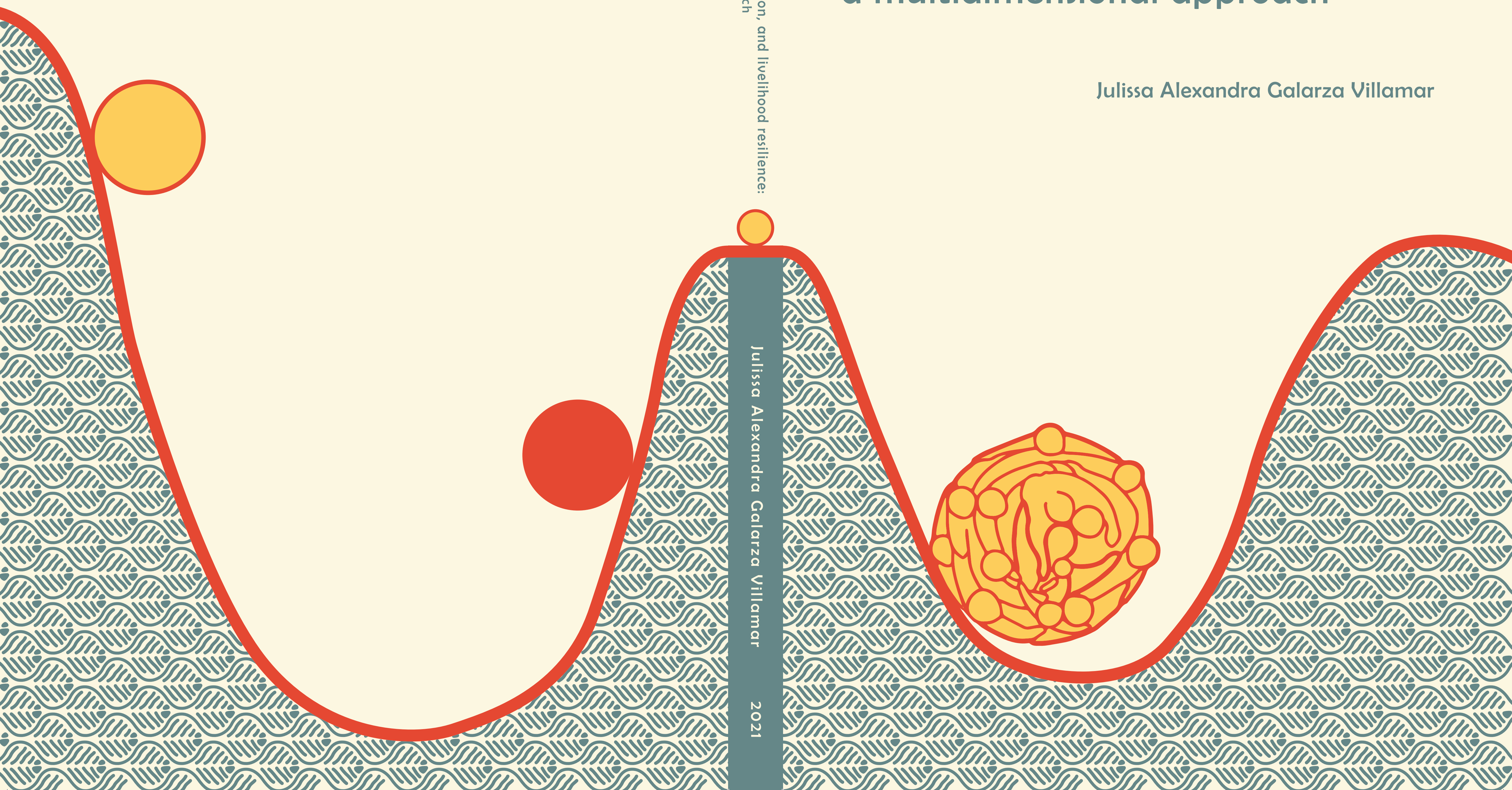
Social capital, collective action, and livelihood resilience

a multidimensional approach

Julissa Alexandra Galarza Villamar



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Julissa Alexandra Galarza Villamar

2021

Propositions

1. Livelihood resilience is a joint-good produced through synergistic cooperation.
   (this thesis)

2. Trust has a critical role in our capacity to "bounce back" from a shock.
   (this thesis)

3. The emergence of new complex problems exceeds the adaptive capacity of laws and policies.

4. Human awareness of the researcher cannot be controlled by any data collection method in social sciences.

5. Structural violence and intersectionality are expressions of a normalized pathological resilience.

6. Motherhood is a natural experiment, full of contradictory hypotheses, bias, and instinctual performance.

Propositions belonging to the PhD thesis, entitled
Social capital, collective action, and livelihood resilience: a multidimensional approach.
Julissa Alexandra Galarza Villamar
Wageningen, 15 January 2021

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Livelihood resilience

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Livelihood resilience

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Julissa Alexandra Galarza Villamar

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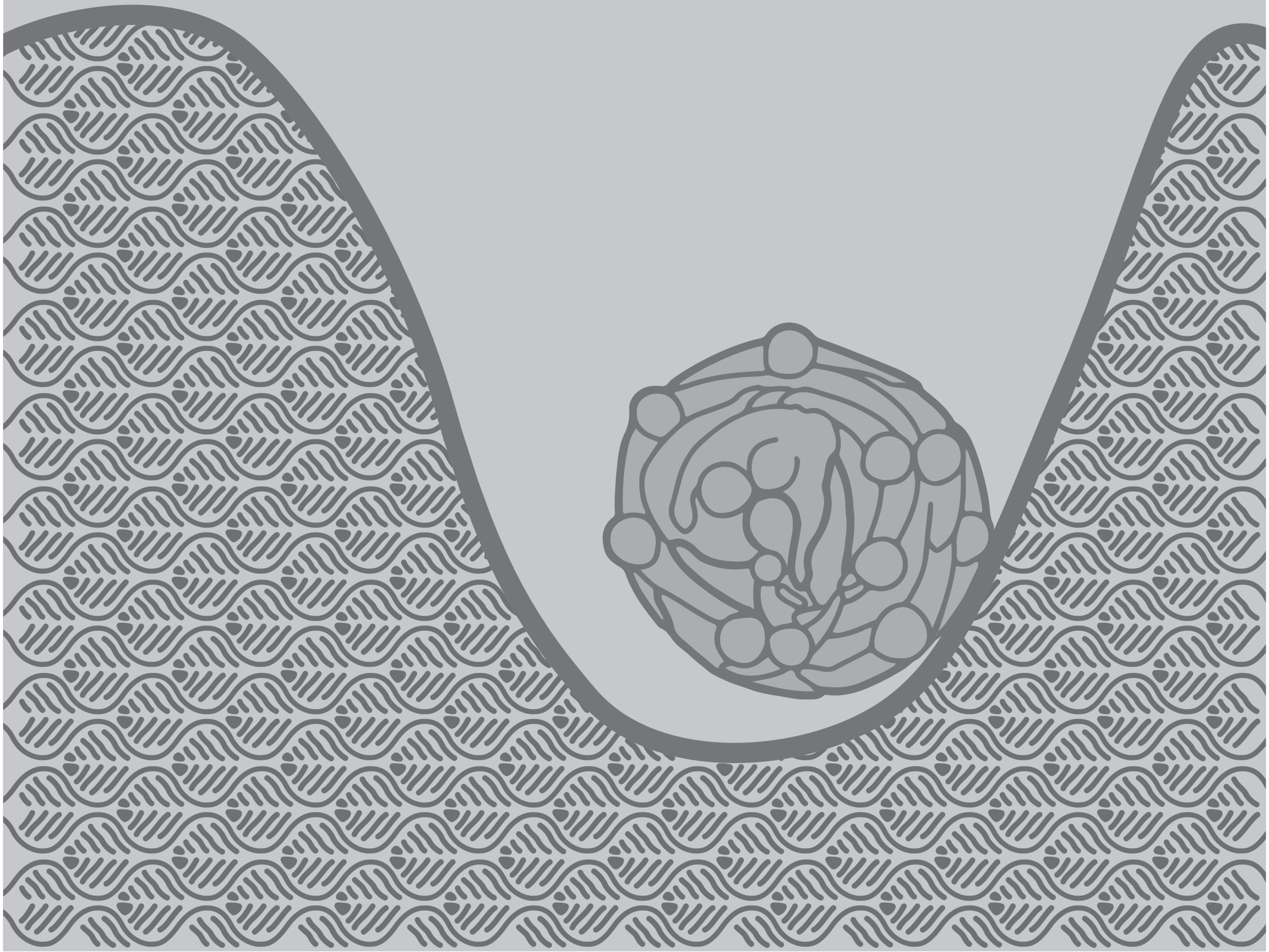
I'm here "... *without pretending to teach*, but to share; *because if the world is round, I don't know what going forward is* (Facundo Cabral)". Therefore, I feel happy to have walked the path with you, my beloved hijito Alejandro.

Estoy aquí "...*sin pretensión de enseñar*, pero sí de compartir; *porque si el mundo es redondo no sé qué es ir adelante* (Facundo Cabral)". Por lo tanto, me siento dichosa de haber andado el camino contigo, mi amado hijito Alejandro.



Chapter 1
General introduction

1.1 Introduction

This thesis portrays the role of human behaviour in the shape of individual and community resilience to covariate shocks from different angles[1]. The focus of this thesis is on farmers' individual and collective responses to floods and pests, and how these influence the resilience of their livelihoods at the household and community levels. Farmers face a great diversity of risks when seeking to maintain their livelihoods: climate change, extreme weather events, market volatility, pests, diseases, and conflicts, to mention some, threaten millions of agricultural livelihoods, especially those of smallholders (Morton, 2007; Harvey *et al.*, 2014; Awal, 2015). Over 70% of the world's farmers are smallholders (with less than 2 hectares), producing over 50% of the total world's crop production, and over 80% of the food consumed in the Global South (Ricciardi *et al.*, 2018, Samberg, *et al* 2016).

Smallholders' develop and maintain their livelihoods under insecure conditions that often involve high degrees of exposure to various threats often related to their geographical location (i.e. floods in lowlands, drought in semi-arid areas, and landslides in mountainous areas) (Blaikie *et al.*, 1994; Altieri and Koohafkan, 2008; Fafchamps, 2010; Harvey *et al.*, 2014). At the same time, smallholders face many challenges in managing biological threats, such as plant diseases and pests, which can undermine the food security of families and communities (Orr, 2003). Natural disasters cost billions of dollars in lost agricultural production, and the increase in the number of outbreaks of transboundary animal and plant pests and diseases is alarming (Jeggo, 2014, p. 255). Such problems have contributed to the disappearance of many agricultural livelihoods although many more, some established for generations, continue to persist, demonstrating their robustness and either healthy or pathological resilience[2].

This research conceptualises agricultural livelihoods as socio-ecological systems (SES) since they involve interactions between human and natural systems. Resilience is the capacity of SESs to 'bounce back'. The resilience of agricultural livelihoods is the conceptual foundation of this thesis. A resilient and healthy livelihood increases people's capacity, across generations, to sustain and improve their livelihood opportunities and wellbeing despite disturbances (Tanner *et al.*, 2015). Whether healthy or pathological, the resilience of socio-ecological systems mostly relies on the self-organization capacity of its human agents (Berkes and Ross, 2013).

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[1] In the risk management literature 'covariate shocks' refer to collective shocks, such as a flood or drought, as opposed to 'idiosyncratic shocks' which refer to shocks experienced by individual households, such as sickness or their house burning down (Pradhan and Mukherjee 2018).

[2] Pathological resilience is characterized by being stuck in a cycle of poverty and ecological degradation and being resistant to more positive configurations or transformation (Allison and Hobbs 2004, Silbert and Del Pilar Useche 2011, Cabel and Oelofse 2012).

International agendas and institutions that aim to reduce poverty, hunger, and food insecurity give a high priority to improving the resilience of households and their livelihoods (see, for example, FAO, 2015). Yet these strategies and development plans, promoted and supported by different actors, can only be effective when they give centre stage to smallholders, the main agents of community development, and take into consideration their perspectives, priorities, and social dynamics (Niehof and Price, 2001). The substantive, empirical, chapters in this dissertation are focused on smallholder behaviour toward environmental and biological covariate shocks, specifically floods and pests. As I develop my arguments I progressively introduce and integrate the lenses of the adaptive cycle of complex systems, social capital, social dilemmas, collective action problems, and disaster risk reduction.

1.2 Conceptual framework

This dissertation interrelates five main conceptual components: resilience, socio-ecological systems, risk, social capital and collective action. The three first components formed the basis of the initial stage of the research (chapter 2). The research questions addressed in Chapters 3, 4, and 5 emerged in a cascade-like way from the progressing research outcomes, which led to the components of social capital and collective action being integrated. This section provides an overview of how these themes were adopted and integrated, as well as the subsequent research questions they raise. Resilience is the starting point from which the conceptual framework was built.

1.2.1 Resilience

Resilience is defined as the ability of a system to absorb disturbance and reorganize itself in response to changes in order to maintain its functions, structures, and evaluations without shifting to a new or novel pathway (Walker and Meyers, 2004; Folke, 2016). According to the theory of the adaptation cycle (Holling, 1973), adaptive capacity (or resilience) is one of the three dimensions that shapes a system's adaptability and is a measure of its vulnerability to unexpected or unpredicted shocks (see Figure 1.1).

Potential and connectedness are the other two dimensions that shape a system's adaptability. Potential refers to the wealth of the system that is available for change and determines the range of possible future options. It includes different forms of capital, financial, ecological, social, and cultural. Connectedness refers to the internal controllability of a system and reflects the degree of flexibility or rigidity of such controls, for example, their sensitivity to perturbation. It determines the degree to which a system can control its future, instead of being controlled by external variables (Gunderson and Holling, 2001).

In this cycle, the systems (ecological, social, institutional or socio-ecological) are prone to experiencing four phases. growth (r), conservation or sustained plateau (k), collapse or release (Ω), and reorganization (α), and it is in these last two phases (together known as the back loop) that define if the system will experience a new growth phase in a new cycle within the same regime. Resilience expands and contracts throughout the cycle (Gunderson and Holling, 2001)

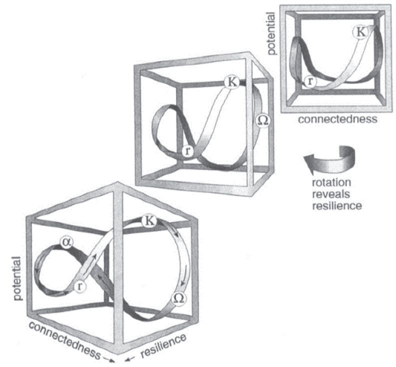


Figure 1.1 the adaptive cycle: The illustration shows how the four phases r, K, Ω, and α are shaped by the dimensions of potential, connectedness, and resilience (Holling, 2001).

When applying the adaptation cycle to livelihood resilience, it can be said that a collapse phase (Ω) can be triggered by any environmental, economic, social and political disturbance that threatens the continuity of peoples' livelihoods. Resilience, by contrast, can be defined by people's capacity to self-organize (α phase) across generations to sustain and improve their livelihood opportunities and well-being (from r to k phase) despite those disturbances (Alinovi *et al.*, 2010; Tanner *et al.*, 2015). Such an approach sees people as the main actors, whose agency, empowerment, rights, and individual and collective actions, define the dynamic processes of social transformation (Tanner *et al.*, 2015).

When we place people at the centre of the analysis, rather than ecosystems, technologies, political contexts, market or resource networks, this emphasizes people's differences. These differences can manifest in relation to peoples' risk perceptions and capacities for taking actions, either individually or collectively (Bahadur, Ibrahim and Tanner, 2010; Cabel and Oelofse, 2012; Scolobig *et al.*, 2015); and to their individual willingness to cooperate or not in order to respond towards a given challenge situation. This latter characteristic is defined by individuals' cost-benefit calculations and in turn, determines the collective cost-benefit distribution outcome (through either social dilemmas or collective action problems) (Ostrom, 2008).

As such individual (households) 'taking action' to 'maintain self-organization', requires both social capital and collective action in order to achieve cooperation, and to move from phase Ω to phase α within the adaptive cycle. Holling (2001) and Allison and Hobbs (2004) provide a more extensive discussion and a graphic representation of the adaptive cycle.

1.2.2 The cascading integration of concepts and theories

The conceptual framework uses (Gunderson and Holling, 2001) adaptive cycle as the main theoretical basis for understanding resilience. This cycle raises and seeks to address questions such as what, to what, why, and how do people establish resilience. Figure 1.2 illustrates how other concepts relate to the different stages and dimensions of the adaptive cycle, untwisting the adaptive cycle's shape for practical and illustrative purposes. In the horizontal direction, it starts with the system's growth phase, which is followed by the conservation, collapse, and reorganization phases. In the vertical direction, it shows adaptive capacity, connectedness, and potential as the dimensions that shape a system's resilience (Gunderson and Holling, 2001; Holling, 2009).

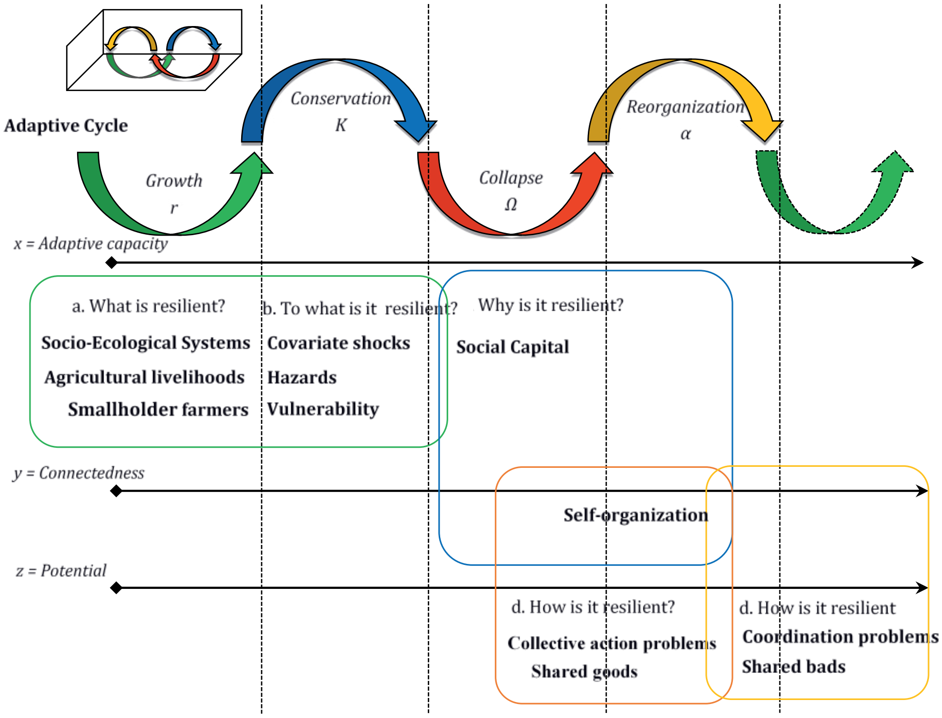


Figure 1.2 Conceptual framework, showing how and where the five main components of the research (resilience, socio-ecological systems, risk, social capital, and collective action) are developed in this thesis. (Adapted from Gunderson and Holling, 2001).

1.2.2.1 What is resilience? Socio-ecological systems and agricultural livelihoods

Carpenter *et al.*, (2001) posed an essential question: 'the resilience of what to what?' The 'what is resilient' question refers to the unit of analysis. In this research, the focus is on socio-ecological systems (SES) with particular attention paid to agricultural livelihoods and households (smallholders) as general and specific study units, respectively.

SESs are understood as systems which include societal and ecological subsystems in mutual interaction with each other (Gallopín, 2006). These are complex systems because they are dynamic and adaptive. Resilience is one of the main properties of an SES. The resilience of an SES supports human well-being, and its adaptability is based on human actions that sustain, innovate and improve the development of current pathways (Duit *et al.*, 2010; Skerratt, 2013; Shaw, Scully and Hart, 2014).

Agricultural livelihoods can be seen as complex SESs (Rivera-Ferre *et al* 2013) since humans intervene in natural systems to provide them with ecosystem services that sustain their livelihoods (Cabel and Oelofse, 2012). The stability of these SESs depends on the ability of those managing them to maintain self-organization in the face of stress and shocks (Berkes and Ross, 2013). From a decision-making perspective, smallholder households take the majority of, and the most important decisions regarding the strategies needed to manage and cope with disruptive events that threaten their food security or other aspects of their livelihoods. Thus, their self-organizational ability – promoting or promoted by cooperation – strongly depends on the social and cultural capital contained and built up within the system (Alinovi, Mane and Romano, 2010; Folke *et al.*, 2016).

1.2.2.2 Resilient to what? The risk perspective

According to Holling (2001), the resilience of a system can be thought of as the opposite of its vulnerability. Following Holling's view, I use a risk approach to specify my insights into the 'to what is it resilient?' issue. A disaster risk reduction approach defines risk as to the probability of harmful consequences that a system can experience as a result of a disturbance. When a risk materializes, it can become a shock, by creating significant negative welfare effects (Heitzmann *et al,* 2002). These can be social, economic, ecological, physical or environmental, or a combination of these. The consequences are determined by the interaction between a hazard and the vulnerability components within the system

A hazard is a natural or human-made event, phenomenon, or activity that has the potential to cause harmful consequences to an exposed system. The harm that the hazard might cause is a function of the degree of exposure, sensitivity, and the system's capacity to cope, respond and recover. These three elements together determine the vulnerability of that system toward the hazard to which is exposed (Blaikie *et al.*, 1994)

Although resilience is not entirely the opposite of vulnerability, in order to operationalize the 'to what is resilient?' question, I translate it to a risk approach language: 'which threat(s) is the system exposed and vulnerable?'. In this research, the specific agricultural livelihood hazards studied are floods (in Ecuador) and crop pests (in Rwanda), to which some units (or sets of units) might be more or less resilient, due to their characteristics, dynamics, and resources.

1.2.2.3 Why is it resilient? social capital and self-organization capacity

Self-organization among households is critical to achieving and maintaining resilience in agricultural livelihood systems. To deepen my insight into 'why is it resilient?' I focus on social capital as a primary source of self-organization. According to the OECD, social capital is defined as "networks together with shared norms, values, and understandings that engender trust and therefore facilitate co-operation within or among groups" (Keeley, B., 2007, p. 103).

It is crucial to acquire a better understanding of how social capital contributes to facing up to covariate (flood, drought, etc.) and idiosyncratic (illness, robbery, etc.) shocks. This can lead to the identification and implementation of policies that complement existing strategies or substitute those that do not contribute to resilience building or reach the most vulnerable. Bernier and Meinzen-Dick, (2014) emphasize that local social capital systems have a key role in providing bonding, bridging, and linking capital that allows individuals, households and communities to better cope, adapt, and self-transform through risk smoothing and sharing practices or mobilizing resources from outside of the affected communities.

Environmental and biological shocks are covariate disturbances that affect whole communities (to a greater or lesser extent) and can lead to the occurrence of diverse idiosyncratic shocks. Cherry et al (2015) highlight that covariate shocks are difficult to contain locally, but that idiosyncratic risks can often be managed by communities. A variety of informal risk-sharing mechanisms, such as food sharing, remittances, rotating saving, or unstructured loans, have been documented; with this resource sharing done among group members, family and neighbourly ties and/ or through self-organized activities (Fafchamps, 2010).

1.2.2.4 How is it resilient? Problems of collective action, and shared goods and bads

'Maintaining self-organization' among at-risk people requires not only social capital but a subsequent collective action to achieve a common goal. For example, bonding social capital within households and building networks of reciprocity can be important for coping with the impact of extreme weather. However, without collective action initiatives; this does not necessarily facilitate pro-active adaptation and the enhancement of well-being (Adger, 2003).

Collective action has been extensively studied in the field of natural resource management (Ostrom, 2008), showing how human and social capital formation is critical in solving many communities' development problems in this field (Krishna, 2004; Ostrom and Ahn, 2007). Social dilemmas are critical to either creating or hindering the conditions for achieving collective actions.

Social dilemmas define a situation where two or more individuals would be better off if all cooperate, but fail to do so because of self-seeking choices that benefit them individually (Dawes, Kragt and Orbell, 1988). Kollock (1998) sees this as a situation where individual rationality leads to collective irrationality.

Few studies have integrated collective action problems to social capital theories, and even fewer have focused on resilience within a SES context. However, research on risk pooling and social dilemmas gives us some guidance on how to approach these underexplored topics. One of them is the importance of the motivations to cooperate in the face of a shock (Cherry, et al, 2015), on which I draw extensively. This research explores the role of collective action to protect a good from the harmful consequences of a hazard. At the same time, it also looks at how to control and prevent a potential threat. In order to deepen my understanding of the issue of 'how is it resilient?', I focus on the role of collective action problems in hindering or enabling livelihood resilience in the face of floods and pests.

1.3 Research questions, objectives, and methodological approach

The overall purposes of this research are:

- to better understand smallholders' rationale for cooperating under a shock scenario and its relationship to their current livelihood resilience at a household and community level, and:
- to explore multiple theoretical frameworks and mixed methods to disclose individual decision making' motivations in the face of covariate shock.

As a consequence of the initial integration of the conceptual components, and the progressive findings through the research, more specific research questions, objectives, and methodological approaches evolved, as shown in Figure 1.3.

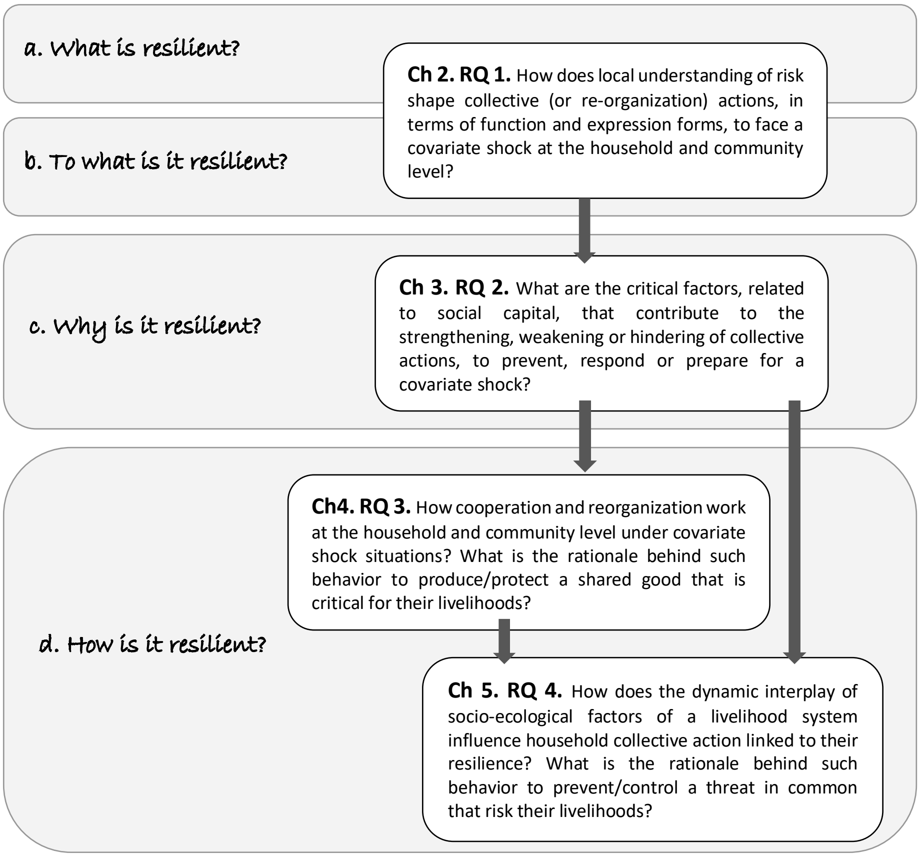


Figure 1.3 Research questions that emerged in a cascade-like process emergence throughout the thesis.

1.3.1 Specific objectives

As this research progressed, new research questions emerged together with new methodological challenges. As such the objectives were both theoretical and methodological. On the one hand, I pursued a better understanding of the links among the different theoretical components. On the other hand, I pursued, adapted, and designed the methodological processes and tools needed to collect the data that help me to understand those links. See Table 1.1.

Table 1.1 Theoretical and methodological objectives

Research questions	Theoretical objectives	Methodological objectives	Output
1	To better understand livelihood resilience through the theoretical lens of disaster risk management.	To develop and apply a participatory resilience assessment, from a disaster-risk perspective, where users define what is at risk, why it is important, and how it should be measured.	Chapter 2

Research questions	Theoretical objectives	Methodological objectives	Output
2	To explore the role of social capital in mobilizing peoples' resources during a covariate shock situation.	To develop and apply a tool that operationalizes the integration of resilience and DRM concepts to assess the role of social capital in coping with shocks.	Chapter 3
3	To articulate, through the lens of sense-making, smallholders' behaviour (and individual motivations) and management strategies for social risks and how they affect collective action and livelihood resilience.	To use social dilemma games as a situational experience and an elicitation tool for smallholders to discuss their motivations and visualize the complex social dynamic.	Chapter 4
4	To better understand the role of social dilemmas and collective action in managing a public bad threatening livelihood resilience in the context of complex systems.	To use experimental and simulation game techniques to study individual decision-making in interaction with SES factors that enhance or hinder the prevention and control of a public bad.	Chapter 5

1.3.2 Research design

Creswell (2009) suggests a framework composed of three pillars to design research. These are philosophical worldview, the strategy of inquiry, and research methods. He argues that these three are interconnected, see Figure 1.4. Therefore,

"the researcher needs to think through the philosophical worldview assumptions that they bring to the study, the strategy of inquiry that is related to this worldview, and the specific methods or procedures of research that translate the approach into practice" (Creswell, 2009, p. 5).

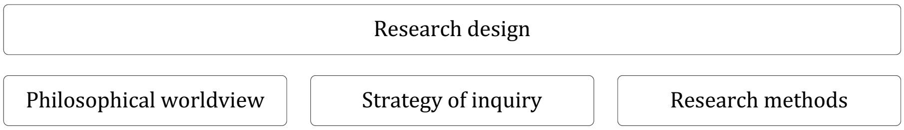


Figure 1.4 A framework to design research, based on Creswell (2009)

1.3.2.1 Philosophical worldview

Accordingly to my research purpose, I assume a pragmatic philosophical worldview. Pragmatism suggests that if a set of theories and tools are useful in a given research context, then its application is valid. Thus, it focuses on the 'outcome of the action' rather than a set of rules. Pragmatism places the research questions at the centre of the inquiry and all the methodological decisions are linked to them. Thus, it supports using a diverse range of research methods, as far as these are useful to answer the questions within their context. For a detailed description of the different philosophical worldviews see (Creswell, 2009; Leavy, 2017).

1.3.2.2 Research strategy

Yin (2002) argues three factors are influencing the choice of an inquiry strategy (i) the type of research questions, (ii) the extent of control that the researcher has over behavioural events, and (iii) whether the focus is on contemporary or historical events, (see Table 1.2). The two types of questions that predominate in this research are 'how?' and 'why?'. My purpose is to understand how social capital works under shock situations, and how it relates to livelihood resilience with a particular focus on the at-risk people's perceptions and their sense-making of their experience. This research attempts to make sense of behavioural events rather than to measure or control them. Therefore, I use a case study strategy, which is appropriate for these purposes.

Table 1.2 Relevant situations for different research strategies (source: COSOMOS corporation, cited in Yin, 2002)

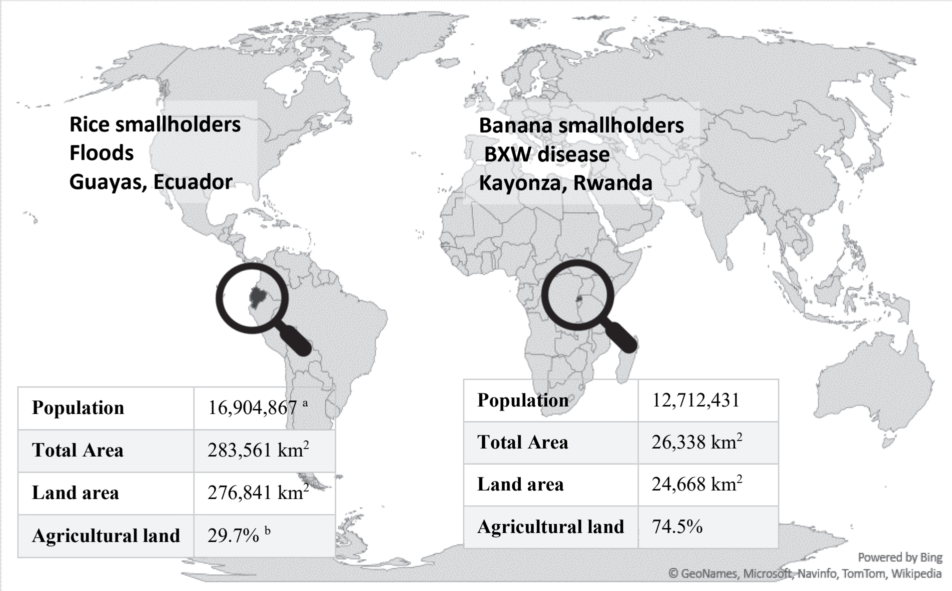
Strategy	**Form of the research question**	**Requires control of behavioural events?**	**Focuses on contemporary events?**
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case study	How, why?	No	Yes

1.3.2.3 Case studies

This research uses two single case studies. In chapters 2, 3, and 4, I focus on the case of rice smallholders cropping in flood-prone areas of Ecuador. Chapter 5 focuses on the case of banana smallholders facing the threat of *Xanthomonas* Wilt Disease in Rwanda. See Figure 1.5. Both countries are considered to be developing economies, where agriculture is a fundamental – and highly vulnerable – livelihood for millions of smallholders (Vallejo-Rojas, Ravera and Rivera-Ferre, 2016; Eckstein, Hutfils and Winges, 2019).

The case of rice smallholders cropping in flood-prone areas of Ecuador was selected because it is representative of a covariate shock situation. Rice farming is one of the most vital agricultural livelihoods in Ecuador (Guerrero, Samudio and Farías, 2011). Although smallholders (with less than 5 hectares) produce 45% of the country's rice, they only own 17% of the land (INEC, 2008). Rice smallholders located in the low basin of the Guayas River, are exposed to floods and droughts since the river caudal can vary from 230 to 1,500 m3/second (Nolivos Alvarez & Santos Dávila, 1998; Gonzales, 2008 cited by Tapia, 2012). Despite the socio-ecological and economic challenges, rice is a staple part of the diet and traditional livelihoods dating back to at least the 1870s

(Espinosa, 2000). Therefore, whether healthy or pathological, its prevalence shows a degree of resilience. I use this case to link social capital to livelihood resilience from the perspective of cooperation toward the goal of coping together with a flood. To do so, I studied progressively, in chapters 2, 3, and 4, how and why people continue their rice (and other) livelihoods despite the floods, from a social capital perspective.



Population	16,904,867 [a]
Total Area	283,561 km^2
Land area	276,841 km^2
Agricultural land	29.7% [b]

Population	12,712,431
Total Area	26,338 km^2
Land area	24,668 km^2
Agricultural land	74.5%

Figure 1.5 Location and general information for the selected case studies. [a] population estimated in 2020, [b] agricultural land estimation 2011. Source: https://www.cia.gov/library/publications/the-world-factbook/docs/rankorderguide.html.

The findings from chapters 2,3,4 led to a new interest: how and why people prevent and control a common threat, such as an infectious disease, to preserving their livelihoods. A collaborative research program offered opportunities to study this in the context of banana farming in Rwanda. In chapter 5, I study the case of banana smallholders (with less than 1 hectare) in Rwanda, threatened by the Banana *Xanthomonas* Wilt Disease (BXW). Banana is one of the most important sources of food security and livelihoods for millions of farmers in East and Central Africa, among them, Rwanda (Tripathi and Tripathi, 2009). BXW is caused by the bacterium *Xanthomonas campestris pv. Musacearum*, and infection can result in yield losses up to 100%. It is highly transmissible through infected plant material, cutting tools, long-distance trade, and animal vectors (Tinzaara *et al.*, 2016). There is no cure for the disease, and complete eradication is not possible. Once the pathogen is established in a stem, it will inevitably die. However, collective efforts in good preventative agricultural practices and early response to disease outbreaks can contribute to its control and management (Tripathi and Tripathi, 2009; Blomme *et al.*, 2017; McCampbell *et al.*, 2018).

1.3.2.4 Research methods

The thesis follows a mixed-method design, supported by other complementary research approaches. Chapters 2 and 3, follow an *exploratory sequential approach*. The research begins by exploring the topic through qualitative methods, and then use its findings to develop a quantitative instrument or subsequent quantitative phase (Creswell, 2015). In both chapters, qualitative information from the first research phase served to develop quantitative research tools through a quantizing method (the process of transforming qualitative codes into quantitative variables). Chapter 4 followed a nested mixed approach, where one method was used as the primary one, and additional data were collected using a secondary method (Creswell, 2009; Leavy, 2017). In this chapter, I nested the quantitative results of a game into the outcomes of a focus group discussion. Chapter 5 follows an *explanatory sequential approach*. The research begins with quantitative methods, and then qualitative methods are designed to explain the quantitative findings in depth. In this chapter, I first apply a public bad experiment, followed by a focus group discussion. Table 1.3 provides a summary of the methods applied in these four chapters.

Table 1.3 Description of chapters 2, 3, 4 and 5

	Chapter 2	**Chapter 3**	**Chapter 4**	**Chapter 5**
Chapter name	Local understanding of disaster risk and livelihood resilience: the case of rice smallholders and floods in Ecuador	The strategical role of social capital on DRM and livelihood resilience: rice farmers and floods in Ecuador	Linking cooperative behaviour and livelihood resilience within a shock context: the case of rice smallholders' saving groups in Ecuador	Adding emergence and spatiality to a public bad game within the context of a socio-ecological system: collective action to fight an infectious disease outbreak
Case study	Rice production in flood-prone areas in Ecuador	Rice production in flood-prone areas in Ecuador	Rice production in flood-prone areas in Ecuador	Banana production and the spread of BXW disease in Rwanda
Description	Development of a participatory risk assessment to better understand livelihood resilience from a local perspective.	Links between community resilience and social capital, and their implications for disaster risk reduction.	Relationship of within-group cooperation, collective livelihood resilience, and shocks.	Role of human cooperation in preventing a public bad in the context of social-ecological systems.
Research design	Case-study design	Case study design.	Case study design	Lab in the field experiment
Sampling method	Snowball	Snowball	Convenience	Quota

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Approach and method	Mixed. Exploratory sequential	Mixed. Exploratory sequential	Mixed. Quantitative nested in qualitative	Mixed. Explanatory sequential
Quantitative	Quantizing	Quantizing	Descriptive statistics	SES modelling in a board game, field experiment design.
Qualitative	Focus group Oral storytelling	Focus group In-depth interviews	Focus group	Focus group
Arts-based	Visual arts practices (drawing)	-	Social dilemma game (play building)	-
Data analysis methods	Codification of qualitative data (oral and drawings). Quantizing.	Codification of qualitative data. Quantizing.	Descriptive statistical analysis of game results, the codification of qualitative data.	Descriptive statistical analysis of test game results.

Chapters 2 and 4 also integrate an art-based approach within their mixed-method approach. Arts-based research recognizes that art has the ability to express people's awareness and knowledge. Multiple non-verbal ways of knowing can be used in this approach, such as sensorial, kinaesthetic, and imaginary (Gerber, 2012, cited in Leavy, 2017). In chapter 2, I use a drawing technique to elicit individuals to self-construct contemporary flood events (Guillemin, 2004; Zweifel and Wezemael, 2012). In chapter 4, I use gamification (in the format of a social dilemma game) to create a temporary shared experience among participants. Drawing and gamification were tools that supported a subsequent qualitative approach, such as storytelling and focus group discussion, for achieving collective sense-making. In chapter 5, I use the principles of SES simulation in board games (García-Barrios et al., 2017), and lab-in the field games (Cardenas, Janssen and Bousquet, 2013), to explore human decision-making under dynamic conditions.

1.4 Thesis outline

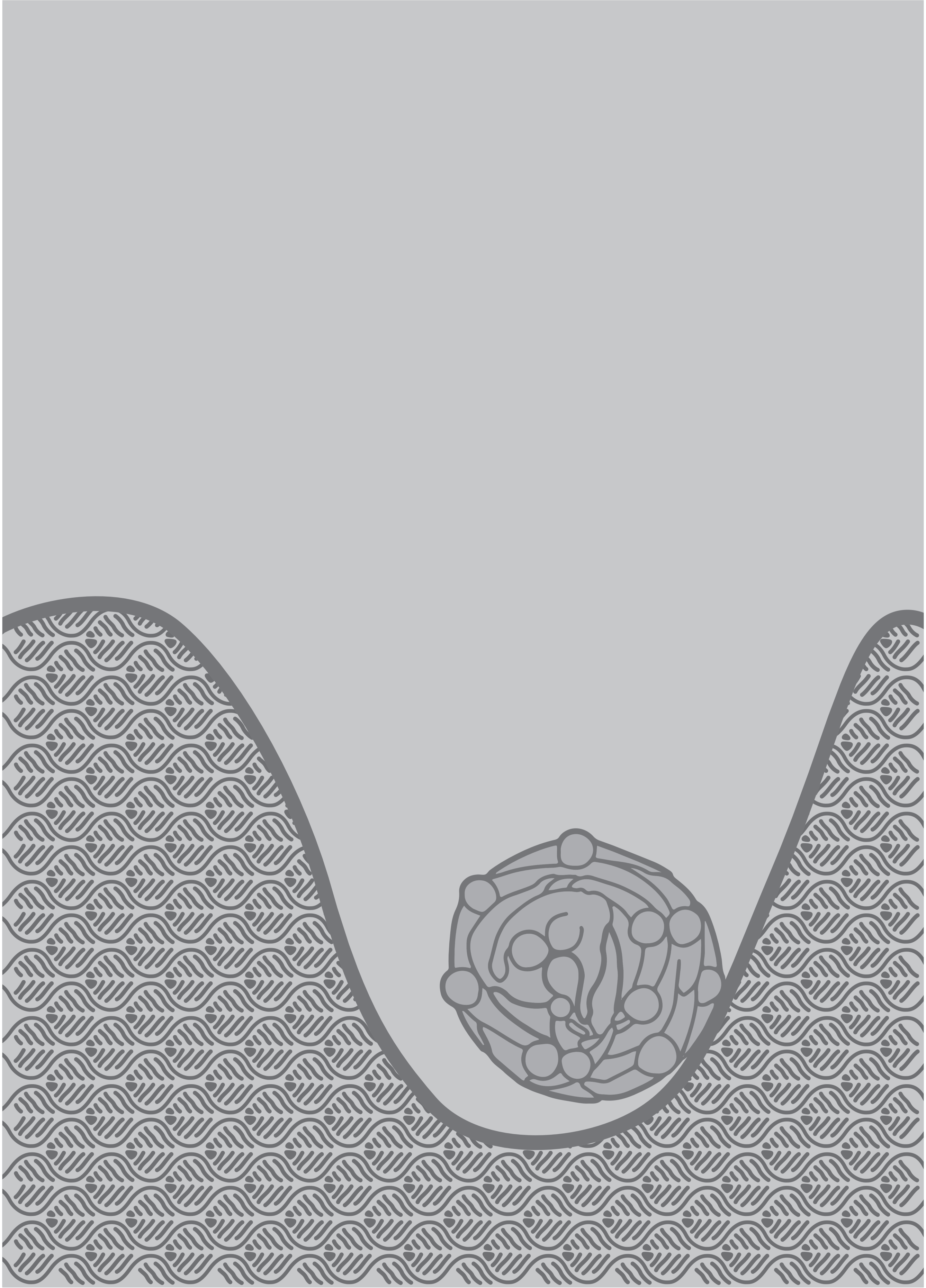
As indicated in Figure 1.2, the chapters in this dissertation explore smallholders' behaviour toward disruptive events and its implications in supporting or undermining the resilience of their livelihoods. This is done through the lens of the adaptive cycle, which provides the principal theoretical approach. Chapter 2 addresses the questions of 'what is resilient?' and 'resilient to what?' in the context of rice smallholders in flood-prone areas in the lower basin of the Guayas river basin in Ecuador. The purpose of this study is to better understand the meaning of livelihood resilience from a local perspective. To do so, a participatory risk assessment that reflects such perceptions through a risk approach lens is developed, described step-by-step, and tested. The research tools were tailor-made for the specific socio-economic and ecological features of the chosen region, hazard, and the nature of agricultural livelihoods. Two of the most relevant findings were that self-organization and having a social network were to fall back on are critical in preparing for, responding to, and coping with shocks.

In Chapter 3, I explore why livelihoods are resilient. Following on from Chapter 2 (and based at the same location), I look more deeply at the critical role that social capital plays in mobilizing resources during a shock situation, again from a resilience perspective. In so doing I integrate insights from the disaster risk management cycle, the adaptive cycle, and the theory of social capital. The purpose is to generate a framework that provides a systematic analysis of the different forms of social capital employed at different stages of a shock and their efficacy. The framework is applied to the responses of rice smallholders' actions in coping with and responding to flooding events. It reveals the presence of social dilemmas involved in producing or protecting shared (or interdependent) goods, including labour force, safe water, livestock and mobility.

Building on the findings of chapters 2 and 3, chapters 4 and 5, explore how resilience works in terms of self-organization capabilities. In Chapter 4, I explore the role of social dilemmas in protecting or producing shared or interdependent goods, which are critical to livelihood resilience at the household and community level. The research continues with the case of rice smallholders facing flood shocks in Ecuador. Here I examine self-organization through the lens of collective action, by using a field economic game as a tool to provoke discussion about smallholders' individual motivations to cooperate or defect in moments of covariate shocks (floods). The field-experiments were used to create a temporary common experience of shock and dilemma, a situation that the smallholders were not unfamiliar with. This was followed by focus group discussions, which revealed how various 'tangible and intangible commons' are at risk during a flood and the individual and collective processes of prioritization that emerge to deal with each of them.

The dynamic process of cooperation evidenced in Chapter 4, raised new questions about how resilience works in terms of self-organization. In Chapter 5, I explore resilience by adding the emergent phenomenon of complex systems. The focus is on the role of social dilemmas and collective action in preventing or controlling a threat (conceptualized as a public bad) to livelihood resilience. To do so, I study the role of collective action and social dilemmas among banana smallholders in Rwanda to prevent or control the spread of *Xanthomonas* Wilt Disease. The research outputs are a conceptual framework that adapts the socio-ecological system framework to the application of risk governance and a novel game-based (an experimental board game combined with focus group discussion) methodology to study cooperation under an emergent socio-ecological challenge.

Chapter 5's game design and testing in the field showed the importance of including the emergent phenomena and the space dimension when studying collective-action problems. The results revealed how the interplay of multiple factors, such as perceptions, social dilemmas and coping capacity, shapes cooperation and coordination. Given time and budgetary restrictions, deepened by the COVID-19 pandemic, the work developed in this chapter will continue in the future through cooperation with other research. The final chapter of this dissertation discusses the results, findings, lessons learnt and new questions that arose from the empirical work (chapter 2 to 5) which could be the basis of future research.



Chapter 2
Local understanding of disaster risk and livelihood resilience: the case of rice smallholders and floods in Ecuador

Galarza-Villamar, J., Leeuwis, C., Pila-Quinga, G., Cecchi, F, Párraga-Lema, C.

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Abstract

On the premise that a system's resilience is partially a function of its capability to manage risk, this paper systematically presents a step-by-step process to develop and apply a participatory risk assessment as an approximate way to better understand livelihood resilience from a local perspective, specifically within the context of rice smallholders located in flood-prone areas in Ecuador. This process is characterized mainly by (i) approaching smallholders to ascertain the livelihood assets that are relevant to them, how they could be understood as being at risk, and how their at-risk situation should be measured and interpreted; and (ii) using drawings and stories as a combined research tool for refreshing memory in the process of data collection. The differentiated research process showed that (i) including local knowledge and interpretation of risk from the beginning of the assessment tool construction results in an easier application in the field; (ii) drawing and storytelling as a combined tool, on the one hand, helped participants to provide detailed information about facts, feelings, and social dynamics, and on the other hand allowed us to indirectly assess their willingness to collaborate and the strategies to do so; and (iii) popular or innovative strategies, involving tangible and intangible resources, identified through every step, proved to be a link between local resilience and risk management capabilities.

Keywords: livelihood resilience; risk disaster; participatory assessment; flood; rice; smallholders

2.1 Introduction

Resilience building has attracted considerable attention from scientists and policymakers in the last decade. A relevant example is that, in 2005, the United Nations International Strategy for Disaster Reduction (UNISDR) created the Hyogo Framework for Action (HFA) 2005–2015: Building the Resilience of Nations and Communities. As a result of the lessons learned and the gaps and new challenges identified, in 2015 UNISDR created the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030, shifting its attention from disaster management to disaster risk management and prioritizing the understanding of disaster risk in all its dimensions as a primary step toward enhancing the resilience of people and their livelihoods (UNISDR, 2015). In this paper, we present a participatory risk assessment that aims to contribute to such understanding.

Even though designing policies and projects that enhance resilience is among the world's top priorities, the methods used to diagnose such policies and projects have not proved to be fully successful. The literature shows that most of them are based on maps and mathematical modelling, used mainly by governments and institutions responsible for disaster risk management (Arbon *et al.*, 2013). Although these methods and tools are essential for increasing knowledge and designing and planning projects and policies, they are very limited in their use of local knowledge, perceptions, and strategies, which are also essential to understand and enhance resilience at the local level (Pain and Levine, 2012; Mapfumo *et al.*, 2013; Reed *et al.*, 2013).

In the context of dynamic systems, such as agriculture-based livelihood systems, some authors define resilience as a "bounce forward ability" (Siambabala *et al.*, 2011), which is not a state but a dynamic process within a context-specific nature of risk, determined by (i) the diversity of opportunities, (ii) the connectivity between knowledge and information across stakeholders at different scales, (iii) the form of knowledge blending, (iv) risk distribution, (v) shock redundancy over the whole system, and (vi) its social structures (social cohesion and capital) (Norris *et al.*, 2008; Bahadur, Ibrahim and Tanner, 2010; Mitchell and Harris, 2012).

Resilience measurement faces great challenges when it has to span disciplinary boundaries. Therefore, most proposed frameworks tend to focus on a specific combination of measures and use available data, rather than adopting a normative approach. The dynamic nature of change, the context-specific nature of risk, and the capacity complexity linked to resilience impede systematic measurement, leading to considering proxies or simple frames for evaluation (Mitchell and Harris, 2012).

In addition to the methodological limitations to understanding resilience, there are also challenges in first defining the lens through which resilience should be studied. Although definitions separate resilience from risk and its determinants (vulnerability and hazard), and resilience is not the opposite of vulnerability, a risk approach could be considered as a promising alternative to understand resilience (Mitchell and Harris, 2012). Consequently, an increasing number of studies are using risk management to operationalize and measure resilience for more practical purposes (Mitchell and Harris, 2012), on the basis that a system is likely to become more resilient to shocks if it is capable of managing risk more effectively. This means reducing, transferring, or sharing risk, and preparing, responding, or recovering efficiently from an impact (Twigg, 2009).

The acknowledgement of these challenges to understanding resilience, its development, and its implementation evidences a need to fill those blanks through the proper involvement of local people and their views in the policy and research debate. Therefore, the purpose of this research is to develop and apply, within an agriculture-based livelihood resilience context (rice smallholders and floods), a participatory risk assessment whose key features are that (i) users define the livelihood assets that are important to evaluate and the parameters under which these livelihoods should be considered to be at risk and (ii) qualitative and participatory research techniques are used as the main research tools in order to understand smallholders' capability to manage flood risk and therefore become more resilient.

Given that our research looks for an approach that merges the need to operationalize resilience in a more practical way and the need to include local knowledge and perception in the discussion, a risk approach is chosen, as it provides empirical evidence on using participatory research techniques for assessing disaster risk at the local level as a potential enhancer to understand resilience (Blaikie *et al.*, 1994; Pelling, 2007; Niekerk and Annandale, 2013).

Taking as a reference the road map for disaster risk reduction (DRR) and climate change adaptation (CGA) developed by Gaillard and Mercer (Gaillard and Mercer, 2013), this research aims firstly to contribute to the step whereby scientific and local knowledge converge to assess risk (see Figure 2.1).

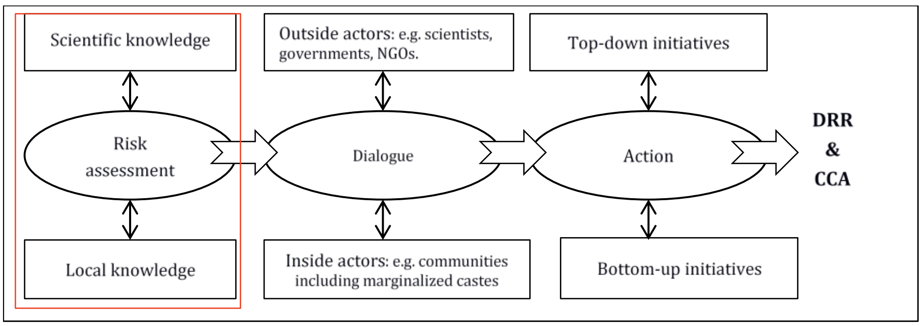


Figure 2.1 Road map for DRR and CCA (Gaillard and Mercer, 2013)

2.2 Research context

In order to visualize the operationalization of theories and approaches and to contextualize the applicability of the developed methodology, a case study and risk scenario are described first. Then, the main theoretical definitions and their pertinence to the case study and risk scenario components are summarized.

