Games and sustainable futures for agrobiodiversity and smallholder farmer organizations

Federico Andreotti

Propositions

1. Smallholder farmer organization perspectives must be included in the transition towards more biodiverse and sustainable futures. (this thesis)

2. Games are effective facilitation tools to foster social learning on agrobiodiversity dynamics. (this thesis)

3. Quantitative and qualitative research methods and data must be equally valued by researchers.

4. Transdisciplinary research is a double-edged sword for participants and researchers.

5. It is embarrassing that Wageningen University hasn't had a female rector.

6. Creativity and optimism are essential characteristics for society's survival in times of global crisis.

7. Unusual and artistic proposition representations are essential for society-science interactions.

Propositions belonging to the thesis entitled
Games and sustainable futures for agrobiodiversity and smallholder farmer organizations

Federico Andreotti
Wageningen, 12 December 2022

Games and sustainable futures for agrobiodiversity and smallholder farmer organizations

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Games and sustainable futures for agrobiodiversity and smallholder farmer organizations

Federico Andreotti

Thesis

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For my family

TABLE OF CONTENTS

I

Chapter I

Introduction

1.1 Background

The world population is rapidly growing and is expected to reach 9.8 billion people in 2050 (WEF 2010), raising the challenge for farmers to feed the planet. To ensure food security, farmers should invest not only in producing more but also in providing food with higher nutritional value (De Schutter, 2011; Horlings & Marsden, 2011). A farming system that includes the production of multiple plant species, known as agrobiodiversity, can potentially enrich human diets (Brush 1995; Li & Siddique, 2018) and open opportunities for niche markets (Parrish et al., 2006; Zimmerer et al., 2017). Agrobiodiversity accounts for all the different species cultivated on farm and in the landscape combining modern and wild crops (Kahane et al., 2013). Of the approximately 30,000 species of edible plants present on earth, only around 7,000 have ever been cultivated or used for human consumption, and only 150 are commercially cultivated and marketed (Esquinas-Alcàzar, 2005; Li & Siddique, 2018). Furthermore, such species support the local food security and nutrient availability against the globalization of Andean smallholder diets, where pasta and rice substitute local grains and/or traditional and high nutritive foods (Berti et al., 2014). Local varieties are mostly produced for home consumption in marginal areas where external inputs are limited (Altieri et al., 1989; Wezel et al., 2017). Besides home consumption, agrobiodiversity, in the form of local varieties or underutilized species, has great potential to reach the local and the global market, but no clear governance instruments are established for the recognition, promotion and commercialization of these species (Pallante et al., 2016). Such a lack of organization and support does not strengthen the current smallholder organizations' practices (Andreotti et al., 2022). Therefore, there is a need to strengthen smallholder organizations by exploring their perspectives toward sustainable futures using participatory research approaches such as serious games and future approaches (Bazile et al., 2021).

1.2 Agrobiodiversity and smallholder organizations

Smallholder farmers produce more than 30% of the global food supply (Ricciardi et al., 2018) while maintaining its genetic diversity (Fanzo, 2017; Dardonville et al., 2020). Hundreds of Neglected and Under-utilized Species (NUS), which are mainly grown by smallholder farmers as subsistence crops, are at risk of extinction (Li & Siddique, 2018; Wezel et al., 2020). In addition, smallholder management and practices related to other plant species that foster agrobiodiversity are disrupted by agricultural intensification practices such as input-intensive monoculture systems and plantations (Mariel et al., 2021).

In recent decades, the concept of agrobiodiversity, including NUS, have attracted global interest, leading to the transformation of these crops such as quinoa, teff, and minor millets from "traditional foods" into "superfoods" that appeal to health-conscious Western consumers (McDonnell, 2021; Andreotti et al., 2022). When a specific crop receives

a sudden increase in demand and production it is called "Crop boom". Most famous examples are palm oil in Indonesia (Gilbert, 2012; Sibhatu, 2019), cacao in West Africa (Clough et al., 2009; Andreotti et al., 2018), and coffee in Latin America (Pinilla & Willebald, 2018; Beveridge et al., 2019; Andreotti et al., 2020). Booms are generally triggered by rapidly increasing consumer demands (Hall, 2011), which creates a rise in market prices. Producers consequently swiftly change to cultivating the booming crop (Mahanty & Milne, 2016; Ornetsmüller et al., 2018). In the medium- and long-term, the booms tend to negatively affect agroecosystems causing land-use to change and negatively affecting local natural resources (McDonell, 2015; Pinilla & Willebald, 2018). Hence, crop booms are commonly followed by a period of production decline, due to overproduction and/or environmental crisis, and, finally, by a period of crop cultivation stabilization. This process is referred to as a boom-and-bust cycle (Clough et al., 2009; McDonell, 2015). This phenomenon promoted the creation of smallholder organizations, such as associations or cooperatives, to facilitate the cooperation of different smallholders in the same landscape to produce enough quantity for the local and the global market (Tschopp et al., 2018).