2.2.1 Case study and risk scenario

In recent decades, Ecuador has been the scene of a considerable number of natural phenomena that have particularly affected the most vulnerable population: the poor in rural areas. In Ecuador, 36.3% of the population lives below the poverty line; 61.5% of these live in rural areas. The trend of natural disaster events in Ecuador manifests a gradual increase in number and impact severity. Figure 2.2 shows that 45.2% of the natural disasters reported between 1996 and 2016 were floods.

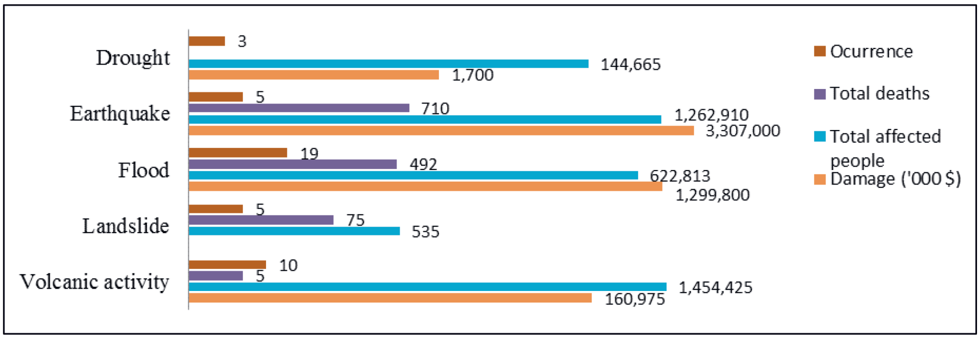
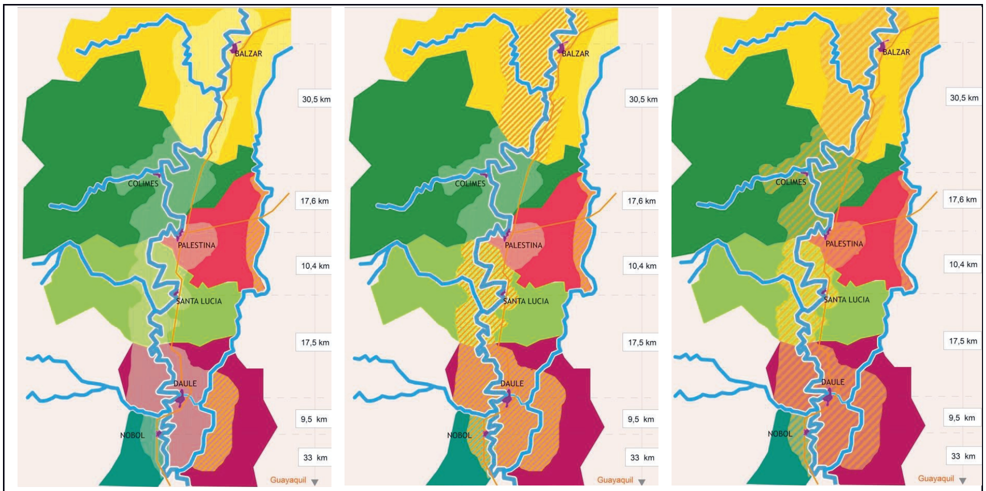


Figure 2.2 Natural disaster statistics between 1996 and 2016 (The International Disaster Database, www.emdat.be)

Rice farming is one of the most important activities in Ecuador, and it is concentrated in Guayas Province (59%). It is considered important, among other reasons, because it covers 399,020.74 hectares of its territory, 45% of its producers are small farmers (from 1 to 5 ha., owning 17% of the land) (INEC, 2008), and most national social demands are associated with the rice economy (Guerrero, Samudio and Farías, 2011). Its main water source is the Guayas River Basin, whose flow volume varies between 230 and 1,500 m^3/second during the dry and rainy seasons, respectively. Rice is cultivated mainly in its middle and lower basins (altitude below 40 meters), which during the rainy season are vulnerable to floods and during the dry season lack water for producing between 1 to 2.5 rice cycles per year (González, Acosta and Andrade, 208AD; Nolivos Alvarez and Santos Dávila, 1998).

According to the Ecuadorian Secretariat for Risk Management (SGR), the floods reported during the periods 1982–1983, 1997–1998, 2008, and 2012 caused economic losses estimated at over US$ 7.140 million. The greatest damages were reported in the provinces of Manabí, Guayas, and Los Rios, mainly in the agricultural sector. During the 2012 rainy period, 184,008 hectares in the lower basin of the Guayas River and the Chone River estuary were flooded; these belonged mainly to rice smallholder farmers (SENPLADES, 2012). The loss of rice yields could represent over 70% of the yearly income for a modest peasant family in this region; it is therefore of primary importance to enhance the resilience of local people and their livelihoods (Silva, 2016).

The case study chosen to operationalize the selected theories and apply the developed methodology is smallholder households producing rice in flood-prone areas of Guayas Province (cantons Balzar, Nobol, Daule, Palestina, Colimes, and Santa Lucía), within the low basin of the Guayas River. Figure 2.3 shows the six cantons where the study was carried out, and three different flood scenarios: average (2010), above-average (2012), and extraordinary (1997–1998), the last two being the focus of this study.



a) Average b) Above average c) Extraordinary (El Niño)

Figure 2.3 Flood scenarios in the study area

2.2.2 Operationalization of main concepts and approaches

The concepts set out in Table 2.1 have a wide variety of definitions in the scientific literature. However, the most suitable definitions for understanding the developed and applied methodology within the context of the case study have been selected.

Table 2.1 Definitions of main concepts and their operationalization in the case study

Theoretical components	**Definition according to chosen literature**	**Operationalization within the case study**
Socio-ecological system	A system that includes societal and ecological subsystems in mutual interaction (Gallopín, 2006).	Smallholder households cropping rice in the low Guayas river basin.
Risk disaster	The probability of harmful consequences or losses (physical, social, economic, environmental, cultural, or institutional) resulting from interactions between hazard and vulnerable conditions, in a given area and over a period of time (Thywissen, 2006; UNISDR, 2009; Birkmann et al., 2013).	The probability of rice smallholders and their livelihood assets being negatively affected by a flood.
Livelihoods/ *Livelihood assets*	Livelihoods are the capabilities, assets, and activities required to make a living. The assets are the means of production (natural, social-political, human, physical, and financial capitals) available to a given community that can be used to generate sufficient material resources for the community's survival (Carney, 1998 cited in (Morse and McNamara, 2013)).	The developed and applied methodology includes those livelihood assets that are recognized by the community as being important to protect or recover in the face of floods.
Hazard/ *Hazard potential*	A physical event, phenomenon, or human activity that has the potential to cause loss of life or injuries, property damage, social and economic disruption, or environmental degradation. Its potential is characterized by its probability (frequency) and intensity (magnitude or severity) (Blaikie et al., 1994).	Floods are natural hazards with the potential of disrupting or damaging rice farming systems and other local smallholders' livelihoods, in addition to causing loss of life, injuries, or diseases.
Vulnerability	Vulnerability (of any system) is in the function of three elements: exposure to a hazard, sensitivity to that hazard, and the capacity of the system to cope, adapt, or recover from the effect of those conditions (Smit and Wandel, 2006).	A measure of rice smallholders' ability to resist hazards, as a function of the exposure and sensitivity of their livelihood assets, in addition to their societal coping capacities.
Exposure	The extent to which a unit of assessment (including its physical and human attributes that are spatially bounded to resources and practices that may also be exposed) falls within the geographical range of a hazard event (Turner et al., 2003; Birkmann et al., 2013).	The extent to which rice smallholders' livelihood assets, resources, and practices fall within the geographical range of a flood event.
Sensitivity/ *Susceptibility*	This describes the predisposition of at-risk elements (social and ecological) to suffer harm or modifications (directly or indirectly) by a disturbance (Brooks, 2003; Birkmann et al., 2013; Reed et al., 2013).	The predisposition of rice smallholders' livelihood assets to suffer harm or modifications (directly or indirectly) as a result of a flood event.
Coping capacity/ *Societal response capacity*	This is determined by limitations in terms of access to, and mobilization of, the resources of a community or a social-ecological system to respond (lessen potential damage, take advantage of opportunities, or cope with the consequences) to an identified hazard, including pre-event, in-time, and post-event response measures (Turner et al., 2003; Birkmann et al., 2013).	Rice smallholders' capabilities or resources to preserve, protect, or restore their livelihood assets before, during, and after a flood.

Theoretical components	**Definition according to chosen literature**	**Operationalization within the case study**
Household disaster resilience	The capacity of a person or people sharing a living arrangement to sustain their household even under stress; adapt to changes; be self-reliant if external resources are limited or cut off, and learn from the experience to be more prepared for next time. It is not a state but an ongoing process, and it will depend on a range of relatively small actions and activities that build resources, preparedness, and resilience networks (Arbon et al., 2013).	The capacity of rice smallholders' households (and community) to sustain and improve their rice-oriented economies and complementary livelihood opportunities, by means of their coping, adapting, and transforming capabilities to face a flooding shock.
Livelihood resilience	The capacity of people across generations to sustain and improve their livelihood opportunities and wellbeing despite environmental, economic, social, and political disturbances (Tanner et al., 2015).	

2.3 Methodology

Thaddeus (2003), cited in (Yanow and Schwartz-Shea, 2015), p.281, states that "methodological reflection is about designing prosthetics appropriate to the commitments that ground the researcher and her or his research community." Therefore, it is appropriate to highlight that the proposed methodology is committed to contributing to the integration of at-risk people's knowledge and perceptions into the development of more endogenous resilience-enhancing action plans and policies. This is of increasing interest to the research community in the fields of disaster risk reduction, climate change adaptation, rural development, and other related subjects (UNISDR, 2005; Bradford *et al.*, 2012; Cadag and Gaillard, 2012; Arbon *et al.*, 2013; Mapfumo *et al.*, 2013; Niekerk and Annandale, 2013; Fox-Lent, Bates and Linkov, 2015; Gall, Nguyen and Cutter, 2015; Scolobig *et al.*, 2015; Ofoegbu *et al.*, 2016).

In order to achieve the research objectives and overall commitment, a participatory approach was chosen, and mixed research methods were applied for gathering and analysing data. The research was composed of two phases: an exploratory phase and an applicatory phase.

The purposes of the exploratory phase were to (i) identify the livelihood assets that are important for smallholders to protect, preserve, renovate, or replace in the face of flooding shocks and (ii) ascertain and understand the parameters on which farmers base their own evaluation of the hazardousness of a flood and the vulnerability of assets. The synthesized outputs of this phase were (i) information that contributes to rapidly identifying local resilience strategies and (ii) the development of a participatory risk assessment for application in a different and bigger sample during the applicatory research phase.

The purposes of the applicatory phase were to (i) apply the developed participatory risk assessment in order to ratify the information gathered in the first phase and generate a rapid scan of the at-risk situation of the involved communities and their livelihoods, (ii) identify the main livelihoods where common or particular strategies have made a difference to their at-risk situation within and between communities, and (iii) compile a baseline for deepening research on the potential use of endogenous strategies as enhancers of resilience. The synthesized outputs of this phase were: (i) a basic risk characterization report for each community and (ii) qualitative information that contributes to widening knowledge on local resilience strategies. Figure 2.4 presents a summary of the two steps.

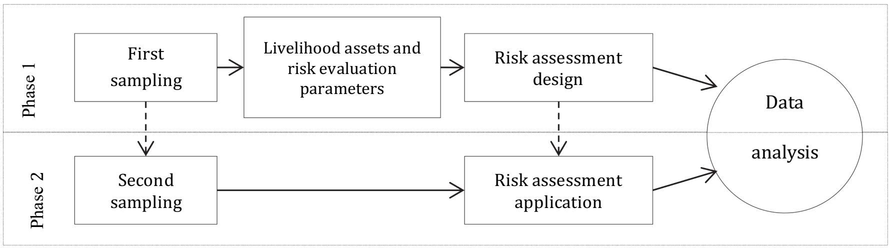


Figure 2.4 Methodological path followed for participatory risk assessment

2.3.1 Exploratory phase

2.3.1.1 Sampling frame and purposes

In the first phase, quota and snowball sampling strategies were used. Rice smallholder farmers were identified who (i) have lived and are currently living and cropping rice in flood-prone areas; (ii) have experienced important flood events such as those reported in 1982–1983, 1997–1998, 2008, 2010, and 2012; and (iii) have a good knowledge of the study areas and their social fabric and dynamics.

The purposes of this first sample were to: (i) provide the main information source to design a participatory risk assessment and (ii) identify and refer other farmers in similar flood-related conditions to participate in the second study stage, where the risk assessment would be applied.

2.3.1.2 Data collection

The design of the participatory risk assessment consisted of involving the sample, which included mainly formal and informal community leaders, older farmers, former managers of irrigation boards, among others, in (i) the identification of main livelihood assets that, according to them, should be evaluated to assess the risk of being affected by a flood at household and community level within their socio-ecological and economic context; (ii) defining the meaning of vulnerability in terms of exposure, sensitivity, and coping capacity for each identified livelihood asset; and (iii) defining the meaning of the hazardousness of a flood in terms of duration, severity, and frequency.

The sample was composed of 30 people who were invited to participate in individual sessions of semi-structured interviews and storytelling between August and October of 2015.

Each session lasted on average two hours and was composed of four main stages, starting with (i) an initial interviewee self-description of the household, livelihood, and community to which the participant belonged; followed by (ii) a descriptive memory recall of under-regular-above average rain and flood events in terms of duration and frequency. Then, (iii) the worst remembered flood event was described in detail (storytelling), including the characteristics of the rain, the flood and its origin (river overflow or puddle formation), the flood's direct or indirect impact on their livelihood assets (severity), and their pre-during-post event strategies.

During the three stages, the researcher asked the interviewee for explanatory details when this was considered necessary, mainly during the storytelling, from which arose the vulnerability meaning of the participant's main livelihood assets in terms of exposure, sensitivity, and coping capacity. Besides, the interviewee identified flood-prone areas by superimposing hand-drawn maps over base maps generated by the SGR.

2.3.1.3 Data analysis

The data collection process outputs were notes, records, and transcripts of each interview, containing qualitative and quantitative information, which were the main inputs to define (i) the livelihood assets; (ii) the vulnerability of assets to be assessed in terms of exposure, sensitivity, and coping capacity; and (iii) flood hazardousness measuring scales in terms of severity, duration, and frequency, which would be used to construct the matrixes for the (i) livelihood vulnerability evaluation and (ii) flood hazardousness characterization, which together comprise the participatory risk assessment. The information was analysed using a categorization and coding approach. As respondents used a great number of words and expressions typical of the region, no software was used for the analysis in order to have enough flexibility to interpret and understand transcripts within the local context.[3] The main steps followed were:

2.3.1.3.1 First step: Define the livelihood assets to be evaluated

The first step is primarily important for the evaluation of vulnerability and hazard (in terms of severity). A pre-set list of livelihood assets was developed before the fieldwork, but it changed during the data collection as some of the assets were not as important as thought at a beginning or because respondents agreed that the assets should be divided into other sub-assets. An example of this is the division of private infrastructure into "house" and "wells"; this is further explained in the results and discussion sections. Figure 2.5 summarizes the step-by-step process

[3] The use of software for qualitative data analysis did not provide additional benefit or enough flexibility for this case.

to identify main livelihoods out of the collected qualitative information, starting from a "pre-set list of livelihood assets" to the clustering of "newly defined list of livelihood assets" in broader categories.

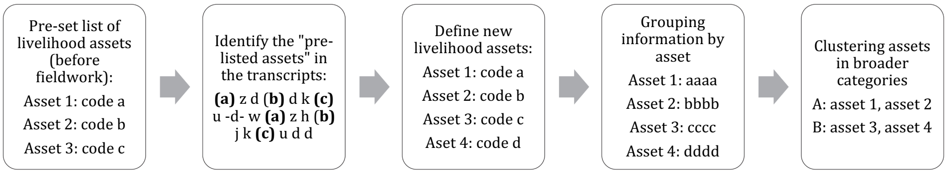


Figure 2.5 Categorization and coding process of information for livelihood asset identification and clustering

2.3.1.3.2 Second step: Develop the livelihood vulnerability evaluation matrix

The livelihood assets identified in the transcripts (mostly from the storytelling section) were analysed in terms of vulnerability indicators, creating new codes for exposure, sensitivity, and coping capacity. For example, every time that something relating to the "distance to the river" of a certain livelihood asset such as a "house" appeared, this text was coded as an "exposure characteristic of the house".

Later, the "exposure" texts applying to the "house" were analysed in terms of "the best location" and "the worst location" for a house when facing a flood. Thus, if respondents asserted that a house on the river's edge could be easily washed away by floodwaters, the "worst" location related to being at the edge of the river and scored 5 points, and the "best" location scored 1 point for vulnerability. The same exercise was repeated for each vulnerability indicator within each livelihood asset.

Finally, the compilation of "best" and "worst" situations for each combination was synthesized and located in a matrix, called the livelihood vulnerability evaluation matrix. Figure 2.6 shows an example of the construction process for a specific asset (infrastructure-house) and its minimum and maximum scores for exposure.

Livelihood assets		Vulnerability indicators		
		Exposure	Sensitivity	Coping capacity
Asset A	Asset A.1	1: 5:		
	Asset A.2			
Asset B	Asset B.1			
	Asset B.2			

Livelihood assets		Vulnerability indicators		
		Exposure	Sen..	Cop..
Infrastructure	House	1: Far from the edge of the river 5: At the edge of the river		

Figure 2.6 Development of the livelihood vulnerability evaluation matrix

2.3.1.3.3 Third step: Develop the flood hazardousness characterization matrix

To design the flood hazardousness characterization matrix, the qualitative description of flood events served to construct scales of harmfulness from 1 (the minimum) to 5 (the maximum) points in terms of duration, severity, and frequency (Blaikie *et al.*, 1994). The duration and frequency variables characterizing the hazard (flood) were respectively scored, taking the longest experienced flooded period and the shortest return period as the highest level of harmfulness (5 points), and vice versa (1 point). The severity variable was the average result of individual scoring of the maximum (5 points) and the minimum (1 point) experienced harm caused directly or indirectly by the flood on their livelihood assets. Figure 2.7 shows an example of how flood hazardousness in terms of severity was scored from 1 to 5 for each evaluated asset (Asset 1, 2, 3, etc.).

Hazard indicators	From 1 to 5
Duration	From shortest to longest period (time)
Severity	From no significant damage to absolute loss
Frequency	From shortest to longest return period

	Asset 1	Asset 2	Asset 3	Average
Flood severity	1: Minimum or no damage 5: Absolute loss			Between 1 and 5

Figure 2.7 Development of the flood hazardousness characterization matrix

2.3.1.3.4 Fourth step: Sampling process for the second stage

Finally, the identified and suggested rice smallholders were inventoried, and their livelihood characteristics and geographical location were verified before they were approached to participate in the second research phase.

2.3.2 Applicatory phase

2.3.2.1 Sampling frame and purposes

In the second phase, a homogeneity sampling strategy was used in order to ascertain a local understanding of floods more in-depth and facilitate the logistics for the participatory risk assessment. This homogeneity was characterized as small-scale rice cropping in flood-prone areas as the main livelihood. There was one sample group per canton, and each one was composed by 15 to 25 rice smallholders from different rural communities within the canton, totalling 105 people.

In order to apply the participatory risk assessment, one workshop per group was performed. The emphasis throughout the assessment was on linking participants' individual and collective tangible and intangible livelihood resources with the direct and indirect impacts of floods events, to evaluate risk according to their best and worst lived experiences, applied strategies, available resources, and perceptions.

2.3.2.2 Data collection

Different qualitative and quantitative tools were applied in each workshop step in order to gather the information that led to the characterization of vulnerability and hazard according to the indicators and measuring parameters identified in the first phase. The main tools used were agricultural calendars, scoring matrix, group discussion, and individual memory recall through drawing and story sharing. Figure 2.8 shows two drawings developed by one of the participants during one of the sessions, illustrating the landscape during the rainy and the dry season of 1998–1999.

The main steps in the participatory risk assessment were (i) identification of flood scenarios, (ii) characterization of local livelihood systems, (iii) impact evaluation of floods and flood-related events on livelihood assets, and (iv) historical reconstruction of a selected flood event.

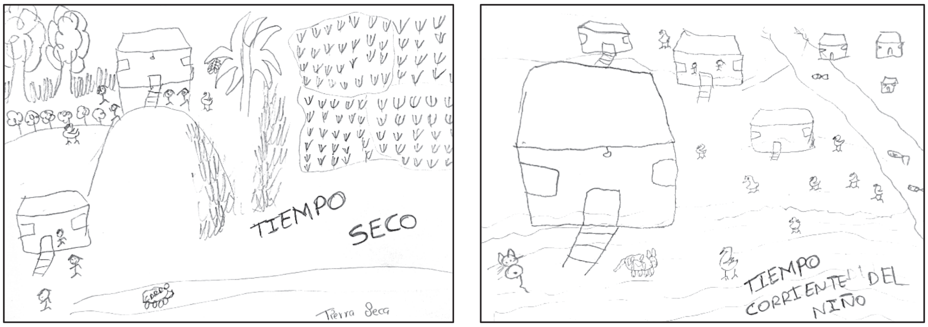


Figure 2.8 Drawings developed during the participatory risk assessment. Left side: landscape during the dry season at Balzar Canton. Right side: same landscape during El Niño phenomena in 1998–1999

2.3.2.3 Data analysis

The qualitative and quantitative data obtained from the workshops were the main items used to measure group (one per Canton) vulnerability and hazard during subsequent sessions of desk work. In order to measure vulnerability, the qualitative information obtained and recorded was transcribed, categorized, and scored according to the vulnerability assessment matrix by an interdisciplinary research team. For the hazard characterization, the three indicators were directly scored by participants during the workshop. In addition, the information regarding years of worst experienced events and frequency were verified using secondary sources.

Finally, the degree of risk of being negatively affected by an above-average flood event was calculated following the equation $Risk = vulnerability * hazard$, using as data average values obtained per canton from the vulnerability and hazard matrixes. In addition, in order to identify significant differences between cantons' average results, a two ways ANOVA test and ANOVA test with repeated measures (with 95% degrees of confidence) were performed, considering the six cantons as the repetitions and the livelihood asset and vulnerability indicator as the grouping levels. The data were analysed using the STATA statistical software.

2.4 Results

2.4.1 Livelihood asset identification for assessing vulnerability

According to respondents, the assets that are important to protect, preserve, renovate, or replace in the face of flooding shocks can be clustered in four main groups of sub-assets: (i) infrastructure, (ii) sources of income and own-consumption, (iii) basic resources for life quality, and (iv) social structure. Respondents' perception of vulnerability for each sub-asset, in terms of (i) exposure, (ii) sensitivity, and (iii) coping capacity, is reported in this section. In addition, at the end of each explanation, the resulting matrixes for assessing vulnerability per sub-asset are shown. As mentioned in section 2.3, the matrixes take into consideration the respondents' views and interpretations, and use a scale from 1 to 5 to score vulnerability according to the best and worst expected scenario, respectively. Extreme values, 1 and 5, are briefly described in Table 2.2.

2.4.1.1 Infrastructure

Three main groups of infrastructure assets were identified: (i) public infrastructure, (ii) houses, and (iii) wells.

Public infrastructure and services, such as schools, bridges, or electricity, could be severely damaged or interrupted by flood events, and a costly external intervention was needed to resume their functionality, as reported in 1997 and 2012 (Vos, Labastida and Bank, 1999; SNGR, 2014). Whereas the infrastructures' exposure and sensitivity features are related to their proximity to the river and infrastructural conditions (construction design, materials, and maintenance), their coping capacity is related to the community's need for external intervention to repair any damage.

Smallholders considered houses and wells as their main private goods. Regarding houses, different exposure scenarios can be found that combines proximity to the river and floor level. The lowest and highest exposure scenario was recognized as being when the house is (i) far from the river and built on tall pillars and (ii) at the river edge and built at ground level, respectively. House sensitivity is related to construction materials. The traditional tall houses are built using wooden planks, bamboo cane, and wood pillars, and more modern houses are built using concrete or mixed materials at ground level. Coping capacity is related to the household's need for external intervention to repair any damage.

Participants strongly agreed that wells should be analysed separately from houses as a private good because their reconstruction could cost more than reconstructing their houses, and their loss would mean losing water for consumption and irrigation during the next rice-cropping dry season. It was also explained that post-disaster help usually does not contemplate financially supporting well reconstruction. Wells' exposure and sensitivity features are related to their proximity to the river and infrastructural conditions, and their coping capacity depends on their operational level. Table 2.2 shows the resulting matrix for assessing the vulnerability of infrastructure.

Table 2.2 Matrix for assessing the vulnerability of infrastructure

Sub-assets	*Vulnerability indicators*		
	Exposure	Sensitivity	Coping capacity
Public infrastructure	1= very far from a water body 5= very close to a water body	1= in excellent condition 5= in deplorable condition	1= people can fix the damage from their own resources 5= high external intervention required to fix the damage
House	1= very far from a water body and house built on tall pillars 5= very close to a water body and house built at ground level	1= in excellent infrastructural condition 5= in deplorable infrastructural condition	1= people can fix the damage from their own resources 5= high external intervention required to fix the damage
Well	1= very far from a water body 5= very close to a water body	1= in excellent infrastructural condition 5= in deplorable infrastructural condition	1= it remains operational 5= it collapses and requires reconstruction

2.4.1.2 Sources of income and own-consumption

The main on-farm source of income is rice production, with fruit trees and farm-animal husbandry usually for own-consumption. Off-farm activities are agriculturally oriented too, but vary according to age, gender, and location.

Smallholders cropping rice in flood-prone areas where floods are experienced regularly produce only one or two cycles per year, starting at the end of the rainy season. Those producing a second rice cycle are usually at risk of losing the harvest at the end of the cycle, due to unseasonal floods. Crop exposure and sensitivity are related to proximity to the river combined with the ground level and to the phenological stage of the plant, respectively. Farmer coping capacity is related to economic activity diversification to respond financially if the harvest is lost.

Fruit trees are usually planted around the house, and their exposure and sensitivity are related to their proximity to the river and stem height, respectively. Poultry and pigs are raised on the land surrounding the house or in a simple structure next to the house; their exposure is related to the availability of floating infrastructure to shelter them during flood periods, and their sensitivity is related to their current health condition. Farmer coping capacity is linked to the available information about the status of the flooding in neighbouring communities and roads, as this influences their decisions. If informed opportunely, farmers harvest the fruits and select animals to be sold or kept for their own consumption before perishing by drowning or diseases. In conditions of isolation, traders access flooded areas in canoes and buy animals at very low prices.

A few cows are usually owned by households in some areas of the river basin as a traditional way of having access to ready cash. Their exposure is related to their mobility options (access to higher lands) during floods and their sensitivity to their health conditions, as they are moved on foot. Household coping capacity is linked to the household's resource sufficiency and flood information for the timely lease of non-floodable land. The importance of social networks and financial resources increases considerably during unseasonal or flash floods, because rental prices are higher, and places can be taken rapidly by the renter's family members or friends.

Off-farm activities, such as day labour on farms or in the agricultural industry, are carried out jointly with on-farm activities to complete the household's basic budget. Exposure and sensitivity are related to the capability of the worker household members to get to their workplace: this means owning or having access to any kind of effective transportation means (canoe, equine, motorbike). Sensitivity is related to whether the worker household member can be easily replaced in his/her workplace, either because of absence or being late due to complicated travel arrangements. Coping capacity is linked to the availability of other off-farm work during the flood period, if the job or workplace is lost or inaccessible. Table 2.3 shows the resulting matrix for assessing the vulnerability of sources of income and own-consumption.

Table 2.3 Matrix for assessing vulnerability of sources of income and own-consumption

Sub-assets	*Vulnerability indicators*		
	Exposure	Sensitivity	Coping capacity
Rice farming	1= rice is cropped on high ground and far from water body	1= rice is ready for harvesting	1= diverse economic activities
	5= rice is cropped at the edge of water body	5= rice is in seedling stage	5= rice-dependent economy
Fruit trees	1= on high ground and far from water body	1= tree over 2 meters tall	1= local information on flood is available

Sub-assets	*Vulnerability indicators*		
	5= at the edge of water body	5= tree under 1 meter tall	5= no information is availableat a good price
Poultry and pigs	1= own floating infrastructure for temporary animal husbandry	1= animals in excellent health condition	1= farmer can sell the animals at a good price
	5= no floating infrastructure available	5= animals in deplorable health condition	5= farmers have to sell the animals under production costs
Cows	1= the animals are taken temporarily to areas not prone to flooding	1= animals in excellent health condition	1= sufficient resources (social and financial) for the timely lease of non-floodable land
	5= the animals remain on the farm during the flood	5= animals in deplorable health condition	5= no social networks in areas not prone to flooding or no financial resources to rent land
Off-farm work	1= farmer can effectively travel to his/her off-farm workplace	1= the farmer is difficult to replace in the workplace	1= off-farm vacancies available
	5= the household is isolated	5= the farmer is easily replaced in the workplace	5= no off-farm vacancies available

2.4.1.3 Basic resources for life quality

The interviewees agreed that their health and access to food and safe water are their main resources to preserve a basic standard of life quality. Household health exposure, which was mistakenly expected to be related to proximity to the floodwaters, was related to current health conditions; sensitivity, to access to medical care; and coping capacity, to accessibility to effective health insurance.

During floods, canoes can make a difference to accessibility to a primary resource such as food. The interviewed sample asserted that, during the flood reported in 2012, those who owned a canoe could go further to buy food or get it from humanitarian aid organizations. Canoes also served to exchange food with neighbours or neighbouring communities. Not having a canoe in the household or among community members led to their being isolated or solely dependent on external help. In addition, it was explained that, during long flood periods, for example, six continuous months as in 1998, the only way to cope with food scarcity was by fishing. Therefore, exposure was linked to transportation capability to reach food sources; sensitivity, to the amount of private food stock; and coping capacity, to the presence of fish in floodwaters.

Safe water consumption could be considered one of the most worrying aspects, because of the great challenge for households in the area to access water that is neither cloudy nor saline, nor contaminated. Wells are the regular sources of clean water, but, during floods, wells might just work partially or totally collapse. When this happens, the next sources are neighbours who might still have an operational well, and then there are traders or external help. Thus, exposure is related to the accessibility of safe water. Another less visible, but extremely important, feature is contamination. Respondents reported experiencing "upset stomach at least twice a month", related to the consumption of clear water obtained from the flooded area and passed through homemade sieves. Thus, sensitivity was linked to the quality of the water to which households had access. Finally, they explained that they engaged in those risky practices because of the difficulties in terms of time, transportation, or economic means to access safe water; this is related to their coping capacities. Table 2.4 shows the resulting matrix for assessing vulnerability of sources of human health, food access, and drinking water.

Table 2.4 Matrix for assessing vulnerability of basic resources for life quality

Sub-assets	*Vulnerability indicators*		
	Exposure	Sensitivity	Coping capacity
Human health	1= household members are in excellent health conditions 5= household members are in deplorable health conditions	1= permanent access to medical care 5= no access to medical care	1= access to effective health insurance 5= no access to health insurance
Food access	1= household owns effective transportation means (canoe, equine, motorbike) 5= condition of isolation	1= private food reserves 5= dependence on external food supply	1= enough fish in the flooded area for local fishing 5= there are no fish in the flooded area
Safe water consumption	1= source (pipeline, well, others) for safe water supply. 5= no source (pipeline, well, others) for safe water supply.	1= water safe for human consumption 5= water unsafe for human consumption	1= easy access to safe water 5= no access to safe water

2.4.1.4 Social composition

Social composition can be easily identified throughout all the previously described variables; however, it was found important to designate a separate variable to partially measure vulnerability related to people with special needs within the household and the community, and the belongingness of people to formal or informal groups within the study area and its relation with floods.

People with demanding medical care needs due to life-threatening (temporary or permanent) health conditions and people with cognitive and physical limitations were grouped in the variable of "people with special needs". Their exposure is related to the need for specialized care, such as cardiologist, neurologist, neonatologist, or nurse caregiver, and their sensitivity is related to accessibility, as there might not be specialists at the local medical centre. Coping capacity is linked to the available transportation to the medical centre where the specialist can be found and the degree of difficulty in transporting the patient by these means.

Formal and informal groups have different roles in food and water accessibility, infrastructure reconstruction, or logistical arrangements, to mention but a few. The exposure and the sensitivity of household and community livelihoods are related to the formal or informal sense of belongingness of people to groups and their skills for effective communication, as a main source to plan and implement collective strategies in order to cope with a shock. Table 2.5 shows the resulting matrix for assessing vulnerability of social composition.

Table 2.5 Matrix for assessing vulnerability of social composition

Sub-assets	*Vulnerability indicators*		
	Exposure	Sensitivity	Coping capacity
Presence of social groups with special needs	1= no demand for specialized care	1= permanent access to specialized care	1= easy transportation to a medical centre
	5= high demand for specialized care	5= no access to specialized care	5= difficult transportation to a medical centre
Formal or informal social groups	1= belongs to a formal group or feels integrated into an informal group	1= effective communication before, during, and after a flood	1= high degree of planning
	5= no group integration	5= no communication before, during, and after a flood	5= no planning

2.4.2 Understanding flood hazardousness

At the start of the data collection stage, it was thought that floods originating from river overflow or puddle formation should be considered. However, respondents agreed that river overflow was the main and most important flood origin for local rice farmers, because it can happen slowly and progressively or very abruptly.

Although measuring duration, severity, and frequency by means of qualitative information provided by households is quite challenging and less accurate than historical information gathered through specialized tools, this method offered the opportunity to understand what is "bad" and "not so bad" for farmers when they are talking about flood hazardousness, based on their past experiences.

This section explains respondents' views and interpretations of flood hazardousness and summarizes them in two matrixes, the first focusing on severity and the second integrating duration, frequency, and severity, to characterize overall flood hazardousness. Both represent the extremes on a scale from 1 to 5, according to the lowest and highest expected damage, respectively. Extreme values, 1 and 5, are briefly described in Table 2.6.

2.4.2.1 Severity

In this research, severity was understood as the damage caused directly or indirectly by floods to some of our respondents' resources, which they identified as houses, rice crops, farm animals, on-farm and off-farm labour, fruit trees, water and wells, human health and safety, access to schools, mobility, and communication. Some of the flood-related hazards were soil and water salinity, animal and human diseases, strong winds, and thieves.

2.4.2.1.1 Houses

The degree of damage to houses was related to the possibility of the household remaining in the house during the flooding period. Partial scenarios are possible, for example: if a tilting house is flooded above ground level, a male family member usually remains in it in order to protect the household's belongings from thieves. Thus, a maximum level of damage occurs when the house is totally uninhabitable.

2.4.2.1.2 Rice crop

Flood severity in rice production is linked to the current and the upcoming rice season. In the first case, factors associated with flood severity include: purchased or recycled seed, amount of land cultivated, phenological stage, the purpose of the harvest, resulting in rice quality if the harvest can be partially saved, amount of pending debt, among others. In the second case, severity is related to: the amount of time it takes for water to drain or evaporate from the land, soil quality, crop pests and diseases, amount of waste left in the soil.

2.4.2.1.3 On-farm labour

The main on-farm activities relate to rice production and farm-animal husbandry. When a flood submerges everything, households become involved in artisanal fishing in the area. However, in some cases, the water level is not high enough to preserve fish, nor can it be easily drained to initiate other agricultural cycles. This last situation would be considered a high flood severity scenario.

2.4.2.1.4 Off-farm labour

During floods, it is usual to engage in agricultural labour on large farms in other provinces or in various jobs in nearby cities. When large farms are also affected, or main roads and cities are also flooded, production and commercialization decrease dramatically in the region. Job vacancies are few or non-existent.

2.4.2.1.5 Animals and fruit trees

Losses of fruits and farm animals are expected when the water level is high, or floods start abruptly. However, one of the worst scenarios is when a high-water level remains for a long period, because the trunks rot and the trees fall or must be felled. In the case of animals, poultry and pigs could survive for few weeks on floating infrastructures, but later pests, skin conditions, and lack of food and water are the main reasons for them to die or become neither consumable nor marketable.

2.4.2.1.6 Water and wells

Wells are the main source of water at home, especially for cooking, drinking, and personal hygiene, and, during the dry season, they are one of the only sources of water for rice irrigation. Their great importance stems from the fact that, even if the house is partially or totally uninhabitable, rice production can still take place in the next dry season if the well is functional. In addition, well reconstruction can be much more expensive than making the house habitable (at least temporarily) and usually requires the hiring of external labour. The need for a complete well reconstruction, combined with the lack of resources to get water from other sources, is considered the highest level of severity.

2.4.2.1.7 Human health and safety

The main hazards relating to human health conditions and safety during floods were (i) the huge increase in the presence of snakes, and less frequently crocodiles; (ii) the collapse of septic tanks and the release of faecal material into stagnant water; and (iii) mosquito and rodent proliferation. These were recognized as the main vectors of diseases or injuries. Main causes of death during floods are snake bites and the lack of anti-venom sera, and one of the main epidemics is dengue fever. Stomach and skin are the most usual complains. The longer the period that the water remains stagnant, the higher the water level inside the house and the more household members are affected by any of the mentioned (or other related) threats, the higher the severity is considered.

2.4.2.1.8 Access to basic education

The rainy season usually coincides with the school holiday period. However, when the rainy season and floods start earlier or extend later than expected, classes become very irregular or are completely suspended. In addition, the school infrastructure could be severely damaged or educational material could be lost, resulting in either in the next school term starting later or in students facing unpleasant study environments.

2.4.2.1.9 Mobility and communication

Floods cause major changes to daily routines, and owning means of water transportation (such as canoes) or having neighbours willing to share or rent theirs makes the difference in households' social life and access to diverse basic resources by means of sharing, exchanging, or buying. This parameter is strongly linked with the household's social network and the social values within the community, and could be considered one of the most practical issues to address in order to mitigate some of the impacts of floods in daily living. Respondents acknowledged that households living in communities where individualism is the norm usually face greater degrees of isolation and therefore difficulties in planning strategies to cope with generalized shortages or idiosyncratic shocks. Table 2.6 shows the resulting matrix for assessing flood severity in relation to nine livelihood assets.

Table 2.6 Matrix for assessing flood severity

Resources	*1= Minimum severity*	*5= Maximum severity*
Houses	No damage	Totally uninhabitable
Rice crops	No harvest loss, minimum investment, good soil quality	High investment, present and future harvest losses
On-farm labour	On-farm labour can continue the same or be diversified	No on-farm labour is possible
Off-farm labour	Off-farm labour can continue the same or be diversified	No off-farm labour is available
Farm animals	Remain consumable or marketable	Total loss
Fruit trees	Fruits and trees are not damaged	Fruits and trees are totally lost
Water and wells	Wells continue to function, and water is reachable and consumable	Non-functional wells and water hardly reachable or consumable
Human health and safety	People stay healthy and safe	Health and safety decrease majorly over time
Access to basic education	Flood is during school holiday and schools are not damaged	Flood is during school term, schools are extremely damaged, and classes are suspended.
Mobility and communication	Diverse means of mobility and communication	Total isolation condition

2.4.2.2 Duration and frequency

The respondents agreed that the flood experienced in 1998–1999, as a consequence of El Niño phenomena, was the worst scenario they could remember in the last 20 years, explaining that some areas were flooded for more than six months. They asserted that, after 12 weeks of being flooded, the affected infrastructure, the sources of income and own-consumption, human health, and access to food and safe water decreased considerably in quality and quantity, or were almost non-existent. Two other events considered as devastating as that in 1998 occurred in 1982–1983, also as a consequence of El Niño phenomena, and in the rainy season of 2012. There are two windows of approximately 15 years each between these three events.

This was the generalized view; some respondents, however, pointed out that their communities are flooded every year during the rainy season. Those expecting long-lasting floods have already developed different strategies to partially cope with the yearly event that might last around three months, but those who expect flooding for short periods (maximum one week) within the rainy season usually take several risky farming decisions. In such cases, the duration and severity of the flooding are what make the difference regarding flood hazardousness. Table 2.7 shows the resulting matrix for assessing flood hazardousness.

Table 2.7 Matrix for assessing flood hazardousness

Hazard indicators	*1= Minimum*	*5= Maximum*
Duration	≤ 1 week	≥ 12 months
Severity	no major damage	absolute loss
Frequency	every 15 years	every year

2.4.3 The at-risk situation of involved communities and their livelihoods

2.4.3.1 Vulnerability

A two-way ANOVA and an ANOVA test with a repeated measures arrangement, both with 95% degrees of confidence, show that there is a significant difference between the cantons (p=0.0019), livelihood assets per canton (p<0.001), and livelihood assets per vulnerability indicators (p=0.005). From these results, it can be said that, even though the six groups share similar socio-economic and ecological characteristics, each one faces different challenges. Furthermore, there is a need to take a closer look at those differences in order to understand their vulnerability and, therefore, the potential strategies to strengthen local resilience.

Table 2.8 presents the vulnerability indicator results, showing the means per canton, per livelihood asset per canton, and per livelihood asset per vulnerability indicator.

Table 2.8 Vulnerability indicator results per community and livelihood asset

	Basic resources				On-farm				Infrastructure				Off-farm				Social				Mean/ Canton
	Cop	*Exp*	*Sen*	*Mean*	*Cop*	*Exp*	*Sen*	*Mean*	*Cop*	*Exp*	*Sen*	*Mean*	*Cop*	*Exp*	*Sen*	*Mean*	*Cop*	*Exp*	*Sen*	*Mean*	
Balzar	*3.0*	*4.0*	*5.0*	*4.0*	*2.0*	*3.0*	*3.0*	*2.7*	*4.0*	*5.0*	*3.0*	*4.0*	*5.0*	*5.0*	*5.0*	*5.0*	*3.0*	*1.0*	*1.0*	*1.7*	*3.5*
Colimes	*3.0*	*3.0*	*3.0*	*3.0*	*5.0*	*5.0*	*4.0*	*4.7*	*4.0*	*5.0*	*3.0*	*4.0*	*5.0*	*5.0*	*4.0*	*4.7*	*4.0*	*4.0*	*4.0*	*4.0*	*4.1*
Daule	*3.0*	*4.0*	*4.0*	*3.7*	*4.0*	*4.0*	*2.0*	*3.3*	*4.0*	*5.0*	*3.0*	*4.0*	*5.0*	*5.0*	*5.0*	*5.0*	*4.0*	*2.0*	*3.0*	*3.0*	*3.8*
Nobol	*3.0*	*2.0*	*3.0*	*2.7*	*4.0*	*4.0*	*2.0*	*3.3*	*4.0*	*5.0*	*3.0*	*4.0*	*2.0*	*2.0*	*2.0*	*2.0*	*3.0*	*3.0*	*5.0*	*3.7*	*3.1*
Palestina	*3.0*	*4.0*	*3.0*	*3.3*	*4.0*	*4.0*	*2.0*	*3.3*	*3.0*	*5.0*	*3.0*	*3.7*	*5.0*	*5.0*	*5.0*	*5.0*	*4.0*	*3.0*	*5.0*	*4.0*	*3.9*
Santa Lucía	*5.0*	*4.0*	*5.0*	*4.7*	*3.0*	*4.0*	*3.0*	*3.3*	*3.0*	*4.0*	*3.0*	*3.3*	*4.0*	*5.0*	*3.0*	*4.0*	*4.0*	*2.0*	*5.0*	*3.7*	*3.8*
Mean	*3.3*	*3.5*	*3.8*	*3.6*	*3.7*	*4.0*	*2.7*	*3.4*	*3.7*	*4.8*	*3.0*	*3.8*	*4.3*	*4.5*	*4.0*	*4.3*	*3.7*	*2.5*	*3.8*	*3.3*	*3.7*

Descriptive statistics illustrate that Balzar (3.5) and Nobol (3.1) have the lowest average values, and Daule, Palestina, Colimes, and Santa Lucía have higher ones, ranging from 3.8 to 4.1 points of vulnerability. Statistical contrasting of cantons in terms of livelihood per vulnerability indicator (exposure, sensitivity, and coping capacity) shows that all cantons' means differ significantly in all the livelihood assets, except infrastructure.

The similarity in infrastructure vulnerability can be explained by the facts that (i) all the groups are totally or partially located within flood-prone areas; (ii) most houses use traditional construction methods and designs; (iii) infrastructure improvement interventions are few and usually made after infrastructure has been severely damaged; (iv) reconstruction costs of houses and wells are considered high by households, but wells (in spite of being more expensive) are prioritized; and (v) damage to local roads exceeds regular coping capacities at the household and community level in all the studied groups.

In terms of "on-farm activities", Balzar's group displayed the lowest vulnerability (2.7). In this study area, preserving old trees and planting them around the house is a traditional practice, and trees are more abundant here than in the other groups. Trees are already in a productive stage, as they were planted over eight years ago. Mango, orange, tamarind, guava, banana, cocoa, and passion fruit trees can be found, and short cycle crops for own-consumption such as maize and yucca. In addition, poultry and pigs are usually kept on floatable infrastructure, and cows are sent to friends or family members on higher ground.

The Colimes canton presents a contrasting scenario (4.7), where on-farm activities depend on rice production, little farm crop diversification is seen, and the ownership of large farm animals is not as usual as in Balzar. Farm diversification is not a common practice in rice production-oriented communities like these, where farmers try to maximize the amount of land under rice, even invading land belonging to the river. Rice production is a traditional activity in the region, and most farmers say that they feel comfortable with it. In addition, there is a traditional dynamic of indebtedness, where farmers borrow money for every rice cycle from informal lenders with minimum formal requirements and high interest rates. This traditional circle of indebtedness is one of the main motivations for farmers to take risky cropping decisions and the low proactivity on farm diversification.

Balzar, Daule, and Palestina display the highest vulnerability values (5) in the "off-farm activities" parameter. Nobol displays the lowest (2). This can be attributed to the distance or accessibility to urban areas or main cities (such as Guayaquil), where household members can be hired to perform non-agricultural activities. Some communities in Balzar and Daule find it more beneficial to stay locally to fish for the daily meal, because travel costs usually exceed off-farm wages earned. Even though Nobol and Daule are similarly close to the city, Daule's flood-prone areas are bigger and can become less accessible. In addition, the tradition of having a canoe is being lost, because people sold their canoes or engines when highways and roads began to be built.

Access to "basic resources", such as food, safe water, and health, is also related to accessibility to urban areas or the reachability of outsiders' help. On the one hand, Nobol is the least vulnerable (2.7) on this parameter because of its closeness to urban areas in the Daule canton and Guayaquil city, which facilitates accessibility to resources. On the other hand, Balzar's group affirmed that they experienced isolation during the 1997–1998 and the 2012 floods. To compensate for the inaccessibility of food and water sources, food kits were provided by external help and had to last at least two weeks. According to respondents, these were insufficient to meet family needs (at least five members), and that is why they self-organized by sharing or exchanging food and water, using canoes. Other strategies such as decreasing the number of daily meals from three to two and reducing portion sizes were mentioned.

Balzar's "social composition" parameter is significantly different (from p=0.01 to p<0.001) from that of all the other groups, showing the lowest vulnerability (1.7). Most Balzar respondents affirmed that they belonged formally or informally to a group and felt highly engaged with their community. During the individual interviews and collective workshops, several stories of cooperation and self-organization during the 1998–1999 and the 2012 floods were shared, and, throughout the session, participants showed that they were familiar with one another's living situations, needs, and experiences. However, respondents also admitted that they were facing serious challenges in developing preventive strategies.

It should be added that the "social composition" parameter results were found to be among the most relevant. As seen in Table 2.5, this parameter includes a short overview of "presence of social groups with special needs" and the sense of "belonging to a group and its performance", but it also contributes to information obtained in parallel to the other parameters. Both criteria, in addition to reflecting the people's acknowledgement of "having community members with special needs and its implications for their vulnerability", also reflect how community member recognize themselves as "caretakers" of "those with special needs" and "self-help" agents at different community scales, under situations of shock and scarcity.

Contrasting cases, such as (i) older people living alone and with chronic health conditions and receiving care (including food, water, or transportation) from different community members and (b) people experiencing great difficulty in getting neighbours' permission to cross their land to access the main river flow in order to travel faster by canoe to other communities, show how this parameter has a transverse role in livelihood asset sensitivity and coping capacity. Figure 2.9 shows the degree of vulnerability for each canton in terms of exposure, sensitivity, and coping capacity.

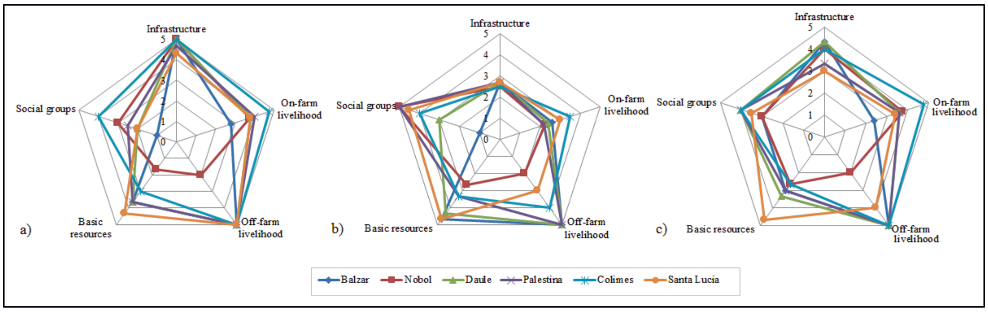


Figure 2.9 Vulnerability results in terms of (a) exposure, (b) sensitivity, and (c) coping capacity for the different livelihood assets and cantons

2.4.3.2 Hazard

Respondents from the Palestina, Daule, and Nobol cantons reported experiencing above-average floods quite frequently (every two to five years), and participants from Colimes, Santa Lucía, and Balzar reported less frequency (returning periods over six years). In terms of severity and duration, participants rated indicators and explained their answers focusing on the 1997–1998 flood period, which was selected by the groups as the worst recent important flood event, as the land remained flooded from 12 to 32 weeks.

"On-farm labour" (excluding rice production) and "rice crops" proved to be the most affected by floods during this period, followed by "water and wells" and "human health and safety", whose quality and accessibility declined notably over the duration of the flood. Even though "mobility and communication" and "access to schools" were on average less affected than other assets, participants reported that educational centres in Balzar, Palestina, and Colimes suffered extensive damage during the long flood periods; and Daule, Palestina, and Colimes reported facing greater challenges to mobilization due to the lack of canoes.

Santa Lucía and Palestina proved to be the least affected in terms of "fruit trees" and "off-farm activities". In the first case, this was because few trees are planted on farms in these locations. In the second case, it was because, even under extreme flood scenarios, both cantons preserve non-flooded areas where large rice farms (over 40 hectares) are located and where labour is hired. With regard to "farm animals", Nobol was the least affected, as households could promptly relocate them on floatable infrastructure or sell them to urban residents. Even though Daule is also close to the urban area, respondents reported that most animals drown or die from pests.

On average, houses experienced the least damage. This is because (i) most houses are built on tall pillars, and therefore the floor level is about 1.5 to 2 meters above the ground and (ii) for most of the flooded period, the water level remains a few steps away from the door. Even though houses built at ground level can be found in all cantons, in Colimes this is more common, and this is why this group was the most affected.

The resulting hazard value, obtained from the average of the severity, duration, and frequency indicators, shows that the six groups perceive flood hazardousness as medium (3/5) or high (4/5). Figure 2.10 shows the results for severity and average hazard for each canton.

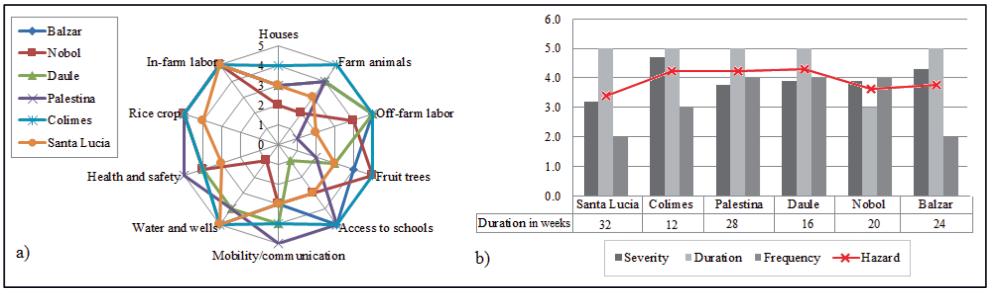


Figure 2.10 The left side figure (a) shows the severity results per livelihood asset. The right-side figure (b) shows in bars the average results per canton for the three hazard indicators: severity, duration, and frequency; a red line indicates the average hazard; under the graph, the number of weeks under flood per canton is provided.

2.4.3.3 Risk

In this section, the calculated degree of risk of being negatively affected by an above-average flood event ($Risk = vulnerability * hazard$) is represented in terms of probability *(%)* and interpreted using a risk matrix.

All the groups proved to have a "high" to a "very high" degree of risk. As seen in Figure 2.11, Colimes (16.8), Daule (16.4), and Palestina (16.1) proved to be at "very high" risk, and also interpreted as having a probability of 67.2%, 65.5%, and 64.6%, respectively, of being negatively affected by an above-average flood event. Cantons Nobol (10.9; 43.4%), Santa Lucía (12.7; 50.7%), and Balzar (12.8; 51.4%) proved to be at "high" risk.

Even though the degree of risk is alarming for all the studied groups, it is important to highlight and recognize from the vulnerability and hazard results, the features that triggered those results. Figure 2.11 shows a (a) general risk matrix to help us to allocate the (b) results obtained per canton and quickly visualize the risk landscape in the study area.

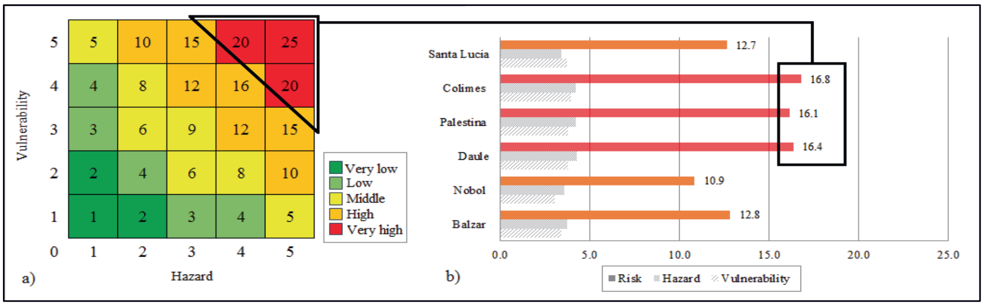


Figure 2.11 On the left side: figure (a) risk matrix; on the right side: figure (b) risk results per canton.

2.5 Discussion and conclusion

In this paper, we wanted to systematically present the step-by-step development and application of a participatory risk assessment whose main features were (i) that users define livelihood assets to be measured and evaluated and (ii) the use of qualitative-participatory research techniques as main tools for gathering information, with an emphasis on the use of drawing and story sharing. The reason for developing this methodology with those specific features was to explore its potential for increasing our understanding of local livelihood resilience from a risk-approach perspective, whereby it is considered that, the more capable smallholders are of managing flood disaster risks, the more resilient they are.

2.5.1 Users as main definers of livelihood assets to be evaluated

The participatory construction of the methodology resulted in a more differentiated and realistic representation of locals' livelihoods and their interpretation of risk (vulnerability and hazard). Measuring vulnerability and characterizing risk according to locals' own metrics made the application of the methodology easily understandable for respondents, who rapidly became engaged with the measuring exercise. In addition, measuring flood severity in relation to its impact on their livelihoods facilitated the linking of the meaning of flood harmfulness to the assets that are meaningful for locals in the context of local (traditional or innovative) practices, such as paying fees, renting canoes, accessing/renting places for animals on higher ground, sleeping in canoes to guard possessions, fishing, and so forth.

The transformation of qualitative information into quantitative information gives a brief overview of the "at-risk" situation of the different groups and at the same time opens the window for policymakers and practitioners to ask questions such as "If all the groups are in very similar socio-economic and economic circumstances, but the results show differences in "at-risk" situations and coping performances, then what do they need in order to be able to cope better or become more resilient? In order to answer this question, it is important to enrich assessment reports with well-systemized qualitative information that allows advisors and decision-makers to design more effective proposals at the local level, under time and financial constraints.

2.5.2 The meaningfulness of drawing and storytelling

It was observed during the construction and the application of the methodology that the mixed use of drawing and storytelling (based on the drawings) was very effective in providing detailed information about facts, feelings, and views in regard to an event (floods).

When the moderator asked the group participants about "which of their livelihoods were in danger during the most recent and worst flood event and how did they manage that", respondents had difficulty remembering information in detail, such as the level of the water and its consequences, where the different kinds of animals were located during that period, or what their landscape looked like.

On the one hand, the individual drawings helped the participants to remember a specific event, including in the drawings all the livelihood assets that they considered to be most relevant and the landscape. In addition, different practices could be distinguished in the drawings, as participants showed where the animals were located (floating infrastructure, roof, and so forth), the means of transportation or connectivity (canoes, hanging bridges, and so forth), the type of house infrastructure and its relation to the water level, among others.

On the other hand, the performance of this step prior to the story sharing allowed participants to enrich their stories, not only focusing on their tangible livelihoods (shown in the drawings), but also including their household members, neighbours, and other actors in the stories, revealing other intangible strengths and limitations (recognizing the neighbour who helped their family, the social mechanism to exchange food and water with others, and so forth).

In addition, an interesting observed phenomenon was the intervention of some group members during an individual story sharing, taking also a co-protagonist role, such as the friend who shared his canoe, took his family member to the hospital, exchanged rice reserves for water, or collaborated in the construction of a temporary bridge.

Therefore, it was found that the combination of drawing and shared storytelling not only was an effective tool for reviving memory, but also offered the possibility of indirectly assessing and gathering information about the respondents' willingness to collaborate and the different strategies to do so.

2.5.3 Strategies linking resilience and risk

From the vulnerability matrixes generated in the exploratory phase (see 2.3.1.3), it can be seen that many of the statements giving a meaning of low or high vulnerability to each livelihood asset are actually strategies that have been developed locally. Furthermore, adopting those practices could make the difference between coping better or not with a flood, or being more resilient, e.g. having a fixed place to rent on higher ground to send cows during flooding periods is a strategy found through the development of the vulnerability matrix (see Table 2.3).

In addition, the identified intangible resources were found to be transversal elements to perform better in the face of a shock. Some shared stories showed that the intangibles have an important role in future performances, within different nature situations. For example, sharing or exchanging food at a time of shortage due to severe floods could strength social ties among neighbouring communities; and denying the use of a canoe to transport a neighbour or asking for a high fee could break friendships or hinder a community member from engaging in common projects that require cooperation.

That said, it was found that finding popular or innovative strategies and intangible resources through every step of the methodology development and application was an additional benefit of this research, which exceeded our initial expectations. The strategies found are considered to be of key importance for understanding how people deal with risk using the available resources, including intangible resources such as social networking, sense of identity, or reciprocity. These different strategies could serve as a starting point for policymakers and researchers to orientate plans and investigate more specific issues, taking into account local knowledge, experience, and historical background in responding to shocks.

2.6 Acknowledgements

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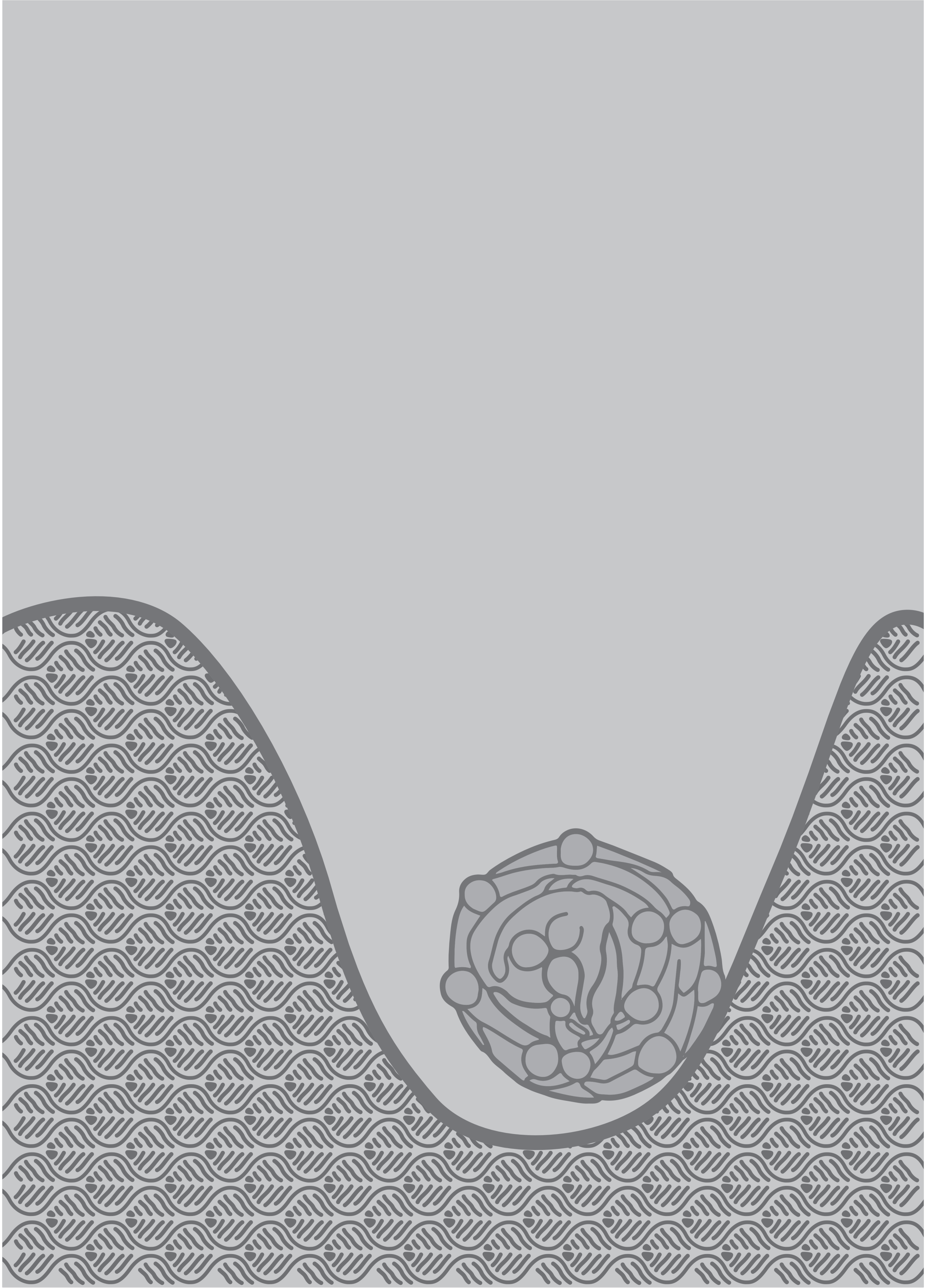
leaders in the cantons Daule, Palestina, Colimes, Balzar, Nobol, and Santa Lucía where this study was conducted.



Chapter 3
Rice farmers and floods in Ecuador: the strategic role of social capital in disaster risk reduction and livelihood resilience

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(Manuscript to be submitted)

Abstract

Social capital plays an essential role in resilience building and disaster risk reduction. Empirical studies show that social capital networks help make resources available in disaster situations. However, there is still a gap in the literature regarding the relationship between social capital, resilience, and disaster risk reduction (DRR). The purpose of this research is to understand and explain the role of social capital as a resource mobilizer during times of shock and the potential implication of this for DRR and resilience building. To do so, we develop and apply a framework that integrates the concepts of (a) resilience, through the lens of the adaptive cycle theory, (b) social capital, in terms of social relationships, and (c) the disaster risk reduction cycle. This article describes: (i) how the DRR and adaptive cycles relate in terms of actions and time, and (ii) the transversal integration of different forms of social capital - in terms of social relationships - into the DRR and adaptive cycles. We apply the framework to the case of rice smallholder farming in flood-prone areas in the lower basin of the Guayas River in Ecuador. We find that households' potential is critical to sustaining other dimensions of resilience throughout different forms of social capital (in terms of social relationships). The availability of resources (canoes, food, water, knowledge, skills and others) that households have to exchange or share within the community (bonding social capital) sets the connectedness (control) limits at other levels of social capital. Bridging social capital is relevant to access temporary refuge for animals, water, food, and loans when resources at local levels become scarcer, especially as the period of flooding becomes prolonged. When local demands exceed the available resources (in quantity and quality), connectedness is mostly low at all social capital levels, especially at the bridging level. The lack of resources creates conditions that strengthen unhealthy social relationships at the bridging social capital level, such as locals' dependency on opportunistic arrangements. The use of this framework helped us to systematize our data and give us an overview of how the coping strategies of rice smallholders contribute to, and inhibit, their resilience during a flood and their transition to recovery.

Keywords: resilience; disaster risk management; coping strategies; adaptive cycle; social capital; flood; smallholders

3.1 Introduction

Community resilience has become increasingly relevant in research and policy within the context of disaster risk reduction (Tanner *et al.*, 2015). The development of plans, frameworks and tools that embrace community resilience as a way of responding to, and recovering from, shock has also increased. In recent years social capital has begun to be explicitly incorporated as a core component in some such developments. However, it is still the case that far less attention is paid to social infrastructure than physical capital. As such, the potential of developing social capital remains underutilized, in spite of its proven benefits (Aldrich, 2015, 2018).

Disasters can destroy all types of capital, but social capital is the least affected (Dynes, 2002). No amount of investment in physical capital is able to eliminate all risks and vulnerabilities. Strengthening social capital, which strengthens community resilience, is a relevant and complementary approach. Several empirical studies show that social cohesion and social networks are essential in disaster management and increasing local resilience (Dynes, 2002; Pelling and High, 2005; Aldrich, 2015; Sanyal and Routray, 2016). They show how individual and community social capital networks make resources available in disaster situations; these resources may include information, aid, informal insurance, childcare, emotional support, group mobilization, and keeping people from leaving stricken regions (Aldrich, 2011; Aldrich and Meyer, 2015).

The scientific literature linking social capital, resilience, and disasters risk reduction (DRR), can be found in a variety of domains – including economics, sociology, ecology and disaster studies – and in different combinations. Theories and terminologies might differ, but the contexts of their application overlap or are closely related. However, there is still not a comprehensive overview of this tripartite relationship (Aldrich, 2011, 2017; Adger *et al.*, 2012; Australian Red Cross, 2012; Tanner *et al.*, 2015; Folke *et al.*, 2016). This research aims to fill this gap by exploring the theoretical and practical links between community resilience and social capital, and their influence on disaster risk reduction.

This research is framed within the context of agricultural livelihoods, households, communities and natural hazards which together form a dynamic system. The interactions of humans and nature create a socio-ecological system (SES) (Gallopín, 2006). Following this logic, in this paper we develop and apply a theoretical framework built on concepts of (a) resilience and the adaptive cycle theory, (b) social capital categorized in terms of interpersonal relationships, and (c) the disaster risk management cycle (Gunderson and Holling, 2001; Holling, 2001; Putnam, 2001; Baas *et al.*, 2008; Aldrich, 2017). In this paper, we analyse local coping strategies in order to help us to better understand and explain the role of social capital in mobilizing peoples' resources so that they are more able cope with a shock situation. We also address the influence of the interactions between these different forms of social capital on resilience building and DRR.

3.2 Development of an integrated conceptual framework

In this section, we outline the relevant theories across different research domains in order to develop an integrated conceptual framework. In so doing we first summarize different definitions of resilience and DRR. We then explore the convergences complementarities and divergences between resilience and DRR concepts. Finally, we introduce definitions of social capital in order to build a conceptual model that incorporates these three themes. We then use this integrated conceptual framework to pose and seek to answer specific research questions related to the influence of social capital on resilience and DRR.

3.2.1 Linking DRR and Resilience (through the adaptive cycle of change)

The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030 prioritizes enhancing the resilience of people and their livelihoods as a disaster risk management strategy: *"Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience"* (UNISDR, 2015). This is a clear acknowledgement of the pivotal role of social capital in enhancing resilience, and shows the importance of including the development of social capital within risk reduction strategies.

Disaster risk reduction refers to the legal, institutional, administrative and policy mechanisms and procedures involved in the management of risks and disasters. The DRR cycle includes four phases, see Figure 3.1. In the pre-disaster phase, the aim is to strengthen the capacities and resilience of households and communities. The prevention and mitigation of hazards and preparedness actions (to limit the adverse effects of hazards) are required to protect lives, livelihoods and property. When a shock strikes, disaster response actions take place, with communities and relief agencies focused on saving lives and assets. In the post-disaster phase, the focus is on recovery and rehabilitation. Here, the goal is to move back to normal socio-economic patterns, and integrating pre-disaster action aspects into development activities in order to strengthen resilience and thus better cope with future shocks (Baas *et al.*, 2008; UNISDR, 2015).

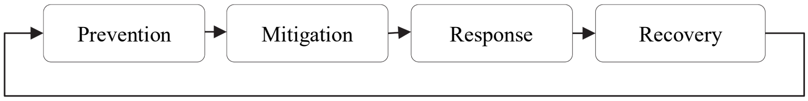


Figure 3.1 The DRR cycle (based on *Baas* et al.*, 2008)*

In a socio-economic system (SES), resilience is defined as the ability of a system to absorb disturbance and reorganize in response to changes and maintain its functions and structures without major deviation from its pathway (Walker and Meyers, 2004; Folke *et al.*, 2016). SESs are always changing, and are considered to be complex adaptive systems. Their adaptive behaviour, or resilience, is most often understood and explained by the adaptive cycle of change. This cycle views the system as moving through four phases. In the exploitation or growth phase (r), rapid colonization of recently disturbed areas occurs. In the conservation phase (k) a maximum population is attained, and energy and material accumulation slow down. At the end of the two phases, many resources have been accumulated and the system is vulnerable to disturbances. In the release or 'creative destruction' phase (Ω), these agents cause a sudden release of accumulated resources. In the reorganization phase (α), the system is restructured to minimize losses, and the remaining resources are reorganized to become available for the next exploitation phase. Transitions between phases have been observed, except direct shifts from release or reorganization phase to conservation phase (Walker and Salt, 2006).

While the system – ecosystems, agencies, and people – moves through its four phases, its resilience to a crisis is shaped by three dimensions: potential, connectedness and adaptive capacity. The potential represents the resources or capital accumulated, which determines the number of alternative options for the future. It sets the limits to what is possible. In a social context, this is represented by the accumulated networks of friendship, mutual respect and trust, and institutions of governance. Connectedness is the degree to which a system can control its own destiny. It reflects the relative strengths of internal control processes and the outside world. When it is high, the behaviour of aggregated elements is dominated by inward relations. When it is low, their behaviour is dominated by outward relations and affected by outside influences. Adaptive capacity determines a system's vulnerability to unexpected disturbances and surprises that can exceed its connectedness (Gunderson and Holling, 2001; Holling, 2001).

This approach considers adaptive capacity as a dynamic property of a system that works on interdependence with the potential and connectedness dimensions, within a context-specific risk. See Table 3.1. for a brief description of the expected system's behaviour through phases and dimensions.

Table 3.1 The adaptive cycle of a system at a glance: phases, dimensions and definitions (Based on Gunderson *and Holling, 2001)*

Adaptive cycle		Phases			
		Exploitation: Growth and colonization	Conservation: Accumulation/ storage of energy/material.	Release: Energy/material release	Reorganization: Restructuring and innovation
Dimensions	Potential or wealth: The options possible for change: 'the available resources'.	Low: resources are slowly accumulated.	High: many resources available for other uses.	Low: triggered by an agent of disturbance; resources decline.	High: leftover resources become available for future developments.
Dimensions	Connectedness or controllability: The degree to which a system can control its own destiny.	Low: mutually supportive interrelations start and increase.	High: It becomes over-connected and rigidly controlled.	Low: tight organization is lost; feedback regulatory controls are weak	Low: internal regulations are weak.
Dimensions	Adaptive capacity: The opposite of system vulnerability.	High: starts with the strongest ones (individuals, species).	Low: vulnerable to surprises, accidents waiting to happen	Very low: inherently unpredictable	High: room for experimentation and testing.

Disaster risk reduction and the adaptive cycle of change (a lens for studying resilience) are related and complement each other in terms of their actions and chronologies: prevention – growth, mitigation – conservation, response – release, and recovery – reorganization (see Figure 3.2). The cycles run within a given scenario of risk, where one of the potential outcomes is that the system maintains its functions in spite of a shock – by virtue of its resilience. In an agricultural-based livelihood SES, such actions are driven by humans. This highlights the importance of social infrastructure in coping with shocks, and recovering from their effects through self-organization. This means, going from a response–release to a growth–prevention stage by drawing on the system's self-organization capabilities.

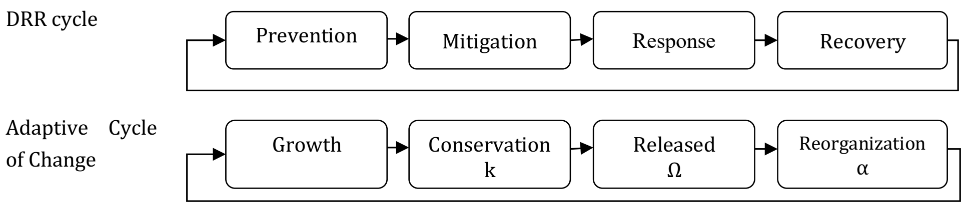


Figure 3.2 Linking DRR cycle and Adaptive Cycle of Change

3.2.2 Integrating Social Capital, Resilience and DRR

In the disaster response literature, social capital "consists of resources embedded in social networks and structures, which can be mobilized by its actors. It acts as a resource, which is embedded in the social structure, which provides assets for individual action" (Dynes, 2002). This categorization of social capital in terms of interpersonal relationships has become widely accepted. It distinguishes three categories that are considered to be both a site, and outcome, of reciprocity, see Table 3.2. *Bonding social capital* describes emotionally close individuals, who are tightly connected to a particular group: family, friends or work colleagues within the same community. *Bridging social capital* emphasizes connections between people with different social identities who share common interests or goals: a network of people from different communities or groups. *Linking social capital* defines relationships that vertically cross group boundaries: a network that connects 'regular' citizens with those with power or influence (Woolcock, 1998; Putnam, 2001; Patulny and Lind Haase Svendsen, 2007; Sanyal and Routray, 2016).

Table 3.2 Social capital categorization in terms of household interpersonal relationships

Social Capital	Household community a	Neighbouring communities b	Individuals/institutions of power c
Household a	$a \leftrightarrow a$ Bonding social capital	$a \leftrightarrow b$ Bridging social capital	$a \leftrightarrow c$ Linking social capital

Adapted from Sanyal (2016)

Livelihoods and community resilience are useful concepts to introduce into this framework as a way of expressing social capital and its relevance. Livelihood resilience is defined as the capacity of households and communities to sustain their livelihoods across generations despite disturbances (Tanner *et al.*, 2015) whereas community resilience is defined as the collective ability to deal with those disturbances through cooperation (Norris *et al.*, 2008). The livelihood and the community resilience approaches view people as the main agents settled within dynamic processes of social transformation, whose success at being self-organizing is dependent upon their social networks and their relationships of trust and reciprocity. In other words, peoples' ability to self-organize is based on their social and cultural capital (Alinovi, Mane and Romano, 2010; Folke *et al.*, 2016).

In livelihood resilience terms, it can be said that a collapse phase (Ω) is any environmental, economic, social or political disturbance, threatening the continuity of peoples' livelihoods, the resilience of which is defined by people's capacity to self-organize (α phase) across generations to sustain and improve their livelihood opportunities and well-being (from r to k phase) in spite of those disturbances. Networks of trust and reciprocity constitute people's capital (options for change). Agency and empowerment contribute to people's governance of hazards (connectedness or controllability). The characteristics of households and communities and their vulnerability, together with their capacities for self-organization and innovation and their knowledge determine their capacity to respond and successfully recover in order to start a new development stage within the same regime and thus their resilience (Alinovi, Mane and Romano, 2010; Tanner *et al.*, 2015; Galarza-Villamar *et al.*, 2018).

In summary, social capital is essential for self-organization, and is essential to effectively respond (response phase in DRR) to a shock (the release phase in the adaptation cycle). In order to operationalize these convergences, the three main components of interest (social capital, resilience and DRR) can be integrated, as shown in Table 3.3.

Table 3.3 Conceptual framework to explore the role of social capital on Resilience and DRR

DRR cycle		Prevention	Mitigation	Response	Recovery
Adaptive cycle		Growth	Conservation	Release	Reorganization
Dimensions	Potential				
	Connectedness		**Social Capital** Bonding – Bridging – Linking		
	Adaptive Capacity				

3.2.3 Developing research questions from the theoretical framework

This research is focused on (i) the specific time frame of a disturbance event, (ii) the stage of response-release, and (iii) bonding and bridging social capital (See

Table 3.4). In order to apply the framework, we first defined the meaning of the potential, connectedness and adaptive capacity dimensions, in terms of the release phase of the adaptive cycle and the response phase of the DRR cycle, (see

Table 3.4). Second, we formulated specific research questions about how bonding and bridging social capital might be integrated and formulated within the release-response stages (see Table 3.5).

Table 3.4 Definition matrix that explains the integration of the Adaptive Cycle dimensions during the release phase and the response phase in the DRR cycle.

			DRR cycle
			Response phase
Adaptive cycle	Release phase	Potential	The resources available to people to respond (response phase in DRR) during a shock (release phase in the adaptive cycle theory). In short, this will be referred to as 'available resources'.
		Connectedness	The degree to which people can control their own, and others', response actions and outcomes (response phase in DRR) during a shock (release phase in adaptive cycle theory).
		Adaptive Capacity	The characteristics that limit peoples' vulnerability (brought from the growth and conservation phase in the adaptive cycle theory, and the prevention and mitigation phase in the DRR cycle).

As seen in Table 3.5, the specific research questions guided the data collection and analysis, within the conceptual framework and research scope.

Table 3.5 Specific research questions to guide the practical application of the conceptual framework

			Social Capital		
DRR	Adaptive Cycle		Household a	Bonding $a \leftrightarrow a$	Bridging $a \leftrightarrow b$
Response phase	Release Phase	Potential	What resources (knowledge, networks, goods, etc.) does a household have to cope with the shock?	How do local networks help households manage or access resources to cope with the shock?	Under what circumstances do social ties with neighbouring communities provide resources to complement/supply local needs?
		Connectedness	To what degree is the household in control of its situation during the shock?	To what extent is the local network capable of providing for the needs of its members before it is influenced or in need of others?	To what extent do these networks dominate/ influence/ contribute to locals' coping actions?
		Adaptive Capacity	What characteristics influence or shape the household's response to shock?	What are the limits to which the community strategies and resources can respond to a shock? What kind of strategies arise to face the shock when these limits are reached?	What kind of social strategies emerge, that go beyond local networks in seeking to cope with the shock?

3.3 Methodology: applying the integrated conceptual framework

In this section, we describe how we apply this framework to a specific case study: smallholder households producing rice in flood-prone areas of Guayas Province in the lower basin of the Guayas River, in Ecuador. The purpose of the case study is to explore how useful the framework is understanding and explaining the role of social capital in mobilizing peoples' resources during a shock.

3.3.1 Case study background

The data used in this research is part of a qualitative data set gathered by Galarza-Villamar *et al.*, (2018) which aimed to develop and apply a participatory risk assessment in order to understand and explain livelihood resilience from a risk perspective. It was carried out in the flood-prone areas of the cantons of Balzar, Nobol, Daule, Palestina, Colimes, and Santa Lucía (see Figure 3.3). The focus was on two different flood scenarios: above-average (2012), and extraordinary (1997–1998). The participatory risk assessment was applied through workshops using one sample group in each canton. Each group was made up with 15 to 25 rice smallholders from different rural communities within the canton, totalling 105 people (for details see *ibid*).

Figure 3.3 Study area.

The emphasis of the participatory risk assessment was on linking participants' individual and collective livelihood resources, both tangible and intangible, with the direct and indirect impacts of flood events, in order to evaluate risk according to their lived experiences, coping strategies, available resources and perceptions. The design of an evaluation tool based on locals' metrics resulted in an easy understanding and rapid engagement during the assessment application. The tool made use of participatory methods, such as interviews, focus groups, drawing, and storytelling, to reconstruct past flood events individually and collectively *(ibid)*. It emerged that drawings and storytelling were particularly powerful tools to reconstruct past events and reveal coping strategies that might otherwise have been overlooked and the central role of social capital (see Table 3.6).

The study found that knowing the local strategies was the key to understanding how people deal with risk by using the locally available resources, including intangible resources such as social networking, sense of identity, or reciprocity. The participatory risk approach helped us to systematically identify household and community strategies that limit or enhance livelihood resilience.

Table 3.6 Summary derived from Galarza-Villamar 2018

Title	Local understanding of disaster risk and livelihood resilience: the case of rice smallholders and floods in Ecuador
Purpose	To better understand livelihood resilience through the theoretical lens of disaster risk management.
Case study	Smallholder households producing rice in flood-prone areas of Guayas Province (in the cantons of Balzar, Nobol, Daule, Palestina, Colimes, and Santa Lucía), within the lower basin of the Guayas River
Methodology	The development and application of a participatory resilience assessment, from a disaster-risk perspective, where users define what is at risk, why it is important, and how should be measured.
Methods	Participatory methods: interviews, focus groups, participatory mapping, drawing, and storytelling through several workshop sessions involving a total of 105 people.
Findings	The use of locals' metrics resulted in an easy understanding and rapid engagement during the assessment application. Drawings and storytelling helped to reconstruct past events and reveal coping strategies, many of them based on social capital. Systematic identification of household and community strategies that limit or enhance livelihood resilience.

The data and research findings of this study are the starting point for the current research, the aim of which is to go one step further: to understand the role of social capital in mobilizing people's resources to cope with a shock. From the qualitative dataset pool, coping strategies that relate social capital to different kind of resources were selected for analysis. The focus is on the strategies based on different forms of social relationships that households used to mobilize resources in order to cope with livelihood challenges during periods of flooding. Table 3.7 shows the general characteristics of farmers within the study area, (for details see Pila-Quinga and Galarza-Villamar, 2016).

Table 3.7 Characteristics of smallholders in the study area (*Pila-Quinga and Galarza-Villamar, 2016)*

Type of farmer	Amount of land	Products	Farm animals	Rice cycles
Subsistence farmer	Less than 1 ha. Located in very low areas.	Main: rice. Secondary: mangoes, bananas, cassava, sweet potato and vegetables	Hens, pigs and ducks.	Between 0 and 1.
Rice smallholder – monoculture	Between 2 to 5 ha. Located in low areas.	Main: rice. Secondary: mangoes, bananas, cassava, guavas, lemons, oranges, plum, currants, passion fruit, melon, corn, papaya, cocoa and vegetables.	Hens, pigs, ducks and a horse.	Between 1 and 2 cycles.
Rice smallholder – diversified	Between 2 to 5 ha. located in both high and low areas.	Main: rice, maize and/or cocoa. Secondary: mangoes, bananas, cassava, guavas, lemons, tamarind, orange, plum, gooseberries, passion fruit, melon, papaya and vegetables.	Cows, chickens, pigs, ducks and a horse.	Between 1 and 2 cycles of rice and one of maize.

3.3.2 Framework application

We see that the framework can be used either as a data systematization tool (Figure 3.4.a) or as a starting point to guide the methodological research design and data collection process (Figure 3.4.b). Both applications can be used to understand and enhance the role of social capital in resource mobilization when responding to a shock response and making the transition to reorganization (recovery).

We used the conceptual framework in order to guide a systematic analysis of the available data in terms of its theoretical relevance to resilience, DRR, and social capital, see Figure 3.2. This strategy was adopted as we were making use of a pre-existing database of qualitative data. Using the specific research questions set out in Developing research questions from the theoretical framework 3.2.3, we looked at the coping strategies found in Galarza-Villamar *et al.*, 2018 in terms of resource mobilization scenarios for different types of assets, the different stakeholders involved as agents of mobilization, and the characteristics of the situations that the interactions between the two gave rise to. See Table 3.8.

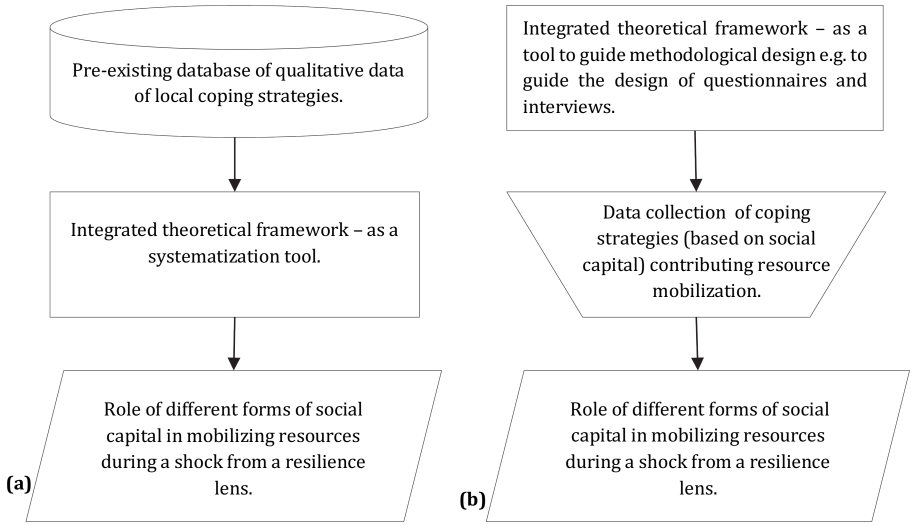


Figure 3.4 (a) Application of the framework to analyse an existing database (applied in this research), (b) Application of the framework to guide the methodological design and data collection process (alternative application).

Table 3.8 Steps followed to apply the framework as a data systematization tool

Step 1. Make an initial list of coping strategies from the pre-existing databases found in Galarza-Villamar 2018.
Step 2. Use the research questions shown in Table 3.5 to do initial filtering of the data in terms of the levels of social capital involved in implementing the strategies: i.e. the household and bonding and bridging levels of social capital
Step 3. Match each coping strategy to a livelihood asset: access to food, access to water for domestic use, transportation and spatial connectivity, rice production, and the survival of farm animals.
Step 4. Value each coping strategy's influence on resource mobilization to better cope with the shock (respond) and further reorganization (transition to recovery) as positive (+1) or negative (-1).

A valuation of the strategies, as positive (+1) or negative (-1) influence, was done to give a quantitative and descriptive dimension to the analysis. This allowed a simplified visualization of how different coping strategies that are adopted and use different levels of social capital, can have either a positive or negative influence on resilience by either enhancing or limiting resource mobilization. Table 3.9 shows an example of these positive and negative valuations. These valuations were assessed on the basis of locals’ perceptions and narratives of the impact of these strategies on their lives during and after times of flooding.

Table 3.9 Examples of coping strategies evaluated as positive (+1) or negative (-1), depending on their influence on peoples' capacity to respond to and recover from flood situations.

	Specific research question	Coping strategy	Analysis	Valuation
Example 1	Under what circumstances do social ties with neighbouring communities provide resources to meet/complement local needs?	Locals request informal loans from several informal lenders (at a high interest rate) to cover family food needs.	These loans allow the household to access food, but this action reinforces conditions of vulnerability.	The valuation for this action is (-1) because it reinforces vulnerability.
Example 2	How do local networks influence the ways that households manage/access the resources needed to cope with the shock?	Locals exchange food and water based on their individual reserves.	Exchanging food is an indication of self-organization. This is a positive community attribute to cope with current and future shocks.	The valuation for this action is (+1) because it strengthens coping capacities.

3.4 Results

This section describes the results of applying the integrated conceptual framework. The input data are households' and community strategies that were involved in interactions between social capital and resource mobilization to cope with a flood. The results are described within the categories of resources that households need to access or to protect in order to ensure their survival and the continuity of their livelihoods: food, water, transportation means, rice harvest and farm animals.

Access to food

"She (elder woman) is alone here, but we bring her food and take care of her" (Female, Daule, 2016)

Rice is the main food in the family diet in the study area. Families reserve part of their rice harvest from the dry season to eat during the rainy season and potential flood periods as they know the risks of losing the rice harvest, due to floods or pests, in the rainy season are very high. Fruit trees are also a traditional part of the family farm landscape and are used to supplement the family's diet. During the floods experienced in 1998 and 2012, farmers harvested the fruits as soon as possible, before the trees died, and tried to manually save the rice ready to harvest that was underwater.

The harvested rice was dried under the sun, and could only be used for self-consumption due to its high levels of humidity. It was stored in the facilities of rice peeler factories free of charge until they needed it for household consumption. If the water levels were high enough during the flood, some farmers went for fishing, while others hunted wild birds to supplement their diet. Floating cane structures were built to house their surviving small farm animals (chickens, ducks and pigs). Rice, fish, fruits, vegetables and farm animals were shared and exchanged among neighbours. Yet, the longer the flood lasted, the fewer food resources were available to exchange. Trees died, and as the water level decreased fishing was no longer possible, while the rice reserves were finished in a few weeks.

As households are numerous, their own reserves and exchanged food and food aid supplies could only last few weeks. Families reduced their meals from 3 to 2 per day, and more active exchange with neighbouring communities took place. Rice peeling factories lent households peeled rice for consumption, which had to be paid back in the next harvest season. This kind of arrangement was not always possible, since it depended on the distance between the farmer and the factory, the relationship between the parties, and the general shortage of rice in the area. Farmers who owned a canoe could go further to look for food and supplies, to commercialize them within the community.

Respondents reported that humanitarian aid from the government and non-profit organizations also contributed to their food supplies during the 2012 flood. Trucks with food supplies would come to the nearest non-flooded communities to distribute the food. The amount of food was based on the number of family members. As few families owned a canoe, or were able to get transportation to the supply points, many people used these resources as a market opportunity. People from the flooded area who owned a canoe would seek extra supplies in order to commercialize them. In addition, some families that were not living in the flooded area also claimed to be in need of those supplies. The basic strategy to access more free supplies was to report a higher number of family members, or to act in partnership with other families in the vicinity.

Access to a canoe was very important to access food supplies. Canoe owners and their close friends had more opportunities to go to other communities to buy more food for their own families at lower prices. Access to a canoe as an informal public means of transport improved access to food. Unfortunately, even those who could overcome these transportation limitations found that their financial resources were extremely limited, and often needed recourse to informal lenders to finance their purchases. Many respondents reported that borrowing money from informal lenders at high interest rates (between 10 to 45% per month) was their only solution for buying food, with the capital and interest being repayable after the next harvesting season.

Table 3.10 Summary of strategies for access to food that include different forms of social capital across the potential, connectedness, and adaptive capacity dimensions of the adaptive cycle.

Release phase (Ω)	Household a	Bonding social capital $a \leftrightarrow a$	Bridging social capital $a \leftrightarrow b$
Potential	(+1) A few rice sacks saved from the dry season. (+1) Harvesting fruits before the trees die. (+1) Harvesting flooded rice that is dried manually and only suitable for self-consumption.	(+1) Fishing within the flooded areas and hunting wild birds are practised within groups. (+1) Exchanges of rice and fruits/vegetables/fish among neighbours.	(+1) Selling some fish to neighbouring communities. (+1) Households get loans of rice sacks from rice peeling factories (+1) Government and NGOs distribute food from non-flooded neighbouring communities, mainly during the first months.
Connectedness	(-1) Daily meals are reduced from 3 to 2 per day. (-1) Food supplies from humanitarian aid can be irregular and last only one week.	(-1) Fishing was not possible when the water level fell too low.	(-1) Non-flooded neighbouring communities also suffer generalized shortages due to accessibility constraints. (-1) Several members from the same household register as head of a different household to get multiple handouts.
Adaptive capacity	(-1) Households are numerous (around 6 members) and only have enough food to last a few weeks.	(-1) Food exchange became unfeasible as households' food stocks decreased.	(+1) The few farmers that own a canoe lend or rent it to others to buy food in other communities. (-1) Households access loans from informal lenders at high interest rates, or in exchange for a portion of next season's harvest.

3.4.1 Access to water for domestic use

During the floods of 1982-1983 and 2012, some people's land was under stagnant water for up to 10 months. Although their homes surrounded by water, they did not have water for domestic consumption. The available water was either turbid, saline, or contaminated by the collapse of septic tanks and drowned animals. Although most households had a well, most of these collapsed and became filled by sediment, which made them unusable.

During these periods, precipitation was one of the first options to collect clean water. Each household collected rainwater from their roof in buckets. As it did not rain daily, families would quickly run out of water. The next option was to ask for help from friends and neighbours. Some households within the affected communities had wells in slightly higher lands and shared this water, in small quantities, free of charge. Some groups of neighbours were enterprising enough to connect plastic hoses to local pipelines or water wells for common use. These connections were made with the consent of the water source owner and mostly free of charge, due to family ties and friendship.

As water is a daily need, and both the rain and help from neighbours were not sufficient to meet daily demands, thus informal water markets emerged. If there were no operative wells within the community, some community members who owned motor canoes would get water from neighbouring communities, a service for which they charged. The government also intervened, sending water trucks to the nearest non-flooded communities to distribute water to those in need. This involved several family members going to the meeting point with containers to fill and bringing them back home by canoe. The water was being distributed according to the number of family members, but many families got more water by lying about the number of members and later sold the surplus water to other families who lacked the means to reach the supply point.

Facing environmental and social constraints, many households reported collecting stagnant water for domestic use, storing and decanting this water in tanks prior to using it. Water for drinking was boiled, but for cooking and personal cleanness was used mostly raw. Many reported experiencing diarrhoea and skin conditions as a result of this.

Table 3.11 Strategies to access to water for domestic use, including different forms of social capital across the potential, connectedness, and adaptive capacity dimensions of the adaptive cycle.

Release phase (Ω)	Household a	Bonding social capital $a \leftrightarrow a$	Bridging social capital $a \leftrightarrow b$
Potential	(+1) Collecting rainwater from the roof for cooking and drinking.	(+1) Friends/neighbours with functioning water wells provide clean water (for free or at a 'fair' price).	(+1) Locals collect water from other communities and transport it by canoe. (+1) The government sent water trucks to provide water from neighbouring communities.
Connectedness	(-1) Water is collected from the flooded area, even if it is turbid. (+1) Water is boiled.	(-1) Water supply is limited and farmers buy water from others with a surplus.	(-1) Some farmers (i.e those with canoes) benefit more and sell the surplus water to others.
Adaptive capacity	(-1) People report suffering from diarrhoea and skin conditions.	(+1) Some farmers attach plastic hoses to a neighbour's water pipeline or water well (with permission) for common use.	(No strategy collected)

3.4.2 Transportation and spatial connectivity

"Someone who does not know how to share does not know how to live in this town" (Male, Palestina Canton, 2016)

During the 1980s, it was common for households to have a canoe (either manual or with a motor) which was often one of their most precious belongings. These canoes were the most important means of transporting people and goods as, at that time, there were hardly any roads in the region. The oldest respondents remembered that during the flood of 1982-1983, considered the worst experienced in recent living memory, owning a canoe was normal and unexceptional. Some men even considered it essential to own a canoe before marrying: "When I got engaged, I bought two cattle and a canoe before getting married".

By the time of the 1997-1998 floods, few families owned a canoe. Most of them had already sold them (or the motor) after some promises of accessibility and after some roads were built in their communities. The use of motor canoe as a self-organized informal public transport took place in times of floods. As the only way to leave their houses was by canoe, families could either rent a rowing canoe or call a motor canoe to pick them up. By the time of the floods of 2012, motor canoes were even scarcer, and for many people, the only options were to stay at home or to venture out by foot when the water receded to a safe level.

Nowadays, even in areas where annual floods are more the rule than the exception, the tradition of owning a canoe per household has decreased. On average most communities have around three motor canoes that can offer transportation services. The people who offer this service are usually well known within the community. Transportation by motor canoe is free of charge for the owner's family members, and costs between 0.25 and 0.50 US dollars for neighbours. Those lacking access to a canoe, run the risk of isolation. While some disadvantaged people living in more accessible areas can get help from the canoe operators, it is common that mothers with young children and people with mobility impairments experience long periods of isolations at home.

Table 3.12 Strategies for "transportation and spatial connectivity" that include different forms of social capital across the potential, connectedness, and adaptive capacity dimensions of the adaptive cycle.

Release phase (Ω)	**Household** a	**Bonding social capital** $a \leftrightarrow a$	**Bridging social capital** $a \leftrightarrow b$
Potential	(+1) Some households own a canoe. (-1) Canoes are becoming a less common belonging.	(+1) Families and friends share their canoes without cost. (+1) Canoes can be accessed by other locals for small fees.	(+1) Locals living at the edge of the river can easily reach other communities by canoe through the river.

Release phase (Ω)	Household $\boldsymbol{a}$	Bonding social capital $\boldsymbol{a} \leftrightarrow \boldsymbol{a}$	Bridging social capital $\boldsymbol{a} \leftrightarrow \boldsymbol{b}$
Connectedness	(-1) Most households decided to sell their canoe after the construction of some roads.	(-1) Households depend on canoe owners to transport people and supplies.	(-1) Locals not living at the river' edge need to cross through the land of those living there. This can be at a cost.
Adaptive capacity	(-1) Some people report experiencing long periods of isolation at home, especially those with mobility impairments and mothers with young children.	(+1) Some neighbours build improvised wooden bridges that connect one house to the next one until reaching a walkable byroad.	(+1) Other transportations means are informally offered from the nearest dry roads: these include horse, donkey, motorbike or motor tricycle.

Canoes are the most effective way to reach other towns or cities, such as Guayaquil, in times of flood. Living at the river margin is considered an advantage in spite of its risks. Such a location in combination with owning a canoe is considered a privilege. When ground transportation is not an option, those living inland must ask permission to those living at the river margin to access the river through their properties. This access can be free or involve a small fee, depending on the type of social relationship.

A canoe is invaluable in times of flood. It is the main means to transport assets and people. The complementary use of horses and donkeys is also frequent, as cars and motorcycles can easily get trapped in the mud and water. Motorbikes and motor tricycles belonging to those in neighbouring communities offer transportation services from non-flooded locations. All these means of transportation belong to few individuals within or in neighbouring communities. As such having a social relationship with the operators and owners plays an important role in being able to reach people, places and assets in times of emergency and scarcity.

Even though most respondents stressed that “everything here is shared. Those who do not know how to live remain without eating.”, yet a few also said that “there is no one to count on”. This group of respondents are located closer to the road and none of them own a canoe. People access the road by building cane bridges from one house to the next one in a chain (see Figure 3.5). Generally, they do not work together in the bridge construction, but each family builds its own bridge to the next house.

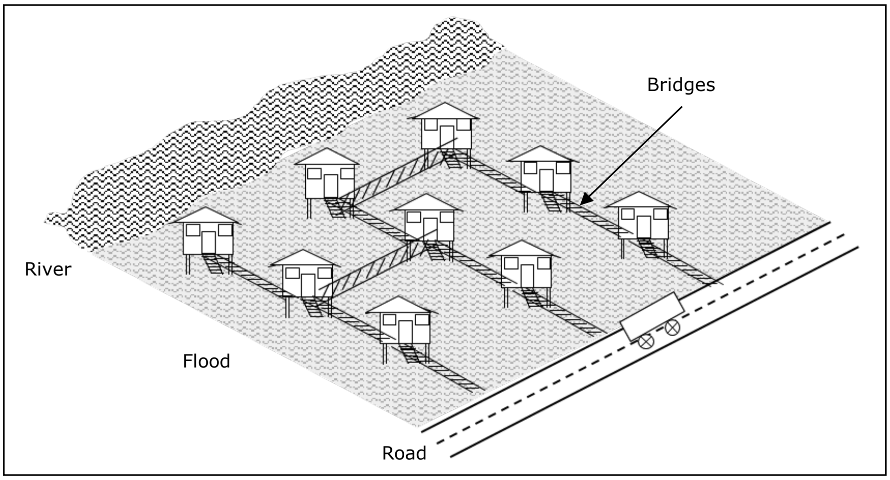


Figure 3.5 Houses connected by bridges in order to reach the main road.

3.4.3 Rice production and credit

"Here we all produce rice, these are what we know how to do" (Male, Santa Lucía canton, 2016)

Farmers' decision making about whether to crop rice once, twice or, two and half times a year varies according to a range of factors: one of which is 'the rumour factor'. For smallholders located in highly flood-prone areas close to the river, the decision sometimes is taken based on rumours of how the weather is going to behave. Is El Niño coming? Is the rainy season going to be heavy? During the flood of 2012, a year that the region was not affected by El Niño but by heavy rain, many farmers decided to crop during the rainy season. Due to the rumours of a period of heavy raining coming, farmers adopted some of the following strategies to decrease the potential economic losses in case of a flood did occur.

- Use of long-grain varieties (which means higher investments) during the first cropping season to get higher economical returns, and using short-grain varieties during the rainy seasons which meant less investment which could be written off if the harvest was lost to flooding.
- Broadcast sewing during the rainy season to reduce costs, and when farmers are able to start a third rice cycle, they use short-grain varieties, transplanted to reduce the risk of overturning.
- Farmers with higher land produced seeds to plant them earlier in the lower lands and reduce the length of the cycle term, with the aim of harvesting before any possible flooding.

- Farmers generally invest in certified seed for first rice cycle of the year but often recycle seed from the first cycle to use in the second cycle to reduce costs (in case of floods).

The phenological stage of the crop at the moment of the flood influences the extent of a farmer's losses and this can vary from farmer to farmer. Respondents explained that if the rice is ready to harvest when it becomes covered by water, they might still be capable to rescue part of it. Different kinds of self-organized activities take place to do this. A group of neighbours might work together to harvest it manually as quickly as possible. Then the rice is dried under the sun and reserved for self-consumption. If enough farmers have crops ready for harvest they sometimes get together and collectively rent a harvesting truck and operator. For this to work the crops have to be ready harvest at the same time, which is rarely the case, so collective arrangements for mechanized harvesting are not that common. Besides, during times of flooding, it may be impossible for mechanized harvesters to access the plots, or the land might be too wet for a harvester to be safely used on it.

Despite reducing investment in rice production and self-organization strategies to harvest the rice that is underwater, farmers' economic losses can still be significant. They often need to take out loans to sustain production and meet family needs. Reliance on informal lenders is a common practice: during every cropping season farmers may borrow between 400 to 1000 dollars per hectare, at interest rates that can be between 10% and 40% per month. The debt must be paid back with the production at the end of each cycle. When production is lost due to floods, informal lenders forgive the interest momentarily, but the capital value must be paid back. When the debt cannot be paid, it increases and must be paid with the production of the next rice cycle. Farmers can easily get trapped in a cycle of indebtedness with one or more informal lenders.

A self-organization response to the indebtedness problem in the area has been the creation of community-saving banks. These saving banks are initially supported by an external institution that contributes seed capital for its foundation. Each member adds a certain amount of money to the seed capital. Every month each member has the right to get a loan for production at a low interest rate. There are few of these initiatives, and those who belong to these groups reported that they do not borrow money from informal lenders anymore or, at least, that they have decreased the amounts and frequency of informal loans. Saving bank members said that these organisations offer more than just financial support. For example, in the case of the death of a family member, the other members will collect money for the funeral expenses. Farmers from different neighbouring communities can belong to the same saving bank, and these community banks may belong to larger farmers' associations.

The social fabric built through the saving banks and other small farmer organizations allows smallholders to access to other sources of support: the rice peeling factories. The factories lend money for rice production at lower rates of interest than an informal lender in exchange for paddy rice at the end of the season. In times of flood, the peeling factories allow farmers to store their rice (that has been preserved for family consumption in the previous season), as they do not have dry places to storage it. Farmers request their rice from the factory whenever they need some (see section 2.4.1). Even though these strategies are helpful to farmers in times of crises, smallholders have limited bargaining power and have to accept the arrangements under which they receive a low price for their rice. Such practices compromise the chances of making a profit out of rice production in the coming season. This can drive farmers to take out new loans from different kind of lenders in order to cope with family needs and the next production season.

Table 3.13 Strategies for rice production and credit that include different forms of social capital across the potential, connectedness, and adaptive capacity dimensions of the adaptive cycle.

Release phase (Ω)	**Household** a	**Bonding social capital** $a \leftrightarrow a$	**Bridging social capital** $a \leftrightarrow b$
Potential	(+1) Use of recycled rice seeds and different seed varieties. (-1) Use of informal loans (at high interest rates) to finance production.	(+1) If a flood strikes when the rice is ready to harvest, farmers self-organize to manually harvest the crop or rent a harvesting truck when this is feasible.	(+1) Belonging to community saving banks. (+1) Financial relationship with rice peeling factories and other lenders.
Connectedness	(-1) Rice production represents main or even only income source.	(-1) The harvesting truck cannot always access or work the land. (-1) Harvesting time is not uniform.	(-1) Price fluctuations. (-1) Low bargaining power.
Adaptive capacity	(+1)Farmers with land in high and low areas, crop tomato and maize in the high lands and rice (with low investment) in the low lands during the rainy season. (+1)Yucca and maize are planted in some rice pools walls, around the houses and at the edge of drainage channels as a source of food/income during floods.	(+1) Pumping water out of rice pools is done through neighbours informal self-organization free of charge.	(+1) If the harvest is lost, informal lenders tend to forgive the debt's interest and wait for payment of the capital until the next harvesting season. (-1) Farmers get trapped in an indebtedness cycle. (+1) Rice peeling factories make rice 'loans' for domestic consumption.

Households' individual conditions are critical at the moment of a flood since they determine the resources that will be available to support the family, share or exchange. In the case of rice production, the conditions in the area are partly determined by the farm's agricultural diversity. The most common condition is a farming family living on their own land, where the main agricultural activity is growing rice. However, some farmers own land in slightly higher lands (and live there) and have small plots of rice production in flood-prone areas. These farmers make higher investments in rice production during the rainy season, and can fall back on crops such as maize that they produce in the higher land during the rainy season.

Some farmers practise crop diversification. Rice is planted in pools divided by walls of compacted soil, and some farmers produce yucca and maize on the top of these walls. During times of flood, the rice may be lost, but the maize and yucca survive. Another strategy is to produce rice on ridges during the rainy season as it is more likely to survive the flood. However, both of these strategies are uncommon (see Figure 3.6).