Smallholder organizations adapt simple or complex collective governance schemes to facilitate their collaboration (Bazile et al., 2012a). Most schemes decide common landscape production rules, such as collective rotations and share machinery such as tractors (Fagandini et al., 2019). More complex forms of collective governance, such as collective trademark and Participatory Guarantee Systems (PGS) (Loconto & Hatanaka, 2018) are mostly developed in Latin America (Kaufmann et al., 2022). PGS organizations develop a first-party certification scheme in which smallholder farmers and local actors decide common rules together and ensure that everybody respects the rules. Smallholder organizations from all around the world showed the potential to develop an adaptative and sustainability strategy to fight the current environmental crisis, such as climate change (Tittonell 2020) and pandemic crises (Zimmerer and de Haan, 2020). For this reason, smallholder organizations are the main actors who work in the development and research project with local institutions, such as associations or regional/national government and international organizations, as research institutes and agencies (Tschopp et al., 2018). While many projects have been developed to support the development of top-down plans, few started considering the first place smallholder organizations' perspectives (Isaac et al., 2021). Exploring local perspectives and identifying key actors that have long-term relations with smallholder organizations should be the first step when planning/developing research and development projects. By doing so, it may be possible to highlight and promote local strategies to fight against the current crisis. Such strategies include sustainable practices and agrobiodiversity management.

1.3 Exploring sustainable futures

This thesis aims to explore sustainability transition pathways by studying smallholder organizations' perspectives and local agrobiodiversity, agricultural practices, and governance instruments. The concept of sustainability transition is increasingly used in research and beyond to refer to the process of transforming current agricultural and food systems towards sustainable alternatives (Meynard et al., 2017; Gaitán-Cremaschi et al., 2019). Sustainability transition envisions the development of new pathways shaping future, more sustainable agricultural and food systems (Altieri, 1989; Van der Ploeg et al., 2019; Schiller et al., 2019).

New transition pathways can couple technological innovations such as agronomic practices with non-technological innovations such as cooperation between actors (Bergez et al., 2014; Meynard et al., 2017; Gaitán-Cremaschi et al., 2019). Sustainability pathways are used to create alternative agricultural and food systems which evaluate new perspectives from agricultural practices at the individual to the collective smallholder organization at the landscape level (Duru et al., 2015; Schiller et al., 2019). Landscape approaches play a central role in such a sustainability transition (Nelson & Phillips, 2018; Andrieu et al., 2019) by aiming to harmonize agrobiodiversity conservation and market and development goals through the joint effort of smallholder organizations (Sayer et al., 2013).

Several methods have been applied in research to support future scenario creation and evaluation, mainly based on two approaches: forecasting and backcasting. Forecasting approach includes evaluating future scenarios (Vergragt & Quist, 2011; Hazard et al., 2018). For example, supporting farmers' land-use decisions at the landscape level by discussing their socio-economic benefits (Hazard et al., 2018). Forecasting can limit the participant imagination for different perspectives from the ones presented in the workshop (Villamor & van Noordwijk, 2011). In contrast to the forecasting approach, which explores future systems from current systems, backcasting is an approach that focuses on what *should* happen in the future rather than what could happen (Vergragt & Quist, 2011; Kok et al., 2011; Duru et al., 2015). Backcasting as an approach allows participants to define a desirable future from which the steps required to reach this future vision are identified in a backward order as the so-called opportunities and potential events that challenge reaching the vision, which are the so-called obstacles (Kok et al., 2011; Davies, 2014; Duru et al., 2015; Kishita et al., 2016). Applying these methods in combination with other facilitation tools, such as focus groups, interactive interviews, and serious games can be part of a participatory research approach, also known as the action research approach. In this research, action research methods were applied for studying desirable futures through a backasting approach and analysing the dynamic

across agrobiodiversity, smallholder perspectives, practices and organizations towards sustainability transition (Figure 1).