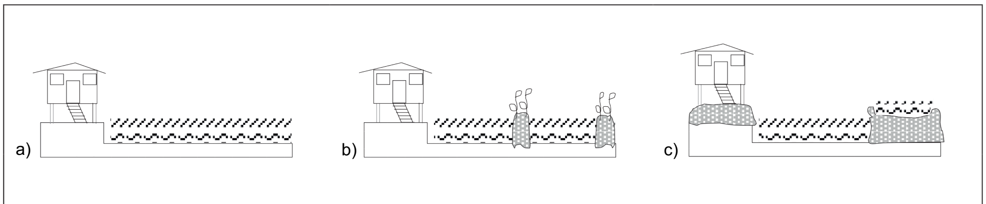


Figure 3.6 (a) Traditional rice crops in pools, (b) rice pool walls to crop maize and yucca, (c) ridges to crop rice.

People we spoke to said that in the flood of 1998-1999 the stagnant water sat in the pools for rice production for over 10 months. In 2012, the water remained for around 6 months. Stagnant water presents a problem for starting the next crop season. Farmers developed a self-organization strategy to solve the problem, pumping the water out in a chain. Farmers farthest from the river pumped their stagnant water into the pools below theirs until it got the pools closest to the river where it was pumped into the river (see Figure 3.7). While there is a generally a fee charged for pumping water from the river to the pool during the dry season, after a flood, this is generally done free of charge.

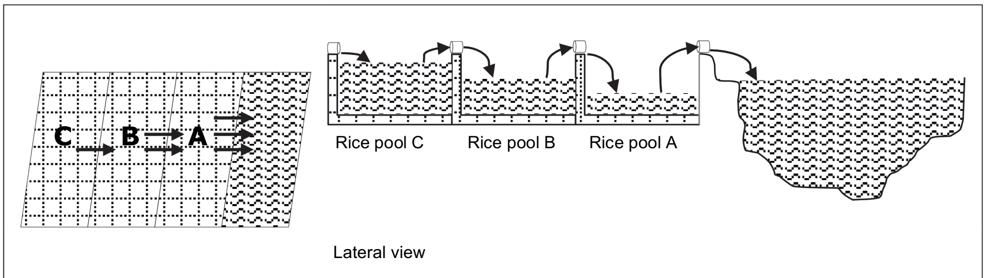


Figure 3.7 Rice pools water pumping

3.4.4 The survival of farm animals

“To save your cows, you need good friends in the higher lands” (Male, Balzar canton, 2016)

Most smallholders in the study area have chickens and ducks for self-consumption and keep a few pigs and cows as a source of revenue. Respondents reported that during the floods, most chickens were drowned. In order to protect their animals, some farmers built rafts to house them. As the days went by, the risk of losing the animals to pests or starvation increased. Refrigerated storage of the meat was not possible due to the erratic (or complete lack of) electricity supply. Therefore, the animals had to be quickly consumed or marketed. Many dead animals were just thrown in the water, which became contaminated by their decomposing corpses. The surviving animals were essential as a strategy for accessing other supplies. Families, friends, and neighbours exchanged animals, for food or water. Some farmers sold their animals to traders from neighbouring communities who came in canoes and only offered very low prices. Farmers fumed at “*having to sell our chickens for the price of eggs*”.

Many households keep a few cows as a traditional form of savings, to be sold when the household needs ready cash. Their survival depended on finding temporary arrangements to shelter them, to which they had to be moved on foot. Farmers who expected the floods (due to rumours) or who were located in very low areas, sometimes arranged the lease of a non-floodable land in advance. These arrangements were mostly done with friends and family members with land in higher areas for low prices. The fee included shelter and food, as these areas are rich in grass during the rainy seasons. When the floods started, those who had not made a leasing arrangement, or lacked social networks with those in the higher lands, faced difficulties in finding safe shelter for their cows. Cattle rustling is a serious threat during when moving cattle and placing them in a provisional shelter. In order to improve the probability of having a safe journey, many farmers said that they made the journey with other farmers at the same time.

When the water level receded respondents said that the most feasible way to restart raising farm animals was to take out an informal loan. These are very popular in the area, despite high monthly interests that range between 10 and 45%.

Table 3.14 Strategies for “farm animals’ survival” that include different forms of social capital across the potential, connectedness, and adaptive capacity dimensions of the adaptive cycle

Release phase (Ω)	**Household** a	**Bonding social capital** $a \leftrightarrow a$	**Bridging social capital** $a \leftrightarrow b$
Potential	(+1) Cows tend to survive and can be walked to higher lands. (-1) Chickens and pigs die from drowning, pests, or lack of food.	(+1) Surviving animals are shared and exchanged among family, friends and neighbours.	(+1) Locals have friends and family in higher lands that rent them a place to house their cows.

Connectedness	(+1) Homemade rafts are built to house surviving chickens and pigs. (-1) Dead animals are thrown into the stagnant water causing its contamination.	(-1) The exchange of chickens and food is limited as the number of animals and conservation means are both limited.	(-1) Chickens and pigs are sold for very low prices. (-1) Places to allocate cows can be limited. (-1) Cows can be stolen by rustlers on their way to higher grounds.
Adaptive capacity	(-1) Farmers must wait until the water recedes before raising animals again. (+1) Cows come back to the farm after the flood.	(-1) Generalized shortage of farm animals. (+1) Farmers self-organize to bring back cows to their farms.	(-1) Informal loans are needed to restart animal raising.

3.5 Analysis: the role of coping strategies in livelihood resilience

The purpose of integrating the adaptive and DRR cycles and social capital in terms of social relationships was to develop a conceptual tool to analyse the role of social capital in mobilizing resources and enhancing resilience and DRR. To do so, we have analysed the local strategies of rice smallholders to cope with floods, focusing on the role of social capital to mobilize key resources needed during the crisis. We applied the integrated framework to five categories of assets: access to food, access to water, transportation and spatial connectivity, rice production, and the survival of farm animals. By using the framework, we visualized how different forms of social capital interact in resource mobilization across the different dimensions of resilience: potential (P), connectedness (C), and adaptive capacity (AC). These interactions are strategies that can either limit or strengthen livelihood resilience, and we valued each analysed strategy as either (1) positive or a negative unit. Figure 3.8. (a and b) shows a summary of the positive and negative interactions that different strategies based on different forms of social capital had for resource mobilization and resilience.

These figures show that local strategies have a mostly positive influence on resilience in the potential dimension. This result shows the coherence of this framework since potential (or people's available resources to respond) represents the resources that need to be mobilized through different levels of social capital to cope with the crisis. The strategies with a positive influence on the potential reflect the availability of resources, such as canoes, food, water, knowledge, skills, labour, and other resources, that different households have to exchange or share. The strategies with a negative influence on the potential refer to practices such as food rationing by reducing the number of meals per day, which reinforce vulnerability conditions (See Table 3.10).

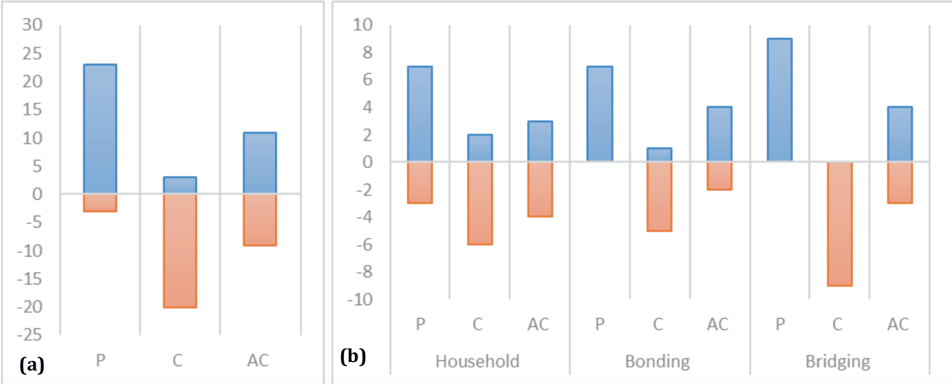


Figure 3.8 (a) General balance between the positive and negative influence of coping strategies related to different resilience dimensions. (b) Balance between positive and negative influence of coping strategies related to different resilience dimensions (Potential – P, Connectedness – C, and Adaptive Capacity – AC) and forms of social capital.

Conversely, coping strategies reveal mostly a negative connectedness. As connectedness refers to the degree to which people can control their and others' response actions and outcomes during a shock, this result indicates mostly low levels of local control. Why is the locals' response control limited? Based on the analysis of the qualitative data, we see that because resources are scarce, they are not sufficient to see people through a prolonged flood, which can last several months. Therefore, sooner than later, locals' responses heavily rely on external support. This negative influence is more evident in the bridging social capital, because as scarcity and need create breeding grounds for unhealthy social relationships such as, for example, the expensive commercialization or unfair distribution of water (See Table 3.11).

The coping strategies reveal an almost equal mixture of positive and negative aspects of the adaptive capacity dimension. This is because the same strategies that are used to adapt to an adverse situation, can reinforce conditions of vulnerability that last longer than the flood. For example, to cope with a money shortage, households take out loans from informal borrowers, at a high interest rate, agreeing to pay the debt with the next rice harvest. While this strategy brings an immediate solution to the cash shortage, it reinforces a consistent cycle of indebtedness (see Table 3.10 and Table 3.13).

3.5.1 The household level

As part of this study, we added the household level of social capital. The purpose was to explore the resources, conditions, and strategies available at the smallest social unit of the community (households) that define the resources, conditions, and strategies available for the other levels of social capital (bonding and bridging). Figure 3.9summarizes the results in terms of each asset considered and the resilience dimensions (potential, connectedness, and adaptive capacity).

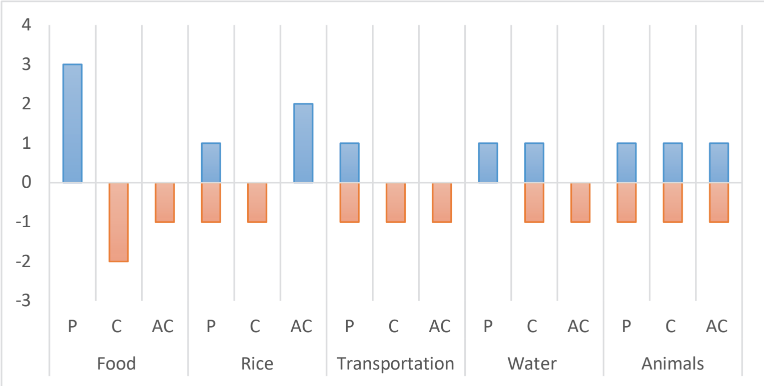


Figure 3.9 coping strategies at the household level on the access to different livelihood assets

The resources available at the household level set the conditions in which the strategies of sharing or exchanging resources through bonding social capital can take place. What households have is what creates a pool of resources for the community for cooperative strategies. For example, the practice of keeping aside sacks of rice during the dry season and harvesting fruits before trees die due to the flood provides options for food exchange among neighbours. In the case of water for domestic consumption, if some households preserve their wells in working condition, they can provide water to other households whose wells have collapsed or been contaminated. To ensure animal survival, household skills in building rafts to prevent chickens and pigs from drowning can be the basis to secure sources of food or other resources that they are lacking.

Although there is generally a diversity of resources at the household level, in general, they are limited in both quantity and quality. While households can prevent animals drowning by building rafts, the animals may die from hunger and pests a few weeks after the flood starts. The lack of electricity, and therefore of working refrigerators, make it unfeasible to preserve their meat. Therefore the animals' meat needs to be consumed or sold (very cheaply) before, whilst it is still fit to eat. At the same time, families are numerous, and those with fewer reserves and or more family members will run out of reserves sooner. In the case of transportation, few households now own canoes, which are the only suitable transportation means during a flood. All these constraints lead to a situation where individual households have limited control over their response to shocks.

The initial conditions of vulnerability, such as poverty, poor health among household members, or having few resources to participate in sharing and exchanging practices, are critical. Because families are numerous and financial hardship is widespread in the area (communities are largely reliant on rice monoculture, which can be lost during a flood), we can see that no strategies have a positive influence on connectedness nor adaptive capacity in terms of accessing food. On the other hand, creativity and willingness are also important. In the case of rice production, we found that diversification, by producing maize and yucca (on the borders of the rice production pools) or producing rice on ridges during the rainy season (see Figure 3.6), positively influenced household adaptive capacity.

3.5.2 The role of social bonding capital

In Figure 3.10, we can see that bonding social capital (based on local networks) has an important positive contribution to adaptive capacity for all assets. During a flood period, it is unfeasible that a household is self-sufficient, therefore local networks play a critical role in creating a diverse pool of resources to meet the needs of the community. Access to food and transportation are the most reliant in bonding social capital, especially during the first weeks of the flood period. Yet we also observe that these strategies have a negative influence on connectedness for all types of access since all these resources are scarce at the local level.

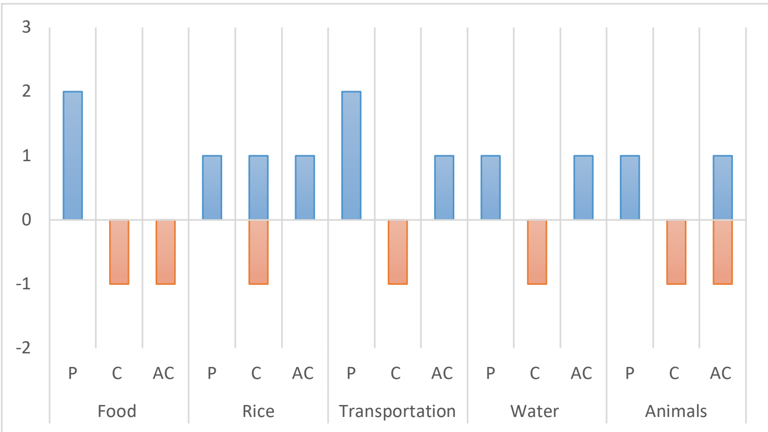


Figure 3.10 coping strategies at the bonding social capital level on the access to different livelihood assets

Although local networks have an important role, their capacity to provide solutions is limited by the generalized vulnerability at the local level. Food is the resource most affected, and the community might only manage to be self-reliant for a few weeks or months even if they employ sharing mechanisms. In the case of rice production, farmer's organizing themselves to pump water out of the rice production pools contributes to livelihood resilience, since this allows farmers to restart their productive activities sooner (see Figure 3.7). However, although these self-organization activities improve farmer's prospects, their capacity to restart agriculture is limit by the lack of other inputs. In order to cope with flooding, households, and the community as a whole, need to rely on broader social support networks.

3.5.3 The role of bridging social capital

As the resources that can be mobilised through bonding social capital level are limited, the affected communities need to create networks with external individuals and institutions that have more power to make the lacking resources accessible or available. In other words, they need to rely on bridging social capital strategies. Figure 3.11 shows the positive and negative influences of bridging social capital in terms of the five analysed assets. On the one hand, bridging social capital can have a positive influence as it allows households to access the resources they lack, such as cash, water, or food. On the other hand, the negative influence is linked to the often unfair conditions under which this access takes place, such as high interest rates, low prices paid for animals, or high prices for buying water.

Ensuring the survival of animals through bridging social capital strategies has the highest amount of negative effects on adaptive capacity. Communities affected by the flood have limited options to commercialize their animals before they succumb to hunger or disease. As a consequence, outsiders buy their animals, mainly small animals such as pigs and chickens, at low prices. An opposite example is a case of ensuring the survival of cows. In this case, long-lasting networks between farmers in lowlands and higher lands often make it possible to find a safe place to keep the cows until the flood recedes.

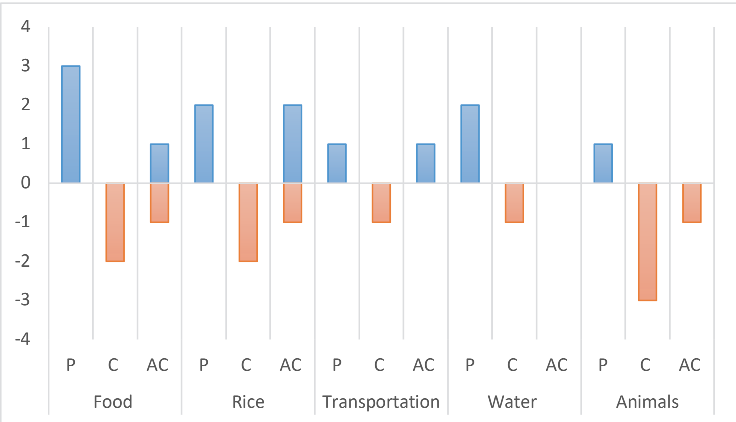


Figure 3.11 coping strategies at the bridging social capital level on the access to different livelihood assets

Strategies at the level of bridging social capital, as at the other levels, are also limited by the quantity and quality of available resources. However, in this case, they are also limited by opportunistic behaviour that strengthens unhealthy social practices, such as inequality, unfairness, corruption, and opportunism. The limits of bridging social capital strategies also lead us to consider the importance of linking different social capital strategies. Although linking social capital is not considered in this study, the results lead us to reflect on the lack of regulations and effective flood disaster risk management plans in the area.

3.6 Discussion and conclusions

This paper has sought to systematically present the development and application of a framework that integrates concepts of (a) resilience and the adaptive cycle theory, (b) social capital, in terms of social relationships, and (c) the disaster risk management cycle. The reason for developing this framework with these specific concepts was to explore the role of social capital as a way of mobilizing resources during a socio-ecological shock.

3.6.1 The central role of social infrastructure in mobilizing resources

One of the main messages of this research is that, while we cannot deny that all types of resources are important, social infrastructure plays a central role in mobilizing them. The use of the framework makes evident the importance of households having access to some initial basic resources (such as reserves of food or water, or a canoe) in order to be able to participate into networks of support and cooperation. It also makes explicit that different forms of social relationships have both positive and negative influences on the use, protection or distribution of those resources during a shock event.

A lack of resources creates more opportunities for unhealthy social relationships within the same or neighbouring communities since it decreases the bargaining power of households lacking resources. Some examples are financial dependency on informal lenders (Table 3.10 and Table 3.13) or unequal accessibility to formal aid distribution channels (Table 3.11). On the other hand, the availability and diversity of resources at the household level allows space for developing healthy social interactions. Some examples are the practices of sharing or exchanging food, water, labour or access to transport in a synergic way to cope with shortages (Table 3.10 and Table 3.11).

3.6.2 The practical value of acknowledging social capital as a key resource mobilizer

We consider that the added value of the framework we have developed relies on the practical use that policymakers and practitioners can make of it. One of the strengths of using the framework as a lens to relate social capital to resource mobilization is that it a clearer picture of how specific resources (food, water, transportation, among others) are coupled in practice with different forms of social capital. This information can be valuable when designing and implementing more targeted mechanisms to support resilience building and DRR practices at the local level.

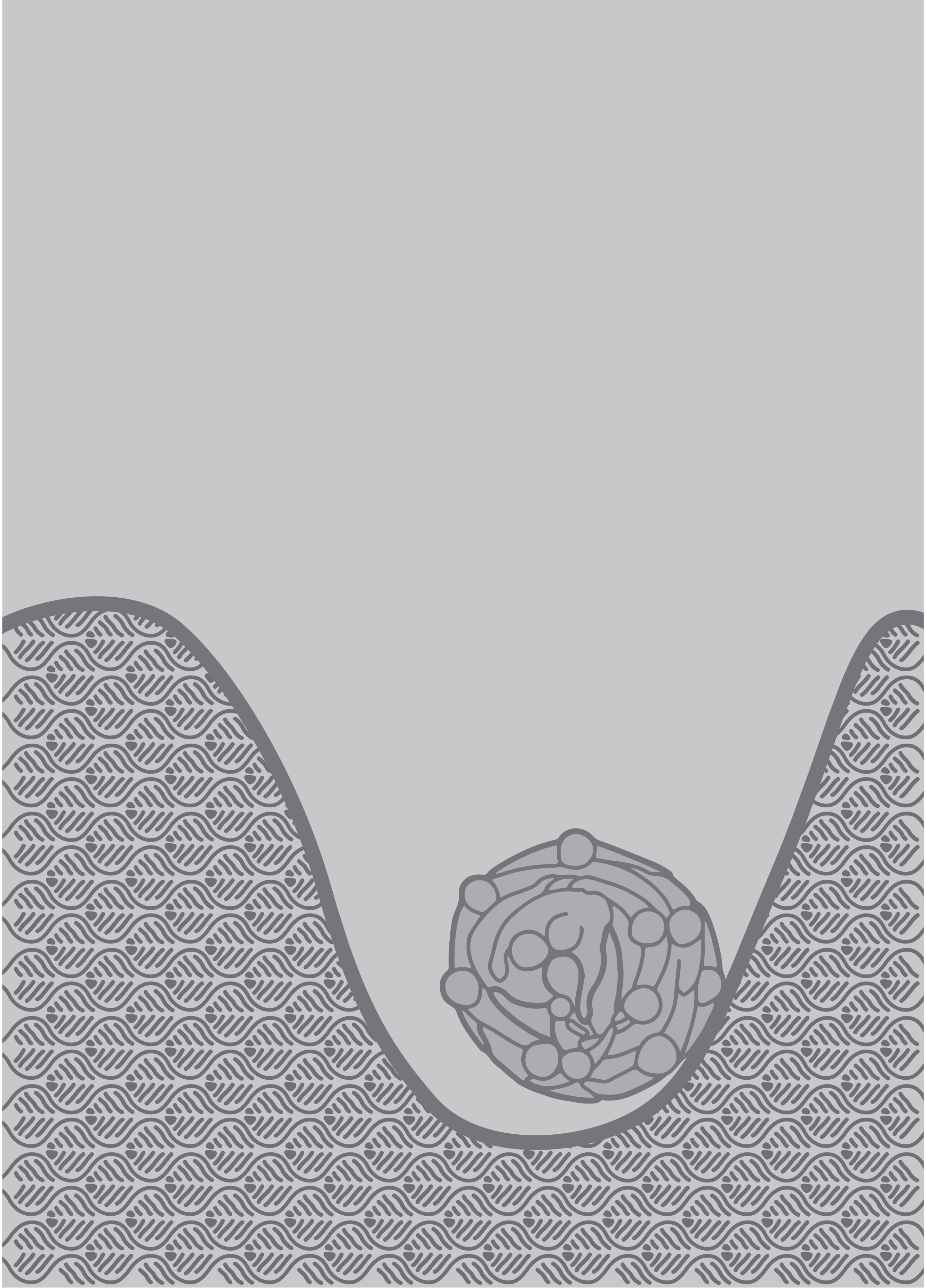
To exemplify this, we draw on data from the findings relating to the strategy of accessing food (see Table 3.10). One of the strategies considered to be positive was neighbours exchanging rice for fruits/vegetables. Smallholders' reserves of rice allowed them to access other types of foods through mechanisms of cooperation and reciprocity. The more diverse (fruits, vegetable, chickens) households' livelihoods were, the more resources they had to consume or exchange. This insight could be valuable for policymakers and encourage them to design mechanisms to support livelihood diversification. As such, diversification is not only relevant for food security or biodiversity, but also for disaster risk preparedness and resilience. Within the same example, a strategy considered as negative was when several members from the same family registered as the head of a household to get more benefits from the government aid than their neighbours. A deeper knowledge of how this practice takes place during a crisis in the area could help practitioners to adjust the logistics for aid distribution.

3.6.3 The usefulness of the framework in exploring the role of social capital in other stages

The systematic and coherent integration of concepts has allowed us to dissect general coping strategies into more specific 'social infrastructure – resource mobilization' relationships (see Tables 10-14). Although this research applies the framework within (i) the specific time frame of a disturbance event, (ii) the stage of response-release, and (iii) bonding and bridging social capital, it could be potentially applied far more widely. We consider that this framework could also be used to explore the role of social capital for resource mobilization at other stages. For example, to explore the role of bonding and bridging social capital during a mitigation-conservation stage (prior to a shock).

3.7 Acknowledgements

This study was funded by the SENESCYT (Secretaría de Educación Superior, Ciencia, Tecnología e Innovación) and ESPOL (Escuela Superior Politécnica del Litoral) through a postgraduate study grant, and was developed as part of the InunDaule project, carried out by AVSF (Agronomes et Vétérinaires Sans Frontières) in Ecuador. Special gratitude goes to Geovanna Pila and Eduardo Rodríguez (AVSF), and the community members and leaders in the cantons of Daule, Palestina, Colimes, Balzar, Nobol, and Santa Lucía where this study was conducted. We would also like to thank Nicholas Parrott of TextualHealing.eu for improving the English language content.



Chapter 4
Self-organization, defection and resilience: How flood-prone rice farmers in Ecuador make sense of (non-) cooperation during times of crisis

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(Manuscript to be submitted)

Abstract

Self-organization is a critical pillar of resilience and is inherently related to continued cooperation under duress. This research studies how group members make sense of cooperative and defective choices under different shock situations, and how those decisions are related to the resilience of their livelihoods. Formal saving groups, formed by rice smallholder cropping in flood-prone areas of Ecuador, are studied to reveal individual motivations to cooperate (or not) and their relationship with livelihood resilience. To do so, we use a social dilemma game mimicking a 'saving box' – a local community-based financial institution – followed by a focus group discussion. Rather than seeking to test behavioural theories, the lab-in-the-field game is used as a tool to create a temporary shared experience among participants, triggering their thought processes around real-life situations. After the game ended, the anonymised results were shared with participants and formed the basis of a focus group discussion in which the central theme was participants' motivations and the meaning of their choices—sensemaking. In the game, participants confronted the dilemma of whether or not to repay a debt to a community fund under hypothetical individual shocks (family crisis), or covariant shock (price fluctuations, and flooding). During the focus group sessions, participants openly talked about the rationale of their choices under different scenarios. Under individual shocks, they agreed that it makes sense to try hard to at least partially pay their debts—as their effort would be recognized and they would probably get financial or non-financial support from the group in return. Conversely, participants expressed with collective shocks, such as floods, it may be preferable not to pay back the loan, reserving their resources to cope with urgent individual and collective needs. Those resources are critical to carrying out collective coping strategies, based on sharing and exchanging within the community, which was considered to be a higher priority than debt redemption. Participants gave a higher priority to producing community coping capacities during collective shocks than to keeping the saving box afloat. The same held true for depressed rice prices, except here the community had fewer individual or collective coping strategies, especially as many are largely or wholly dependent on rice production for their livelihoods. The results illustrate the existence of complex and multi-dimensional community sharing and coping norms that would probably not have been captured by standard public good games. Methodologically, this study highlights the potential of quantitative experimental games as tools to elicit self-exposure and collective sense-making thought focus groups—to better understand the intricacies of local group-dynamics and resilience mechanisms.

Keywords: sense-making, focus group approach; social dilemma games; livelihood resilience; shocks

4.1 Introduction

Resilience is the ability of a system to absorb disturbance and reorganize itself by making changes that maintain its functions without shifting to a new pathway (Walker and Meyers 2004, Folke 2016). Livelihood resilience refers to peoples' capacity to sustain and improve their livelihood opportunities and well-being across generations despite disturbances (Tanner et al. 2015). In this study, we focus on the livelihood perspective, because it places greater emphasis on humans and their needs, agency, empowerment, rights, and capacity to adapt. Individual and collective actions provide a solid foundation for self-organization, a critical strategy for rebounding from shock (Tanner et al. 2015).

Existing studies in community development and psychology attribute resilience to different sets and combinations of capacities. Ifejika Speranza et al. (2014), assert that resilience relies on the community's buffer capacity (through access to assets), self-organization, and learning capacity. Cinner and Barnes (2019) state that assets, flexibility, social organization, learning capacity, socio-cognitive constructs, and agency are the factors that provide resilience. Berkes and Ross (2013) include people–place relationships, knowledge and learning, social networks, collaboration, and leadership. Faulkner et al. (2018) propose community resilience as a property that emerges from attachment, leadership, community cohesion and efficacy, community networks, and knowledge and learning. Although factors vary, social self-organization is a factor that persists, and the one that we focus on this study.

Self-organization had been extensively studied by economists since it is the main principle of collective action, which seeks to achieve common goals through collaboration and coordination (Ostrom 1998). Social dilemmas, which are defined as a situation in which two or more persons receive a higher payoff for a non-cooperative choice (defection) than for a cooperative choice, but all members are better off if all cooperate than if all defect (Dawes et al. 1988), play a leading role in hindering the formation, maintenance and development of cooperation (Ostrom and Ahn 2007).

Cooperation problems in a multiple-person social dilemma can be defined as a collective action problem for the production or the use of a joint good from which it is difficult to exclude others (Kollock 1998), due to reasons such as the physical nature of the resource, the available technology, or existing laws and traditional norms and values (Ostrom 1993). A joint good can be understood as a good whose benefit is private, but 'whose attainment involves the cooperation of at least two (but usually far more) individual producers' (Hechter 1988).

Social dilemmas have not been widely used as an approach to understanding collective action problems related to community resilience, but the approach contains a promise. Rabinovich et al.

(2019) conducted a qualitative exploration of the challenges facing pastoralists in attempting to prevent soil erosion, using community resilience and social dilemmas approaches as theoretical lenses. A social dilemma approach helps us to understand community resilience as a collective attribute (Chaskin 2008), restricted by self-interested choices and actions, the absence of which would affect both cooperators and defectors.

In this study, we look at livelihood resilience through the lens of a joint-good, where community members obtain private benefits through individual and collective actions but are hindered by social dilemmas. The research focus is on smallholder farmers, and their capacity to sustain their livelihoods individually and collectively despite disturbances. It is relevant since, smallholders by virtue of their numbers and agency, represent the voice and action for their livelihoods' resilience, which in turn relies on their self-organization and cooperation capacities, which in turn heavily influenced by social dilemmas (Ostrom 2000, Niehof and Price 2001).

Social dilemmas, which hinder cooperation, and consequently self-organization, are mostly studied throughout quantitative experimental games. These test social dilemma theories by choosing specific variables and repeated controlled settings. However, the outcomes are not always easy to interpret because the results do not always follow theoretical predictions (Hagen and Hammerstein 2006). The purpose of this research is not to test behavioural theories, but to better understand (un-)cooperative group-dynamics through the lenses of resilience and sense-making.

Our research questions are:

- how do smallholders make sense of their cooperative or defective behaviour in a shock situation, and;
- how does such a sense-making process link to their livelihood resilience?

We apply a focus group approach to engage in the sense-making process, preceded by a social dilemma game as a tool to provide a temporary shared experience to participants, rather than as an experiment. The purpose of combining both research tools in a qualitative context is to explore the complex and multi-dimensional social factors involved in (un-)cooperation sense-making.

4.2 Theoretical and methodological approach

From a theoretical perspective, our research focus has three keywords: social dilemmas, cooperation, and collective sense-making. To summarize definitions, cooperation involves working together to the same end, social dilemmas are the situations that hinder cooperation due to self-seeking motivations (Kollock 1998), and collective sense-making is the process of assigning meaning to experience and creating order out of events by making sense of them (Kramer 2016).

Human cooperation and social dilemmas have been largely studied in economics through the use of experiments, also known as economic games, for testing theoretical models of human behaviour (Hagen and Hammerstein 2006). On one hand, games are a simplified version of real-world social dilemmas problems so one can carefully choose theoretical components to study, and specific variables in repeated controlled settings (Ostrom 1998, 2006a). On the other hand, their results offer a normative solution (Haselhuhn and Mellers 2005) consisting of cooperators and defectors. They are however the most appropriate methodological tool to articulate behaviour, local norms formation, and outcomes (De Herdt 2003).

From a joint good perspective, public good games are standard experiments to measure cooperative preferences (Bluffstone et al. 2020). These have yielded outstanding advances for the understanding of human behaviour, for example by studying the relationship between group identity, communication, punishment, rule designing and cooperation (see Ostrom 2006b for a summarized review). However, field research, as well as experiments, have found that individuals in everyday life do not always follow theoretical prescriptions. Therefore, the interpretation of game results is still challenging because individual motives are often linked to social factors (Ostrom 1998, Hagen and Hammerstein 2006, Ostrom and Ahn 2007) and fundamentally driven by sense-making (Chater and Loewenstein 2016).

Peoples' collective sense-making process can be approached through a focus group methodology (Wibeck et al. 2007). While this approach is less reported than experiments in social dilemmas and cooperation literature, there are some relevant examples. Oria et al. (2018) applied them to study the social dilemmas hindering sustainable mosquito trapping in order to try to control malaria in Western Kenya. Adger et al. (2017) examined and tested how moral reasoning toward social dilemmas underpins or legitimizes governance and practice on adaptation to climate change risks. Uronu (2018), explored the collective action challenges in facilitating access to financial services among smallholder farmers in Tanzania and Eijgelaar et al. (2016), assessed Dutch consumer's social dilemmas faced with carbon labelled holiday trips.

Focus groups are controlled group discussions, where group interaction is explicitly part of the method. Its goal is to gather views and opinions from participants in a context of mutual influence (Barbour, Rosaline & Morgan 2017). Focus groups offer researchers the opportunity the see the sensemaking process (Wibeck et al. 2007), or *"how views are constructed, expressed, defended, and (sometimes) modified during the conversation* (Wilkinson 1998)*"*. Sense-making is ongoing, grounded in identity construction, retrospective, enactive of sensible environments, and driven by plausibility rather than accuracy. The given meaning to an experience does not have to meet objective senses of truth in order to be accepted (Weick 1995, cited in Merkus et al. 2017).

The literature reports numerous advantages of using focus group discussions. They can generate a wide range of data very quickly. They enable participants to highlight the issues that are important to them. They create the conditions for an interactive discussion, which allows us to collect data that would not be accessible in individual interviews. A focus group allows participants to share their views, as well as hear others', and rethink their views in light of new information. It triggers the finding of similarities and differences in common experiences (Morgan 1996, cited in Hennink and Leavy 2014) and goes beyond an individual perspective and creates a floor for the collective construction of meaning (Kook et al. 2019).

Yet, the literature also reports some limitations. Participants might intervene as individuals, rather than interact as members of a group. Focus groups can create conditions that limit participants from sharing 'socially unacceptable' opinions. Some participants may dominate the proceedings. Others might not express their real views due to unseen hierarchical settings that influence the session. Finally, time may be limited, and so relevant issues might only be discussed superficially (David and Sutton 2004, cited in Hennink and Leavy 2014). Thus, facilitating a focus group requires a range of skills, good planning, and a safe environment. Building trust and rapport with participants, eliciting interaction, offering impartiality and being flexible is essential to manage the group dynamics (Monique 2017 cited in Barbour, Rosaline, &. Morgan 2017).

Hydén and Bülow (2003) argue that focus groups have a particular limitation on eliciting interactions as members of a group rather than as individuals, which is how to establish a common communicative ground. A group can be conceived as a set of individuals sharing (i) general social features or experiences (i) a set of values, norms, roles, and goals, or (iii) a temporary situation that focuses their cognitive and visual attention. Several studies have combined focus groups with other research technics, such as audio-visual presentations and serious games (Douwes et al. 2018, Radhakrishnan et al. 2019) to create settings where an experience is shared temporarily.

In this study, we propose to use a focus group approach supported by the use of a social dilemma game, see Figure 4.1. First, the game is played to create a temporary experience of a social dilemma among participants, rather than as a behavioural prediction tool. This shared experience facilitates self-exposure and participation. Then the results of the game are used to trigger a focus group discussion that explored why people cooperated or defected in the game under different shock scenarios, and how this would affect their capacity to cope with shocks and preserve their livelihoods as individually and collectively in real-life.

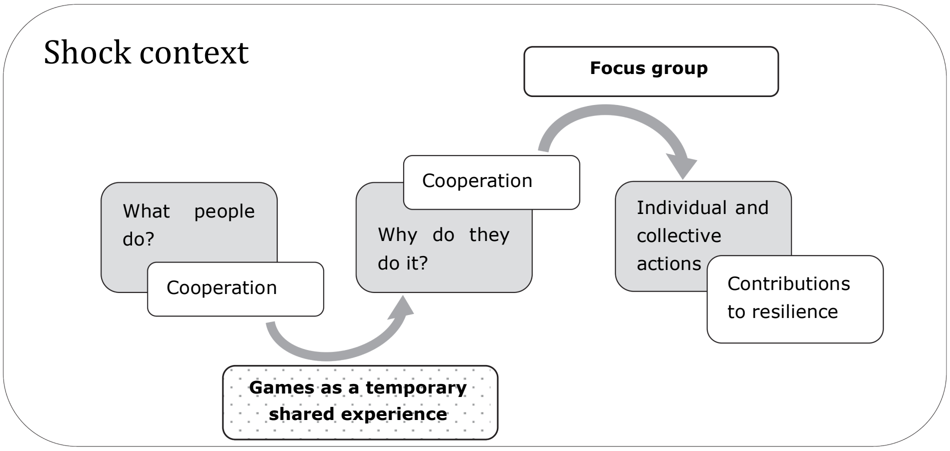

Figure 4.1 Conceptual and methodological framework

This methodological strategy intends to lead participants to perceive themselves as individuals sharing (i) a common experience (the game), (ii) common values, norms, roles and goals (based on the case study context), and (iii) a temporary situation with a common focus (the results of the games had theoretical consequences for the whole group).

4.3 Setting and empirical strategy

Cinner and Barnes (2019) argue that resilience scholarship tends to assume that there is a "desirable state". However, such a state is usually determined as 'desirable' by the elite rather than the marginalized. In the agricultural context, smallholder farmers are both the poorest and most marginalized in the world, yet they are equally the essential actors in addressing the challenges of climate change, food security, risk management, and poverty (ASFG 2013).

In this research, we study the case of rice smallholders cropping under risky conditions in the lower basin of the Guayas River in Ecuador. The focus is on community saving-boxes, which is a local strategy to access credit during the cropping season and maintain their livelihoods. This means we draw two assumptions: First, rice production is a desirable state for farmers. And, second, a community saving-box is a collective action strategy that helps to keep rice production running smoothly.

4.3.1 Saving boxes in Ecuador

In 1879, the first "saving box" was formally established in Ecuador by a group of artisans, due to their ineligibility for credit from the commercial banking system. Since then, saving boxes have emerged as a formal mechanism made up of associated people who pool and mobilize their savings and self-manage a credit system (Jaramillo Moreno 2015). Under Ecuadorian legislation, these are constituted in the legal form of private foundations with a social purpose, and are considered as full credit entities, with strong local roots, that are integrated with the national financial system, and specialize in channelling popular savings and financing families and small and medium enterprises. They cannot open agencies or branches, can operate solely with their members and cannot raise funds from third parties (Junta de Regulación del Sector Financiero Popular y Solidario 2013).

Smallholders in rural Ecuador are usually ineligible to obtain credit from commercial banks, among other reasons, because their agricultural activities exceed the banks' risk thresholds. In this study, the case of rice farming was chosen, since 45% of its producers are smallholders and are located in flood-prone areas in the lower basin of the Guayas River (Guerrero et al. 2011). Smallholders in this often need to have recourse to informal credit channels and one of the most common is usury, in spite of its illegality. Usury operates through different kind of agents and its monthly interest might be up to 45% a month. Farmers can pay their debt in money or rice, but easily get trapped in a cycle of indebtedness. Rice farmers often need a loan in order to start a new rice cycle, which they repay at the end of the cycle when the harvest is sold, approximately every four months (Santos Ordonez 2016).

In this region saving boxes are used as a mechanism to access financial working capital and (partially or totally) break dependence on usurers (Santos Ordonez 2016). Many of them emerged and quickly disappeared, but some few have persisted through time in spite of shocks. Two saving boxes were included in this study, based on (i) a lifetime of ten years or more, and (ii) its members' geographical exposure to floods within the parishes of Santa Lucia, Daule, Nobol, Colimes, Palestina, or Balzar. Both saving boxes started through partial external financial funding and the monetary contribution of its members, but only one of them continues receiving technical support. Currently, both of them have around 30 members and can access credit every four months at approximately 3% monthly interest. Credits are invested in rice production and members can also access emergency funds to support them in case of death or accidents within the household. Besides, a fee is paid cyclically for administration purposes, that can range between 2 and 5 dollars.

4.3.2 The social dilemma game

The game follows the traditional structure of a public good game, where "cooperators confer benefits on others with some cost to themselves, whereas defectors exploit the benefits without such contribution to others" (Sasaki and Unemi 2011). It was designed to confront subjects (smallholders), under field conditions, in a multiple person social dilemma concerned with their willingness to paying back a loan, or not that they receive from the saving box, in the face of different individuals or collective shocks (playing scenarios). [4]If members cooperate sufficiently to the joint good, all the members benefit, but if there are defections (non-payers) all of them are affected, because the production of the joint good (savings) is doomed to fail. The participants were 35 members who had belonged to a saving-box in real-life for over 10 years. The game sessions took place in their own meeting centres. Figure 4.2 shows a scheme of the game and the way it was framed.

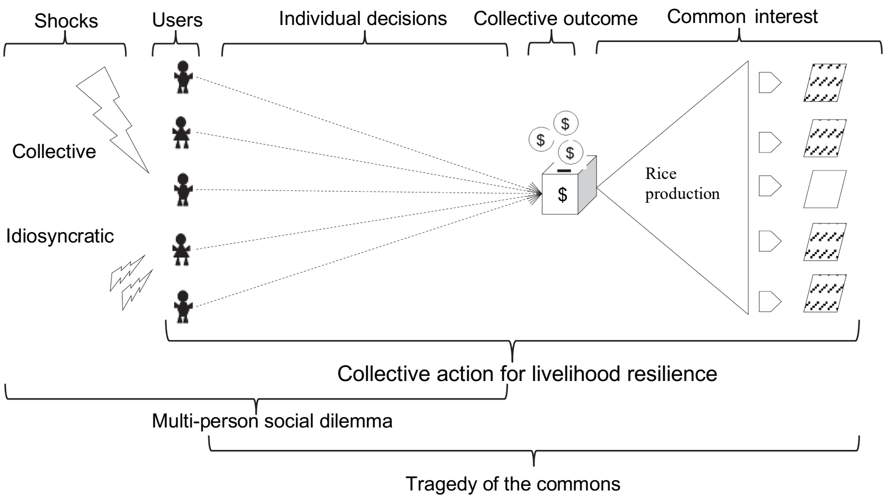

Figure 4.2 Game structure. Five players constitute a temporary saving-box. These are confronted with the dilemma of repaying a loan under different individual and collective shock scenarios. The main purpose of keeping the saving-box running is to access credits during the cropping rice season.

The game design took into account real saving box features, such as interest rates, emergency funds, institutional support, crop seasonality, credit amounts, and common investment interest. It was based on the following features /rules.:

- each rice cycle lasts approximately 4 months,
- most farmers in the area produce 2 cycles and a few of them 2.5 cycles per year,
- saving box loans are between 300 and 500 USD dollars,
- a nominal extra contribution is made by users for administrative purposes every cycle,

[4] In the risk literature these are referred to as 'idiosyncratic' (such as death, injury or unemployment) risks that generally only affect individual households and 'collective' risks that affect many households in the same geographical area (i.e. community shocks, such as natural disasters or epidemics), (See Pradhan and Mukherjee, 2016)). We have chosen to use the more widely-understood terms to describe these types of risk.

Chapter 4

- loans and payments are made per rice cycle because the money serves to finance it and some of the profits are recycled back into the savings box,
- the monthly interest is 3% in most saving boxes with slight variations.

The players were therefore familiar with the hypothetical scenarios in each scenario in terms of the way that a saving box operates and the potential shocks to which members are exposed throughout a year.

The game storyline is that an external organization support a group of five smallholders to create a saving box. The organization contributes US$2,000 and each member contributes US$100, giving the saving box an initial sum of US$2,500. The saving box reserves US$500 for emergencies and lends US$ 400 to each partner for rice cultivation, which must be paid at the end of each rice cycle (4 months). Since the monthly interest is 3% and a US$ 2 fee is paid for administration purposes, each member should end paying back US$450, and the saving box would add US$240 to its financial capital every rice cycle.

The rules of the game are: if (in case A) the saving box grows to US$2,550 or more, showing growth on its initial financial capital, it will continue to receive technical support and an extra financial incentive from the promotor organizations, in case B the box's capital is between US$2,300 and US$2,500, in which case it will continue receiving technical support but no financial incentive, and in case C the capital falls below US$2,300, in which case both the technical support and financial incentives will be removed. Figure 4.3 shows an approximation of the explanatory table shown to players during the workshop.

If one of them pays:	If I pay: $ 450	$ 400	$ 350	$ 300	$ 250	$ 200	$ 150	$ 100	$ 50	$ -
$ 450	$ 2,750	$ 2,700	$ 2,650	$ 2,600	$ 2,550	$ 2,500	$ 2,450	$ 2,400	$ 2,350	$ 2,300
$ 400	$ 2,700	$ 2,650	$ 2,600	$ 2,550	$ 2,500	$ 2,450	$ 2,400	$ 2,350	$ 2,300	$ 2,250
$ 350	$ 2,650	$ 2,600	$ 2,550	$ 2,500	$ 2,450	$ 2,400	$ 2,350	$ 2,300	$ 2,250	$ 2,200
$ 300	$ 2,600	$ 2,550	$ 2,500	$ 2,450	$ 2,400	$ 2,350	$ 2,300	$ 2,250	$ 2,200	$ 2,150
$ 250	$ 2,550	$ 2,500	$ 2,450	$ 2,400	$ 2,350	$ 2,300	$ 2,250	$ 2,200	$ 2,150	$ 2,100
$ 200	$ 2,500	$ 2,450	$ 2,400	$ 2,350	$ 2,300	$ 2,250	$ 2,200	$ 2,150	$ 2,100	$ 2,050
$ 150	$ 2,450	$ 2,400	$ 2,350	$ 2,300	$ 2,250	$ 2,200	$ 2,150	$ 2,100	$ 2,050	$ 2,000
$ 100	$ 2,400	$ 2,350	$ 2,300	$ 2,250	$ 2,200	$ 2,150	$ 2,100	$ 2,050	$ 2,000	$ 1,950
$ 50	$ 2,350	$ 2,300	$ 2,250	$ 2,200	$ 2,150	$ 2,100	$ 2,050	$ 2,000	$ 1,950	$ 1,900
$ -	$ 2,300	$ 2,250	$ 2,200	$ 2,150	$ 2,100	$ 2,050	$ 2,000	$ 1,950	$ 1,900	$ 1,850
-$ 50	$ 2,250	$ 2,200	$ 2,150	$ 2,100	$ 2,050	$ 2,000	$ 1,950	$ 1,900	$ 1,850	$ 1,800

I pay:	$ 450	$ 200	$ 100
One of them pays:	$ 250	$ 250	$ 250
The other three pay:	$ 450	$ 450	$ 450
Emergency fund:	$ 500	$ 500	$ 500
The saving box sums:	$ 2,550	$ 2,300	$ 2,200

	If the saving box sums:	Continues operating	Receives technical support	Receives financial incentive
Case C	$ 2,250 or less	Uncertain	No	No
Case B	$2,300 to $ 2,500	Yes	Yes	No
Case A	$2,550 or more	Yes	Yes	Yes

Figure 4.3 Game rules explanatory tables

The game had four scenarios, which were applied consecutively with the same group of five players. Groups were randomly formed with smallholders at the beginning of the session, and they were not told the number of scenarios beforehand.

Players were asked to imagine that each round represented one rice cycle taking place during the rainy season within their own region. In each scenario, players had to decide, without communicating with the other players, whether to pay back their debt totally, partially or not at all. Individual answer sheets were given to players to mark one choice out of ten options, ranging from US$ 0 to US$ 450.

Table 4.1 Playing scenarios

Scenarios	Description
S1	Participants played the game under ’ideal conditions’, briefly described as the absence of death or unexpected disease, and exceptional floods or droughts.
S2	Some players were assigned as being affected by a domestic calamity, such as an unexpected disease, death, or outstanding family conflict.
S3	All players were shocked by a negative rice price fluctuation. Some were assigned as being ’less affected’, assuming that their harvest was pre-sold to a trader who pays a slightly higher price than the average. Other were assigned as ’more affected’ because they had not contracted the sale of their harvest and the available market price was much lower for them.
S4	A seasonal flood hit the region. Some players were assigned as ’less affected’ assuming their crop was located in slightly higher lands. Others were assigned as ’more affected’ as a result of being located in lowlands at the edge of the river.

The description given for each playing scenario was purposely incomplete. This gave players enough freedom to fill in the ‘information gaps’ based on their real-life experiences and to later talk more elaborately about their motivations for their choices in the ensuing focus group discussion. All the shocks were assigned randomly and anonymously to players.

The participants were told that after the game, results would be discussed in a focus group, but those individual choices would remain anonymous. In order to protect anonymity: (i) players groups named their saving box as they preferred during the game, but these names were changed to unrelated codes before presenting the results, and (ii) the answer sheets did not contain the players’ names, only numerical codes chosen randomly from a list of 500 numbers.

4.3.3 The focus group session

The social dilemma game was used as the first step in creating a situational experience and as a tool to prompt participant smallholders to discuss their choices, motivations and to visualize the complex social dynamics. Once the game session was finished, players had 15 minutes to socialize within the workshop location This transition between the sessions, was purposely planned, to allow the smallholders the opportunity to talk among themselves about the game and their perceptions and expectations before the official focus group session started. The focus groups' sessions lasted approximately 60 minutes and used smallholders' background information and the experiences and results of the game as the discussion material.

The focus group was performed with the participation of the 35 players and a moderator, who was in charge of eliciting smallholders to participate, using the game results as the opening material for discussion. The objective of the focus group was voluntary self-exposure and interaction among the participants, to provide information about their motivations, the social dynamics surrounding their decisions, and how these related to sustaining their livelihoods (mostly rice production) in the face of shocks in real-life situations.

The session design took into account that the researchers could not know the game results in advance. It also assumed that: (i) players' anonymous choices were made under their individual perceptions of the given scenarios, and (ii) players were aware that game results would be exposed, but remain anonymous. This meant that moderator led participants through the session to further elaborate, share, and co-construct how did they made their choices under the different scenarios presented to them, how they influenced their choices, and why.

4.4 Results

In this section, we first present the results from the game and then from the focus group session. The quantitative results obtained from the game do not have any experimental value since the game was neither designed nor performed as an experiment. Instead, it was used as a tool to create a temporary shared experience, to elicit self-disclosure and discussion in the next step: the focus group discussion. We shared the results from the game described in this section to participants at the starting of the focus group session, which started with questions such as: What do you think about the results? Why do you think did the results turned out like this? And, how do you feel about those results?

4.4.1 Game outcomes

In the first scenario (S1 – ideal conditions), 6 out of the 7 groups, were able to generate a common amount that exceeded the initial US$2,550, and therefore this fitted the case A: only 1 group into case B. In the second scenario (S2 – domestic calamity), 3 groups fitted into case A, 2 into case B, and 2 into case C. The median additional savings box for the 7 groups in the first two scenarios was US$450. In S1 the minimum amount paid was US$250 and in S2 it was US$150. During the third and fourth scenarios, the overall amount dropped drastically, with 6 and 5 groups fitting into case C, with a median repayment of US$350 and US$250 respectively. The minimum paid amount was US$0 in both these later cases. The maximum amount paid in the fourth scenario was US$450. Table 4.2 shows a summary of the group performance per scenario and the case (A, B or C) where each group fitted as a result of their within-group individual choices of payment.

Table 4.2 Overall saving box performance by scenario

	Total sum per group				Case per group			
	S1	S2	S3	S4	S1	S2	S3	S4
Group	Ideal	Domestic calamity	Price fluctuation	Flood	Ideal	Domestic calamity	Price fluctuation	Flood
A	2700	2650	2150	2000	A	A	C	C
B	2750	2550	2350	2050	A	A	B	C
C	2550	2050	2050	2350	A	C	C	B
D	2650	2500	2150	1700	A	B	C	C
E	2700	2600	1800	2300	A	A	C	B
F	2600	1950	2150	1150	A	C	C	C
G	2350	2450	1600	750	B	B	C	C

We compared the players that were assigned as ’unaffected or less affected’ by shocks to those who were ’affected or more-affected’, and their individual payments choices. We observed that some players who had an advantageous assignation only made a partial payment of their debt. At the same time, some of those in the disadvantaged category also made a partial payment of their debt.

Figure 4.4shows that under “S1” or “S2” circumstances, 4% and 7% respectively of players decided to pay between 50% and 75% of their debt, despite not facing serious constraints. Figure 4.5 shows that 70% of the players decided to pay more than 75% of their debt despite being assigned as experiencing a “domestic calamity” in S2.

In the case of collective shocks, as in S3 and S4, most players (assigned as less affected as well as more affected) chose to make a partial payment. Among those assigned as more affected, 10% chose to pay more than 75% when the shock was a flood (S4). When the shock was related to low rice prices (S3), 22% of players assigned as more affected decided to repay less than the 25% of their debt.

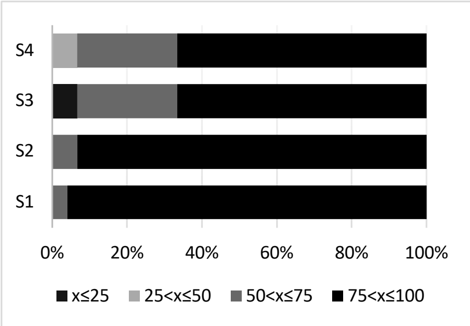

Figure 4.4 Proportion of players assigned as unaffected or less affected and their payment performance by scenario.

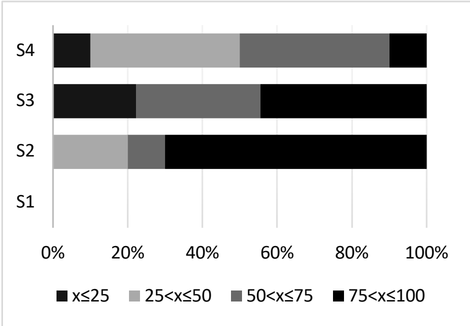

Figure 4.5 Proportion of players assigned as affected or more affected and their payment performance by scenario.

Summarizing these results, it can be observed that cooperative behaviour (willingness to pay) decreased markedly during scenarios 3 and 4, the scenarios where players faced collective shocks, (negative price fluctuations and flood events). Figure 4.6 shows a radar chart per treatment, including the individual payment decision of the 35 players, where the shadow represents the amount of money that the 7 groups were able to gather in each treatment. This shows that under collective shocks, cooperation is crowded out and the joint good (the saving box) fails.

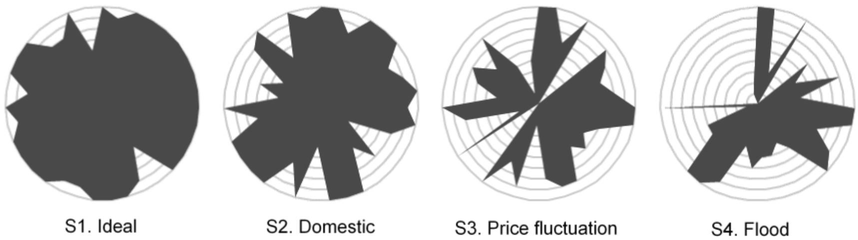

Figure 4.6 Radar chart showing results of the 35 observations (individual choices) per scenario

4.4.2 Focus group discussions

The results of the game raised many questions, such as: why some players still pay when facing individual stocks, such as a domestic calamity? Why those assigned as less affected in the face of a collective shock also decide to default on their payments? Why the willingness to repay is lower when the shock is related to a negative price fluctuation in rice that in a flood? How are these results related to their long-lasting relationship (more than 10 years) as group members of their saving boxes, considering these shocks are common experiences in the real-life? These and other questions were discussed during the focus group, which also identified new questions based on further discussions about the game's outcomes.

During the focus group participants reacted to and discussed the results of the game. One common response was: "Maybe that was me. I did it because...". Some players spontaneously identified some of the results as their own, in spite of the results being exposed anonymously, and they voluntarily explained their reasons for their decisions. Other players added further explanations, developing further the reasons behind their own choices. There were no conflicts among players during the interactions, and supportive comments were offered concerning the information given by players explaining the personal or community-related circumstances surrounding different kinds of shock.

4.4.2.1 Individual shock scenarios

Under *"good enough"* (referring to results from scenario 1) conditions most players repaid their full debt in order to keep the saving-box working and protect the common good. However, some other argued that *"There is always someone who gets sick, something that gets expensive or some plague in the crop",* and these were reasons for some people only partially paying their debt. In addition, there was a universal consensus that in real life the loan from the saving box only partially finances the investment needed for rice production. In spite of common efforts to run their real saving boxes for over10 years, participants admitted: *"Many of us still rely on usurers"*. It happens because the rice production cost per hectare can reach 1,200 USD, and the saving box (in real life) can only make loans of up to 500 $ to its members. People said that they were trapped in a cycle of indebtedness that sometimes prevents them repaying their full debt to the saving box, as a significant part of profit needs to be set aside to repaying usurers' high interest rates. These factors were not considered in the game but emerged from participants' own experiences. Ongoing indebtedness to usurers was also understood as an individual shock situation and shows the importance of allowing players to fill in the stories' blanks with their own experiences of real-life situations.

In the case of the second scenario, in which some players were affected by a domestic calamity, all players assigned as affected chose to repay at least part of their debt. Some participants said that they would choose to pay because *"If I stay right with them, then they will help me too"*. It was felt that their efforts to make some payment would be recognized by other members, who would help them financially and non-financially during the family crisis. Such help might consist in providing help in caring for a sick household member, organising community activities to raise funds to buy medicine, or providing food in case of need. There was also the case of players who were not assigned as affected who did not pay, although no players admitted to making this choice during the focus group.

Under individual shock situations, players explained that arrangements to fully pay a debt are made verbally and may allow for negotiating a time-extension or making payments in instalments. If the affected member is unable to pay the debt, the debt sometimes is divided among the other members, who pay his or her debt in order to allow the saving box to continue working smoothly. If the debt cannot be absorbed by the other members, they can fall back on other fund-raising alternatives, such as organising a football or traditional board game tournament or organising a food selling event in which locals and neighbouring communities participate.

4.4.2.2 Collective shock scenarios

In scenarios 3 and 4 (price fluctuations and a flood event, respectively), the majority of players chose non-payment or partial repayment. When the results were shared, the players argued: *"If everyone is in a crisis, who is going to have enough to share with me?".* They explained that during a disadvantageous price fluctuation, they have few coping options because all of them mostly (if not solely) depend economically on rice production. One of their main concerns during a price crisis is that most of them are also indebted to other lenders as well as the saving box or have promised their rice as part of the payment to suppliers of agricultural inputs, pilling factories, or other lenders. In addition, the lack of infrastructure to store rice makes them depend on other actors in the rice market, and *"if we do not sell, the rice would get spoilt"*.

In the case of a flood event, players argued that regardless of being less affected or more affected by a flood, there are always uncertainties such as: *how long will the flood last? Will we receive help from the government? Do we have enough food and water? Will our animals survive or our water well collapse? If I start paying, what money is left to support my family?".* Players argued that a flood has negative effects for everyone in the area: *"We sell a chicken for the price of an egg to outsiders who come to buy our animals very cheaply. We sell them before they drown or get sick".* Since it is common that saving box members are also neighbours, the players agree that saving money to cope with the shock within and outside the household would be a priority.

Players noted during a flood period exchanging or sharing is not just restricted to family members: *"One has to have sharing and exchanges"*. Players reported that during 2012 floods and in more recent years (for some players), people regularly exchanged rice for bananas, yucca or maize, crops that are mostly grown for self-consumption purposes on some farms. Water exchange or sharing was also common because those who are located on lower land often see their water wells collapse or become contaminated. Communal labour contribution is also a common practice. If the house of a community member suffers damage and needs repairing, members of other households will provide their labour. This practice may include members and non-members of the saving box and can be even between neighbouring communities. Therefore, for most repaying a debt to the savings box becomes a less important priority than sharing and exchanging resources, and *"After that, we open the savings box again".* Participants affirmed that they have done this before in real-life situations. In summary, the non-cooperative choices towards the saving box can be aligned to the economic-theoretical expectations of strategic defaults under collective shocks (Bhole and Ogden 2010), but the discovery of alternative forms of cooperation, which we had not factored in, represents an important finding in this research.

From the focus group discussion it emerged that while participants considered a flood as life and livelihood-threatening shock, they also considered themselves as having some endogenous and self-reliant coping strategies, both as individuals and groups. This was not the case for price-related shocks. This difference in coping capacities could explain the difference in the game result between scenarios 3 and 4. During a flood, community individuals can draw upon others' resources and synergistically share their own. When the shock is price-related actions that can be taken through self-organization are more limited. During the focus group session, players identified and discussed two main issues. Firstly, they acknowledged that an even a 'small' missed repayment could affect the viability of the saving box and therefore negatively affect all group members. Second, they recognized that being solely economically dependent on rice production made them more vulnerable and less capable to cope with shocks.

4.4.3 Making sense of the differences between scenarios

Under a state of individual shock, some players who were assigned as affected decided to at least partially repay their debt in order to gain social recognition by its fellows and further support which, according to respondents, is not just limited to financial aspects, and at the end of the day might even exceed their debt repayment. As such this practice appears to be not only important for building a good reputation and gaining recognition within the group but to be a form of investment, since the act of partial payment may trigger other members too, individually and collectively, support the affected member.

Under collective shocks, an uncoordinated strategic default was observed, regardless of whether the shock was price-or-flood-related. However, there were differences in the potential for, and dynamics of, cooperation between the two cases. Under a price fluctuation shock, the players saw themselves as having limited options to cope individually or collectively due to their high reliance on third party lenders. Yet the same players reported several dynamics of non-financial cooperation that they could fall back during a flood scenario. Even though the potential for financial cooperation was limited under a flood scenario, social exchanges among saving box members and even members of other communities were commonly practised usually involving the sharing and exchanging of both tangible and intangible resources in order to cope with the shock.

4.5 Reflections

The purpose of qualitative research is to make sense of, describe, and to explain the social world. In this research, we used a game and a focus group discussion with the aim of making sense of cooperation under shock situations and understanding how those decisions are linked to livelihood resilience. In this section, we reflect on the results from both a theoretical and methodological perspective. Although the results are not conclusive, and the study is exploratory, we consider it is worth doing more research on the interactions between social dilemmas and livelihood resilience.

4.5.1 Coping with shocks through synergic cooperation

The theory of the adaptation cycle (Holling 1973), argues that a shock leads to a release of accumulated resources. This does not necessarily mean a loss of those resources (since they might have been accumulated precisely to deal with a shock). The transition from accumulation to a release of resources could be equated to the principle of energy conservation, not in the strict thermodynamic sense of the theory, but in the practical understanding of the social dynamics found in this research. This principle states that the energy, or capacity of doing work, can be neither created nor destroyed, but only transformed.

In this case study it could be said that smallholders own different kinds of 'energy': agricultural inputs, infrastructure, social networks, labour, knowledge and skills, both individually and at the group level, that allow them to sustain their livelihoods. The 'energy' of a saving box is a bit like a battery. It gives the members 'energy' (i.e. liquidity) during the planting season, but it needs recharging after the harvest, otherwise, it will run flat. As such, this tangible joint good depends on users' willingness to pay (cooperation as a form of energy) in order to continue financing members' rice production. When a flood occurs, as in the case of scenario 4, different forms of the smallholders' energy are released to mitigate the situation. Yet at the same time, some rice will be lost and some animals drowned, reducing smallholders' income and ability to feed themselves. As a result, they cannot, or choose not, to repay their debt to the savings box.

However, even though the game results indicate a release of smallholders' financial 'energy' the focus group also revealed that other forms of cooperation (also 'energy') occurred in real-life flood scenarios as a response to the shock. Most saving box members would prioritise focusing their efforts in exchanging or sharing food, water, means of transportation, labour, and logistical or social support in order to cope better with the shock. This cooperation went beyond the membership of the saving box, including whole communities (and sometimes farther afield). This allows the synergistic combination of a more diverse range of resources, knowledge, and skills to work together developing community resilience to floods.

4.5.2 The joint benefits of community resilience

Smallholder's resilience to floods can be seen as a partial result of the synergy of different household's resources and can be understood as a joint good. Such resources represent a pool of resources (such as water, food, canoes) to cope with a flood, individually and collectively. The production of this joint good (community resilience) would fail if one or more individuals were to invest fewer efforts and resources in being prepared to cope with a flood.

Therefore, if everyone decides not to cooperate (or not to self-prepare) with their own tangible and intangible available resources within the community by means of sharing, exchanging or working together to cope with the flood, each one would face greater challenges in coping individually with the shock. For example, some community members store pilled rice during the dry season to eat or exchange for water during expected flood periods.

As with other joint goods, it is difficult to exclude community members from the resources needed to cope with a flood, mainly due to social factors. For example, very few community members own canoes, but everyone knows someone who does own a canoe. Due to issues of reputation or in expectation of reciprocity, those who own canoes may find it difficult to exclude other community members from using them.

Figure 4.7 shows how users reported providing or making use of their own resources under flood scenarios (S4). Even though players were not in communication during the game session, they were acting collectively in not paying or only partially paying their debt, as an uncoordinated form of strategic default. This reflects how punishment disappears under this shock scenario (S4), as it is implicitly agreed as part of common knowledge, or a social norm, not to cooperate financially but to cooperate through other tangible and intangible resources to achieve different common goals, such coping with the flood or strengthening social ties. Both goals become important strategic factors to continue working together as a community and sustaining their traditional livelihood means, of rice production, throughout a difficult time.

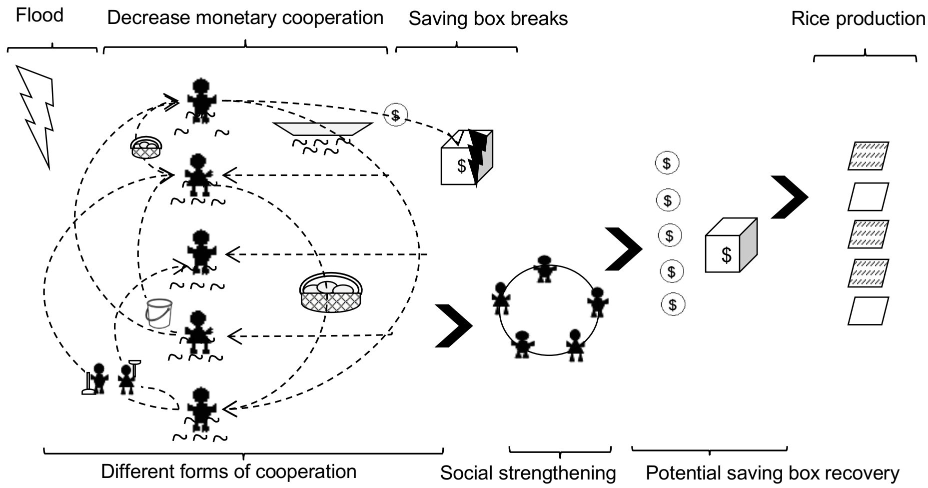

Figure 4.7 Cooperation forms under flood events

4.5.3 Defection is not necessarily non-cooperative behaviour

In economics, game theory recognizes cooperators and defectors, altruists and selfish people (Kollock 1998). If we were to rigorously stick to this view, it could be said that once enough smallholders decide not to pay, the resource (the savings box) is lost due to a lack of cooperators. However, by amplifying our understanding of smallholders' rationale under conditions of collective shock, we can see that the resource is not gone, but has changed its form. The money that would have been paid to the saving box is manifested in food, water, labour, transportation, logistical support, and even future mutual exchange expectations, that emerge as an intangible, yet exchangeable, currency that allows them to preserve their community cohesion, identity and trust.

In other words, saving box members are actively and individually deciding to abandon a tangible common good (the saving box) for something that is intangible, their social ties and their community resilience to a shock. While the maintenance of the saving box serves aids their resilience in the short run, the investment of their social capital serves their long-run resilience, making it possible to reopen the tangible good, (the saving box) in the future, and the possibility of successful self-organization within other collective activities.

This leads us to propose the premise that cooperation that serves to maintain the resilience of a community and its livelihoods, can be framed in layers, which are prioritized differently under different scenarios. Our empirical data shows that there is one layer in which farmers cooperate for the common purpose of keeping a saving box that allows them to finance their agricultural activities. This layer includes a tangible common good (the saving box), where cooperation could be objectively quantified (money). However, under a collective shock scenario, this layer was no longer a priority, and individuals cooperation became much more complex and dynamic, serving another common resource, community resilience to floods. Figure 4.8 shows a diagram based on the results obtained in scenario 4 (flood scenario).

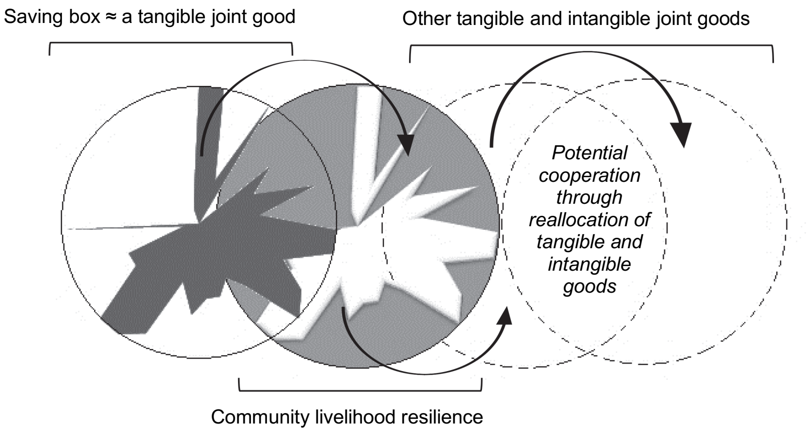

Figure 4.8 Common community goods and the transformation of cooperation forms. The grey shadow in the upper circle is the money that was contributed by players to the saving box. The empty area within the circle could be understood as the loss of the resource, but in the next circle, the grey space within the circle represents the allocation of other tangible and intangible goods in order to cope with the current shock. The next circles represent other common goods that are still unknown to us, but under different circumstances could be prioritized, resulting in a different configuration of the forms of cooperation.

4.5.4 Eliciting sense-making through social dilemma games

Since the game was not designed to control conditions as an economic experiment does, the results do not intend to anticipate subjects' behaviour under stress conditions, but to use a tangible common good (the saving box) as a means to explore other more intangible common goods. For example, non-financial cooperation within a collective stress situation is a behaviour that would not have easily be detected using an economic approach (multi-person social dilemma games). Experimental approaches aimed at understanding social dilemmas could be useful participatory tools for understanding the reasons behind individual decisions and their relation with collective resilience (household and community livelihood resilience).

The use of a framed game as an eliciting tool allows to players to recognize situations that they face in their daily lives and to complete the 'withheld information' with information based on their own experiences, knowledge, and perceptions. This provides a rich information source for researchers. Equally, both researchers and players have the opportunity to give and receive feedback. While players could explain about subsequent or parallel circumstances that influence their choices under different kind of shocks, researchers also have the opportunity to formulate or to guide the discussion through to new questions to better understand individual decision making and its relations to livelihood resilience.

4.5.5 Informing economic game design and theory

This approach could also serve as an exploratory stage prior to the design of laboratory or field economic games in different settings, to (i) frame the games more accurately and (ii) to decide among a wider range of variables of interest. Figure 4.9 shows an alternative model for designing an economic game. The squares in unbroken lines represent the standard steps and those in dashed lines the proposed additional steps, where: 1) a naive hypothesis is selected based on theory, 2) a game is designed based on that hypothesis, 3) the game is played but instead of finishing at the end of the game, its results are shared to elicit participation in a focus group session, 4) the qualitative data obtained in the focus group provides information to develop a new hypothesis, on which 5) a new game is designed that 6) provides evidence to either accept or reject the tested hypothesis. This, in turn, can help elaborate more complex economic models and theories, that better mimic real-life behaviour.

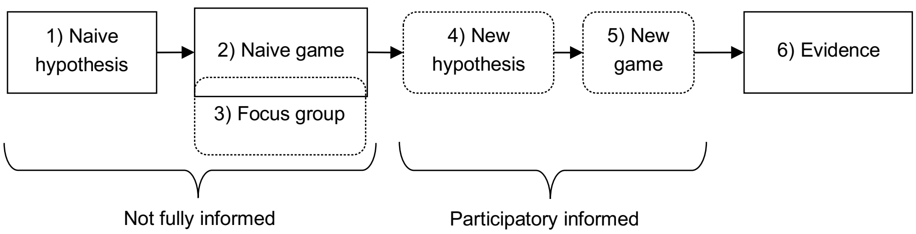

Figure 4.9 Alternative model for designing an economic game

Feedback from focus groups could form the basis of designing an experiment to test related hypotheses. For instance, participants indicated they might not repay their loan to the saving box because of their obligations to other informal lenders. An experiment could allow participants to choose between informal savings and borrowing from different lenders (See Bauchet and Larsen 2018, and Baland et al. 2019 for example of lab-in-the-field microfinance experiments related to ROSCA). In light to the discussion around flood shocks, participants indicated "we sell our chickens for the price of an egg, outsiders come to buy our animals very cheaply before they die". Based on this information, an experiment could reflect a devaluation of all assets and the choices individuals make about selling or keeping existing assets.

4.6 Conclusions

This exploratory study – involving actual members of savings groups who have been working together for more than 10 years – shows that cooperation and defection make sense in different ways under different shock scenarios. Under individual shocks, participants agree that it makes sense to at least pay part of the debt, to gain support as a reward for their effort. On the other hand, participants find that in other types of crisis other forms of cooperation need to be prioritized (e.g. directly helping each other physically and financially) more than loyalty toward the saving box. The meaning of these experiences is, we think, significant in this specific context of a group of people who have shared experiences of real-life shocks and membership of saving boxes for over 10 years.

By emphasizing the quantitative and qualitative results in the flood scenario, we observed an inherent link between 'alternative' forms of cooperation and resilience. Although a saving box is by itself, a strategy to build livelihood resilience among smallholders, its prevalence in face of a shock does not seem to be an indicator of resilience in other fields. As players reported, coping with a flood is the priority and sharing individual efforts by providing one's own tangible and intangible resources to do so becomes more important than repaying a debt. Thus, financial cooperation to build livelihood resilience takes second place to build community resilience against a flood.

Since this is an exploratory study, we consider that further research is needed to better understand the form in which different forms of cooperation and self-organization are linked to resilience under shock scenarios and draw some theoretical and methodological reflections from this research.

Community resilience is a joint resource achieved through self-organization and cooperation. Its users contribute to the common purpose of coping collectively with a disturbance by using their individual tangible and intangible resources synergistically. The availability of those resources might be at the cost of the unavailability of others. Therefore, defection toward the production of a joint-good might not necessarily be non-cooperative behaviour, but a strategy to target those resources to individually and collectively cope with collective shocks.

The use of experimental games can contribute to creating temporary shared experiences of social dilemmas, and subsequently to self-exposure and discussions during a focus group session. The results of their qualitative implementation can offer information to design participatory informed experiments.

4.7 Acknowledgements

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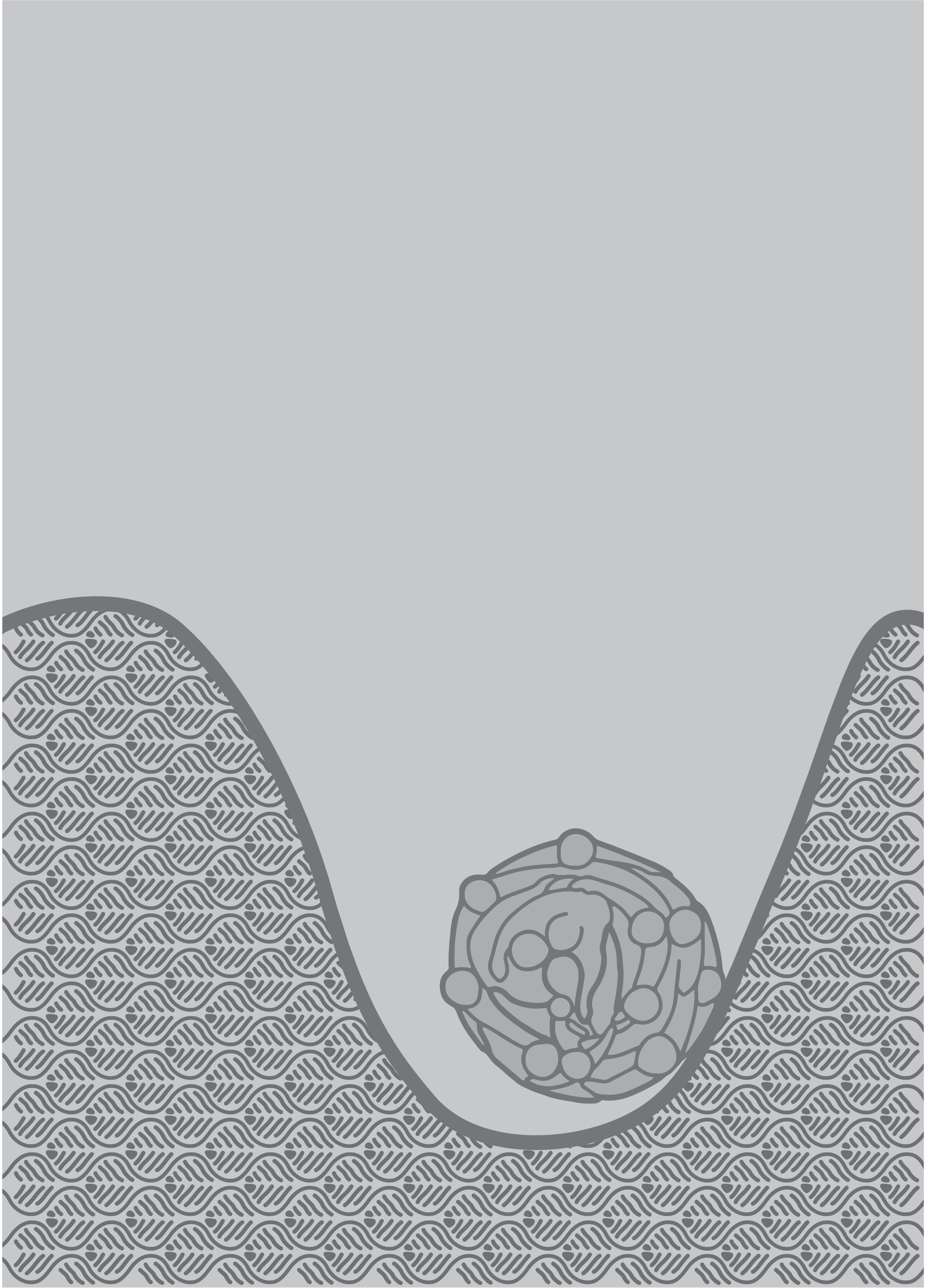

Chapter 5
Adding Emergence and Spatiality to a Public Bad Game within the Context of a Socio-Ecological System: Collective action to fight an infectious disease outbreak

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Abstract

Human decision-making plays a critical and challenging role in addressing problems within socio-ecological systems (SES), such as the prevention and control of a public bad. Infectious diseases, in humans, animals, or plants, are examples of challenging public bads. Farmers are daily confronted with dilemmas regarding public bad management since their decisions and actions may or may not create favourable conditions for pathogens to manifest in their hosts. Those actions are both the cause and effect of interactions between multiple factors and may create the risk conditions in which a public bad can occur in a system. This research aims to contribute understanding about the effect of human actions on the complex interactions that create or avert a public bad, and the influence of different forms of risk communication on those actions. Using a complex adaptive system approach we designed an experimental board game, the Musa game, with features from economic experiments, agent-based models, and role games, to study farmers' individual and collective actions under three treatment conditions. The Musa game differs from other game and experimental methods in that it adds attributes of SES and its emergent phenomena as well as spatiality. By adding these attributes the method allows us to show how the individual and collective actions of various entities lead to the emergence of typical system outcomes (conditions that are (un)favourable to pathogens) and individual decisions about infectious decision management. To conceptualize our method, we used the case of Banana *Xanthomonas* Wilt disease in Rwanda. The Musa game gives insights into how farmers' individual and collective decision-making interplays with other factors and the characteristics of the SES and creates the conditions that hinder or enhance the spread of Banana *Xanthomonas* Wilt. To calibrate the method and develop suitable data analytics approach we additionally tested it in four villages in eastern Rwanda. Analysis of the qualitative and quantitative test data preliminary showed that individual farmers' actions are influenced by perceptions of risk and, in turn, affect both individual and collective performance in managing the disease. Additionally, it appears that a combination of possession of technical knowledge about the disease and opportunities to communicate about the disease and a collective disease management strategy leads to the best individual actions as well as collective performance.

Keywords: socio-ecological systems, livelihood resilience, emergence, public bad, infectious diseases, games.

5.1 Introduction

A collective action problem occurs when the uncoordinated actions of individuals result in sub-optimal and less beneficial outcomes than coordinated actions would. In rational choice-based approaches, this problem occurs when self-interest driven individuals fail to choose beneficial coordinated actions (Olson, 1965). Individuals' decision making toward a good or resource that benefits everyone is influenced by social dilemmas. These are situations in which every person is better off if everyone cooperates, yet this cooperation fails due to conflicting individual interests (Dawes, Kragt, & Orbell, 1988). In other words, it is a situation in which individual rationality leads to collective irrationality (Kollock, 1998).

Public goods (PG), such as public infrastructure or the environment, are non-excludable and non-rivalrous. Common goods (CG), such as a community forest or the groundwater, are non-excludable and rivalrous. The difference is that, while the use of a public good by one individual does not affect the availability for another, the use of a common good does. The production or maintenance of a public good, or the use of a common good, is related to the prevention of a public bad (Sonnemans, Schram, & Offerman, 1998). In 1832, Lloyd sketched out a, now famous, example: a common land with pasture where anyone may let their cattle graze (Lloyd, 1980). Each herdsman adds one more animal at a time to increase their profit. After some time, the land becomes overgrazed, and all the cattle die. Hardin (1968) called this *the tragedy of the commons*. Although all herdsmen would prefer to have more and not less grass to feed their cattle, nobody achieves this because of self-interest driven choices.

Following the same logic, a problem related to the prevention of a public bad is the production of a public good or sustaining a common good. As illustrated in Lloyd's example, public bads reduce benefits and have the potential to impact a significant number of people negatively because they are non-excludable and non-rivalrous (Hall & Harper, 2019). To further illustrate this, we can use an adaptation of Lloyd's example: the cattle of a group of herdsmen graze on a common grassland. An infectious disease that is transmitted through ticks is reported in a few cattle. To reduce the risk of further disease spread, all herdsmen must treat their cattle with acaricides. However, since only a few herdsmen do this in a timely manner all the cattle become infected resulting in high morality (Mutavi, et al 2018). Thus, although all individuals would prefer to have fewer ticks and not more, they collectively fail to achieve this because of the uncoordinated individual actions.

In both Lloyd's example and our adapted version of it, livestock is the main agricultural resource sustaining a herdsman's livelihood. In the first example, this resource is threatened by the hazard of overgrazing, in the second the spread of a tick-borne disease forms the hazard. While overgrazing relates to the overuse of a common good, the spread of the tick-borne disease relates to the management of a public bad. In a real-world context, herdsmen's decision-making is multifactorial and more than the sum of its parts. This property is called emergence (Bonabeau, 2002; Marinescu, 2013). The emergent phenomena create new conditions to which actors and biophysical entities may have to adapt in a continuously evolving process. Emergence is a particular characteristic of complex adaptive systems such as socio-ecological systems (SES) (Schlüter et al., 2019).

Understanding the factors at play in human cooperation is crucial for solving collective action problems to either produce or use a public or common good or to prevent and control a public bad. Our research aims to contribute theoretical and methodological aspects to study the role of human actions to prevent a public bad in the context of social-ecological systems. In this paper, we focus on how farmers' decision-making interplays with other SES factors and creates the conditions that hinder or enhance the spread of Banana *Xanthomonas* Wilt (BXW) disease in Rwanda. To do so, we first develop a theoretical framework to study a public bad problem in SES based on the complex adaptive system approach (Ostrom, 2007; Ostrom, Gardner & Walker, 1994). We adapt the original approach by integrating conceptual thinking about livelihoods, economics and risks; to then add the operational aspects of socio-ecological systems in terms of emergent phenomena and spatiality (section 5.2). Section 5.3 explores how economic games and agent-based models can contribute to the study of collective action problems in SES, and their potential application for studying dynamic public bad problems. Section 5.4 describes the case study of Banana *Xanthomonas* Wilt (BXW) in Rwanda which we used to test our methodological design. This method is then presented as an experimental board game to study individual and collective actions aimed at preventing and controlling a public bad and the interactions with SES-factors (section 5.5). Section 5.6 explores what findings from field testing the game in Rwanda can tell us about individual and collective action in BXW management, and the effects of communication on farmer's actions. Lastly, section 5.7 reflects on the findings and the strengths and limitations of our game method. Spatial analytical methods are applied to interrelate decision-making and emergence. This paper is the first of a series, focusing on the methodological design and test in the field. A paper regarding how to apply the lessons from this research in practice is forthcoming.

5.2 Theoretical framework

Agriculture sustains the livelihoods of 2.5 billion people globally (Coff et al., 2015), most of them smallholder farmers, herders, fishermen, or forest-dependent communities, who generate more than 50% of global agricultural production (Samberg, et al 2016). Agricultural livelihoods can be considered as socio-ecological systems (SES) (Rivera-Ferre, Ortega-Cerdà, & Baumgärtner, 2013) which consist of societal and ecological subsystems that interact with one another, are complex, dynamic, and continuously evolving (Gunderson & Holling, 2001). A SES is said to be resilient if it can absorb disturbances and respond to change through reorganization thereby maintaining its functions, structures, and evaluations, without deviation from its original pathway (Holling, 2001).

We build upon the SES framework originally introduced by Elinor Ostrom (2007) (see also Ostrom & Cox, 2010). Its most elaborate version emphasises both direct and feedback interactions, and also integrates the role of emergent phenomena in the system. In this study, we integrate emergence in our theoretical framework, and also design a methodology based on games to operationalize it. Ostrom (2007) proposed a multilevel and nested framework to analyse the sustainability of SESs. The main subsystems in this framework are resource systems (RS), resource units (RU), governance systems (GS), and users (U). In her example, the RS is a protected park in a specified territory containing forested areas, wildlife, and water systems. The RU are the trees, wildlife and water systems present in the park. The GS are the institutions managing the park, the specific rules related to the park's use, and how those rules are made. U is the individuals using the park for their livelihoods, recreation, and other purposes. We adapted Ostrom's (2007) original framework for application to a public bad risk management situation in which the assets and units form a livelihood system, which users rely on to generate ecosystem services and make a living, is threatened (Figure 5.1).

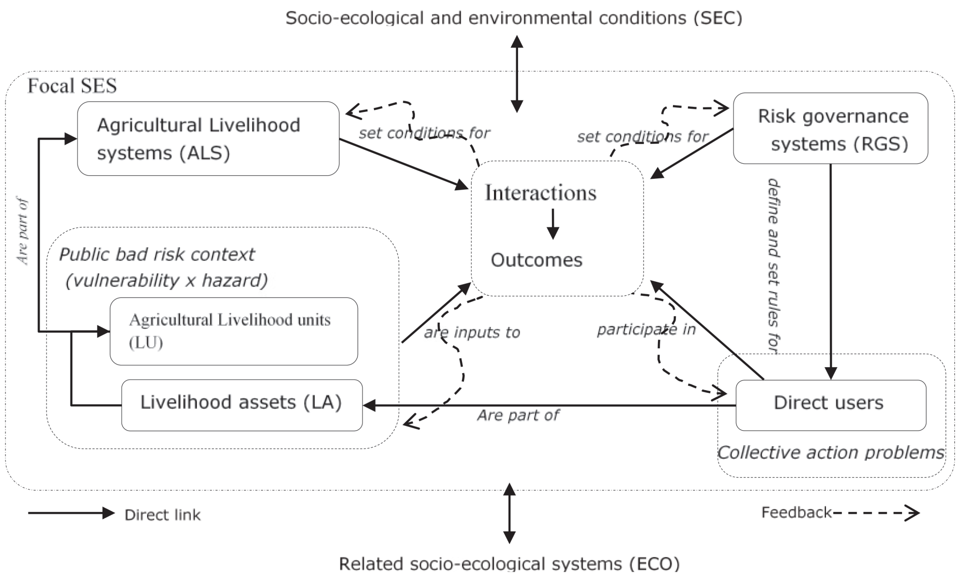


Figure 5.1 The core subsystems within a socio-ecological system that provide the framework for analysing a public bad risk that threatens livelihood resilience, from a risk and collective action problem perspective. Adapted from Ostrom (2007).

Chapter 5

Table 5.1 describes the framework for analysing a public bad risk threatening livelihood resilience shown in Figure 5.1. The descriptions and examples are adapted from Ostrom (2007).

Table 5.1 Description of the components of the framework for analysing a public bad risk threatening livelihood resilience

Components	Description and example
Agricultural livelihood system (ALS)	This is represented by a specific territory where diverse agricultural livelihood activities take place, involving crops, animal husbandry, and related activities and assets that provide ecosystem services to farmers and consumers.
Livelihood unit (LU)	This is a specific agricultural activity providing ecosystems services needed to make a living, e.g. cattle for milk and meat, rice production for human consumption, maize production for human or animal feed.
Livelihood assets	Human: peoples' health and ability to work, knowledge, skills, experience; Natural: land, water, the forest, livestock; Social: trust, mutual support, reciprocity, ties of social obligations; Physical: tools and equipment, infrastructure, market facilities, water supply, health facilities; Financial: conversion of production into cash, formal or informal credit.
Public bad risk context (PBRC)	Conditions of vulnerability and characteristics of the hazard that hinder or limit the probability of a public bad
Vulnerability	The vulnerability (of any system) is a function of three elements: exposure to a hazard, sensitivity to that hazard, and the capacity of the system to cope, adapt, or recover from the effect of those conditions (Turner et al., 2003).
Hazard	A physical event, phenomenon, or human activity that has the potential to cause the loss of life or injuries, property damage, social and economic disruption, or environmental degradation. Its potential can be characterized by its probability (frequency) and intensity (magnitude or severity) (Blaikie, et al, 1996).
Risk perception	Risk perceptions are formed by common-sense reasoning, personal experiences, social communication, and cultural traditions. These are the contextual aspects that individuals consider when deciding whether or not to take a risk, and selecting reduction or preventive measures (Van Asselt & Renn, 2011; Wachinger, et al, 2013).
Risk governance system (RGS)	Rules (operational, collective-choice rules, constitutionals), property right regimes (private, public, common, mixed), network structure (centralized, non-centralized) (Van Asselt & Renn, 2011).
Direct users	Farmers and households that depend on the livelihood unit.
Collective action problems	Coordination of responses to problems among direct users triggered by social dilemmas, risk perception, or coping capacities.
Action Interactions (I) and outcomes (O)	Action situations are where all the action takes place as inputs are transformed by the actions of multiple actors into outcomes (McGinnis & Ostrom, 2014)
Social, economic, ecological, environmental, and political conditions (SEC)	Economic development, demographic trends, political stability, government (settlement) policies, market incentives, media organizations, the biophysical environment and climatic conditions.

Components	Description and example
Related socio-ecological systems (ECO)	Other livelihood systems interlinked to the one in question.
Dashed arrows	These denote feedback from action situations (McGinnis & Ostrom, 2014)
Dotted-and-dashed lines	These surround the focal SES and are influenced by exogenous factors, which might emerge from dynamic processes at larger or smaller scales, either inside or outside the focal SES (McGinnis & Ostrom, 2014)

In our framework, there is an agricultural livelihood system (ALS) where an agricultural activity (x) is the livelihood unit (LU). The direct user(s) (DU) rely on the LU to make a living in a specific territory. To produce and sustain this LU different livelihood assets (LA) are required (human, social, natural, physical, financial). Both the LA and the LU are vulnerable to different types of hazards. The covariate manifestation of the hazard (public-bad risk) in the LU is strongly influenced by the DUs' collective actions to prevent and control the hazard. Those collective actions are constrained or enhanced by multiple factors (risk perspective, social dilemmas, capacity to adapt and respond). The DUs' actions continuously interact with the risk governance system, influencing and being influenced by the set of formal and informal rules and strategies to manage a public-bad risk. If collective action between DUs fails, the likelihood of the risk of a public-bad increase, which then impacts upon the system's interactions and outcomes, possibly leading to the emergence of a public-bad risk that harms various essential LAs and LUs. The damage to the LAs and LUs in turn negatively impacts upon the provision of ecosystem services to the DU and, possibly, other SESs.

Humans intervene in natural systems that provide ecosystem services (i.e. crop or livestock production) to people (consumers) and a livelihood to those providing those services (farmers) (Cabel & Oelofse, 2012). A livelihood includes the capabilities, assets, and activities required for a means of living. It is resilient when people have the capacity, across generations, to sustain and improve their livelihood opportunities and wellbeing despite environmental, economic, social, and political disturbances (Tanner et al., 2015). The performance of agricultural livelihoods largely depends on the accessibility of assets (or capitals): natural, physical, human, financial, and social (Niehof & Price, 2001). Assets are vulnerable to different kinds of hazards, such as natural, environmental or biological hazards. Infectious diseases are among the most challenging biological hazards and can affect humans, animals, and crops. Those same people, animals or crops are also critical assets for agricultural livelihoods. Hence, livelihood resilience to biological hazards, and specifically infectious diseases, is critical for the food security of smallholder farmers and global society as a whole (FAO, 2017).

We further contextualize our framework for the context of infectious disease. There are numerous examples where our framework can support analysis of resilience to a public-bad risk as a result of an infectious disease (Table 5.2).

Table 5.2 components from a SES framework to analyse resilience to a public-bad risk

Host-Livelihood units	Public bad risk conditions (vulnerability and hazards)			Livelihood units Fatality/ Lossesin cases of children age <5 years	Users risk management strategies that require coordination and cooperation
	Disease	Infectious agent	Infection mechanism		
A person (labour, knowledge, etc.)	Malaria	Plasmodium parasite	Transmitted by the bite of the anopheles mosquito	Over 60 deaths per 1000 admitted in cases of children age <5 years	Draining of standing water where mosquitos breed, spraying living and sleeping quarters, and the use of bed nets (Murindahabi et al., 2018)
A person (labour, knowledge, etc.)	Coronavirus	COVID-19 virus	Person to person transmission via respiratory droplets generated by breathing, coughing, sneezing or, hand-mediated transfer from contaminated surfaces to mouth, nose or eyes (ECDC, 2020)	2% case fatality due to alveolar (Xu et al., 2020) damage or respiratory failure	Social distancing, wearing face-masks in public spaces, rigorous disinfection, reporting confirmed cases, pro-active contact-tracing and testing of potentially infected individuals
A cow (meat, milk as food or income)	Tick-borne diseases (Babesiosis, ECF, others).	Different parasites and bacteria	Different kind of ticks spread the diseases	Mortality rate of up to 80% in animals susceptible to ECF	Tick control measures (vaccination, applying acaricides, grass sward height reduction), resistant breeds (Mutavi et al., 2018)
A cow (meat, milk as food or income)	Banana Xanthomonas Wilt (BXW)	Bacteria Xanthomonas campestris pv. Musacearum	Infected plant material, cutting tools, long-distance trade, soil, and vectors such as birds, bats, and insects	Yield losses up to 100% if control is delayed	Cultural management practices (male bud removal, tool sterilization), Complete mat uprooting (CMU), removal of single diseased stems (McCampbell et al., 2018)

The spread of an infectious disease is a public bad because it is (mostly) non-excludible and non-rival. In effect, infectious diseases can affect large numbers of humans (epidemic), animals (epizootic), and plants (empathetic) and can have disastrous socio-economic and ecological consequences. According to the disease triangle model (Scholthof, 2007), the risk of disease damage to a host is a function of the interactions between the environment, host, and pathogen. These interactions are often determined by human behaviour and responses to environmental changes. Human activities enable pathogens to disseminate and evolve, creating favourable conditions for diverse manifestations of infectious diseases (Mayer & Piezer, 2008, p. 3-14). Generally, collective action is required to prevent and control the spread of diseases that threaten (agricultural) livelihoods and to achieve resilience.

Collective action problems are coordination problems challenged by multiple factors, including resilience, socio-economic, and risk (Meinzen-Dick, DiGregorio, & McCarthy, 2004). Resilience stresses the importance of individuals' capacity to adapt and respond as determinants of self-organization (Berkes & Ross, 2013). The economic perspective highlights self-interest-based choices as determinants of collective irrationality, influenced by different forms of social capital, such as trust, identity and reciprocity (Ostrom, 1998). Lastly, risk perceptions are determinants of people's behaviour toward threats (Wachinger et al., 2013). These three factors play a critical role in risk governance. We define governance here as the actions, processes, traditions, and institutions, encompassing state and non-state actors, to bind decisions collectively, without superior authority. Risk governance, then, applies the principles of good governance to the identification, assessment, management and communication of risks. Risk governance, involving various stakeholders, analyses and leads to the formulation of risk management strategies, which need to consider the broader legal, political, economic, and social contexts in which a risk can be managed (Van Asselt & Renn, 2011).

5.3 Methodological background and proposal

Economic experiments have for decades been the most common method to test theories about social dilemmas with specific variables repeated in controlled settings. Laboratory and field experiments have been particularly useful in studying common and public goods in the context of resource and environmental issues. Experimental designs are mostly driven by behavioural and institutional concerns (Kurzban & Houser, 2005). Both laboratory and field experiments involve humans as experimental subjects, in the latter case the participants are familiar with the problem being studied. Ostrom made ground-breaking contributions to collective-action research, using laboratory experiments and case studies to study the role of communication, sanctioning, and institutional rules, among other variables, for achieving collective action (Ostrom, 2006). Inspired by her work, many other researchers have carried out laboratory and field experiments in public goods (PG) and common goods (CG), with most of them keeping the production function externalities and resource dynamics simple (Ostrom, 2003). Because of those experiments we today know that individuals may contribute to the production of a PG or limit their use of a CG, due to reciprocity, trust, identity, or general pro-social behaviour (Rand & Nowak, 2013).

Growing awareness about the human influence on biophysical systems led to the focus of collective action research shifting to socio-ecological systems (SES) perspectives, resulting in new field experimental designs to study collective action problems. For example, Cardenas et al. (2013) designed three field experiments which were framed in fishery, forestry, and irrigation systems. The major design innovation of those experiments was the introduction of the ecological complexities of social dilemmas in environmental and natural resource problems into the behavioural analysis.

Although economic laboratory and field experiments still advance in their understanding of collective action problems, the interpretation of their results remains problematic. This is because individual motives are a function of social norms and other socio-ecological factors (Hagen and Hammerstein, 2006; Ostrom, 1998 and 2007; Ostrom and Ahn, 2007), putting emergence, a particular characteristic of complex adaptive systems such as an SES as a determinant of the socio-ecological outcomes the property of emergence (Schlüter et al., 2019).

An alternative method to understand human behaviour in complex systems is agent-based modelling (ABM), which has gained popularity in recent decades because of its ability to capture emergent phenomena (Bonabeau, 2002). ABM simulates simplified abstract versions of SES, representing the decision-making of autonomous computational individuals or groups of agents and their interactions with each other and with ecosystems. ABM has been used to study phenomena as diverse as traffic, markets, organizations, the diffusion of innovations, adoption dynamics, policy scenarios, and resource management. It is applied to study the interactions between heterogeneous agents that can generate network effects, in which individual behaviour becomes non-linear, path-dependent, and based on memory, learning, and adaptation (Balbi & Giupponi, 2009; Duffy, 2006). The behaviour of each agent is based on a situational assessment, yet restricted by a specific ruleset. Despite the wide use of ABM in different fields, its application in the social, political, and economic sciences is not without barriers. This is caused by human nature which comes with potentially irrational behaviour, subjective choice-making, and complex psychology, and can make the effects of the emergent processes difficult to predict or even counterintuitive (Smith & Conrey, 2007). The main implication of this is that a given social process cannot truly be understood when studied in isolation, out of its context, or frozen in time (Castillo, et al, 2011).

The power of economic experiments and ABM lies in their capacity to simplify the complex and transform it to manageable dimensions. Both, despite their individual strengths, limitations, and degrees of complexity, attempt to anticipate agents' behaviour under different conditions. We believe that the limitation of economic experiments and ABM can be overcome by adding a qualitative component. This can increase our understanding of context-specific motivations and provides the next methodological design step for studying problems around collective action. Clancey (2008, p.28) notes, "We cannot locate meaning on the text, life in the cell, the person in the body, knowledge in the brain, a memory in a neuron. Rather, these are all active, dynamic processes, existing only in interactive behaviours of cultural, social, biological, and physical environments".

To the best of our knowledge (i) neither laboratory nor field experiments have integrated emergent phenomena into their design to study collective action problems, (ii) ABM faces challenges in integrating the complexity of human behaviour into its models, and (iii) there are very few examples where economic experiments and ABM have been applied to study collective action problems to prevent and control public bads (Kurzban & Houser, 2005; Sabzian et al., 2019). We respond to this by proposing a methodology that is a field board experiment (or board game) which adds the attributes of an SES and its emergent phenomena. The experimental design focuses on studying human cooperation under different stimuli in the prevention and control of a public bad in the context of agricultural livelihoods.

5.3.1 The dynamic socio-ecological (DySE) game design method

The SES framework to analyse resilience to a public-bad risk, integrates a host (the livelihood unit), the public-bad risk conditions (the disease, agent, and infection mechanisms), the threat (livelihood unit losses or fatality), and the strategies (based on coordination and cooperation) to prevent and control a public bad (disease spread) into the analysis. For this research, we developed a methodology to operationalize the theoretical framework. It consists of a public-good game design method that integrates emergence and spatiality: *a dynamic socio-ecologic game design method*. The game design method is multidimensional because it considers what I do, what others do, and what 'it' does (e.g. the vector) in space, time, and under certain conditions. The DySE game's purpose is to explore human behaviour and how this intertwines with socio-ecological factors surrounding behavioural decision-making.

The game mechanics include a board representing the geographical space, playing cards representing the livelihood units (humans, banana mats, cows), autonomous players (such as the disease vector or institutional actors who follow some 'real-life' rules), and the decision-makers (human players). We can understand the mechanical part of the game as the *hardware* where we can experiment. This allows us to test the players' behaviour (when facing a social dilemma) under different experimental treatments or scenarios (communication, incentives, punishment, etc.), over the game structure that creates emergent conditions with specific factors. The game is followed by a focus group session to explore the reasoning behind the players' actions, and the results of this are triangulated with quantitative game results. The social dilemmas (i.e. those faced by decision-makers / players), as well as the rules that govern the autonomous-players, are a simplified version of the social, ecological, politico-institutional, and environmental rules governing real-life situations. The social dilemmas and scenarios of stimulus constitute the experimental dimension of the game and can be varied according to the research interest.

Table 5.3 examples of the application of a dynamic socio-ecologic game

Public-bad risk	What I do	What the others do	What it does	Collective impact
Malaria	I drain the standing water where mosquitos can breed	My neighbours do not drain the standing water where mosquitos can breed	Mosquitos breed in standing water close to where I live and become plasmodium vectors	Avoidable sickness or deaths; further impoverishment of poor households, and communities (Ricci, 2012).
COVID-19	I stay at home with flu-like symptoms or get tested for COVID-19	My neighbour goes out to the supermarket with flu-like symptoms and is later tested COVID-19 positive	The virus spreads via droplets of infected saliva when my neighbour coughs in the supermarket	Avoidable deaths; the potential collapse of the healthcare system, need for collective measures and law enforcement (Anderson, et al, 2020)
Banana Xanthomonas Wilt (BXW)	I remove banana flowers and disinfect my machete before working in my neighbours' banana plantation	My neighbour has BXW infected banana mats in his plantation. He does not remove banana flowers nor disinfect his machete before working in my plantation	The BXW bacterium spreads to my banana plantation through my neighbour's machete and infects my bananas	Decrease of local food security; further impoverishment of poor households; loss of livelihoods (Tripathi & Tripathi, 2009)
Gender violence and femicide	I maintain a relationship with my partner in which neither of us assaults the other and we stay away from substance abuse. However, I frequently hear my neighbour is assaulted. I do not report this to authorities.	My neighbour has a drinking problem and violently assaults his wife when he is drunk. People in the community know this but shut their eyes to it, and do not report to authorities.	In a drunken outrage, the man assassinates his wife with a pistol	Gender violence becomes a public health problem (UNODOC, 2018); abused women suffer from mental and physical issues; large numbers of women are killed annually, often by a (former) partner.

The same game methodology can be calibrated and tailored to different contexts. Table 5.3 shows that, in all contexts, the individuals face a social dilemma to take a determinate action. The social-dilemma might relate to an effort or money investment, as could be the case of Malaria and BXW disease, or could also be related to other more intangible aspects, such as the perception of risk or societal norms, as in the case of COVID-19 or gender violence (Bavel et al., 2020; Powell, et al, 2008). In all the examples, the sum of individual defective choices might have a negative (direct or indirect) collective impact that goes beyond the personal temporary benefit. As the purpose of simplification is to explore behaviour under specific but dynamic circumstances, there are many other influential factors in the prevention and control of the same public-bad risk that might not be taken into account. In the next sections, we contextualize the methodology – as the *Musa game* – to the case of banana smallholders in Rwanda, whose production is threatened by BXW disease.

5.3.2 Case study: Operationalization of theoretical framework to the case of BXB in Rwanda

For the development of our method, we chose a case study that represents a typical collective action problem: the transmission of the banana disease *Xanthomonas* Wilt of Banana (BXW) disease by insect vectors and its management by farmers in Rwanda. In this section, we first provide a brief description of the BXW disease problem and the existing practices to prevent and control it. We then operationalize the SES framework (Figure 5.1) for this example (Figure 5.2).

Banana is one of the most important crops in sustaining household food security and livelihoods in Rwanda. However, BXW, caused by the bacterium *Xanthomonas campestris pv. Musacearum*, endangers the livelihoods of millions of farmers in East and Central Africa (Jackson et al., 2015; Tripathi & Tripathi, 2009) and can result in yield losses up to 100%. BXW is highly transmissible and can spread rapidly through infected plant material, cutting tools, long-distance trade, and vectors such as birds, bats, and insects (Tinzaara et al., 2016). The latter become vectors of BXW when visiting a male banana flower of a diseased banana stem in search of food, after which the bacterium is transmitted to the next visited, still healthy, stem with flower. Vector mediated transmission of BXW is especially prevalent in lowland areas with high insect density (Jones, 2018), yet can be prevented if farmers comply with the cultural practice of cutting the male flower with a forked stick as soon as the last hand has developed (de-budding practice) (Tinzaara et al., 2016).

No cure exists for BXW, once the pathogen has established in a stem it will inevitably die. Complete eradication of BXW is considered impossible, however, the disease can be managed with good preventative agricultural practices and early response to disease outbreaks. Disease symptoms appear soon after infection, causing yellowing and wilting of leaves, premature ripening of fruits, brown stains in the fruit pulp, and rotting of the male flower, and eventually wilting and rotting of the entire stem. Infected plots should not be replanted with banana for up to 6 to 8 months due to soil-borne inoculum of the pathogen (Blomme et al., 2019).