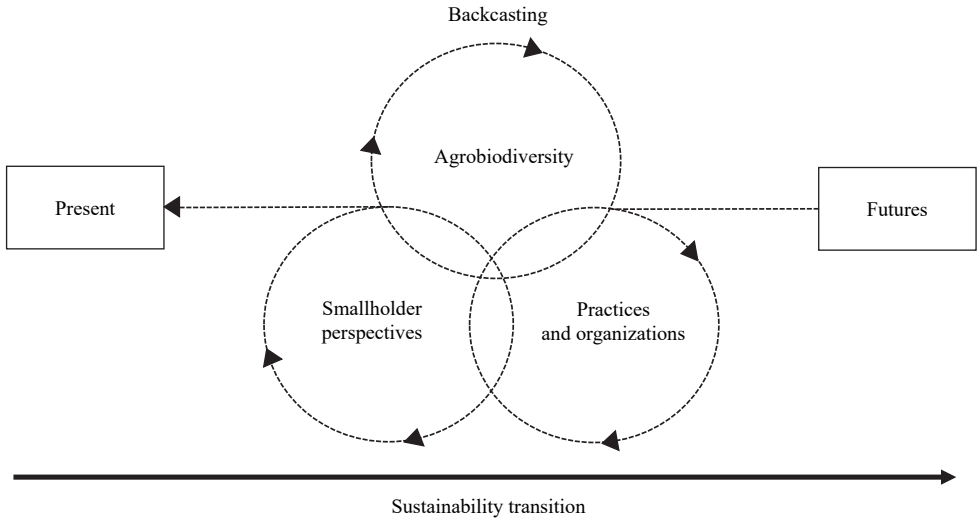

Figure 1. Sustainability transition and backcasting framework. The three circles represent the three dynamic focuses of this research: agrobiodiversity, smallholder perspectives, and practices and organizations. The circles are connected and constantly changing towards time. The backcasting approach is shown with arrows from Futures to Present, encompassing the circles.

I.4 Games for social learning

Games have found fertile ground in environmental research (Rodela et al., 2019) and are being used and studied as experiential learning tools for facilitating decision-making and exploring scenarios (Garcia et al., 2022). By playing a game that mimics part of the real system, stakeholders explore the potential impacts of their actions while sharing their knowledge and understanding of the functioning of the system at hand. This method was conceptualized in research in different domain in the 1970s (Abt, 1970). Since then, the gaming approach has been increasingly used in research and development. One of the most successful examples of a gaming approach in environmental research is the companion modelling approach (ComMod), which aims to facilitate collective learning about complex social-ecological systems among diverse actors (Étienne, 2013). Rethinking and developing management strategies for agroecosystems towards more sustainable agricultural landscapes has been addressed through serious games (Speelman et al., 2010; 2014; García-Barrios et al.; 2015; Garcia et al., 2018) and action research based on local knowledge and beliefs (Bergez et al., 2014; Kishita et al., 2016). Action research allows the study of the farming system as a biophysical, economic, and social subject shaping scientific and local knowledge and practices (Warner, 2007; Hoolohan et al., 2018). In addition, action research has been used extensively to redesign sustainable

farming systems (Altieri et al., 1989; Mendez, 2015; Tejedor & Segalas, 2018). Games have been successfully co-designed and played with smallholder farmers crossing several cultures and landscapes (d'Aquino & Bah, 2013). Some of those games study the management of biodiversity and agrobiodiversity, as in the case of Speelman et al., (2014a) and Garcia-Barrios et al., (2020). Serious games are a well-developed inclusive action research approach to learning about, discussing, and exploring the complexity of the many dimensions of contested landscapes in participatory gaming (Speelman et al., 2017; Moreau et al., 2019).

While such an approach has prospered in environmental research (Garcia et al., 2022), what was lacking was a clear development protocol (Speelman et al., 2021), an understanding of the possibility of adapting current games (van Noordwijk et al., 2020), and an in-depth study of the positionality of researchers and participants (Reyes 2020). Furthermore, other unexplored aspects are related to studying the immediate impact on player perspectives. Such an approach of engaging local actors in the redesign is considered a transformative method that can be part of an overall change process. Specifically, the transformative participatory action research approach has been theorized as a creative method that engages actors in re-discussing and transforming current narratives. While sustainability transition and transformative approach are long-term processes that are impossible to frame completely in short-term project durations, social learning is a significant step to possibly achieve a step of those long-term processes. Social learning has several definitions and applications, sometimes in contrast. Reed et al., (2010) made an effort to review this concept and rephrased the most important components of social learning. They defined it as a result of a participatory process that fosters social interactions in a social network and in which the individual participant and the collective group have at both levels a shift in understanding (Figure 2).

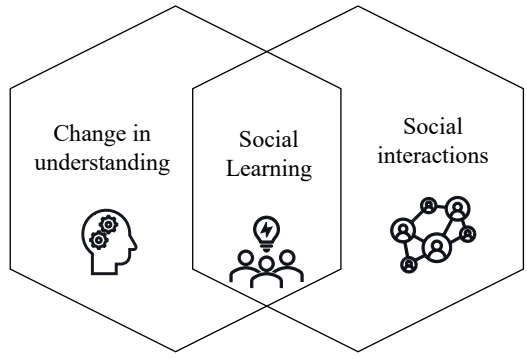

Figure 2. Social learning framework inspired by the description on social learning of Reed et al., (2010). Social learning (Middle hexagon) is the result of having collective social interaction (Right hexagon) and an individual change in understanding (Left hexagon).

2. Research objectives

The main objective of this thesis is to explore the contribution of serious games and methods to explore futures (i.e. backcasting methods) in studying the sustainability transition of agrobiodiversity and smallholder organizations. Several methods were tested in a participatory and action research approach, working together with smallholder organizations in Nicaragua and Peru, envisioning sustainable futures and fostering social learning and collective decision-making within the organizations and with external key actors. I structured this main objective into four sub-objectives:

1. Test the potential of games and future approaches for exploring sustainability transition for agrobiodiversity and smallholder organizations;

2. Explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations;

3. Explore smallholder organizations' future perspectives on agrobiodiversity conservation and sustainable use;

4. Develop and apply an online narrative game as a facilitation tool for social learning and collective scenario evaluation.

3. Case studies

To work on these objectives, research was conducted mainly in two different study areas: in the mountain terrains in Central Nicaragua (Chapter 2) and in the Peruvian high Andes (Chapter 3,4,5). In both case studies, smallholder organizations manage and preserve agrobiodiversity in remote areas. Additionally, in both locations, research and development projects are used to foster the potential of agrobiodiversity for food security, adapt to climate change, fight pests, and open new market opportunities. Working with marginalized smallholder organization in these two countries provided the opportunity to foster a participatory research approach thanks to previous ongoing research and active engagement from the farmers. Further in Chapter 2, a literature review was performed which included two other NUS, teff in Ethiopia and Millet in India. These case studies were addressed together with quinoa in Peru, to develop and assess a framework for adapting crop boom and bust towards sustainability transition.

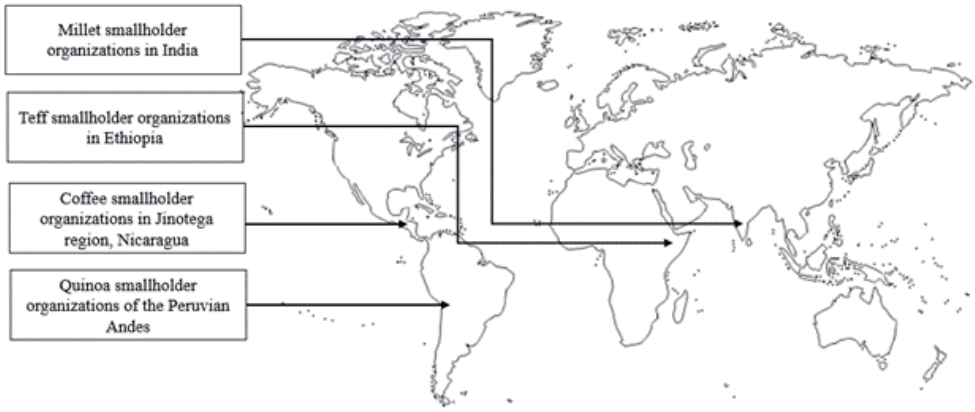

Figure 3. Locations, and smallholder organizations of the case study areas in Nicaragua, Peru, India and Ethiopia.

4. Thesis outline

This thesis is organized into six chapters (Figure 4).