Provision of advice on disease prevention and control, as well as monitoring of and responding to outbreaks, is the responsibility of the government agency Rwanda Agriculture and Animal Resources Board (RAB) on behalf of the Ministry of Agriculture and Animal Resources (MINAGRI). For this they work through the different layers of the country's extension system, reaching down to the level of villages where 'farmer promoters' act as elected village extension agents.

Rwanda's current policy for BXW disease outbreaks prescribes a practice called Complete Mat Uprooting (CMU). This involves uprooting the diseased stem and all lateral stems and shoots (i.e. the entire banana mat) regardless of their infection status. All uprooted material should be buried and covered with soil. Uprooting is advised to take place in an early disease stage to reduce chances of further disease transmission. In high incidence cases (>70% of the banana mats showing symptoms), the whole plantation must be uprooted (Hakizamungu and Rukundo, 2013). Although effective, CMU is also labour intensive, time-consuming, and socially costly and has therefore major implication for food and income production. It has an impact on livelihoods making farmers reluctant to comply with good BXW management practices, which is further exaggerated by perceptions of the (in)effectiveness of disease management. Some farmers hide the disease, by cutting down symptomatic stems or leaves, to avoid enforced uprooting (McCampbell *et al.*, 2018; Uwamahoro, *et al*, 2019). An alternative for CMU exists in the practice of Single Diseased Stem Removal (SDSR). In this case, only symptomatic infected stems, rather than entire mats, are cut, at soil level. This method is a low cost, simple, and less labour intensive. SDSR has been shown to be effective for bringing disease incidence to a minimum level, and especially suitable for smallholder farmers (Blomme *et al.*, 2017).

Regardless of the disease control practice, effective management always requires at least a combination of specific knowledge and know-how (e.g. to understand disease epidemiology, recognize disease symptoms and to uproot diseased stems), timely use of cultural prevention and control practices and, preferably, collective action. A study in DR Congo showed the latter to be more effective for BXW control than individual action (Blomme *et al.*, 2019). Additionally, the government needs to provide effective support mechanisms, e.g. advisory services, monitoring (Uwamahoro *et al.*, 2019). Prevention of the spread of the disease can only be achieved (efficiently) if all the involved stakeholders work in a coordinated manner.

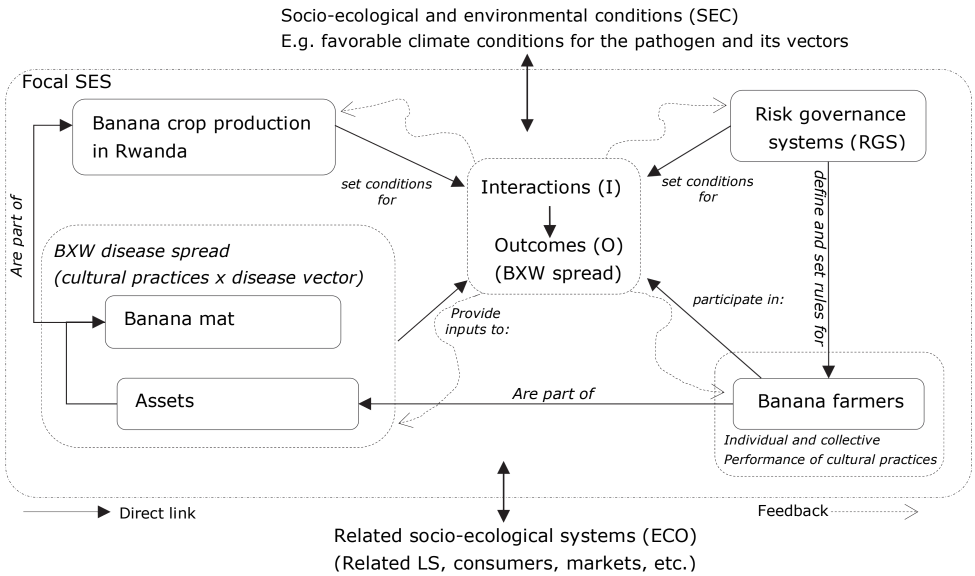


Figure 5.2: The core subsystems in a framework for analysing a public bad risk (BXW disease spread) threatening agricultural livelihoods based on banana production in a socio-ecological system's context from a risk and collective action problem perspective. Adapted from Ostrom (2009).

5.4 The Musa Game: a dynamic socio-ecologic method

In this section, we describe step-by-step the design of the experimental board game to evaluate farmers' performance faced with a hypothetical crop disease outbreak in different risk governance scenarios. We named this game the Musa game. The Musa game is an experimental as well as a participatory evaluation tool, representing principles from an economic field experiment, an agent-based model, and a role game within a dynamic socio-ecological context. The main properties of the game's mechanics and arena are: (1) represent a simplified and abstract depiction of the social-ecological forces that affect farmers' risk perception (and dilemmas) and decision-making about disease management and control; (2) allow for the performance of different risk governance scenarios through specific operationalization of experimental variables for different treatments; (3) make it possible to trace the development of strategic game behaviour through the use of audio-visual data collection methods; (4) simple calculation of individual and collective outcomes (benefits and losses) immediately after the game ends; (5) achievement of common experience through facilitating post-game discussions, and; (6) collection and analysis of qualitative and quantitative data using mixed methods.

Operationalization of the Musa game requires the involvement of real actors faced with the social dilemma to adopt (or not) strategies to prevent or control a public bad threatening their livelihood. Individual farmers' decisions are influenced by the interplay between different farmers, other autonomous agents in the system, and environmental changes. This interplay is simultaneous as each agent plays with its own individual ruleset. The game rules are a simplified version of real-world SES characteristics. To make simultaneous agent actions and system outcomes possible the experimental arena is a square-board that represents the biophysical space where actions and interactions take place. Qualitative tools, such as focus groups or in-depth interviews, are used post-experiment to better understand context-specific motivations behind peoples' decision making.

The Musa game gives an abstract representation of the socio-ecological dynamics between a group of 4 farmers, their banana mats, the bacterial disease agent (BXW), the insect vectors transmitting the disease, and an external agent who monitors the spread of the disease. The game rules are based on the real-life context of banana production in Rwanda. As real-life banana farmers, the players are confronted with a realistic representation of the problems of collective (in)action they face when preventing disease transmission. As in real-life, complete eradication of the disease is impossible. However, minimizing the disease's impact is possible through rigorous and coordinated action. In contrast, uncoordinated action, due to behaviour driven by self-interest, lack of capacity to respond, or poor risk perception, may devastatingly impact livelihoods. Players' profits directly relate to their game performance. The final individual and collective results depend on decisions made by individual players in combination with the influence of events in the game's socio-ecological system. In this section, we present stepwise the theory behind the experimental game design, its implementation and the data analysis strategies.

The board game's mechanics, physical structure, and experimental treatments were designed based on our specific scientific interests. They could easily be adapted for other purposes or contexts and used to study other SES problems.

5.4.1 Operationalizing risk governance models in the game

In the Musa game, farmers encounter a system that is top-down governed. Both the government's and farmers' goal is to minimize the risk of disease spread and preserve the continuity of banana production. Government agents determine which agricultural practices must be employed to prevent and /or respond to a disease outbreak. Players are externally organized through random assignment to a treatment group.

Based on the Newman's (2001) institutional governance models, we have contextualized the dynamics between the government agents and the farmers toward the control of BXW disease, as a rational goal model as this comes closest to the reality in Rwanda today (Harrison, 2016; Van Damme, Ansoms, & Baret, 2014). The rational goal model is oriented toward a centralised distribution of power and arrangements that create conditions for change. The state divides a problem into manageable fragments and sets goals. Power is dispersed across various agencies, and the responsibility to act is at the local level. Focus is on shorter timelines and maximisation of outputs. Performance is tightly monitored, inspected and audited. In terms of goal setting, relationships are vertical, cascading from the government. Relationships are instrumental, pragmatic and there are efficient horizontal connections. It follows a managerial rather than bureaucratic approach (Newman, 2014).

The Musa game aims to test farmers' cooperation when preventing or responding to a public bad risk: BXW disease. While the overall game mimics the rational goal governance model, players, who are actual banana farmers, can also self-govern the public bad risk through various risk governance strategies. For this, we used risk governance principles from Van Asselt & Renn (2011): communication, inclusion, integration, and reflection. According to Van Asselt (2011), these should not be seen as separate steps or stages but rather as principles for every step or stage in a risk governance process. These principles create space for risk governance strategies within a complex, uncertain, and ambiguous risk contexts. As such this approach to risk governance fits with our purpose of studying a public bad risk within dynamic, emergent, and complex socio-economic systems. When testing our game methodology we focused on the communication principle of risk governance which we further describe in section 5.5.5.1.

5.4.2 The physical environment, and mechanics, of the Musa game

The Musa game is performed on a square gameboard. Its sides are divided into six rows and six columns, resulting in a total of 36 cells. The X-axis has alphabetical codes from A to F. The Y-axis has numerical codes from 1 to 6. Individual squares can be identified using the (X, Y) coordinates. The board is divided into 4 quadrants composed of 9 cells each, each cell representing one productive banana mat. Quadrants are identifiable through symbols: square, circle, rhombus and triangle (□, ○, ◊, Δ) (Figure 5.3). The four quadrants together represent one banana production zone (or banana farming community) in Rwanda, with each quadrant representing a banana field managed by one independent farmer.

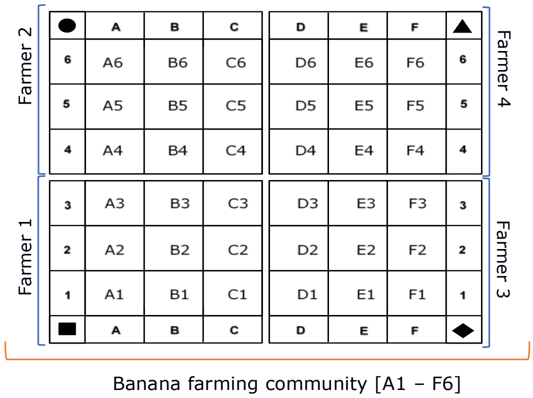
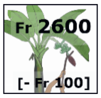
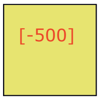


Figure 5.3 Schematic representation of the game board and the different sections of the board as shown to players. Each farmer has 9 cells e.g.: The 9 cells D4 to F6 belong to farmer 4. Each cell contains 1 productive banana mat, e.g.: Cell D4 has 1 productive banana mat. All farmers start the game with 9 productive banana mats.

The game is facilitated by one game master, and played by 4 farmers and 2 autonomous players: an insect, and a monitor (Figure 5.4). As a field experiment, the 4 farmers are people whose real-life livelihood depends on banana production. The movements of the autonomous players are defined randomly by throwing two dices, one with letters and one with numbers (done by the game master), or using statistical software. The combination of the letter and number corresponds with a coordinate on the board, e.g. the combination A and 4 equals the coordinate A4 on the board. The game's socio-ecological conditions are dynamic and defined by the decision-making of farmer players plus the autonomous actions of the insect and monitor.

Upon starting the game, each player has nine stacks of four or five cards (one stack for each cell) representing different health stages of a banana mat depending on players' decisions and locations of autonomous players (see Figure 5.3 and Table 5.4). The different cards have different economic values, ranging from a maximum profit to a maximum loss. The two cards at the top of the stack are healthy banana mats: (1) White (value = 2600, and (2) Green (value = 2500). The next two cards are infected mats: (3) Yellow, and (4) Red. The bottom card is (5) grey card equalling a dead banana mat (value = 0). The backsides of the yellow and red cards are uprooting cards (value = -500). Only cards (1), (2), (3), and (4) can be removed by the player. To eliminate the chance of a player losing all his or her banana mats in one round the cells E2, E5, B2, and B5 (the central position for each player's quadrant) have no white maximum profit card. The composition of cards at the end of the game determines the player's score, i.e. the total profit or loss made.

Table 5.4 Overview of cards in the game

Card	Name	Code	Description
Health stage cards			
	White card	1	Healthy mat with flower
	Green card	2	Healthy mat without flower
	Yellow card	3	A BXW infected banana mat in the first disease stage. An idiosyncratic institutional threat. The card value is Fr. 0
	Red card	4	A BXW infected banana mat in the second disease stage. The card value is Fr. 0. A covariate institutional threat. Cost of uprooting is Fr. 500
	Grey card	5	A dead banana mat that was not uprooted in disease stage one or two. The mat is no longer a threat. The card value is Fr. 0
Uprooting cards			
	Yellow uproot	31	The backside of the yellow uproot card appears when the player decides to uproot a yellow BXW infected mat. The action costs the farmer Fr. 500.
	Red uproot	41	The backside of the red uproot card appears when the player decides to uproot a red BXW infected mat. The action costs the farmer Fr. 500.
Autonomous player cards			
	Insect card	I	Biological threat. The insect is the BXW vector and searches for nectar from a healthy mat with flower. A visited mat becomes BXW infected and turns yellow.
	Monitor card	M	Institutional threat. The monitor represents a government agent monitoring banana mats and intervenes when a yellow or red card is found (code 3 or 4). Codes 1, 31, 41, 5, 6 do not represent an institutional threat, when the monitor inspects them there is no intervention.
Other cards			
	Monitor intervention card	6	Monitor intervention card (uprooting activity in progress). Placed on the stack after a monitor finds a yellow or red card and intervenes.

5.4.3 Farmers: livelihood and risk

For the purpose of the game, we assume that each player relies on banana production to meet the basic weekly income needs to sustain their family's livelihood and be food secure. The behaviour of each player is triggered by the experimental setting and changing socio-ecological conditions. Each banana mat faces two threats: one biological, and one institutional. The biological threat is BXW disease, transmitted by the insect visiting a flower in search of nectar. The institutional threat is the disease control measure of the Rwandan government, existing of random visits by an extension agent whose responsibility it is to contain the disease. The monitor intervenes only when finding a diseased banana mat. Both threats are influenced by the social component, i.e. the farmer's behaviour. This translates into complying with the practice of cutting the banana flower in order to avoid a biological hazard (white card), or of uprooting an infected mat and avoiding an institutional hazard (yellow and red cards).

The goal of the farmer is to safeguard food security and maximize the household's livelihood. The minimum amount of money needed to be food secure is Fr. 15000. Any surplus at the end of the game represents a profit. When the game starts the player has 9 healthy banana mats, 8 with flower (white card) and 1 without a flower (green card) (Figure 5.4), together these represent the maximum amount of money that can be earned:

8 x Fr. 2600 + 1 x Fr. 2500 = Fr. 23300

The maximum profit that can be made by the player is:

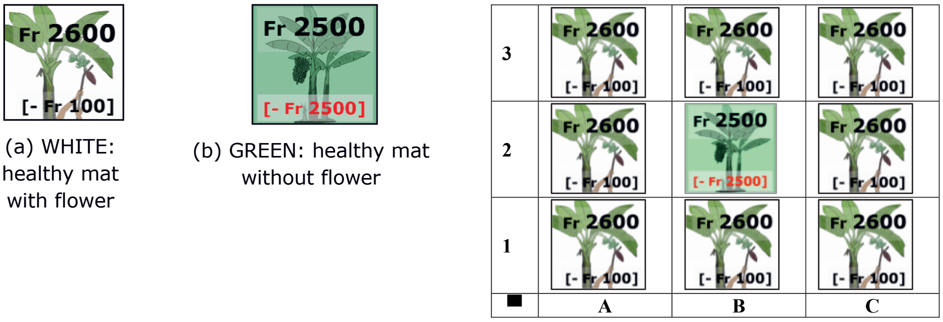
Fr. 23300 – Fr. 15000 = Fr. 8300

Therefore:

$$Net\ income = [(n.cards\ 1\ \times 2600\ Fr.) + (n.cards\ 2\ \times 2500\ Fr.) - (n.cards\ 31\ \times 500) - (n.cards\ 41\ \times 500)]$$

$$Individual\ net\ profit\ = Net\ income - individual\ food\ security\ threshold$$

Each banana mat with a flower is at risk of BXW infection. As a preventative measure against BXW, the player can decide to cut the flower. The investment cost of cutting the flower is Fr. 100, which is represents the real-life mobility and labour effort of the farmer. After cutting, the top card becomes green (value = Fr. 2500 and the mat is protected from the biological hazard.



(a) WHITE: healthy mat with flower

(b) GREEN: healthy mat without flower

(c) initial conditions of the game per farmer

Figure 5.4 Initial conditions for each player/ farmer. (a) A healthy banana mat with a mother plant in the flowering stage is represented by a white card. The card's value is Fr. 2600. If the farmer decides to cut the flower it costs Fr. 100 (b) A healthy banana mat with a mother plant without flower is represented by a green card. The card value is Fr. 2500. (c) all players start the game with 8 white cards and 1 green card. The total value of the 9 cards is Fr. 23,300.

5.4.4 The insect vector and disease progress

The insect player card represents the autonomous insect vector that caries the BXW bacterium which causes BXW in bananas. The purpose of the insect is to find nectar in banana flowers. While doing so the insect can transmit the disease from mat to mat. For the purpose of the game, the insect is always a carrier of BXW. The insect moves randomly in search of a flower (white card), creating the effect of emergence. The random location can be any of the game board's coordinates (A1:F6). By definition, the insect always searches for a white card. If there is no white card at a defined location, the insect moves clockwise (from the perspective of the player in whose quadrant the location is) without considering quadrant boundaries until finding a white card (Figure 5.5). The mat in this location becomes infected with BXW (yellow card value = Fr. 0). This is the first disease stage. In the next round, the player can decide to invest and uproot this mat (yellow uproot card, investment = Fr. 500), or not invest and let the disease progress to the second stage (red card, value = Fr. 0). In the latter scenario, uprooting is again possible in the next round (red uproot card, investment = Fr. 500). If again not uprooted, the mat dies (a grey card, value Fr. 0). A mat in the first or second disease stage is an idiosyncratic institutional threat.

Chapter 5

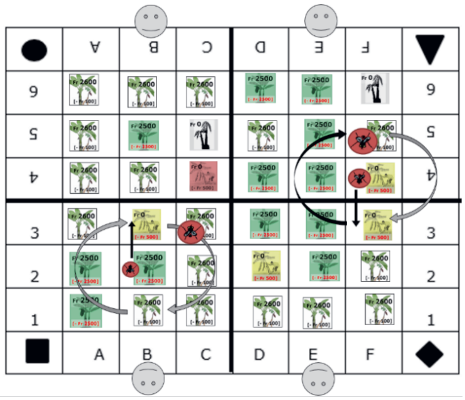


Figure 5.5 Schematic example of how the insect moves until it finds a white card (=with flower)

5.4.5 The monitor

The monitor card represents an extension agent whose responsibility it is to keep the community BXW disease-free. Every game round the monitor checks one banana mat at random, creating the effect of emergence. The random location can be any of the coordinates on the game board (A1:F6), and is also the monitor's final location for that round (Figure 5.6). The intervention takes place (or not) depending on the health status of the mat in that location. If the mat is healthy (i.e. white or green card) or dead (grey card) no action is taken. If it is diseased (yellow or red card) the control measure is performed. The control measure involves uprooting the infected mat plus, depending on infection status, all mats neighbouring the diseased mat either in that specific quadrant (yellow card) or in all quadrants (red card). In both scenarios, the neighbouring mats are uprooted regardless of their health status. Thus six mats (belonging to one or more farmer) could be lost.

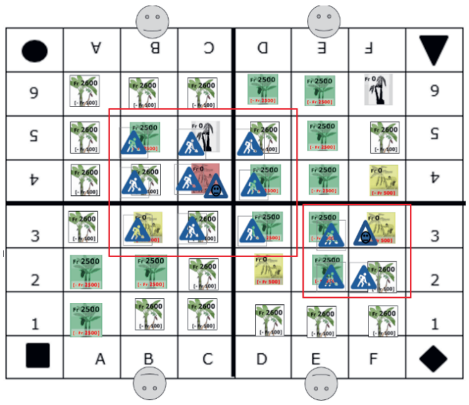


Figure 5.6 intervention rules for the monitor

5.4.6 Identifying corner solutions: fully cooperative and fully defecting playing strategies

The most cooperative strategy is to form blocks of 9 mats from the centre of the board (Figure 5.7). This minimizes the potential harm to neighbour farmers if the monitor discovers an un-uprooted diseased mat. The value 0 represents the initial condition without flower of cells B2, B5, E2, and E5. Values 1 to4 represent the potential order that players could choose to cut flowers in a cooperative strategy scenario. The 3 scenarios assume the maximum investment in cutting flowers per round (=2 flowers/round/player). If farmers defect i.e., fail to invest in cutting flowers and/or start cutting from the centre the other players are more at risk of being harmed by a neighbour's diseased mat.

A

○	A	B	C	D	E	F	Δ
6	4	4	3	3	4	4	6
5	3	0	1	1	0	3	5
4	2	2	1	1	2	2	4
3	2	2	1	1	2	2	3
2	3	0	1	1	0	3	2
1	4	4	3	3	4	4	1
□	A	B	C	D	E	F	◇

B

○	A	B	C	D	E	F	Δ
6	4	3	2	2	3	4	6
5	4	0	2	2	0	4	5
4	3	1	1	1	1	3	4
3	3	1	1	1	1	3	3
2	4	0	2	2	0	4	2
1	4	3	2	2	3	4	1
□	A	B	C	D	E	F	◇

C

○	A	B	C	D	E	F	Δ
6	4	4	3	3	4	4	6
5	3	0	1	2	0	3	5
4	2	2	1	1	1	2	4
3	2	1	1	1	2	2	3
2	3	0	2	1	0	3	2
1	4	4	3	3	4	4	1
□	A	B	C	D	E	F	◇

Figure 5.7 Disease spread scenarios (explained by quadrants) if players perform cooperative strategies A, B or C with the insect assigned randomly to one of the mats without flower in the first round.

5.5 Testing the Musa game in Rwanda and exploring data analysis methods

In April 2020 we tested the Musa game in four villages of Kayonza district in Rwanda's Eastern province to identify possible needs for calibration and explore suitable data analysis approaches. Test games were carried out according to an experimental protocol with the support of trained research assistants speaking both the local language, Kinyarwanda, and English. In this section, we present the experimental treatments and the questions that we asked to evaluate the game design and treatments, and we then explore the qualitative and quantitative results from the test games. Together the test games provide preliminary insights into the kind of knowledge that we can develop from playing the Musa game with real banana farmers.

5.5.1 Experimental treatments: focus on the communication principle of risk governance

Based on our scientific interest in the communication principle of risk governance, the experimental treatments of the Musa game were developed according to different risk communication strategies. The communication principle can be defined as meaningful interactions in which knowledge, experiences, interpretations, concerns, and perspectives are exchanged (Lofstedt, 2003 cited by Van Asselt & Renn, 2011). In the context of risk governance, this could be communication that facilitates interactions within and between different groups of stakeholders such as farmers, policy-makers, and experts. The purpose of communication is to provide risk managers with a better basis to govern responsibly despite uncertainty, complexity, or ambiguity. Communication serves to share information about risks and, create networks of trust and social support to find possible ways to handle risk (Irgc, 2010).

In the Musa game, we test decision making toward preventing a public bad (BXW disease) under three communication scenarios (Table 5.5). In treatment 1, players are not allowed to communicate during the game. In treatments 2 and 3, players have opportunities to communicate that allow them to exchange their interpretations of the game, technical knowledge about and experiences with BXW disease, perceptions of risk, as well as to develop an individual and/or collective risk governance strategy. In treatment 2, players were given an opportunity to communicate before the first round of the game. This scenario is denominated as ‘preventive communication’ because players have not experienced the disease in the game yet. In treatment 3, players were given two communication opportunities: once before the first round (similar to treatment 2), and once in between rounds three and four. The latter communication opportunity scenario is denominated as ‘responsive communication’ since it occurs when players are experiencing the spread of the disease and need to respond to the associated threats. Therefore treatment 3 is a preventive-responsive communication scenario.

From a game mechanics design and contextualization perspective, the test also raised the following questions.

- Is the Musa game easy to understand and attractive to play for actual farmers?
- Does the Musa game sufficiently capture the real-life decisions about dilemmas related to prevention and control of BXW disease?

From an analytical perspective, the test sought to explore how spatial analysis can contribute to the interpretation of the data collected through the Musa game?

From the perspective of an experiment focused on risk communication and its role in governing a public bad, the test sought to explore

- If there is a difference in collective and individual performance in terms of net profit in the different risk communication scenarios?
- If having previous knowledge of BXW disease management affects collective and individual performance in terms of net profit?

- If risk perceptions influence participants' playing strategies for the prevention and/or control of a public bad risk such as BXW disease?

The Musa game test sessions had two phases: In the first phase, farmers played the game for up to 7 rounds. In the second phase, players were involved in a focus group discussion. The quantitative and qualitative data were processed for spatial analysis. The dependent variables for analysis were the individual and collective profits, and the players' preferences to take risk management actions such as either cutting 2 flowers or uprooting one infected mat. The spatial dimensions of such decisions were taken into account by both tracing the position on the board and the round in which actions were taken.

Table 5.5 Dependent, independent and controlled variables of the Musa game experiment

Dependent variables	Independent variables	Controlled dynamic variables
Individual profit outcome Collective profit outcome Decision to cut male flower (0 or 2 flowers per round) Decision to either cut male flower (0 or 2 per round) or uproot one infected mat.	Risk communication: none; preventative; responsive; preventative and responsive.	Farmer game rules Insect vector game rules Monitor inspection game rules Rules in the progression of the disease through the progress of time.

5.5.2 Sample

Test game villages were sampled based on the criteria location, agricultural activity, and reachability. The sample is not and was not intended to be representative since its purpose is limited to test experimental design, game design, and contextual coherence. A total of 48 male and female banana farmers participated in the test sessions, 12 farmers per session, with three individual games played per session. Farmers were randomly selected from a pool of 30 farmers per village whose names had been provided by the village leader or village extension agent. An over-sampling strategy was used to resolve potential no-show issues. For each session 16 farmers were sampled, 12 players, 4 reserves. In case a player farmer did not show he/she was replaced with a person from the reserve list. Reserves present but not needed as players were allowed to observe the game for learning purposes but not to contribute to the game or interact with the players.

To explore the effect of existing knowledge on BXW disease management on the performance we included two types of villages in our test sample: (1) those recently exposed to a BXW knowledge intervention and (2) those not exposed to a BXW knowledge intervention. Of the four villages, three (36 farmers) were villages which had interventions from the ICT4BXW project (intervention status – a). This project operates in Rwanda and developed and piloted a digital extension application specifically targeting BXW prevention and control. In these villages, the extension agent had received training about BXW through the project and used the extension application, and it could be expected that farmers had been exposed to the extension agent's knowledge about BXW. One village (12 farmers) was an ICT4BXW control village where no previous project interventions had taken place (control status – b). Each participant gave informed consent and agreed to participate in the Musa game.

Table 5.6 Overview of the sample used in the test experimental game

Treatment	Boards	Description	Village	Part of ICT4BXW project intervention	Code Treatment/ ICT4BXW/ board	N. players
T1.a	Board 1, Board 2, Board 3.	Non-comm.	Muzizi	Yes (a)	T1.a.b1 T1.a.b2 T1.a.b3	12
T2.a	Board 1, Board 2, Board 3.	Preventive comm.	Kamajigija	Yes (a)	T2.a.b1 T2.a.b2 T2.a.b3	12
T3.a	Board 1, Board 2, Board 3.	Preventive and responsive comm.	Kinunga II	Yes (a)	T3.a.b1 T3.a.b2 T3.a.b3	12
T3.b	Board 1, Board 2, Board 3.	Preventive and responsive comm.	Butimba II	No (b)	T3.b.b1 T3.b.b2 T3.b.b3	12
Total	12 boards; 12 games	3 treatments	4 villages			48 players

5.5.3 Procedure

Each treatment was tested with a game session taking approximately 2 hours. In each session, three games with each 4 players were played. Every game table had two research assistants, one game master and one notetaker. The gameboards and their components (e.g. cards) were placed on separate tables. For each session, a sticker with a unique identifier code was placed on each of the four gameboard quadrants with each identifier being randomly assigned to a participant. A camera attached to a tripod with a horizontal arm to video-record the game. This overhead setup only recorded the boards and the players' hands during the game rounds, guaranteeing player anonymity. As part of the informed consent, players consented to the session being video and audio recorded.

After welcoming a participant a research assistant would lead them to the seat matching his or her identifier. Once all players were seated the session started with a general introduction about the Musa game (e.g. BXW disease, the research project and the objective of the game test). The research assistants then explained the rules of the game in Kinyarwanda, supporting their explanations with demonstrations on the actual board. Participants had the opportunity to play one trial round and ask questions or for clarifications afterwards. Thereafter the game started following the specified treatment protocol.

For each test-game, the coordinates of both monitor and insect were assigned randomly in advance, using statistical software, and equal for every session. In every round, the farmers first decided if and which action they should take. After that, the game master announced the location of first the monitor and then the insect and placed it in the right cell on the board. In each round, the assistant read aloud the position on the board where the monitor and insect card will visit. The players only know where the insect and monitor will visit after they have made their decisions. The notetaking research assistant meanwhile filled a paper-based form to track the farmer/players' actions, the monitor's and insect's locations, and the intermediate game outcomes. The video and audio recordings of the session were used as a back-up to the hand-written data.

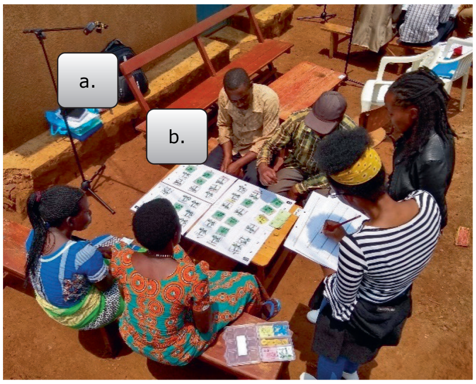


Figure 5.8 Test session in Kayonza. In the picture, four farmers are playing the board game (b) while being recorded (a).

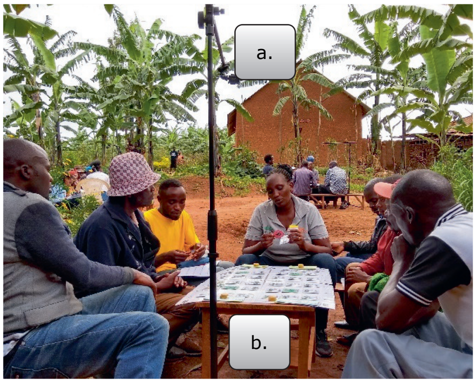


Figure 5.9 Test session in Kayonza with 3 groups of players with a distance between the game tables. Separate video equipment (a) and game kits (b) were used for each table.

5.6 Results and analysis

In this section, we explore the test game results, both quantitatively and qualitatively. First, we assess game acceptance, game vs real-life practices, and perceptions about the different treatments. We then look at how results from the Musa game may inform us about individual and collective benefits and possible relationships between benefits and individual decisions regarding what action to choose, and where to spatially perform that action Lastly, the section looks at learning effects. Given the small sample size and the exploratory nature of the analysis, we do not perform any inferential statistical analysis but use descriptive statistics and descriptive spatial analysis.

5.6.1 Participants receptivity to the Musa game

The responses from the banana farmers who played the Musa game showed that it was well-received and mostly understood by players. Participants expressed gratitude for the game's learning effect: *"Before we'd cut flowers and even uproot the infected bananas but without knowing the reasons why we do that. But after playing this game we understand the importance of cutting flowers and uprooting the infected banana mats"* (T3.b.b2). We also found evidence of social learning mechanisms, especially regarding fighting BXW collectively: *"This game taught us about the way that we should work together with our neighbours when fighting BXW"* (T2.a.b3); and "After playing this game, I recognize that a better way to eradicate BXW disease is to collaborate with my fellow banana farmers by advising each other" (T3.b.b2).

Participants perceived the game as a fun way to learn about BXW disease by playing the game and interacting with their peers. A farmer noted that: "*The game was fun, and [it was] interesting to understand what was happening and why"* (T2.a.b1). Farmers mentioned that playing the Musa game helped them to understand the consequences of their actions: *"The game was amazing, and we have seen that it is better to prevent BXW disease because if we don't do it we lose our investment too (T2.a.b2). Others acknowledged the importance of working together "The game showed me that working together is very important in fighting BXW"* (T1.a.b1).

Farmers reported that the Musa game equipped them with relevant skills: "Honestly I am happy that you gave us these priceless skills on the importance of cutting banana flowers. I wish you could come as many times as you can and teach us more" (T1.a.b1) and said that they wanted to share this knowledge with other farmers "What I get after playing this game, I am going to teach all of these good lessons to my neighbours so that we can work together in combating BXW disease" (T2.a.b2); and "What I can give as an advice is that you need to reach out to every banana farmer in the country, to make them understand how to prevent this dangerous disease and the importance of working together" (T1.a.b1).

From a disease management perspective, participants mentioned learning from both the Musa game rules and discussions with their peers: *"What I learned […] is to share ideas as neighbours by reminding each other to visit each others' fields more often. Besides, […] I learned […] that we should invest in protecting our banana fields"* (T3.a.b3). Some participants were unaware that the BXW could be transmitted by insects and therefore had not prioritized cutting flowers in their fields

"[…] I learned that BXW disease is caused by an insect, this has led me to decide to wake up early every day to visit my field and cut flowers" (T3.b.b2).

Farmers agreed the Musa game is a helpful tool to develop a better understanding about both the disease and the impact that individual actions can have for collective benefit: *"BXW is a very bad disease which can cause a big loss, not only to an individual farmer but also to the whole village and our country. In order to solve the problem of BXW disease, it is better to mobilize our fellow farmers […] through village meetings"* (T3.a.b2). Moreover, the importance of preventative actions for protecting fields and livelihoods became clear: *"What I learned from this game is that we should cut flowers early and uproot the diseased mats immediately"* (T1.a.b3); and *"What I observed through this game is that if we don't protect our fields from BXW it will cause poverty"* (T3.b.b3).

5.6.2 Participants' perception of how the game's representation of decision dilemmas to prevent and control BXW disease accorded with real-life.

Participants agreed that BXW disease is a relevant fight in their daily lives *"The game tells me how to fight BXW and this is a real problem that I have been fighting with for four years"* (T1.a.b2). They also related the game context to their real-life experiences with BXW disease prevention and control: "*… in this game those who did not invest in protection faced losses. The same happens in real life, if you don't invest in protecting your field then you lose"* (T3.a.b1).

The FGD data gives insight into participants' knowledge about cultural practices used to prevent BXW transmission. For example, most players were aware of the practice of cutting the flower: "*The decisions about cutting flowers and uprooting the diseased mats that I had to take in the game were the same as the ones I'm used to taking in real-life"* (T3.b.b3). Others cope differently with diseased mats in real life: "*I'm used to cutting the diseased mat and leaving it in the field, not to uprooting it* (T2.a.b3). Some participants displayed knowledge about other disease infection mechanisms and prevention practices *"I can also get infected by using infected tools like hoes, machetes, or get infected by my neighbour who has BXW in his field"* (T2.a.b3), and *"[In real-life] I have also observed that even bananas which have no flowers are also infected by BXW. So, since you are researchers, I would like you to take this into consideration too"* (T3.a.b3).

Farmers who played in one of the two games treatments with communication (T2-T3) told us that the risk communication style during the game differed from real-life: *"The style of communication during the game was not the same as the one we use in real life, because when you meet someone, the only thing you tell him is if you have been infected by BXW. […] we never discuss together the measures we should take to fight this disease. But during the game, I was able to discuss and share with my neighbours the measures that we can take to fight this disease together"* (T3.a.b3).

Participants experienced this communication as providing an opportunity to learn from others and develop strategies to fight BXW together: *"We also discuss about BXW in real-life but there is a small difference, [in real-life] we might see our neighbour's field infected by BXW but do nothing to help, but during the game, we discussed [...] what we should do (*T2.a.b3*).*

Farmers playing the non-communication treatment (T1) thought that communication was crucial to making better decisions: *"I wished to share ideas with my friends. I even whispered but you caught me and stopped me"* (T1.a.b1). According to T1 players communication would not only allow them to make better individual decisions but also collectively respond to a common threat: *"I think that if we'd had a chance to discuss during the game, I would not have been infected by BXW because we would take action together to fight this disease"* (T1.a.b3).

5.6.3 Overall game performance

Figure 5.10 shows the results from all 12 boards in terms of net profits. In 100% of the games' collective food security and some net profit from the banana production was achieved. Individually, only one player, in T3.b, ended the game with a net debt and became food insecure. The mean average is similar for all games, ranging between Fr.4000 and Fr.4650 for 10 out of the 12 games. Hence, descriptively we observe no significant profit differences between the treatments.

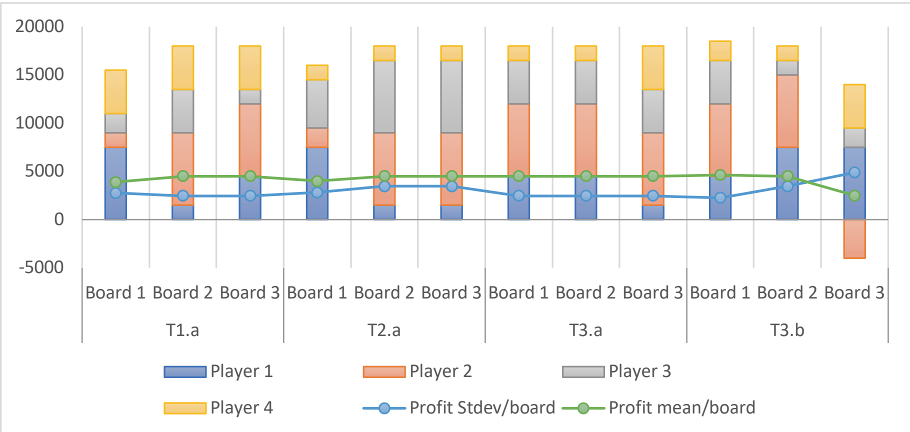


Figure 5.10 Game results in terms of profits per player, per board (4 players/board), per treatment (3 boards/treatment). The blue line shows the profit standard deviation per board. The green line shows the mean profit per board.

Figure 5.11 provides information about differences in the actions that players prioritized in the different treatments. In T1.a and T3.a none of the farmers ended the game with cards representing a risk for themselves or their neighbours (i.e. yellow or red cards). In T2.a and T3.b, some players ended the game while there was still a disease threat (i.e. a yellow and red card in T3.b and a yellow card in T2.a).

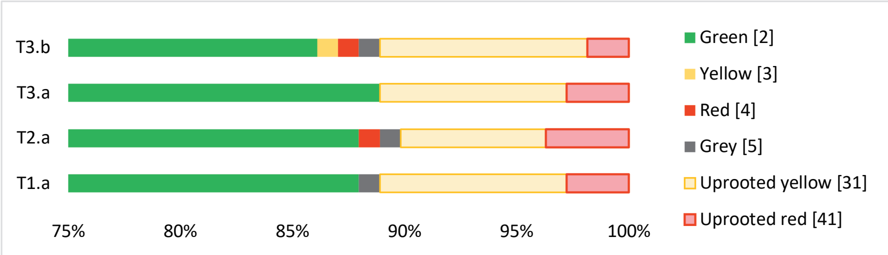


Figure 5.11 Percentage of the type of cards on the board at the end of the game which determined players' profits: green card [healthy mat without flower – code 2], yellow card [BXW infected mat, first disease stage – code 3], red card [BXW infected mat, second disease stage – code 4], Grey card [dead mat – code 5], Uprooted yellow card [code 31], Uprooted red card [code 41].

5.6.4 Spatial locations of decision making: Decisions about where to cut flowers

Since the Musa game is played on a board there is a spatial dimension to players' decision making. Each player shares their quadrant's inner border with the other three players. However, the game instructions did not inform players about what would (hypothetically) be adjacent to the outer borders of their quadrant. The hypothesis is that farmers who decide to take preventive (cut flower) or responsive (uproot diseased mat) action nearer to the inner border (= their fellow players) show more cooperative behaviour than farmers who take actions nearer to the outer border. This because the game rules informed players that their actions can have consequences for both themselves and their fellow players. For data analysis purposes we transcribed the original notation of the board locations from letters and numbers to just numbers (Figure 5.12). Locations 1 to 5 adjoin the 4 players, 9 is the location furthest from the board's centre, and 6-8 sit in between.

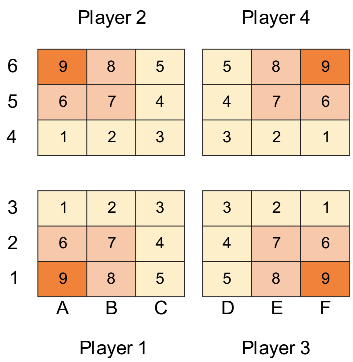


Figure 5.12 Game board map: players' positions and mat locations for data processing purposes.

Figure 5.13 shows the board locations where players cut flowers to prevent BXW spread in each round. In all four treatments players cut flowers in locations 4, 5, 8, and 9 in round 1, which are mainly outer border locations. The mats in those locations never got infected. Location 3 (the most central), was cut in the first two rounds mainly by farmers in T3.a, the treatment with farmers exposed to knowledge about BXW in real life and with two opportunities to communicate during the game. Only in T3.b (groups with two communication opportunities, that do not belong to the ICT4BXW project) did none of the players cut flowers in the most central locations (1-5), while it took until round 4 before the central location (3) was cut.

Although players in T3.a and T3.b had the same communication opportunities they were differences in the flower cutting locations between rounds. The players in T3.a had been exposed to knowledge about the disease in real-life and this may have influenced their ability to communicate about prevention and control practices and work out a (spatially) more cohesive game strategy.

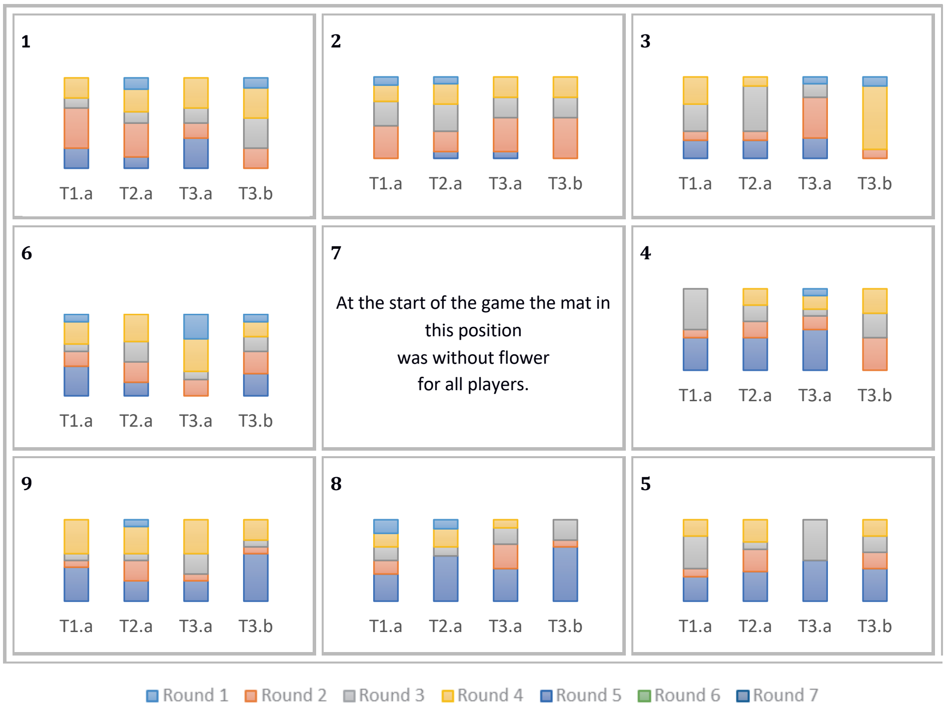


Figure 5.13 Proportion of decisions to cut flowers taken in the 9 board locations in each game round. The figure is presented like a players' section of a board from the perspective of player 1 (see Figure 5.12). Each segment is numbered from 1 to 9, corresponding with locations. Locations 1 to 5 are the board's inner borders. Location 3 is the most central location. Location 9 is the board's outer corner. The bar diagrams within each segment show the proportion of flowers cut in each round per treatment. E.g. in round 1 (light blue colour), many flowers were cut in position 9, the location farthest from the board's centre, and only a few in position 3, the most central location. Location 7 does not show data because all players started the game with a mat without a flower in that position.

5.6.5 Spatial distance-based decision-making analysis: the Musa analysis tool

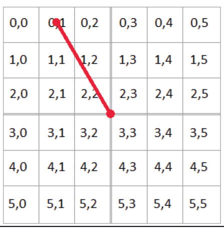
To retrieve the results presented in the following sub-sections, a computational programme, called the Musa analysis tool, was developed to assist with analysing our dataset which includes both decisional and spatial dimensions. The Musa analysis tool was developed using the programming language C Sharp (C#) and its task is to perform different spatial analyses based on distances and relate those to game decisions. The software assumes a uniform distance of 1 x 1 unit between the banana mats (positioned in a segment), and its point of interest is in the central position of each segment. The distance between two random points A and B is given by

$$D = \sqrt{(PI_{Ax} - PI_{Bx})^2 + (PI_{Ay} - PI_{By})^2}\,,$$

where PI is the position of interest for calculation measured from the centre of each segment.

Likewise, all the distances measured during the experiment correspond to the distances between a PI (Point of Interest) of a segment, corresponding to the player's actions, and another PI of a second segment, corresponding to a direct value of the board at that instant of time (Game Round), or the Pc position (Centre position). These measurements were normalized to a scale of values between 0 and 1, which will mean a value of 0 for positions outside the board and 1 for positions where specific actions are taken.

The distance given in values between 1 and 0, will be called the normalized distance or Dn, and will be given by $Dn = \frac{(Dm-D)}{Dm}$, where Dm will be the value of the maximum possible distance between two ends of the board. For calculations where the only reference is the Central Position (Pc), the Dm will be half the diagonal of the board. For practical purposes, it should be emphasized that during the real measurements, for normalized distance (Dn) the closed values of 1 and 0 will not be represented. See appendixes for detailed information of the software methodology.



$$\boldsymbol{D} = \sqrt{((\mathbf{0}+\mathbf{0.5})-\mathbf{3})^2 + ((\mathbf{1}+\mathbf{0.5})-\mathbf{3})^2} = \mathbf{2.91}$$

Figure 5.14 Distance calculation between a random point (0,1) and Pc (Central Position). Notation for each segment is given in coordinates X, Y.

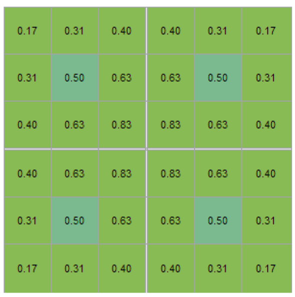


Figure 5.15 Example of the initial board situation in the Musa analysis tool. It shows the values of the Normalized Distance (Dn) for each segment surrounding the Central Position (Pc) of all types of mat's states (healthy, infected, intervened or dead) for a standard board in the initial round.

5.6.5.1 Decision to cut flowers in relation to the minimum distance to a neighbour's mat without flower

Figure 5.16 shows the proportion of flowers that players cut in relation to the minimum distance to a neighbour's mat without flowers (green card). The closer the flower cutting action is to a neighbour's green card, the closer the distance value will be to 1. The graph shows, in intervals of 0.1 distance units, the proportion of actions taken at distances between 0.1 and 0.9. It can be observed that in the complete sample, indifferent of treatment, the decision to cut a flower in round 1 started at a distance of 0.5 (in relation to the nearest green card). It thus appears that participants' flower-cutting actions were not oriented toward forming clusters of green cards in the centre on the board but dispersed in directions closer to the board's outer borders.

As the games progress, the number of green cards on the board can be expected to increase. Therefore, in round 5 we can see that flower-cutting decisions all happen at distances of 0.7 and above (i.e. close to a neighbour's green card).

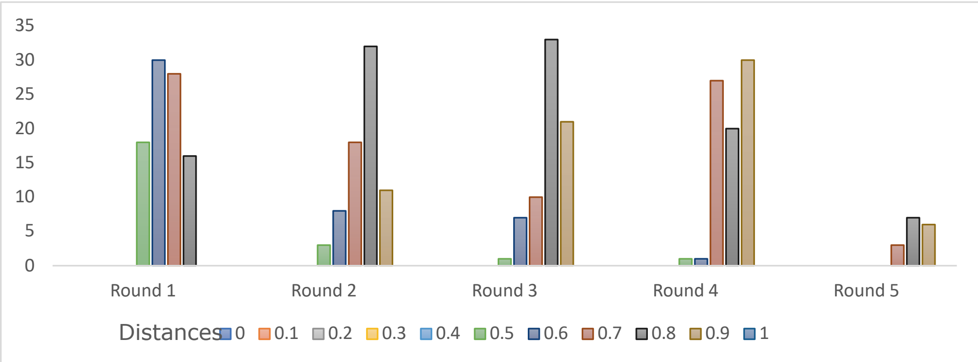


Figure 5.16 Number of flower-cutting decisions in relation to the minimum distance to a neighbour's mat without flower. Distances are shown in intervals of 0.1, from 0 to 1. The distance closest to 1 represents the shortest distance to a neighbour's mat without flower.

When asked about the action to cut flowers during the FGD, participants agreed that cutting as many flowers as possible was the best preventative game strategy *"I cut flowers because when the insect that spreads the disease arrives and finds that the bananas are protected, it will leave and infect where the bananas are not protected"* (T3.b.b3) and those continuous reminders are desired: *" [...] it is always good to keep reminding our neighbours to cut banana flowers in their field"* (T2.a.b2).

5.6.5.2 Decision of uprooting yellow or red mats in relation to the minimum distance to a neighbour's healthy mat with or without flower

Although cutting flowers close to where neighbours also cut flowers did not appear to be a priority for players, uprooting diseased mats did. Even though the monitor did not intervene in any of the game sessions, there was a general perception of risk in regard to the monitor finding an infected mat: "*I was afraid that if the monitor came and found that there was a disease in my mat it would have been necessary for me to uproot other bananas near the sick one. But I was lucky enough to get rid of it before he arrived"* (T3.a.b1); and "*I feared that the monitor might come and punish me for infecting my neighbours' bananas"* (T3.a.b2). Figure 5.17 shows the proportion of yellow cards that were uprooted in relation to the distance to a healthy mat (with or without flower, white or green card). The nearer a player's yellow card is to a neighbour's healthy mat, the closer the distance value is to 1. Positions over 0.8 are the immediate neighbours' locations. Overall, we observe no actions at distances below 0.7. If we relate this to the locations where players cut flowers (with a tendency to cut far from neighbours), it implicitly tells us that most mats vulnerable to disease infection (= white cards) were located near the centre of the board. Thus, if one of those mats becomes BXW infected (yellow card) it is located close to healthy mats and therefore more of a collective threat for all players.

Players in T1.a and T3.a uprooted infected mats more often than they cut the flowers. FGD data confirmed that for those playing in T3.a uprooting infected mats was the main strategy "*We uprooted mats of infected bananas in order to protect the remaining bananas in the field as we have realized that if we do not uproot early the banana might turn to red which can be dangerous not only in my field but also for my neighbours"* (T3.a.b2). These players prioritized uprooting diseased mats over profit-making: *"Although some of us did not get much profit we have at least managed to uproot the infected mats".* They also worked together to minimize overall losses: *"We tried to work together as a team so that no-one would suffer a loss"* (T3.a.b2). Players in T1.a uprooted yellow mats 100% of the time when they were in a position of 0.7from a neighbour's healthy mat and 67% of the time when they were in a position or 0.9 distance from a neighbour's healthy mat. Players in T3.a uprooted yellow mats 60% and 100% of the times when they had them in the same positions. In T2.a and T3.b, the action of uprooting yellow mats decreased to less 71% when infected mats were located more than 0.8 distance from healthy mats. This means that some players let their yellow mats progress to red (second disease stage) and that T3.b players, in contrast to those in T3.a., prioritized cutting flowers over uprooting infected mats " *I cut all the male flowers in my field and uproot later"* (T3.b.b2).

Of the mats progressing from yellow to red (Figure 5.18), players in T3.a uprooted 100% of the time that a mat progressed to red, and these were located at an average distance of 0.8 distance to a neighbours' healthy mat. In all other treatments, the decision of uprooting a red mat was under 75%, meaning that the players allowed the disease to progress from a red to a dead stage (grey card). While not uprooting a yellow mat was a risk for the individual player, not uprooting a red mat put all the players at risk of uprooting if it was found by the monitor. Players in T3.b., who were not part of the ICT4BXW project intervention, took the highest collective risk.

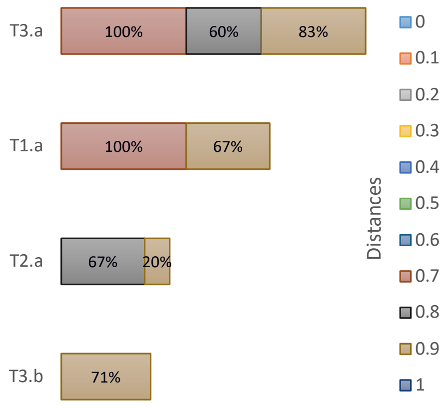


Figure 5.17 Stacked bars showing the proportion of uprooted yellow mats in relation to the minimum distance to a neighbour's healthy mat with or without flower. Distances are between 0 and 1, in intervals of 0.1. Distance closest to 1 represents the shortest distance to a neighbour's mat with/without flower. E.g. players in T3.b uprooted a yellow mat 71% of the times that it was located at a 0.9 distance from a neighbour's healthy mat. This means that the remaining 29% of yellow mats became a red mat in the next round, if not found by the monitor.

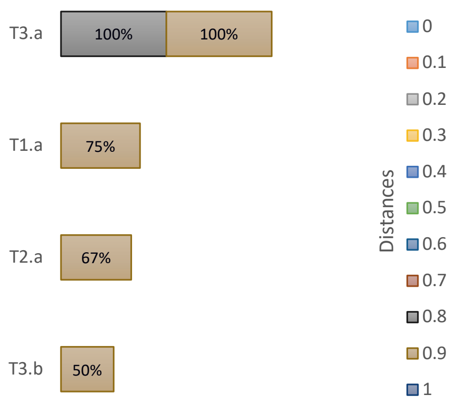


Figure 5.18 Stacked bars showing the proportion of uprooted red mats in relation to the minimum distance to a neighbour's healthy mat with or without flower. Distances are between 0 and 1, in intervals of 0.1. Distance closest to 1 represents the shortest distance to a neighbour's mat with/without flower. E.g. players in T3.b uprooted a yellow mat 50% of the times that it was located at a 0.9 distance from a neighbour's healthy mat. This means that the remaining 50% of yellow mats died in the next round, if not found by a monitor.

5.6.5.3 Decisions about cutting flowers in relation to the distance to an infected mat and the outer border

We also explored the relationship between the decision to cut flowers and the distance to 2 different variables: distance to the outer border (distance toward 0), and distance to the nearest infected mat (yellow or red) of a neighbour (distance toward 1). If the player decided to cut a flower closer to the outer border rather than closer to the nearest infected mat of a neighbour, the value is closer to zero. If the player cut a flower closer to the infected mat, the distance is closer to 1. In Figure 5.19 we see that 66% of players cut the flowers closer to the border, and only under 10% cut flowers in positions near a neighbour's infected mat. These results suggest that players preferred to invest in cutting flowers in positions the farthest from an infected mat. The fact that most farmers decide to cut flowers in positions 0.2 distant to the border (close to the outer border, far from the neighbour's infected mat), suggests that most infected mats are located toward the centre of the board.

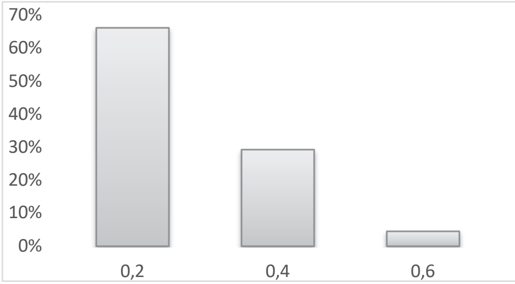


Figure 5.19: Decision to cut flowers in relation to the distance to the outer border and infected mats. The X-axis shows the distances between the outer border (toward 0) and an infected mat (toward 1). The Y-axis shows the proportion of cutting flowers in between both variables (outer border and infected mat).

5.6.6 Exploring the usefulness of neighbours' analysis

We used the Average Nearest Neighbour Distance tool available in ArcGIS to perform an exploratory analysis and calculate the expected mean distance between each feature and its nearest neighbour's location. The feature, in this case, represents the location of a banana mat and its nearest neighbour's mat where a player took an action (either cutting the flower or uprooting an infected mat). The expected distance is based on a hypothetical random distribution with the same number of features covering the same total area (ArcGis, n.d.). To make this analysis possible, we gave a hypothetical geographical coordinate to each location, with a homogeneous distance in metres between features. The purpose of this analysis was to explore the relationship between the progression of the distance between actions taken over time and a player's net income. Our assumption is that the larger the distance in the first rounds, the less cooperative a player's actions (= farther away from the board's centre), resulting in lower, or more unequal, individual net incomes.

We tested this analytical method comparing T2.a and T3.a. As previously described, players in T2.a had one communication opportunity prior to the start of the game (preventive), and players in T3.a, had a communication opportunity prior to the first round (preventive), and after the third round (responsive). Players involved in both treatments belong to a group of farmers that are part of the ICT4XWD project, which provides them with training in BXW management. In Table 5.7.a we see that the mean net incomes are very similar, although the income per player varied. Players 1 and 4 in the game T2.a. made a net income of 16500 Fr., while players 2 and 3 ended the game with a net income of 22500 Fr. In T3.a, the variation among players' net income was less, with 3 out of 4 players gaining net incomes of between 19500 and 22500.

In Table 5.7.b, the board locations where the action took place are shown progressively from round 1 to round 5. The numbers (from 1 to 5) shown in each square denote the round where the action was taken. The actions were either to cut flowers or to uproot an infected mat. We see that players 1 and 4 from T2.a, with the lowest net incomes, initially chose to take these actions in more distant locations but that they became closer to the centre as the game progressed. The final actions of those players (round 5) were in the board's central locations. Players in T3, in contrast, starting from round one took actions closer to the centre of the board and ended the game toward the outer border of the board, hence working in a closest to furthest distance order.

In Table 5.76.c we relate the expected mean distance between the location where actions were taken (features) in each round to the standard deviation of the net income across rounds. Looking at T2.a, we can see that the lower the distance among the positions where the actions were taken toward the game's end (round 5), the higher the standard deviation of the net income (3464 Fr.). In T2.a, the distance among action-taken positions remained dispersed up to round 4 and did not show a trend. In T3.a, we see that the distances increased steadily as the game progressed, resulting in a lower standard deviation of net incomes (2449 Fr). These differences (in trends) between the treatments might be related to players in T2.a not having a communication opportunity between the rounds. This meant that players in T2.a players did not exchange any information that could have contributed to the emergence of a different strategy once the game started.

In public-bad management terms, the results suggest that more communication opportunities contribute to better collective management of risks. Secondly, they suggest that collective action in risk management can create the socio-ecological conditions for a more equal distribution of benefits.

Table 5.7 Relating expected mean distances to net income standard deviations across five rounds.

Treatment 2.a: Preventive (26)

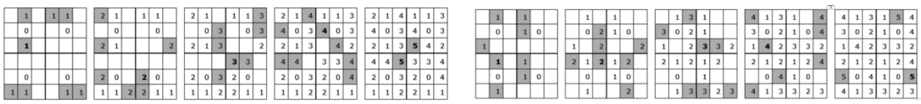
a.

T2.a	*r1*	*r2*	*r3*	*r4*	*r5*
P1	23100	20300	19800	17000	16500
P2	23100	22900	22700	22500	22500
P3	23100	22900	22700	22500	22500
P4	20500	20000	17200	17000	16500
Mean	22450	21525	20600	19750	19500
Sum	89800	86100	82400	79000	78000
Stdv.	1300	1592	2647	3175	3464

Treatment 3.a: Preventive-Responsive (28)

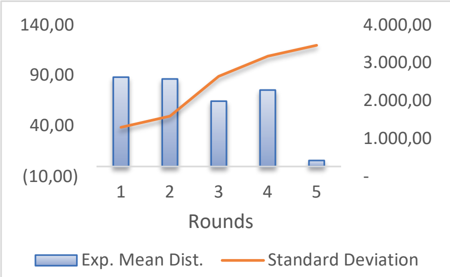
T3.a	*r1*	*r2*	*r3*	*r4*	*r5*
P1	*23100*	*20300*	*19800*	*19600*	*19500*
P2	*23100*	*22900*	*22700*	*22500*	*22500*
P3	*23100*	*22900*	*20100*	*19600*	*19500*
P4	*20500*	*20000*	*19800*	*17000*	*16500*
Mean	*22450*	*21525*	*20600*	*19675*	*19500*
Sum	*89800*	*86100*	*82400*	*78700*	*78000*
Stdv.	*1300*	*1592*	*1407*	*2247*	*2449*

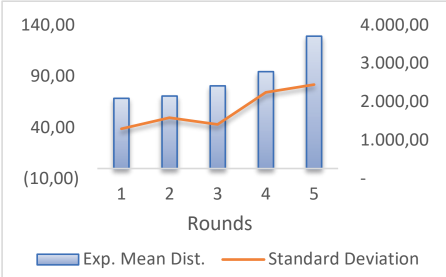
b.



Treatment 2.a: Preventive (26) *Treatment 3.a: Preventive-Responsive (28)*

c.





5.7 Discussion and conclusions

5.7.1 The emergent phenomena and spatial analysis to better understand public-bad risks

This paper builds upon Ostrom's SES framework (2009), a framework for analysing a public-bad risk threatening livelihood resilience, from a risk and collective action problem perspective. Our public-bad adaptation of the framework, like Ostrom's original version, emphasizes the role of emergent phenomena in decision-making. The emergent phenomena are reflected in the experimental game presented in this article – the Musa game – and operationalized for the context of BXW disease management. In the Musa game, the theoretical definition of emergence, the game's entities (e.g. insect, monitor, and farmer players) together with the socio-ecological rules of the system create new conditions that individual players (the farmers) need to adapt to through individual and collective action. The various interactions between the entities and their decisions give rise to the emergence of unpredictable and interdependent risk scenarios. By tracing the data about the what, where, and when, of player's public-bad risk managerial decisions, we were able to better understand how decisions shape the public-bad risk in different circumstances. Through the Musa game, we traced data showing the BXW disease prevention and control decisions that players took. We also looked at the timing (game rounds) and locations (on the game board) of those decisions. The analysis allowed us to link, through spatial analysis, decision-making and risk scenarios that emerged from the decisions of players, together with actions of autonomous entities (insect and monitor). The potential causal relations we identified helped us to develop hypothetical motivations for the decisions made in different communication scenarios.

5.7.2 The influence of knowledge and communication

Exploring the number of decisions to cut flowers closer to the outer border or a neighbour's infected mat, we found that over 60% preferred to cut flowers in mats that were further from a neighbour's infected mat. FGD data suggest that farmers perceived proximity to a sick mat as high risk: *"Although I was in the favourable condition of not being infected by BXW in my field because I cut my flowers frequently, I feel like I still risked BXW infecting in my field because my neighbours had BXW disease in their field"* (T3.b.b2). This suggests that farmers fear making an unworthy investment (cutting flowers) near an infected mat. Farmers experienced uncertainty about whether their neighbour would choose to uproot their infected mats, or to cut more flowers: *Even though I already cut all my flowers I was still afraid because the neighbours still had BXW in their field* (T3.a.b1)*.* Additionally, at least some participants knew that disease transmissions patterns other than insects exist, albeit these were not included in the game: *"I can also get infected through using infected materials like hoes, machetes, or get infected by my neighbour who has BXW in his field"*(T2.a.b3). Therefore, cutting flowers near a neighbour's infected mat presented a higher investment risk since, if not uprooted, that disease mat could be visited by the monitor resulting in loss of both mat and investment. Thus risk perceptions about infected mats and the neighbour's decisions about uprooting probably contributed to sustaining the dispersed strategy.

The game strategy adopted by participants was similar across all treatments. However, we found that over time the strategy changed in groups that had both previous pieces of knowledge about disease management (as a result of being an ICT4BXW intervention village) and multiple opportunities to communicate (treatment 3) and became more cooperative. Players from T3.a had some previous knowledge on BTW disease management and had two communication opportunities during the game. A farmer said: *"If there was no communication, I would not know what measures I should take, and the result would have been a big loss"* (T3.a.b3). These game tables had the highest proportion of uprooting of yellow mats during the game and uprooted 100% of the red mats. Although they initially started cutting flowers closer to the outer border, this changed from round 2 onwards, when players started cutting flowers closer to their neighbours (Figure 5.13).

Although participants in T3.b also had two communication opportunities, their management strategy for preventing disease spread was the least effective. This was the only game in which one player ended up in debt. The playing strategy was focused on the outer borders, and the games ended with more infected mats in the yellow and red stages, representing a collective risk. The number of infected mats uprooted in relation to the distance to a neighbour's healthy mat was the lowest (see Figure 5.17 and Figure 5.18). One difference between groups T3.a and T3.b was previous disease knowledge. Participants in T3.b were not involved in the extension service programme that provided training in BXW disease management since they were an ICT4BXW project control village. The result suggests that the absence of, or incorrect, information has the potential to create greater collective risks.

5.8 Reflection on the Musa game method

5.8.1 The observed phenomena in the game

Based on the quantitative and qualitative results, we observed that most players, in all of the treatments, started the game by cutting flowers from the outer borders. We interpret this strategy as a non-cooperative one since it creates conditions that increase collective risk. But why did farmers choose this strategy? When explaining the game's rules and structure the research assistants explained that the monitor would randomly visit one mat in each round. Players were not told where the monitor came from or where he/she would go after visiting a mat. Yet FGD data suggests that farmers assumed that the monitor watched their actions from somewhere, even when the monitor card was not yet played: "*I felt I was at a high risk because the monitor was somewhere watching or circulating (*T1.a.b1*)".* Therefore, players tried to first satisfy their need to decrease the threat of the monitor if he/she would watch their poor performance on disease management. This suggests that farmers supplemented the information gaps with their personal experiences about (disease) monitoring in real-life. This is not unlikely given the high level of social control and hierarchical structure of Rwandan society, where any person might report about events in their community to a local leader or extension agent. Thus, monitoring is not a foreign concept to farmers. Additionally, we know from reports of extension staff that farmers sometimes 'hide' diseased bananas by being more rigorous in their agronomic practices in places that are visible from the road or close to houses, in an attempt to be seen as a 'good farmer'.

Since the players started the game by cutting flowers mostly toward the outer border, mats in the most central locations were vulnerable for infection by insects for a longer period. The strategies for cutting flowers varied across the treatments. For example, players in T3.a tried to satisfy both the need to show good agronomic performance to outsiders and decrease collective risk. They cut one flower near the border and one flower near the centre. By contrast, players in T3.b focused their flower cutting in locations toward the board's outer border. This (initially) individual strategy created a collective risk and mats in more central positions started to get infected over time.

5.8.2 Reflection on the game's results

Our study results suggest that for effective collective management of public bad risks a farmer needs to have both the right knowledge and the opportunity to build a collective strategy. This finding aligns with Damtew et al. (2018), who found that the provision of technical information about disease managerial practices alone can have a counterproductive effect on disease management decisions. On the other hand, a combination of both information provision and opportunities for communication and internal governance can lead to better decision making.

Risk perception appears as a critical factor. Participants in this study designed their playing strategies based on their perceptions of risk, either from the fear to be found underperforming by the monitor 'watching them from somewhere', or the possibility that their neighbours do not take actions that reduce the collective risk. As a consequence, the sum of the individual decisions to take actions closer to the board's outer border not only created a collective risk but, in some cases, also became a self-defeating decision. Thus, the completeness and quality of the information provided matters. In the absence of complete and trustworthy information self-defeating strategies may be created, all the more if the decisions are taken in a vacuum without consultation, and deliberation, with peers. COVID 19 is one example where the influence of misinformation (or a lack of information) and inaccurate risk perceptions. The rapid diffusion of misinformation and poor individual knowledge resulted in the adoption of counterproductive disease prevention practice at both individual and collective levels. For instance, a resident in the U.S. died after consuming chloroquine (use to clean aquariums) to cure COVID-19, a face new spread through social media. Conspiracy theories spread on social media have also been harmful by undermining public health messages (Barua *et al*., 2020; Pennycook *et al.*, 2020)

5.8.3 The learning effect of playing together

The results of our study suggest that the lack of a collective strategy based on knowledge has the potential to create self-defeating strategies, and new collective threats. However, we also found that playing was an effective and powerful learning tool. Participants repeatedly expressed their sense of gratitude and excitement because they learnt both about technical aspects of the disease as well as interdependencies and collective action requirements. Our findings align with Tafesse *et al*. (2018) who found a need for learning approaches that support the diffusion of both technical disease aspects as well as giving attention to the existence of interdependencies and needs for collective action. Given the feedback that we received from farmers, our method meets those characteristics in that it lets farmers actively experience their interdependence while also teaching them technical disease information. Hence, next to being an experimental tool, the Musa game has potential as a learning tool that could be implemented by researchers and practitioners.

5.8.4 Outlook for the Musa game

Looking at the results of developing and testing the *Musa game*, we conclude that, as a *Dynamic Socio-Ecologic* game design, it can yield rich and insightful data. Additionally, the Musa game provides a promising interactive learning tool. To be conclusive about the effectiveness of the Musa game the experiment needs to be conducted at a larger scale. With a larger sample our preliminary findings and hypotheses, presented in this discussion, could be verified. For example, we could confirm that the lack of exposure to information about BXW management negatively affects the ability to make good management decisions and therefore enhances collective public bad risk. Knowing about the true impact of information is relevant for projects such as ICT4BXW as well as policymakers. Secondly, with a larger sample more in-depth analyses would become possible, for example, to compare data from different age and gender groups or from different geographic locations. Studying the influence of age and gender on decision making and individual as well as collective performance could be especially interesting given that for example women have historically been more excluded from access to information and knowledge. This far the exclusion of women has been mostly addressed as an individual issue, however, the Musa game may shed a different light on this. Another interesting finding to further explore with a larger sample is the collective food security outcome. In our test game, we found almost 100% collective food security, which was unexpected. Playing the game at a larger scale means that we can verify if this finding is chance-based, or related to another mechanism such as the design of the Musa game itself, or Rwandan farmers' willingness to contribute to and comply with the game rules.

While we designed Musa game to study BXW disease management we believe that the same method, in an adapted form, is suitable for a variety of other complex socio-ecological problems too. Examples of suitable problems that could be studied are found in Table 5.32 and include malaria and COVID-19. Lastly, for future application of our method, opportunities for digitizing the Musa game could be explored. A digital version would simplify game implementation, create a more controlled experimental environment, and reduce chances of error.

5.9 Acknowledgements

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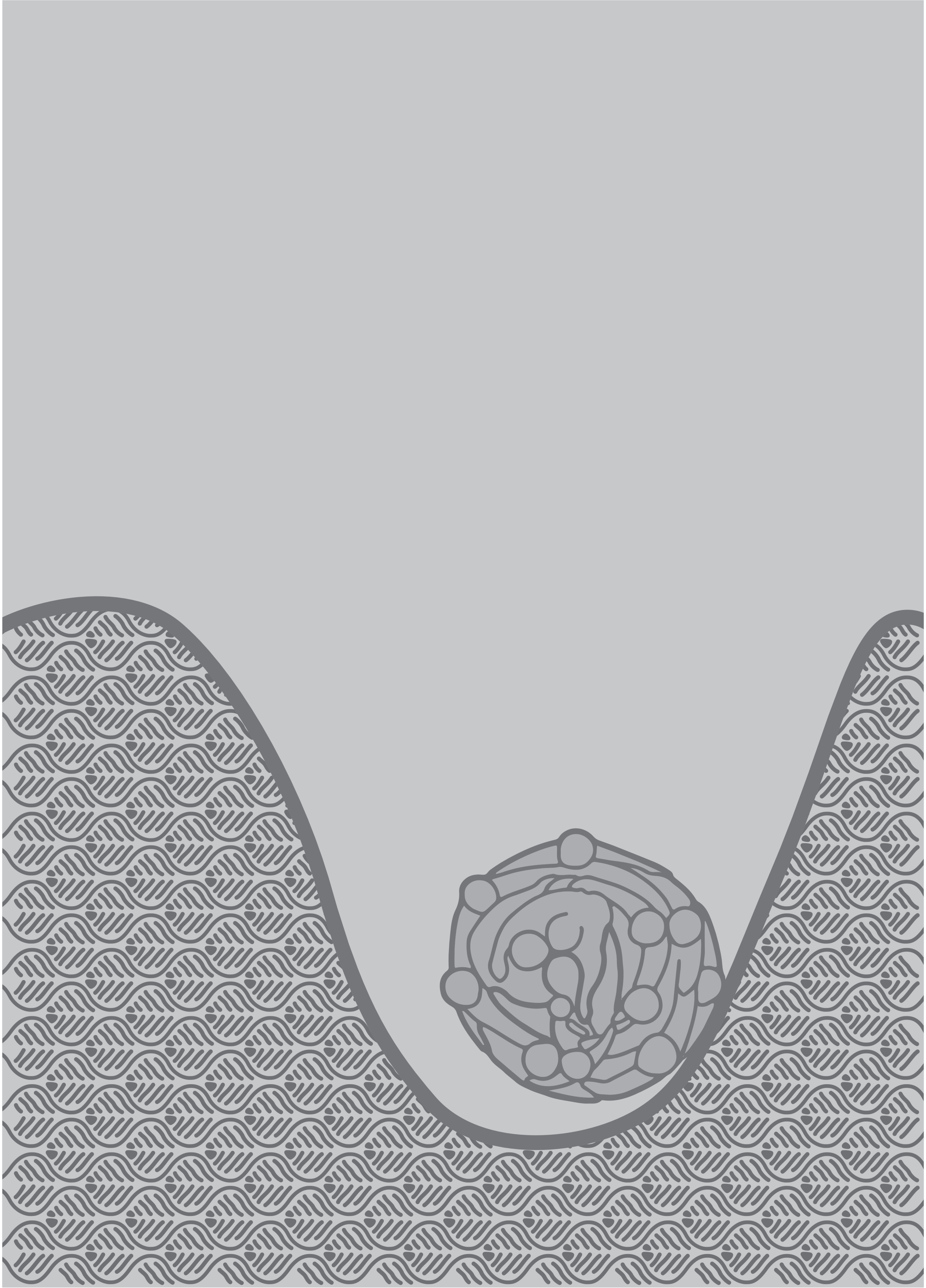
5.10 Declaration of interest

This paper is intended to disseminate research and practices about the production and utilization of roots, tubers and bananas and to encourage debate and an exchange of ideas. The views expressed in the paper are those of the authors and do not necessarily reflect the official position of RTB, CGIAR or the publishing institution.



Chapter 6
Synthesis and discussion

6.1 Introduction

This thesis has aimed to explore, in a multidimensional way, the role of human behaviour in shaping individual and collective livelihood resilience to covariate shocks. The research is based on two case studies: the case of rice smallholders cropping in flood-prone areas in Ecuador and that of smallholders facing Banana *Xanthomonas* Wilt disease threats in Rwanda. Each case study has similar components: smallholders (the main focus of the study), their livelihood systems, and a threat to their livelihood systems. The research focus was motivated by the fact that smallholders are, by number, and by agency the most critical food production (and consumption) global actors as well as the most vulnerable (Blaikie *et al.*, 1996; Fafchamps, 2010; Harvey *et al.*, 2014).

To tackle the multidimensionality of livelihood resilience in this research, I used the Adaptive Cycle as the theoretical spine to understand resilience. This framework focuses on people as the main actors of social transformation and resilience-building rather than ecosystems, technologies, or political-economical contexts (Alinovi *et al.*, 2010; Tanner *et al.*, 2015). In line with a pragmatic worldview, I integrate different theories and methodological tools throughout the chapters, based on the specific needs of the questions that emerged as the research progressed (Leavy, 2017). Therefore, this thesis explicitly worked with, and addresses, theoretical as well as methodological aspects.

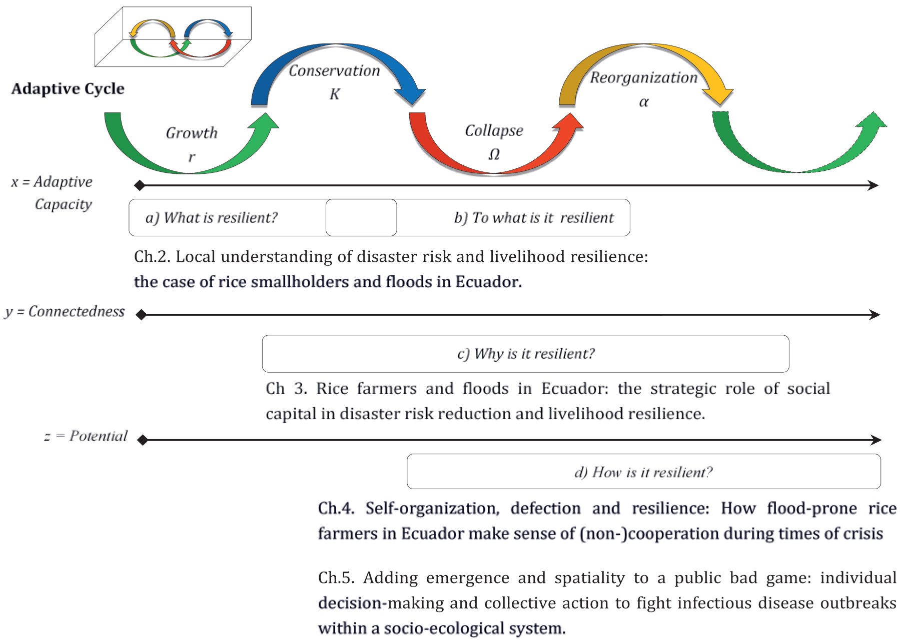


Figure 6.1 Conceptual framework, showing where the five main components of the research (resilience, socio-ecological systems, risk, social capital, and collective action) and the chapters are integrated (Holling, 2001a).

Figure 6.1 shows the conceptual framework based on the Adaptive Cycle (Holling, 2001). The research is organized accordingly to its different phases (growth, conservation, collapse, and reorganization) and dimensions (adaptive capacity, connectedness, and potential) to explore the links between smallholders' behaviour and their livelihood resilience. The research questions arose chronologically, inspired by the findings of the previous stages.

6.2 What is resilient; and to what is it resilient?

In chapter 2, I address Carpenter's *et al.* (2001) essential question: 'What is resilient and to what it is resilient?', posing the research question: *How does the local perception of risk shape collective (or re-organization) actions, in terms of function and expression forms, to face a covariate shock at the household and community level?* To do so, I developed a participatory risk assessment to better understand livelihood resilience from a local perspective, with respondents defining what is at risk, why it is important, and how should be measured. The focus is on rice farming communities settled on flood-prone areas. Initially, I thought that the questions *what is resilient* (the units or the system) and *to what it is resilient* (the disruptive event) would have a straightforward answer: the study units are the rice smallholders and their livelihoods, and the disruptive events are the floods. I found that peoples' perception of the disruptive effects of a flood in terms of the livelihood assets they consider relevant, was less simple than that. What were these livelihood assets, and how did smallholders evaluate their resilience? How should I make sense of their capabilities to cope with a shock? How should I characterize the disruptive power of these events? These questions reshaped my question to 'what is resilient and to what is it resilient from a local perspective?', as a fundamental first step to reflecting on the role of local perceptions in shaping self-organization and resilience-building.

In Chapter 2, I used a risk approach to an approximate local understanding of livelihood resilience (Mitchell and Harris, 2012). From a theoretical perspective, I explored how a disaster risk management lens can contribute to developing a systematic evaluation of locals' perception of risk management, and therefore resilience building (Mitchell, 2013). From a methodological perspective, I explored how a constructivist and participatory research approach contributes to characterize 'what is resilient?' from a vulnerability lens, and 'to what is it resilient?' from a hazard lens (Pelling, 2007). The outcome was the development of participatory risk assessment in which at-risk farmers defined the livelihood assets that I should evaluate, and the metrics I should use to measure and interpret their vulnerability to floods and the hazardousness potential of floods. The result is a scan of the at-risk situation of different communities and their livelihoods involved in the study. The degree of risk of being negatively affected by an above-average flood event

($Risk = vulnerability * hazard$) is expressed numerically and interpreted using a risk matrix, where 25 is the top value of very high risk. The results showed that 3 out of 6 communities were at very high risk, and the remaining ones at high risk. In addition, it unravelled that the meaning associated with different degrees of vulnerability was directly associated with local strategies to cope with a covariate shock. For example, cows were perceived as highly vulnerable to floods, especially when smallholders lacked the social networks to arrange for their housing on higher ground.

Based on the results and findings of this research, I suggest that the local characterization of risk and coping strategies might be used by decision-makers to design more accurate disaster relief management (DRM) plans, or implement them more effectively. The application of a participatory risk assessment at initial stages of DRM plans could offer baseline information, that could be translated into measurable variables and indicators, and lead to the design of evaluation tools suitable for larger samples.

Table 6.1 Local understanding of disaster risk and livelihood resilience: the case of rice smallholders and floods in Ecuador (summary of results from Chapter 2)

Research question	*How does local perception of risk shape collective (or re-organization) actions to face a covariate shock at the household and community level?*		
Objectives	To better understand livelihood resilience through the theoretical lens of disaster risk management.	To develop and apply a participatory resilience assessment, from a disaster-risk perspective, where users define what is at risk, why it is important, and how should be measured.	
Approach	A proxy evaluation of the resilience of peoples' at-risk livelihood by using the risk variables of vulnerability and hazard. The results are descriptive, quantitative, representations of qualitative data.	Methodology to design a participatory risk assessment. Users defined the at-risk assets to evaluate, their levels of vulnerability and characterized the hazard.	The assessment was based on participatory tools (focus groups, interviews, mapping, drawing and storytelling), applied through workshop sessions.
Findings	A participatory risk approach helped me to systematically identify household and community strategies that limit or enhance livelihood resilience.	Risk characterization and measurement based on locals' metrics resulted in an easy understanding and rapid engagement during the assessment application.	Drawings and storytelling were powerful tools to reconstruct past events and reveal overlooked coping strategies and the central role of social capital.
Implications	The local characterization of risk and coping strategies might lead decision-makers to design more relevant DRM plans, that will be more effective on the ground when implemented.	Its integration at initial stages of DRM plans could offer baseline information, that can be translated into measurable variables and indicators, and lead to the design of evaluation tools suitable for larger samples.	Identifying coping practices is challenging because those who carry them out overlook their strategic importance. Visual participatory tools can reveal to the researcher what are 'just normal practices' to the respondent.

6.3 Why is it resilient?

As shown in Chapter 2, despite the high degree of risk of being negatively affected by a serious flood event, communities continue cropping rice in flood-prone areas. This can be either interpreted as a healthy resilience because peoples' livelihoods continue providing those engaged in it a source of making a living. It can also be judged as a pathological resilience because the situation of high vulnerability to floods is continued (Allison and Hobbs, 2004). However, my purpose was not to determine either it is healthy or pathological, so my next question is *why it is resilient?* In chapter 3, I tackle this question by asking: *what are the critical factors, related to social capital, that contribute to the strengthening, weakening, or hindering of collective actions to prevent, respond, or prepare for a covariate shock?* My focus was on smallholders' strategies to face the floods and transit to a recovery stage. Therefore, I explore how a risk-resilience lens contributes to a better understanding of the role of social capital in resource mobilization. To do so, I develop a theoretical framework that built on resilience, risk, and social capital (Gunderson and Holling, 2001; Holling, 2001; Putnam, 2001; Baas *et al.*, 2008; Aldrich, 2017), and a tool to operationalize it.

I limited the analysis to coping strategies based on bonding and bridging social capital taking place during a flood event (Aldrich and Meyer, 2015; Aldrich, 2018). These were analysed in terms of the contribution that social capital made (or not) to risk management and resilience, through a (+/-) grading system that signified whether the effects were positive or negative. I found that local strategies had a mostly positive influence on the different livelihood assets in terms of potential (or the resources that people had available to respond to the situation). This result is reflected in the availability of resources, such as canoes, food, water, knowledge, skills, labour, and other resources, that different households have to exchange or share. However, most strategies have a negative effect in terms of connectedness (the degree to which people can control their and others' response actions and outcomes during a shock). This result is reflected in the limited availability of resources over time, which increases interdependence on external sources of resources.

The framework provided me with a general overview of the negative or positive effect that different strategies at different levels of social capital have on maintaining livelihood resilience. The results suggest, that the more (and more diverse) wealth [potential] within the local pool of resources for coping, the stronger the resource mobilization in facing shortages [respond]. In some cases, opportunistic resource mobilization strategies take place, leading to unhealthy resilience based on inequality, asymmetric power and corruption. Although I limited the framework to analyse the response-release phase, it could also be applied to other risk management-resilience phases: prevention-growth, mitigation-conservation, and recovery-reorganization. The results can inform decision-makers about how the mobilization of resources is influenced by social infrastructure and networks. Its usefulness lies in designing plans that (i) strengthen existing local strategies that promote healthy resilience, and (ii) prevent the normalization or flourishing of opportunistic social dynamics.

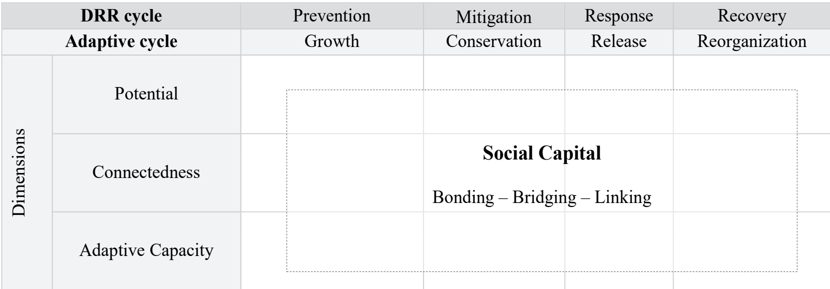


Figure 6.2 Conceptual framework to explore the role of social capital on Resilience and disaster relief? (Gunderson and Holling, 2001; Dynes, 2002; Baas et al., 2008; UNISDR, 2015)

Table 6.2 Chapter 3. The strategic role of social capital on disaster relief management and livelihood resilience: rice farmers and floods in Ecuador

Research question	*What are the critical factors, related to social capital, that contribute to the strengthening, weakening, or hindering of collective actions to prevent, respond, or prepare for a covariate shock?*	
Objectives	To explore the role of social capital in mobilizing peoples' resources during a covariate shock situation.	To develop and apply a conceptual framework that integrates the resilience and DRM concepts in order to show the strategic role of social capital in coping with shocks.
Approach	A conceptual framework that operationalizes adaptive cycle dimensions in terms of social capital functions to mobilize tangible and intangible resources to prepare, respond, or adapt to a covariate shock.	The systematized qualitative data was analysed by a (+/-) grading system, to signal if social relationships have a positive or negative influence on a healthy resilience building.
Findings	The framework found evidence of some forms of social self-organization, but these did not always contribute to healthy resilience. The more (distributed and synergic) wealth there is in the local pool of resources to cope, the healthier is the resource mobilization to face shortages. Lack of local resources leads to opportunistic social dynamics.	
Implications	The framework can also be applied to the phases of prevention-growth, mitigation-conservation, and recovery-reorganization. The results can inform decision-makers about how social infrastructure operates in mobilizing resources, strengthen the local strategies that promote healthy resilience, and preventing opportunism and corruption.	

6.4 How is it resilient? a shared-good perspective

The results and findings of Chapter 3showed that resources must be available and diverse at the household level to be locally-mobilized under equal and fair conditions through relationships based on bonding social capital. This means that local preparedness and social capital are essential (although not sufficient) to build resilience (Aldrich and Meyer, 2015). This understanding led me to the next question: how does livelihood resilience (operationalized as resource mobilization by means of social capital) work? In chapters 2 and 3, I observed social dynamics that could be labelled as non-cooperative when looked from an isolated perspective. This motivated me to explore in Chapter 4 smallholder's cooperative behaviour (or not) toward the production or conservation of strategical shared-goods to respond to a flood. Chapter 4 is limited to a social dilemma dimension through the research question: *How do smallholders make sense of their cooperative or defective behaviour in a shock situation, and; how does such a sense-making process link to their livelihood resilience?*

According to Tanner *et al.* (2015), individual and collective actions provide a solid foundation for self-organization, a critical strategy for rebounding from shock. However, collective actions are hindered by actions and choices based on self-interest, a situation known as social dilemmas (Kollock, 1998; Ostrom, 2000). As such, social-dilemmas play a role in self-organization, and subsequently, in resilience (Berkes and Ross, 2013). From a theoretical perspective, I explore the use of a social dilemma approach to understanding collective action problems related to community resilience as a collective attribute. Rather than testing behavioural theories, I aimed to better understand (un-) cooperative group-dynamics through the lenses of resilience and sense-making. From a methodological perspective, I explore the value of social dilemma games as qualitative tools, rather than as a behavioural prediction tool. Therefore, I designed a framed public good game to create a temporary experience of a social dilemma among participants and elicit self-exposure and collective sense-making during the subsequent focus group sessions (Kramer, 2016).

For practical purposes, I assumed that rice production is a desirable state for farmers (Tanner *et al.*, 2015), and chose to explore their behaviour toward the production or conservation of a community saving-box. This last can be considered as a collective action strategy to keep rice production running smoothly despite farmers' lack of access to formal credit (Jaramillo Moreno, 2015). In the social-dilemma game, rice farmers (who have belonged to a saving box in real-life for over 10 years) had to choose to either pay back a loan or not under different individual and collective shocks scenarios: no shock, domestic, price fluctuation, and flood. The results were fed back to farmers after the game (maintaining respondents' anonymity) and were used as a discussion topic in a focus group session. The focus was on collective sense-making of their individual decisions and its relation to real-life coping capacity as individuals and as a community.

The results from the game showed that 70% of players decided to pay over 75% of their debt when facing domestic shocks. However, such willingness to pay decreased markedly during the negative price fluctuations and flood scenarios. The focus group sessions indicated farmers were willing to repay at least part of the debt under individual shocks in order to be recognized as making an effort by their peers and possibly to access to support, which might be more important than the amount they paid back. However, under collective shocks, farmers' priorities change, and they need to have available (and diverse) resources to share and exchange to cope together with the ongoing shock. Supporting each other during a generalized shortage strengthens social capital, and comes before keeping the saving-box going, which can be recovered when the crisis is overcome.

At first sight, this decision to abandon a specific shared good seemed defective, yet under shock scenarios, it can represent the prioritization of maintaining other shared goods. In this case, resources needed to be available to cope with the shock through synergic cooperation, prioritizing other livelihood assets, such as access to food, water, and mobility, rather than the saving box. This shows the importance of acknowledging and understanding the rationally behind cooperation and the prioritization of the local 'commons' (that contribute to building resilience) under shock events in order design preventable loss strategies for relevant, but not prioritized commons. For example, if saving-boxes are not a priority under flood shocks, institutional mitigation plans could be designed to prevent the saving-boxes from disappearing and/or restoring them after the shock has passed.

Table 6.3 Chapter 4. Self-organization, defection, and resilience: How flood-prone rice farmers in Ecuador make sense of (non-)cooperation during times of crisis

Research question	*How do smallholders make sense of their cooperative or defective behaviour in a shock situation, and; how does such a sense-making process link to their livelihood resilience?*	
Objectives	To articulate smallholders' sense-making and social risk management strategies to collective action and livelihood resilience at the individual and community level.	To use, a social dilemma game as a tool to provide a temporary shared experience to participants, rather than as an experiment, followed by a focus group approach to draw out the sense-making process.
Approach	A conceptual framework to better understand the role of motivations in the conditions to cooperate toward the creation, or conservation, of strategic commons in order to cope with a covariate shock in the short and long run. The framework is operationalized in a 3-phase methodological strategy based on social-dilemma games, focus group discussions, and in-depth interviews.	The game is context-specific, using familiar scenarios (idiosyncratic and covariate shocks) and dilemmas. It creates temporary common dilemmas situations threatening a common good during a shock event. The results of the game are used on the focus group to explore the rationale behind individuals' responses and their implications for diverse commons. In-deep interviews were used to complement the sense-making process of different individuals.
Findings	In the case study, farmers emphasized that trust, reputation, and reciprocity were essential to access community support. Individuals strengthen these social capitals differently when facing idiosyncratic and covariate shocks. In the case of an idiosyncratic shock, farmers preferred to pay their debt to the savings box (at least partially) in order to conserve the goodwill of their fellows. However, in covariate shock situations, like a	

Chapter 6

Research question	*How do smallholders make sense of their cooperative or defective behaviour in a shock situation, and; how does such a sense-making process link to their livelihood resilience?*	
	flood, farmers preferred not to pay, but conserve as many resources as possible to share or exchange among community members in a synergic way. The creation of this 'common pool of coping resources' was more important than preserving the community bank, which could re-start after the crisis if cohesion and trust persist.	
Implications	The sum of individual contributions to produce a pool of resources to cope with a covariate shock (through sharing or exchanging of different forms of capital) expresses how community resilience is a shared-resource.	The proposed approach could serve as an exploratory stage previous to the design of laboratory or field economic games to frame the game more accurately and to decide among a wider range of variables of interest.

6.5 How is it resilient? a public bad perspective

In Chapter 4, I found that decisions and the sense-making of such decisions were the results of dynamically intertwined factors. Thus, those decisions are not only the result but also the cause of the emergence of different scenarios. In Chapter 5, I follow up the *How does resilience work?* by shifting my attention to the prevention and control of a public bad. I limit this broad interest through the research question: *How does the dynamic interplay of socio-ecological factors of a livelihood system influence household collective action to prevent or control a common threat to the resilience of farmers; livelihoods?* My research focused on controlling infectious diseases, which are (mostly) non-excludible and non-rival public-bads (Sonnemans, Schram and Offerman, 1998). Infectious diseases, in humans, plants, or animals, can have disastrous socio-economic and ecological consequences that threaten livelihoods (Wilkinson *et al.*, 2011). To prevent and control public-bad risks, such as infectious diseases, we need collective and coordinated actions (Beaglehole *et al.*, 2004; Leach, Scoones and Stirling, 2010; Yamey *et al.*, 2017; Asingizwe *et al.*, 2018; Damtew *et al.*, 2018).

According to the disease triangle approach, the risk of a disease damaging a host is a function of the interaction between the environment, host, and pathogen. This interaction is often determined by human activities that enable pathogens to disseminate and evolve, creating favourable conditions for diverse manifestations of infectious diseases (Scholthof, 2007; Mayer & Piezer, 2008, p. 3-14). These conditions are emergent, meaning that result of more than the sum of its parts, which are interdependent and dynamic, and therefore take place in a given space and time (Schlüter *et al.*, 2019). I integrate emergence and spatiality, both theoretically and methodologically, in my research design. My purpose is to use social dilemma games and simulation techniques, to study individual decision-making in interaction with SES factors that enhance or hinder the prevention and control of a public bad.

First, I build upon the SES framework originally introduced by Ostrom (2007), a framework for analysing a public-bad risk threatening livelihood resilience, in an SES context from a risk and collective action problem perspective (See Figure 6.3). Then, I develop a dynamic socio-ecological (DySE) game design methodology that takes into account what different human and non-human actors do in a given geographical space, time, and socio-ecological conditions. Next, I apply this methodology –the Musa game – to the case of banana smallholders in Rwanda, whose production is threatened by BXW disease. After that, I integrate the social dilemmas related to farmers' preventive and controlling actions to reduce the BXW disease damages, as well as the different scenarios on which we want to test such behaviours. Then, the methodology was tested with 48 farmers in Rwanda. Finally, the qualitative and quantitative results are analysed. I explore the value of spatial analysis in understanding social dilemmas and decision making linked to the emergence of socio-ecological conditions and to where and when these decisions took place. The Musa game was tested to assess its design (context accuracy, playability and receptivity), and to explore the analytical methods needed to analyse the quantitative results.

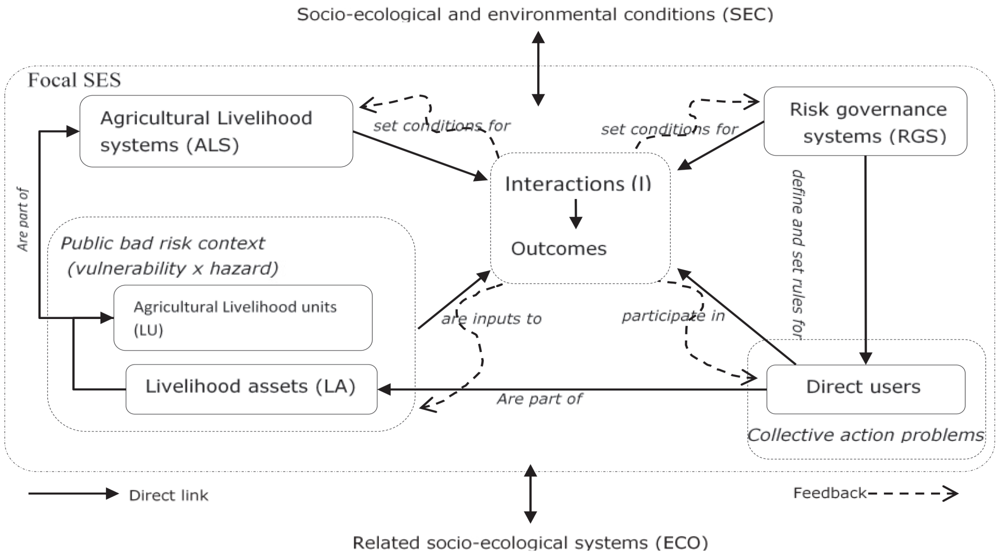


Figure 6.3 The core subsystems in a framework for analysing a public bad risk threatening livelihood resilience, in the context of a socio-ecological system using a risk and collective action problem perspective. Adapted from Ostrom (2007).

Chapter 6

Table 6.4 Musa game description

Feature	*Description*
Game settings	Four farmers play together on a board of 6x6 squares. Each square has one healthy banana mat. Each player owns one quadrant of the board (9 mats). They face risks, and social dilemmas, and must take actions under changing scenarios.
BXW-managing practices	To cut male flowers when the bunch is formed (to prevent infection through insectile vectors) and to uproot infected mats.
Threats	A BXW disease insect vector, that randomly looks for a flower to infect, until it finds one.
	A monitor, who randomly checks for infected mats, to control the spread of the disease by uprooting it (and the neighbouring mats).
Social dilemmas	When and where to cut male flowers
	When and where to uproot infected banana mats
Emergent and spatial factors	The playing rules of different game actors, combined with the positions and the order on which decisions take place, create emergent scenarios.
Time factor	Farmers play for up to seven rounds, during which time the banana mat can evolve from healthy to infected to dead.
Free-riding scenarios	Not investing in cutting flowers but not getting infected by the insect
	Not uprooting an infected mat and not being found by a monitor
Experimental treatments	Three different risk communication scenarios were employed: non-communication, communication before the first round (preventive), and communication before the first and fourth rounds (preventive and responsive).
Decision-making players	Farmers who in real-life belong to an extension program, and a control board of farmers who do not belong to such a project.

The results suggest that the more cooperative the players are in the early rounds (acting toward the centre of the board), the more equal are the profits among them at the end. Those who focused their disease prevention efforts toward the external border consistently ended up with the lowest benefits. All groups started the game cutting flowers toward the outer-border of the board, something farmers tend to do in real life. This created the conditions for banana mats in the centre to get infected and become a collective threat. The groups with two opportunities to communicate who, in real-life, belong to an extension project, uprooted most of their infected mats, followed by the groups with less or no-communication. Groups with two communication opportunities, but not belonging to the extension project, uprooted the least infected mats, and let them progress to death despite the institutional threat they represented. The results of the focus group discussions suggested that the motivation for cutting flowers toward the outer border was based on the belief that monitors were watching from somewhere outside the board (mirroring the real-life situation of monitors observing plots from the road). In addition, as plants became infected, mostly in the centre of the board, players kept the strategy of cutting flowers toward the external border to make sure their investment was done furthest from the infected mats (institutional threat). These findings indicate that communication without knowledge or coordination capacities is not enough to successfully act collectively, and that the institutional environment can create conditions that hinder collective action.

This framework and methodology allowed me to integrate the relevant livelihood units (human, plant, disease vector), the public-bad risk conditions (a disease, and agent, and the involved mechanisms), the threat (livelihood losses or fatality), and the strategies (based on coordination and cooperation) to prevent and control the public-bad risk into the analysis. Although I limited the use of the framework and the methodology to apply it to the case of a BXW disease, it is suitable to analyse resilience to other public-bad risks. The non-excludability and non-rivalry of a public bad is not necessarily the threat itself, which lies in the various direct and indirect potential socio-ecological consequences from its mismanagement. This can be extended to analysing the lack of collective actions to prevent or control other infectious diseases such as Malaria, HIV, COVID-19, disease, as well as non-infectious public health issues, such as gender-based violence, which are (mostly) non-excludible and non-rival public bads.

Table 6.5 Chapter 5. Adding emergence to a public bad game within a socio-ecological system context: collective action to fight an infectious disease outbreak

Research question	*How does the dynamic interplay of socio-ecological factors (host, vector, social actors, context) in a livelihood system influence households' collective actions that affect their resilience? What is the rationale behind the behaviour to prevent/control a common threat to their livelihoods?*		
Objectives	To better understand the role of social dilemmas and collective action in managing a public bad risk threatening livelihood resilience within a complex system.	To use experimental and simulation game techniques to study individual decision-making in interaction with SES factors that enhance or hinder the prevention and control of a public bad.	To explore the usefulness of spatial analytical methods to understand the dynamic relationship between the multiple playing socio-ecological factors, decision making and resilience.
Approach	A framework for analysing a public bad risk threatening livelihood resilience in the context of a socio-ecological system from a risk and collective action problem perspective (adapted from Ostrom, 2007).	A dynamic socio-ecological game design methodology, which adds the attributes of a SES and emergent phenomena. A context-specific game, the Musa game, to explore farmers' cooperation in preventing and controlling the spread of BXW disease.	The development of a computational program, the Musa analysis tool, to assist with analysing the game's results, that includes both decisional and spatial dimensions.
Findings	The framework allows the integration of the relevant livelihood units, public-bad risk conditions, threat and coping strategies, into the analysis.	Analysing the data spatially helped me to understand the role of other factors, such as technical knowledge, risk perception, social trust, and institutional trust influence decision making, collective action, and public-bad management. In addition, players found the game to be a powerful learning tool.	
Implications	The framework and methodology to operationalize the dynamic socio-ecological game can be used to understand the dynamics linking people's behaviour and resilience-building toward other public bads: infectious diseases, and other public-health / welfare problems.		

6.6 Discussion

In this thesis, my purpose was to explore the multidimensional links between human decision-making and the resilience of peoples' livelihoods. From a methodological perspective, I found that the integration of knowledge from multiple disciples and research methods were needed to explore such multidimensionality and to make sense of it. From a theoretical and practical perspective, I found that decision making toward achieving livelihood resilience, as a collective benefit, goes beyond social dilemmas. The ideal-typical example sketched in Text box 1 suggests that: coping capacity, risk perception, institutional setups, and social dilemmas guide peoples' decision making over what, among many options, should be protected or prevented, when, and how, whereby non-cooperative choices in one sphere may imply cooperation in another realm. In this section, I explore the transversal findings from the different chapters that help lead to this conclusion.

Text box 1 Stylized example where decision making goes beyond social dilemmas in a covariate shock context

A rice farmer perceives flooding as a high risk to his livelihood and considers that saving rice during the dry season (risk-perception) is prudent. He wants to repay his debt to the community saving-box during the flood (social dilemma) because he considers it is one of his only credit options, as he is unable to access to commercial credits (institutional setup). However, he produces his rice in a flood-prone area, lives in a high degree of poverty, and is trapped in an indebtedness cycle with an informal lender (reducing his coping capacity). He does not trust that the institutional emergency aid will sufficiently support his household during the flood period (institutional setup). The farmer might want to prepare by storing rice during the dry season to have food during in case of floods, but he needs to sell it all to

6.7 Social capital has a transversal role in resilience

The results contained in this thesis suggest that social capital plays a critical role in building coping-capacity through the synergic mobilization of resources (Sanyal and Routray, 2016). In Chapter 2, rice smallholders' strategies to preserve, protect, or restore their livelihood assets before, during, and after a flood, mostly rely on social mechanisms of mutual support (Aldrich, 2011, 2017). Although individual households' livelihood assets show a high degree of vulnerability to floods, social networks do increase their coping capacity. The survival of cows, major livelihood assets, depends on making strategic arrangements to house and feed them on higher (non-flood-prone) land, with friends or family members. Access to food and water for human consumption is secured through exchange and sharing mechanisms with neighbouring households. Mobility relies on social relationships with community members who own a canoe.

In terms of the *Adaptive Cycle*, we could say that social capital is the fuel that mobilizes the *potential* – the resources available to people to respond – of the system.

The role of social capital on mobilizing resources became clearer in Chapter 3, the results of which showed that local strategies had a mostly positive influence on different livelihood assets in terms of *potential*. This result is reflected in the availability of resources, such as canoes, food, water, knowledge, skills, labour, and other resources, that different households have to exchange or share. However, most of these strategies had a negative effect on *connectedness* – the degree to which people can control their own and others' response actions and outcomes during a shock (Abel, Cumming and Anderies, 2006; Young *et al.*, 2006). This result is reflected in the limited availability of resources over time, which increases interdependence on external sources of resources. The study indicated that the longer the shock; the stronger the need to rely on external actors. The loss of *connectedness* can create opportunistic relationships based on power asymmetries.

We can see that social capital plays a critical role in mobilizing the systems' *potential* (resources) across the different levels of social *connectedness* (control). The study provides some evidence that the more limited is the *potential* and *connectedness* at the local level, the lower the local *coping capacity*. At the same time, the role of social capital in supporting the resilience of livelihoods influences, and is influenced by, the local understanding of what needs to be resilient and when. In Chapter 4, we found that group identity, reciprocity, and trust play a leading role in individual decision making that has consequences for collective resilience (Aldrich *et al.*, 2010; Fehr and Gintis, 2007; Rand and Nowak, 2013). Although the smallholders involved in the study are aware of the importance of preserving a saving-box as a strategy to support rice production, they did not prioritize it under the covariate shock scenarios. Smallholders expressed the need to reserve resources during generalized times of crises, in order to reciprocally meet individual and community needs and to be able to rely on each other during the crisis. They trusted that the saving-box could be restarted when the crisis period is over.

6.8 Livelihood resilience is a joint good

Livelihood resilience, either healthy or pathological, is achieved through collective actions aimed at keeping the system functioning within the same regime (in this case rice production in flood-prone areas, banana production threatened by BXW disease) (Ireland and Thomalla, 2009; Kaganzi *et al.*, 2009; Aldrich, 2017). In Chapter 2, rice farmers' capacity to cope [adaptive capacity] with floods was based on strategies at both the household and community level. Resources such as water, food, canoes, and shared labour, were available to different degrees among community members. These assets constitute a pool of resources to cope [potential] with a generalized shortage through social mechanisms of sharing and exchanging [connectedness]. As such, smallholders' livelihood resilience to floods can be seen as a partial result of the synergy of different households' resources: a joint good. In dichotomic terms, producing or preserving this resilience requires collective action (e.g. through self-preparedness), while free riders can exhaust it, (e.g. by unethically profiting from aid). Resilience, achieved through preventing or controlling a public-bad, is also the result of collective actions. In Chapter 5, banana farmers' individual choices either created the conditions for a collective threat to emerge or to prevent it. Eradicating BXW disease is not feasible (up to now), in the game or in real life. However, through preventive collective actions, it is possible to minimize losses, contributing a joint good to all farmers, such as maintaining food security and their incomes.

A joint good can be understood as a good whose benefit is private, but 'whose attainment involves the cooperation of at least two (but usually far more) individual producers' (Hechter, 1988). It is difficult to exclude others from the benefits of joint goods, due to their physical nature, technology, laws, norms, or values (Ostrom, 1993; Kollock, 1998). In the context of smallholder farmers', it is difficult to exclude community members from the benefits of livelihood resilience (or the harm of its absence). For example, very few of the rice farmers threatened by floods own canoes, but everyone knows someone who does. The main coping strategies rely on synergic exchanges, and it is essential that those facing similar conditions of vulnerability comply with group expectations of cooperation. In the case of banana farmers, the lack of preventive and corrective actions against BXW disease can create the conditions for the disease to spread and cause the loss of plantations beyond one farmer's property. Banana is an essential source of food and income, and the loss of mats contributes to deepening poverty and hunger.

Understanding the benefits of resilience as a joint good allows us to acknowledge that each of us is a key player contributing to our collective capacity to bounce back from shocks and that we are interdependent. Minimizing free-riding is part of the process of building healthy and sustainable resilience, and frees up more resources to build a resilient and equitable society. From a policy-making perspective, this highlights how important it is to strengthen local coping capacities.

6.9 Risk perception and the institutional environment

According to Twigg (2009), a system that is more capable of managing risk (preparing, responding, and recovering) is likely to be more resilient. Risk perception is one of the leading factors in disaster risk management because it influences people's response to threats (Le De, Gaillard and Friesen, 2013; Shaw, Scully and Hart, 2014). Risk perception has received little attention in resilience studies, which rely more on tangible underlying 'determinant' factors: such as assets, livelihood strategies and financial and social capital. However, these studies usually recognize that more subjective factors have to be taken into account to understand the resilience of households and communities (Béné *et al.*, 2019). This thesis found that different perceptions of risk (that, for example, define what is at risk, what the threats are, how the vulnerability is expressed) shape or influence collective action, and thus resilience.

The results from Chapter 2 showed that the meaning of being vulnerable to a risk was directly associated with local strategies to cope with a shock. The more we know about local coping strategies and how they work, the more we can understand how to build endogenous resilience and what can outside agents do to support and complement this. For example, rice farmers said that owning a canoe decreases the vulnerability of different assets, such as access to food and drinking water, selling small animals at a fair price and access to health services (Chapter 2). However, local perceptions of the importance of canoes changed after the construction of some roads with institutional promises of accessibility despite floods. This led most farmers to sell their canoes (or the motors), and nowadays, few farmers own one (Chapter 3).

Chapter 4 showed that cooperation aimed at conserving a public good (the saving-box) was motivated by the perception of how vital it was during a collective crisis. Under individual shock scenarios, farmers considered that repaying their debt was very important in terms of access to credit and showing fellow members their willingness to be active members (which could have benefits later). But, during covariate shocks (price drops and floods), players reserved their resources to engage in coping strategies based on sharing and exchanging resources among households. Farmers acknowledged the need to rely on each other to cope with such shocks, as they expected any institutional aid to be inadequate.

Chapter 5 showed that decision-making toward the control of a public-bad risk (BXW disease) was influenced by perceptions of what and where was the threat (i.e. insect, a monitor, or a neighbour's decision). In the Musa game, all the treatment groups tended to cut flowers (to prevent infection) toward the external border of the board (less cooperative), but mostly uprooted infected plants indifferent to their position (cooperation). Farmers assumed the monitor was watching from somewhere outside the board (although this was not a game rule). In consequence, they tried to show themselves as 'good farmers following prevention measures' to the monitor, looking at their farm from the road. As a consequence, the banana mats toward the board's centre became infected (as they remained vulnerable for a longer time) and became a collective threat, especially if discovered by a monitor. As farmers wanted to prevent causing damage to their neighbours (through a monitor finding an infected mat and uprooting it and surrounding banana mats), they mostly chose to uproot it, irrespective of the location or the round. These findings match the institutional reality of Rwandan banana farmers, who are familiar with a hierarchical structure, with high levels of monitoring, and control. My findings align with other studies that highlight the role of trust in governmental risk managers on individuals' behaviour toward risk, which in turn also influences authorities' capacity to manage risks (Wachinger *et al.*, 2013; Sullivan-Wiley and Short Gianotti, 2017; Fancourt, Steptoe and Wright, 2020).

6.10 The iterative process of a mixed-methods design

As my research progressed, I found there was no straightforward way to identify the methods that would work best to answer my research questions. After a 'trial and error' process, I chose to use a mix of arts-based, qualitative, and quantitative methods. The results of my research suggest that the use of methodologies that elicit self-expression and awake participants' awareness of their actions and consequences provide information that helped me to understand what people do, why do they do it, and how it shapes their resilience. This led me to, explore concepts, theories, and methods from different disciplines. In Chapter 2, the use of drawing and storytelling were successful in to reconstruct past shock events, and identify coping strategies. The use of paper-based (Chapter 4) and dynamic socio-ecological (Chapter 5) social dilemma games, accompanied by focus group discussions, allowed respondents to make sense of their decisions and relate them to with the ways they maintain the resilience of their livelihoods. Table 6.6 shows a summary of the methods applied in the different chapters and the contributions that they made.

Table 6.6 research methods approaches and methods applied in Chapters 2, 3, 4, and 5

Approach/method	*Arts-based*	*Qualitative*	*Quantitative*
Chapter 2	1st. Individual drawings revealed coping strategies, that might otherwise have been overlooked.	2nd. Storytelling (based on the drawings) elicited a collective reconstruction of past events.	3rd. Transforming qualitative codes characterizing vulnerability and hazard into quantitative variables of risk.
Chapter 3		1st. Coding qualitative strategies in terms of social capital (relationships) and livelihood assets allowed the date to systematize.	2rd. Quantitatively assessing social capital strategies as positive/negative allowed me to identify/compare strengths/weaknesses in resource mobilization.

Approach/method	*Arts-based*	*Qualitative*	*Quantitative*
Chapter 4	1st The social dilemma game offered a temporary shared experience and elicited a metacognitive experience from players.	3rd Game experience and exposure of results enriched collective sense-making of cooperation under shock in the focus groups.	2nd Exposure of game results informed players about the collective consequence of their decisions.
Chapter 5	1st Adding a spatial dimension, autonomous players, and emergence in the game elicited a metacognitive experience from the players/ farmers.	3rd The focus group discussions added meaning to players' decision making, contributing to my interpretation of the spatial statistical analysis.	2nd modelling a public-bad risk as SES in a board game served as a representation of bio-physical structure to apply a social-dilemma experiment focused on risk communication.

In Chapter 2, I first attempted to understand how the vulnerability in peoples' livelihoods through in-depth interviews. However, there was a mismatch between what was self-evident or irrelevant to them and me. I found that research in public health issues dealing with chronic conditions (HIV, cancer, diabetes, posttraumatic stress) had vast experience in using drawings and storytelling to disclose information that was otherwise overlooked (Guillemin, 2004; Talwar, 2007; Theron *et al.*, 2011, p.42; Duncan, 2013). Given the opportunity, individuals made drawings of things that they would not instinctively talk about, such as the chickens in the roof, the pigs in cane floating structures, or how floods change the landscape. The storytelling shared sessions helped them as a community to put together the pieces of the story reflected in their drawings and helped me as a researcher to identify the transversal role of social capital. The identification of coping strategies showed that they were linked with expressions of vulnerability.

Chapters 4 (the saving-box game) and 5 (Musa game) show that the use of social dilemma games combined with focus group discussion (FGD) are useful tools to deal with sensitive topics, such as the role of self-interest, the institutional set-up, perception of risk, knowledge, and other factors, in a self-exposed way. In Chapter 5, integrating emergence and spatiality to a public-bad game contributed to a better understanding of how the biophysical environment and individual choices are intertwined and how they shape resilience at the individual and collective levels. Playing a game together prior to an FGD offered players a shared experience, triggering their thought processes around real-life situations, and together make-sense of how these individual decisions contribute to collective resilience (Wilkinson, 1998; Chater and Loewenstein, 2016). Participants in both studies expressed the games had a powerful learning effect about the interconnectedness of their decisions, as well as technical aspects (García-Barrios *et al.*, 2017)

This thesis suggests that the shared experience elicited through playing games, drawing, and storytelling, contribute to awakening individual and plural self-awareness, which are critical conditionals for pursuing collective actions (Kwon, 2008; Bicocchi *et al.*, 2013; Schmid, 2014). These approaches could serve as participatory preliminary steps to encourage at-risk people to engage in working together in risk management plans, which is essential to design local-oriented policies. These research approaches can also serve to inform and build-up sharper prediction tools, which could be a follow-up step to this research. From a methodological design perspective, I found that the mixed methods approach required access to end-users for contextualization and validation, theoretical and methodological contributions from different disciplines (primary and secondary sources[5]), and willingness to go through an iterative process[6] (García-Barrios, Perfecto and Vandermeer, 2016).

6.11 Preventing a public bad and protecting a joint good are not two sides of the same coin

In summary, my thesis results suggest that collective action toward the prevention of a public bad, or production of a shared good is dynamic and interplays with other factors. Social dilemmas, coping capacity, institutional environment, and risk perception, together with biophysical factors, shape individual and collective actions toward resilience building. However, the recent experience with COVID suggests that preventing a public-bad through collective action does not contribute to protecting a joint-good by default. To exemplify, I elaborate on two intertwined public health problems: the case of COVID-19 and the rise of domestic violence. In both cases, the lack of collective response has collective consequences, such as the collapse of health systems and a socio-economic burden to society. While reducing mobility is a measure that reduces the speed of COVID-19 spread, it also increases children's and women's vulnerability to domestic violence due to higher exposure to perpetrators.

In the case of COVID- 19, Goldstein and Wiedemann (2020) assert that higher levels of social and institutional trust will have a successful impact on the containment of the COVID-19 pandemic. Bargain and Aminjonov (2020) found that human mobility declined significantly stronger in high-trust regions (19 European countries sampled) around mid-March 2020, indicating that compliance is better in regions where citizens trusted policymakers before the crisis. Benítez *et al.* (2020) analysed responses to the COVID-19 outbreak in Colombia, Ecuador, Chile, Peru, and Brazil, and found low levels of compliance in mobility reduction, ranging between 20% and 60%

[5] To design the dynamic socio-ecological game, the Musa game, and the Musa analysis tool, I collaborated with researchers in the fields of ecology, serious games, economic games, maths and programming, plant sciences, communication, risk, as well as local key actors.
[6] The implementation of the dynamic socio-ecologic game started in 2017. I explored the Malaria and Potato wilt disease contexts, before contextualizing it as the Musa game. It was possible thanks to collaborative work with the EVOCA project 'ICT and citizen science for Banana Xanthomonas Wilt (BXW) control and prevention in Rwanda' (Conducted by Mariette McCampbell from 2018 onwards).

in different regions. They argue that the pre-pandemic socio-economic context and trust in authorities played a critical role. On the one hand, the lack of a comprehensive management plan, lack of transparency in communication, censorship, and authoritarianism are some of the characteristics of these five countries anti-pandemic measures. On the other hand, the pre-pandemic levels of poverty, economic informality, and crowdedness create wellbeing dilemmas.

Domestic violence refers to violent behaviour within families, either sexual, psychological, or economic (Piquero *et al.*, 2020). Child abuse and intimate partner violence rise are not restricted to the current COVID-19 pandemic times (John *et al.*, 2020). In Hubei, China, police stations reported a tripling in domestic violence reports in February 2020 during the compulsory quarantine (World Health Organization, 2020). An increase in women and girls experiencing sexual abuse, coercion, and exploitation have been reported during other crises that restrict mobility, such as the outbreak of Ebola in West Africa, were quarantine measures were enforced between 2014 and 2016 (John *et al.*, 2020). Isolation measures, negative coping mechanisms, and psychological and economic stresses can come together in a perfect storm to trigger family violence (Van Gelder *et al.*, 2020, in Usher *et al.*, 2020). A pre-pandemic low public trust in authorities and institutions to prevent and combat domestic violence, paired with a lowered institutional capacity to respond, add strength to the storm. As femicide rates are increasing during lockdown times in countries as Turkey[7], Spain[8], England[9], Argentina[10], Mexico[11], and Ecuador[12] (Lund, et al., 2020; Al-Ali, 2020), authorities are calling family, friends, and neighbours to provide support: “if you see something, say something” (Mahase, 2020). However, providing such support is a social dilemma, as 20% of victims of family violence are third persons trying to intervene (Campbell, 2020).

As the above example on the interrelations between the COVID pandemic and domestic violence suggest, social dilemmas, coping capacity, risk perception, and institutional setups influencing individuals’ choices in an intertwined way toward resilience of different shared goods and bads. More research is needed to understand how public-bad preventions and joint-good protection are intertwined. This is fundamental knowledge that is needed to design policies to build healthier multidimensional resilience.

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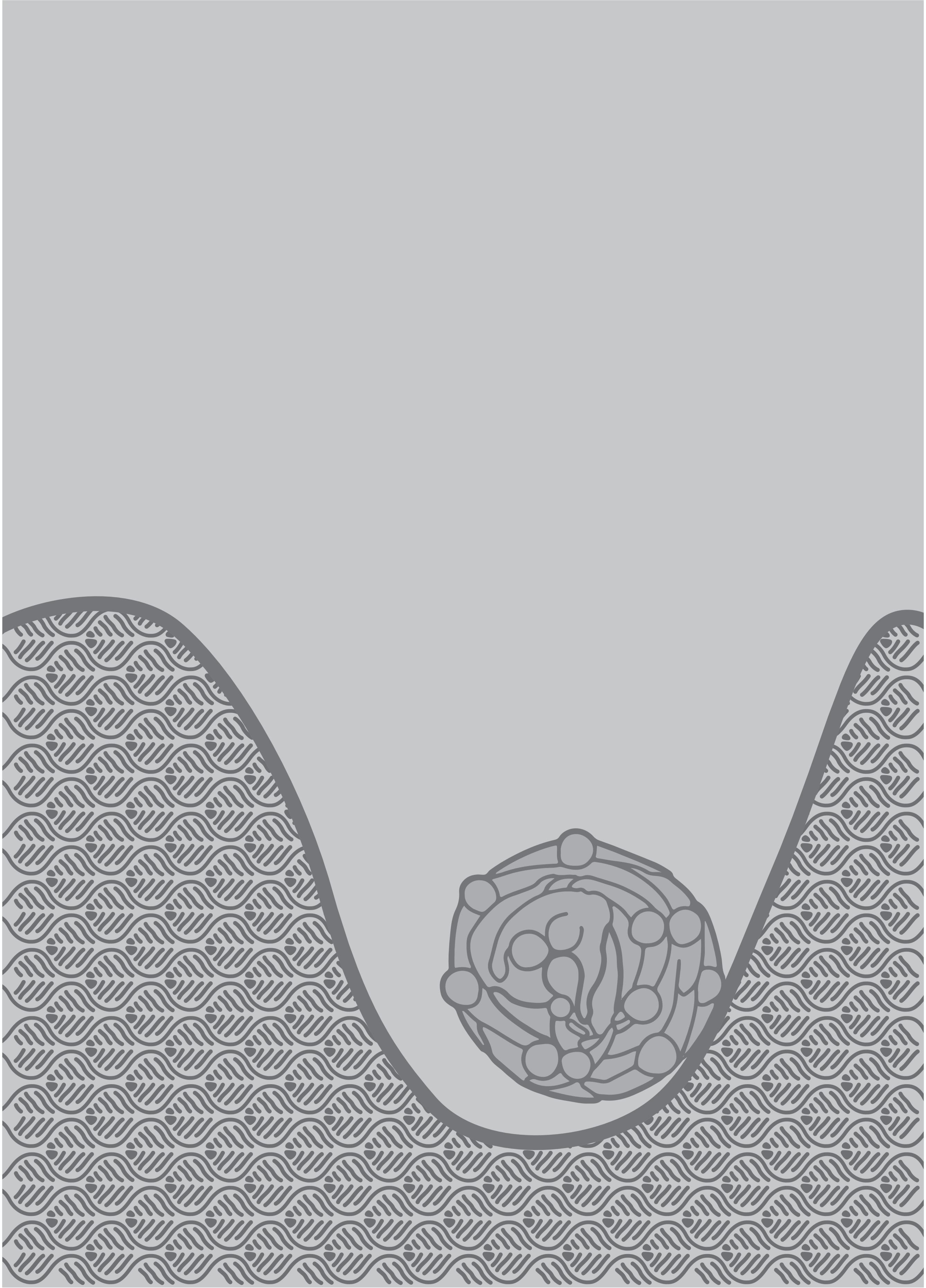
7 https://en.qantara.de/content/covid-19-pandemic-coronavirus-breeds-domestic-violence-in-turkey
8 https://www.theguardian.com/global-development/2020/apr/28/three-women-killed-in-spain-as-coronavirus-lockdown-sees-rise-in-domestic-violence
9 https://www.cbsnews.com/news/domestic-violence-uk-coronavirus-lockdown-3-times-higher-than-average-data-shows/
10 https://www.reuters.com/article/us-health-coronavirus-women-trfn-idUSKBN22V05H
11 https://edition.cnn.com/2020/06/05/americas/mexico-femicide-coronavirus-lopez-obrador-intl/index.html
12 https://www.eluniverso.com/noticias/2020/08/30/nota/7959442/encierro-despidos-crisis-economica-pandemia-covid-19-incidieron

6.12 Final reflections

The purpose of my research is to achieve a better understanding of smallholders' rationale behind cooperation under a shock scenario and its relation to their current livelihood resilience at a household and community level. Livelihood resilience is multidimensional, and therefore defection toward one of its dimensions does not mean a full defection but might mean shifting cooperation toward a different one. Defining a livelihood system requires identifying the tangible and intangible assets that compose it. In the same way, those who make a living from those livelihoods prioritize individual efforts that protect those strategic assets, either tangible or intangible, that are essential in times of generalized crisis. The sum of those individual efforts shapes collective livelihood resilience. Therefore, cooperation and defection are limited conceptual solutions to understanding decision-making in the context of livelihood resilience and covariate shocks. The results of this thesis suggest that risk perception, coping capacity, the institutional environment, and social dilemmas intertwine to influence individual choices, that together with biophysical factors, shape livelihood resilience in a dynamic and emergent way.



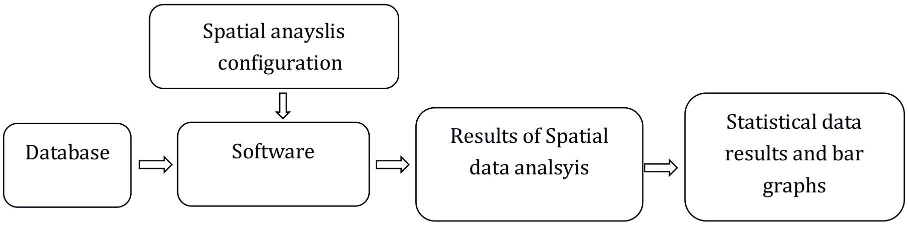
Appendices

Appendix A – from chapter 5

The Musa analysis tool

Software design by John A. Galarza Villamar

The Musa analysis tool is a software program written in the C# programming language. It is a tool that was developed for the analysis and interpretation of data obtained during field experiments with the Musa game. The program has four parts: an interface for loading information from a file with an [.xlsx] extension, a panel that uses a colour code to display the data, a form-type interface for selecting the type of spatial analysis in combination with the type of actions of the participants to be analysed, and a section of bar graphs to display the numerical interpretations of the results obtained from the selected analysis (Figure 1). The main objective behind the development of this program was the need for a customizable, compact, and easy-to-use tool for processing and analysing the experimental data.



The variables analysed in the experiment are the decisions made by participants, which consist of three possible actions: Cut Flower, Uproot Yellow Mat, Uproot Red Mat. These decisions are causal and are directly related to the rules of infection of the mat within the experiment. The appearance of an infection is the resultant of the conditions created by a combination of specific variables and game movement rules. At the same time, the objective is to observe only specific variables of interest, namely the decisions made by a game participant.

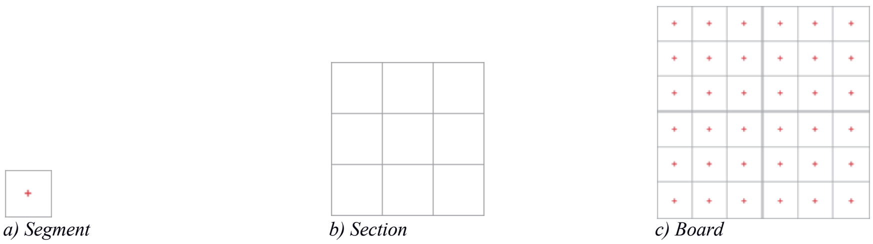


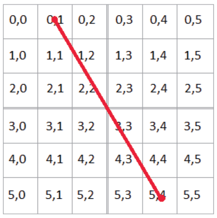
Figure 1 Board components used for software development, where a board has 4 sections and a section has 9 segments.

The data is collected on a flat and uniform 6 x 6 segment board, that is divided into four sections that are assigned to the 4 participants. In order to simplify calculations, we assume that each segment corresponds in size to a 1 x 1 unit of distance. Likewise, its point of interest will be in the central position of each segment, 0.5 units in X and 0.5 units in Y with respect to the upper left corner of each segment. In calculations, the notation used for the position of each segment corresponds to its location by row (R) and column (C) according to the displayed matrix (Figure 2). The expression of the general position of each segment is GP= (R - 1, C - 1), where R and C are values between 1 and 6. However, to take the centre of each segment as the position of interest for a calculation the expression is: PI= (GP_x + 0.5, GP_y + 0.5).

0,0	0,1	0,2	0,3	0,4	0,5
1,0	1,1	1,2	1,3	1,4	1,5
2,0	2,1	2,2	2,3	2,4	2,5
3,0	3,1	3,2	3,3	3,4	3,5
4,0	4,1	4,2	4,3	4,4	4,5
5,0	5,1	5,2	5,3	5,4	5,5

Figure 1 notation used for the position of each segment

Example 1. The distance between two random points A and B, located at the position GPA (0,1) and GPB (5,4), will be given by $D = \sqrt{(PI_{Ax} - PI_{Bx})^2 + (PI_{Ay} - PI_{By})^2}$

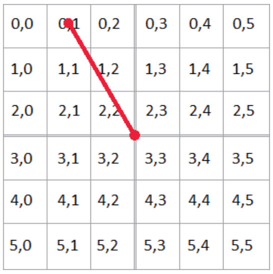


$$D = \sqrt{((0 + 0.5) - (5 + 0.5))^2 + ((1 + 0.5) - (4 + 0.5))^2} = 5.83$$

Figure 2 example 1, distance calculation between two random points PGA (0,1) and PGB (5,4).

For measurements between a random point and the centre of the board, the central point (Pc) is taken as a reference and expressed as Pc: (R / 2, C / 2). The central point is a position of interest for measurements because it represents the only position on the game board where the board sections of all four players meet, and hence decisions of each player near the central point can directly affect the other players in the game.

Example 2. The distance between a random point A located at PGA (0,1) and the central position (Pc) for a 6x6 board, where Pc = (6/2, 6/2) is given by $D = \sqrt{(PI_{Ax} - Pc_x)^2 + (PI_{Ay} - Pc_y)^2}$



$D = \sqrt{((0 +.0\,5)-\ 3)^2 + ((1 +.0\,5)-\ 3)^2} = .2\,91$

Figure 3 example 2, distance calculation between a random point PGA (0,1) and Pc.

Each distance measured in the experiment corresponds with a distance between a PI (Point of Interest) of a segment(corresponding with the player's actions), and a PI of a second segment (corresponding with a direct value of the board) in one moment in time (Game Round), or the Pc position (Centre position).

Said measurements are normalized to a scale of values between 0 and 1, meaning a value of 0 for positions outside border of the board, and 1 for the position that is exactly in the centre of the point of interest/segment, which is taken as a reference for the measurement.

We call the distance given in values between 1 and 0 the normalized distance or Dn, which is given by $Dn = \frac{(Dm-D)}{Dm}$, where Dm is the value of the maximum possible distance between two ends of the board, which is the direct result of the maximum diagonal distance of the board $Dm = \sqrt{R^2 + C^2}$, except for calculations where the only reference is the Central Position (Pc), in which case Dm has the value of the maximum distance between two points of interest of one of the sections of the board, which is maximum half the diagonal of the board $Dm = \frac{\sqrt{F^2+C^2}}{2}$.

For practical reasons, the round values of 1 and 0 will are be represented for normalized distance (Dn) in the real measurements. Given the rules of the game, these values are impossible. The minimum possible value (Vmnp) will be given by $Vmnp = \frac{\sqrt{R^2+C^2}-\sqrt{(R-1)^2+(C-1)^2}}{\sqrt{R^2+C^2}}$, and the maximum possible value (Vmxp) will be given by $Vmxp = \frac{\sqrt{R^2+C^2}-1}{\sqrt{R^2+C^2}}$. Likewise, the Vmnp and the Vmxp when the only reference is the Central Position will be $Vmnp = \frac{\sqrt{R^2+C^2}-\sqrt{(R-1)^2+(C-1)^2}}{\sqrt{R^2+C^2}}$ and $Vmxp = \frac{\sqrt{R^2+C^2}-\sqrt{2}}{\sqrt{R^2+C^2}}$. Since the value of 0 is not possible in the calculation, it has been reserved for distance measurements that do not meet the action criteria between both points. That is, one of the points of interest within the measurement does not exist.

Measurement methodology

For the experiment, there are eight states of the banana mat that are represented by codes: Dead (5), Intervened (6), Green Flower (1), Green (2), Yellow (3), Yellow Uprooted (31), Red (4), Red

Uprooted (41), which for purposes of interpretation were catalogued using the following colour codes.

Figure 4 Card colours codes as used in the software. Note that the Green with flower refers to the White card in the game.

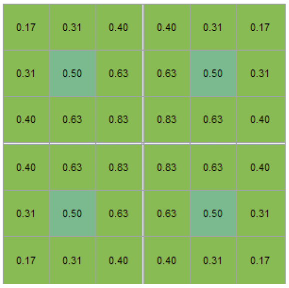


Figure 5 Example of the Initial state of the board game in the Musa analysis tool. It shows the values of the Normalized Distance (Dn) of each segment concerning the Central Point (Pc) of all types of card stages for a board in the initial round.

As mentioned, the events of interest for the analysis are the actions of the players, thereby considering the circumstances on the board when such a decision is made. The actions of the players to consider were: Cut Flower, Uproot Yellow Mat, Uproot Red Mat. Likewise, the events occurring randomly or controlled by game rules were considered, namely: New Yellow Mat, New Red Mat. These events were identified through an algorithm. It compared the board conditions from one round with another round and then quantified and grouped these by their Normalized Distance (Dn) in different analyses.

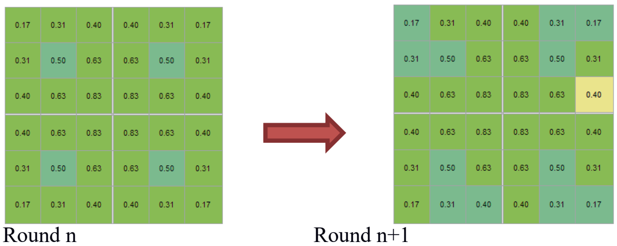


Figure 6 Example: 6 Green Flower mats changed to Green (6 Cut Flower actions). 1 Green Flower Mat changed to Yellow (1 New Yellow Mat event), measurements relative to the centre.

To analyse the distance under specific circumstances, the dashboard has values for as long as there is at least one location that serves as a reference or measurement centre for the other dashboard segments. For example, distances from a yellow mat. All the segments have numerical values that represent their respective normalized distance (Dn) compared to the variable of interest (Yellow Mat). The location of the Yellow Mat has a value of 0 because there is no second Yellow Mat from which it could obtain its distance value (Figure 19). For investigation and analysis of data, employing the software, all the possible analysis variables were parameterized to allow selection of different combinations and observe possible trends in the results these combinations give (Figure 20).

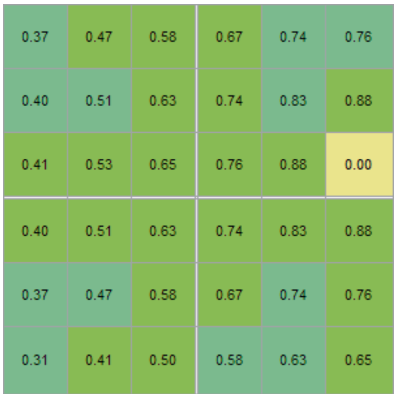


Figure 7 example of numerical values and their respective normalized distance (Dn) compared with the variable of interest (Yellow Mat).

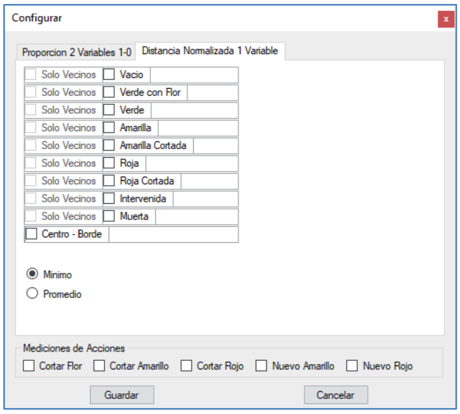


Figure 8 panel of options for analysis configuration

As a practical example, for the spatial analysis of distance, the software is be configured to consider the action to cut flowers. This action is the central reference to measure distances to the Yellow Mat or Red Mat segments only in neighbouring sections. The minimum distance was selected to control for cases in which there is more than one Yellow or Red Mat (Figure 10).

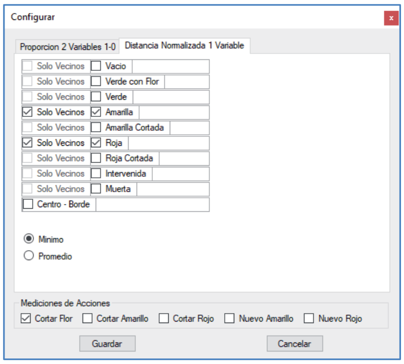


Figure 9 Data analysis configuration window for the example

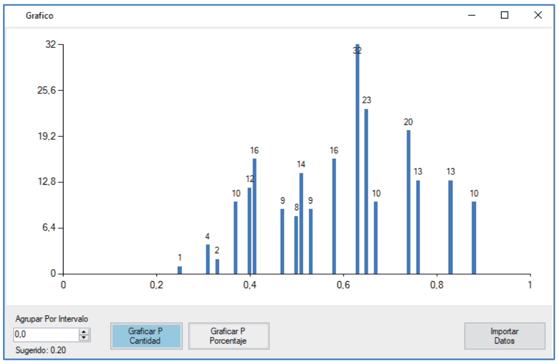


Figure 10 Results based on the configuration of Figure 10

In the graph (Figure 11), the axis Y shows the number of Cut Flower actions that players made and the axis Y shows the Normalized Distance (Dn) between 0 and 1 in relation to a diseased mat when making the decision to cut flowers.

Table 1 number of decisions made at different normalized distances (Dn)

Normalized Distance (Dn)	***Decisions***
0,25	1
0,31	4
0,33	2
0,37	10
0,4	12
0,41	16
0,47	9
0,5	8
0,51	14
0,53	9
0,58	16
0,63	32
0,65	23
0,67	10
0,74	20
0,76	13
0,83	13
0,88	10

We can see that there is a uniform distribution in the example results (Table 1). However, due to the nature of the calculation, the are distances among them that are very similar. For example, distances such as 4.0 and 4.1 or 0.50 and 0.51). For practical reasons and to simplify data analysis these values can be grouped.

To group data, a uniform distance interval is defined for the data of the variable that is to be analysed. In this particular case, it will be the distance to which all the sampled distance values will approximate. These are defined as Values close to the interval (Vi) and given by $Vi = Round\left(\frac{V}{I}\right) * I$, where V is the real value, and I is the selected interval.

Table 2 Example: Values Close to Interval (Vi) of Normalized Distances (Dn) obtained, for an interval of 0.1.

Normalized Distances (Dn)	*Values Close to Interval (Vi)*
0,25	0,3
0,31	0,3
0,33	0,3
0,37	0,4
0,4	0,4
0,41	0,4
0,47	0,5
0,5	0,5
0,51	0,5
0,53	0,5
0,58	0,6
0,63	0,6
0,65	0,7
0,67	0,7
0,74	0,7
0,76	0,8
0,83	0,8
0,88	0,9

Table 3 Decisions Grouped by Vi

Values Close to Interval (Vi)	*Decisions*
0,4	38
0,5	40
0,7	53
0,8	26
0,6	48
0,9	10
0,3	7

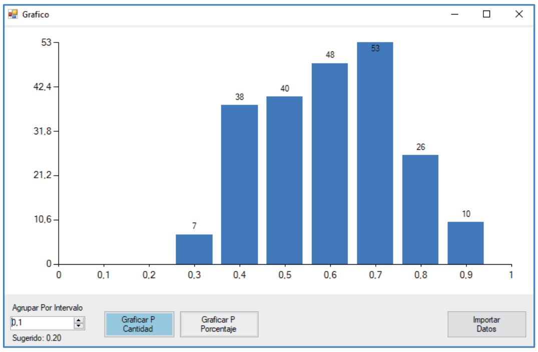


Figure 11 Graph of grouped results with an interval equal to 0.1

Since the interval value can be very relevant in the analysis, an optimal interval value for the data pool can be calculated. For this purpose, an empirical value is calculated defined as Maximum Interval Value (Vim). The Vim is the quotient of the arithmetic mean of the distances between the Values Near the Interval (Vi) and the Real Value (V), and the selected interval (I), $Vim_I = \frac{\left(\frac{2}{I}\right)\sum_{k=0}^{n}|Vi_k - V_k|}{n}$, where Vi is the value close to the interval I, V is the actual value, I is the selected interval value, and n is the amount of data.

With the initial results obtained through the calculations done as exemplified by Figure 12 as input, the Vim values for the intervals (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9) are calculated (Figure 13). For these interval values, we discard all those in which the number of intervals contained in the range from 0 to 1 is less than or equal to 1 since for these the grouped values would give the lowest possible resolution and would not have a significant value for the analysis. The Contained Intervals (Ic) will be given by, $Ic = Floor\left(\frac{1}{I}\right)$, where I is the selected interval.

Table 4 Contained Intervals (Ic) values for the intervals (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9)

Intervals	*Contained Intervals (Ic)*
0,1	10
0,2	5
0,3	3
0,4	2
0,5	2
0,6	1
0,7	1
0,8	1
0,9	1

Ic values less than or equal to 1 are discarded because the only suitable Interval values for this analysis are the intervals: 0.1, 0.2, 0.3, 0.4 and 0.5. When calculating the Vim values for these intervals we get:

Table 5 Calculated Vim values

I	*Vim*
0,1	0,511
0,2	0,533
0,3	0,481
0,4	0,444
0,5	0,511

Therefore, when looking for the highest possible uniformity in the distribution for the grouped data, the VI value closest to 0.5 will belong to an interval of best-distributed data. Other statistical criteria could be considered for the selection of a grouped interval for the data, such as the standard deviation of the values with respect to the interval, the selection of the minimum possible interval, the minimum amount of data grouped in the said interval, among others.

Selecting 0.2 as Interval, we can observe in the following graph a distribution similar to the 0.1 intervals. The difference with figure 12 is greater visibility of possible trends, which is useful for analysis.

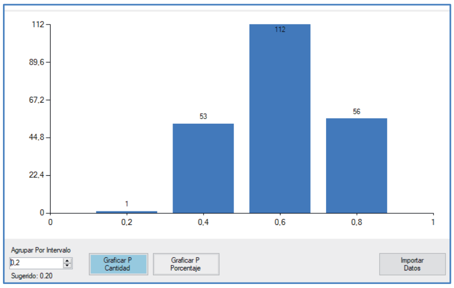


Figure 12 distribution example with an interval of 0.2

Despite observing a trend in the results, the data of these random events must be contrasted with the actions taken. That is, comparing the event (action) with the participant's decision (reaction). This contrast is necessary because the trends observed from a single analysis might be caused by a rule intrinsic to the game and not the players. Therefore, in the second example, two analysis configurations are performed. The first to get the appearance of Red and Yellow Mats on the board in relation to a Neighbouring Mat with Flower. The second analysis is to obtain the number of Red and Yellow Mats that were uprooted in relation to a Neighbouring Mat with a Flower (Figures 14 and 15).

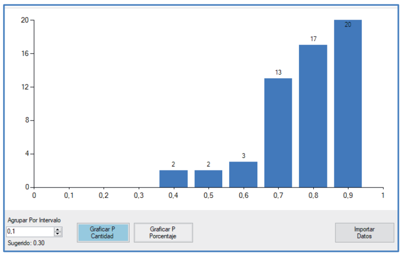


Figure 13 Appearance of Diseased Mats in relation to Healthy Mats

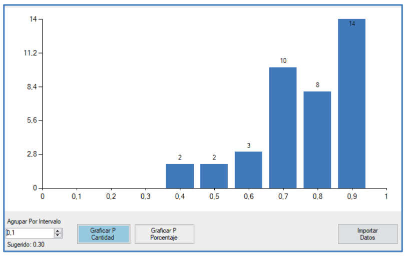


Figure 14 Cutting of Diseased Mats in relation to Healthy Mats

When comparing the results, an increasing trend of uprooting actions in relation to distance is visible which is similar in both graphs and is caused by the appearance of diseased mats (Red or Yellow) (Random Variable). However, by contrasting the information obtained, we can observe a higher frequency in the decision-making of uprooting diseased plants in the farthest distances from the Healthy Plants.

Appendix B – from chapter 5

Consent form for game experiment "The Musa game" (Adapted version in English)

Researchers: Mariette McCampbell, Julissa Villamar Galarza, Knowledge, Technology and Innovation group, Wageningen University

Purpose of the research

The research that we ask you to participate in is an experimental field board game about the decision making of Rwandan banana farmers about management of Banana Xanthomonas Wilt (BXW/Kirabiranja) disease. This research activity is part of the ICT4BXW project, that is implemented by the International Institute of Tropical Agriculture (IITA) in collaboration with RAB in Rwanda.

What we expect from you

You will be playing this game together with three fellow banana farmers from your village. Each of you has been randomly selected to participate in this game. Your participation in this research is voluntary. Before playing the game we would like to ask you a number of questions about you, your banana farm, and your experience with BXW management. After the game we would like you to participate in a group interview, together with the other players. The questions will be about the game itself, if you learned things from playing the game, and if the decisions and events in the game were similar or different to your real-life experiences as banana farmer.

Storing and use of data

We collect digital surveys, audio, and video files from this research. The audio and video will only be used for research purposes, and not be shared outside the project. We use the data collected during the game activity for research purposes, it can be used for publications, but also to inform further studies, activities of the ICT4BXW. Your data will be stored in a secure database, and anonymized before making it open data.

Taking part in the study

When you sign the consent form it means that you agree that: You have received and understood information about the research project and the experimental game. You were able to ask a question about the research and they were answered to you. Your participation in the research is voluntary, and you can refuse to continue or withdraw at any time without having to give a reason, until data collection and analysis has been finalized. You understand that participating means playing the experimental game, being observed during the game, and being asked to answer questions about your experiences. Photos may be taken. The game will be recorded on video, only capturing the game board and the actions on there. The group interview will be audio recorded.

Use of the information in the study

When you sign the consent form it means that you agree that: The information that you provide may be used for reports, publications, and online communication. Identifiable personal information, such as your name or where you live, will not be shared beyond the study team without your permission. You received information about data storage. You give permission for the data of the experimental game to be deposited in a database after being anonymized, and made available to other researchers for future research and learning.

In case of any questions you can contact the ICT4BXW project research assistant: Mr. Charles Mwizerwa

Do you agree to the above and participation in this research activity?

Yes/no

Signatures

Participant

____________________ ____________________ ____________________

Name Signature Date

Researcher

____________________ ____________________ ____________________

Name Signature Date

Inyandiko yemeza imiterere yumukino (version in Kinyarwanda)

Abashakashatsi: Mariette McCampbell, Julissa Villamar Galarza, Knowledge, Technology and Innovation group, Wageningen University.

Intego y'ubushakashatsi

Ubushakashatsi tugusaba kugiramo uruhare, ni igeragezamukino rigendeye ku ifatwa ry' ibyemezo kubanyarwanda babahinzi burutoki kubigendanye nuburyo bwo kwirinda icyorezo cya kirabiranya (Xanthomonas Wilt/BXW). Ubu bushakashatsi ni kimwe mubikorwa byumushinga ICT4BXW, washyizweho na IITA kubufatanye na RAB.

Icyo tubategerejeho

Urakina uyu mukino ufatanyije nabandi bahinzi batatu b'urutoki baturuka m'umudugudu utuyemo.buri umwe muri mwe yatoranyijwe kuburyo bwamahirwe kugirango yitabire uyu mukino.kugira uruhare murubu bushakashatsi ni ubushake. mbere yo gutangira umukino tukubaza ibibazo bijyanye nawe,ubuhinzi bw'urutoki rwawe, ndetse n'ubumenyi kuri Kirabiranya.Nyuma y'umukino harabaho ibazwa ryo mu itsinda nabagenzi bawe.Ibibazo bigendanye numukino ubwawo.

Ibikwa n'Ikoreshwa ry'amakuru

Dukusanya amakuru mu buryo bugezweho dufata amajwi n'amashusho murubu bushakashatsi. Amakuru akusanyijwe mu mukino akoreshwa ku mpamvu z'ubushakashatsi, ashobora gukoreshwa mu nyandiko ariko kandi yakoreshwa mu bundi bushakashatsi bwimbitse n'ibikorwa by'umushinga ICT4BXW. Amakuru watanze azashyirwa mububiko bwizewe kandi yigweho mbere yuko atangazwa.

Kugira uruhare mubushakashatsi

Nasobanuriwe amakuru agendenya n'umushinga w'ubu bushakashatsi hamwe n'igerageza ry' umukino. nabajije ibibazo bigendanye n'ubushakashatsi kandi nahawe ibisubizo binyuze.

Ku bushake bwanjye, ntagahato, nemeye kugira uruhare mu igerageza ryumukino kandi nshobora kwanga cyangwa nkikuramo igihe icyo aricyo cyose, kugeza igihe amakuru shingiro yafashwe akanasesengurwa ntampamvu ntanze.

Nsobanukiwe ko kugira uruhare muri iri geregeraza ryumukino, nkabonwa igihe ndigukina kandi nkabazwa ibibazo bijyanye nibyo nigiyemo.

Nemeye ifatwa ry'amafoto mugihe cyigerageza ryumukino n'ibazwa ryo mu itsinda.

Appendices

Nemeye ko mu igeragezamukino hamwe n’ ibazwa ryo mu itsinda hafatwa amajwi cyangwa amashusho .

Ikoreshwa ry’amakuru yafashwe mu bushakashatsi

Nsobanukiwe ko amakuru ntanze ashobora gukoreshwa muri raporo, inyandiko ndetse no mu itumanaho ryo kuri murandasi. Nsobanukiwe ko amakuru y’umuntu bwite yafashwe ashobora kundanga,nk’amazina yanjye cyangwa se aho ntuye, atazasangizwa ahandi hanze y’abashakashatsi mu gihe nta ruhushya ntanze.

Nsobanukiwe ko amakurushingiro yanjye azabikwa mu bubiko bw’ibarura. Nemeye ko hazerekanywa isoko y’amakuru yanjye mu bushakashatsi. Nemeye ko amazina yanjye bwite

yazashyirwaho mu kwerekana isoko y’amakuru.Ntanze uburenganzira ko amakurushingiro yo mu igerageza mukino yabikwa mu bushyinguro bw’amakuru nyuma yo kuvanwaho isoko yayo no gushyirwa aho ashobora. kubonwa n’abandi bashakashatsi bayakoresha mu gihe kizaza.

Hagize ibindi bibazo wifuza kumenya kumushinga wabaza umushakashatsi wungirije wuyu munshinga ICT4BXW Bwana Charles Mwizerwa

Uremera kugira uruhare mu
bushakashakatsi bwavuzwe haruguru?

o Yego   o Oya

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Thesis summary

This thesis explores the role of human behaviour in shaping livelihood resilience to covariate shocks at the individual and collective level from a multidimensional perspective using two case studies. In Chapters 2, 3, and 4, I study livelihood resilience in the case of rice smallholders cropping in flood-prone areas of Ecuador. In Chapter 5, I study livelihood resilience in the case of banana smallholders facing the threat of Banana Xanthomonas Wilt disease in Rwanda. I use the Adaptive Cycle as the theoretical spine of this thesis to understand livelihood resilience in terms of potential (having resources to cope), connectedness (control over their future), and capacity to adapt. In Chapter 1, I introduce the overall research purpose, questions, and design. Concepts and theories related to social capital, risk, and social dilemmas are integrated into the research across the different chapters. To understand livelihood resilience, we follow three key questions: what is resilient and to what is it resilient? why is it resilient? and how is it resilient?

In Chapter 2, we investigate what is resilient and to what is it resilient? through a participatory approach and disaster risk management theoretical lens. The specific research question is, how does local understanding of risk shape collective (or re-organization) actions, in terms of function and expression forms, to face a covariate shock at the household and community level? To answer this question, we developed and applied a participatory resilience assessment, from a risk perspective, where users define what is at risk (what is resilient), why it is important, and how its probability of being affected by a risk (to what is it resilient) should be measured and interpreted. Different research tools were applied to identify livelihood assets, characterize their vulnerability, and characterize the hazard potential of floods to their livelihoods. Individual drawings combined with group storytelling sessions about past flood events were particularly useful in identifying indicators of vulnerability and hazard based on their understanding of risk. We found that the meaning of being at risk was directly associated with local (individual and collective) strategies to cope with a shock relied on social capital relationships. Further, local involvement in the assessment tool design resulted in a rapid engagement and understanding of the tool. The results showed that all groups evaluated were at high or very high risk. Despite the high degree of risk, rice cropping is a livelihood that has persisted through generations; therefore it can be said it exhibits some degree of resilience (either healthy or pathological).

In Chapter 3, we explore why is it resilient. As chapter 2 had shown that coping strategies were mostly related to social capital, we focus on the role of such in resilience building. Specifically, we ask, what are the critical factors, related to social capital, that contribute to the strengthening, weakening, or hindering of collective actions to prevent, respond, or prepare for a covariate shock? We develop a conceptual framework that integrates concepts of resilience, disaster risk

management (DRM), and social capital to explore this question. We focus on coping strategies that are based on bonding and bridging social capital relationships. Then, we operationalize the framework through a tool that assesses if social capital contributions to DRM and resilience are either positive or negative contributions to transition from a shock to a recovery stage. Our results show that some forms of self-organization do not always lead to a healthy resilience, especially when there is a high dependency on external resources. Opportunistic and power-unbalanced dynamics take place when locals cannot sustain strategies of sharing and exchanging resources to cope collectively. Therefore, the more and diverse are the local resources, the healthier (in terms of resilience) are the dynamics to cope with the shock.

In Chapter 4 and 5, we seek to understand how livelihood resilience works. On the one hand, we first found that livelihood systems, such as rice in flood-prone areas, subsist despite high risk, mostly because of coping strategies based on social capital. On the other hand, we found that the amount and diversity of resources at different levels of relationships mark the type of resilience that is built. In Chapter 4, we ask how do smallholders make sense of their cooperative or defective behaviour in a shock situation, and how does such a sense-making process link to their livelihood resilience? Specifically. we explore how people make sense of their cooperation toward a public good (a saving-box) that is meant to strengthen the resilience of rice livelihoods at a local level. We use a public goods game as a tool to create a shared experience, rather than an experiment. A focus group discussion followed the game to make sense of when and why farmers choose to cooperate in different idiosyncratic and covariate shock scenarios. We found that farmers consider there to be no ideal and safe situations, therefore their choices are based on the assumption that there could always be an idiosyncratic shock. Nonetheless, in that scenario, they choose to cooperate (through repaying a loan) to the conservation of the public good. However, under covariate shocks, such as floods, they choose not to cooperate toward the conservation of the public good, but rather prioritized saving their resources to be able to participate in local exchanges of food, water, labour, or other resources that are critical to cope collectively with a generalized shock.

In Chapter 5, we explore why a livelihood is resilient from a public bad perspective. The specific research question was, *how does the dynamic interplay of socio-ecological factors of a livelihood system influence household collective action to prevent or control a threat in common that risk their livelihoods' resilience?* To answer this question, we develop a conceptual framework for analysing a public bad risk threatening livelihood resilience, in the context of a socio-ecological system from a risk and collective action problem perspective. Then, we design a dynamic socio-ecologic game methodology, which adds SES attributes and its emergent phenomena to the game experience. Next, we design a context-specific game, the Musa game, to explore farmers' cooperation to prevent and control Banana Xanthomonas Wilt (BXW) disease spread. Finally, the game is tested with actual farmers, and results analysed through a developed spatial statistical tool. We found that factors such a technical knowledge, risk perception, social trust, and institutional trust influence decision making (in terms of what to do, where, and when), collective action, and public-bads management. Furthermore, this study also introduces the game as a powerful tool for studying technical aspects of the diseases and showing the importance of collective action to prevent the disease.

In Chapter 7, I synthesize and discuss the main contributions of this thesis. From a research design perspective, I found that studying the multidimensional links between human decision-making and livelihood resilience requires the integration of concepts, theories, and methods from different disciplines. In the context of shocks, this thesis suggests that risk perception, coping capacity, institutional environment, and social dilemmas all have important influences on individual choices, and therefore collective actions. At the same time, these decisions are influenced by (and influence in turn) the biophysical factor, from which different expressions of resilience emerges. Therefore, livelihood resilience can be seen as a consequence of the sum of dynamic, interdependent, and synergic individual actions, providing either a joining benefit (by producing or preserving a shared good) or harm (by failing in preventing or controlling a public-bad). We discuss how further research should explore the dynamics behind cooperation and resilience building to increase our understanding of risk and resilience.

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Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
PhD Research proposal writing	WUR	2014	6
Research methodology: from topic to proposal	WASS	2016	4
GIS in practice	SENSE, PE&RC	2016	2.5
Qualitative data analysis with Atlas.ti: hands on practical	WASS	2017	1
Video for data collection, ECS67400	WUR	2018	3
Serious gaming for participatory research	WASS, PE&RC, SENSE	2018	0.8
Advanced qualitative research design and data collection	WASS	2018	4
Quantitative data analysis: multivariate techniques, YRM 50806	WUR	2018	2
Companion modelling	WASS, PE&RC, WIMEK	2020	1.5
WASS introduction course	WASS	2020	1
B) General research related competences			
'Uso de juegos económicos como herramienta de auto-evaluación y fortalecimiento del capital social: caso de la caja de ahorro Unidos somos más, Santa Lucía - Guayas – Ecuador'	Jornadas Interdisciplinarias de Estudios Agrarios y Agroindustriales Argentinos y Latinoamericanos, Buenos Aires.	2015	1
Presenter in session Nature & risk management	WASS PhD day	2017	1
'Including local understanding of risk and resilience through a participatory risk evaluation process: rice smallholder farmers and floods in Ecuador'	Resilience 2017, Stockholm	2017	1
'Linking cooperative behaviour and livelihood resilience within a shock context: the case of rice smallholders' saving groups in Ecuador'	Resilience 2017, Stockholm	2017	1
Presenter in session Resilience and its application	WASS PhD day	2018	1
C) Career related competences/personal development			
Lecturer at socioeconomics course	ESPOL	2014	1.5
Lecturer at agricultural extension course	ESPOL	2015	1.5
Negotiation Theory and Practice	WASS	2016	0.5
Publish for impact	WUR Library	2017	0
'Games and focus groups for eliciting talking'	EVOCA workshop	2017	1
Lecturer at Integral Approaches in Communication, Health and Life Sciences course	WASS	2018	1
'Dynamic games: BXW disease in Rwanda'	EVOCA workshop	2019	1
Basic Dutch 1 and 2	Wageningen in'to Languages	2019	2.4
Collaboration at EVOCA project	KTI	2018-2020	3
Total			**42.7**

*One credit according to ECTS is on average equivalent to 28 hours of study load

Appendices

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