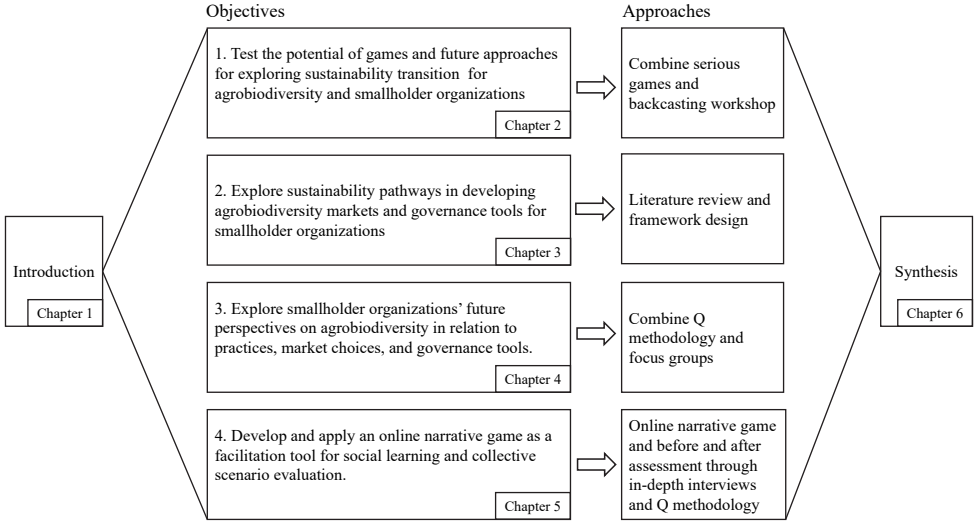

Figure 4. Overview of the thesis chapters

Chapters two, three, four, and five are the core of the research work. Chapter 2 presents an illustration for adapting serious games, RESORTES game (Speelman et al., 2014), for coffee-based smallholder organizations in Nicaragua. Here, the combination of games and methods to explore futures were tested for exploring sustainability transition

for agrobiodiversity and smallholder organizations. In chapter 3, a literature review and framework were developed to explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations. We specifically prepared the terrain for the coming two chapters, studying and analyzing how quinoa production and market in the Andes can lead to sustainability transition for smallholder organizations. Quinoa here is an example of a NUS, which became a global market product from a staple food, showing how agrobiodiversity can develop at the local and global levels. Furthermore, in this chapter, we tested the framework with other crops that represent NUS: minor millets in India and teff in Ethiopia. In chapter 4, we compared the knowledge gained in the previous chapter with quinoa smallholder organizations in the high Peruvian Andes, exploring their future perspectives on agrobiodiversity in relation to practices, market choices, and governance tools. In doing so, we started a participatory research process using Q methodology and focus groups. Such an approach continues in chapter 5, where we assembled the different quinoa smallholder organizations' perspectives into an online narrative game, SCENE game, to be played with fairtrade retailers. This approach was necessitated by covid restriction and the impossibility of engaging in the fieldwork. Additionally, through this chapter, we fostered the inclusion of smallholder organizations' perspectives on novel fair and sustainability certification schemes for agrobiodiversity and sustainability transition. In chapter 6, I presented a general discussion reflecting on the main findings and proposing perspectives and future avenues for the research and methods used.

2

Chapter 2

Combining games and backcasting to support collective scenario evaluation: an action research approach for sustainable agroforestry landscape management

Andreotti, F., Speelman, E. N., Van den Meersche, K., & Allinne, C. (2020). Combining participatory games and backcasting to support collective scenario evaluation: an action research approach for sustainable agroforestry landscape management. Sustainability Science, 15(5), 1383-1399. https://doi.org/10.1007/s11625-020-00829-3

ABSTRACT

The combined and interacting effects of land-use change, resource extraction and climate change threaten the sustainability of millions of mainly smallholder farms in tropical agroforested landscapes. In many of these landscapes, coordinated action among stakeholders at landscape level would help to address challenges such as pests and diseases, price crises and climate change. However, methods to facilitate the co-production of sustainable landscape management in such complex multi-stakeholder systems are currently largely lacking. In this paper, we present a novel approach to explore pathways for the sustainability transition of agroforestry systems. By combining participatory forecasting and backcasting approaches, based on serious games and future vision development, we explore relevant agroforestry management strategies for reaching sustainable future coffee-based agroforestry landscapes. We focused our research on the challenges faced in the main coffee-producing area in Nicaragua. Here, we organized five participatory game sessions to explore farmer decision-making processes, farming strategies and to develop new networks and stimulate social learning among farmers. In the associated backcasting workshop, the most influential game session participants joined technicians, researchers, and municipality officials to collectively envision sustainable future landscape management. In all game sessions, farmers developed diversified coffee-based agroforested landscapes characterised by increased density and diversity of shade trees, for the purpose of income diversification as well as forest conservation. During the backcasting workshop, the participants identified policy instruments and community-based solutions for the transition to sustainable landscapes. Our participatory approach facilitated discussion on landscape planning among farmers and other stakeholders and allowed the outline of a pathway towards the collective envisioned future landscape. The combination of participatory forecasting and backcasting proved to be a helpful tool to support multi-stakeholder processes towards sustainable landscape management in this and other complex landscapes.

Keywords:

Sustainability transition, Transformative change, Forecasting, Role-playing game, Agroecology, Future studies.

1. INTRODUCTION

The concept of sustainability transition is increasingly used in research and beyond to refer to the process of transforming current agricultural and food systems towards sustainable alternatives (Meynard et al., 2017; Gaitán-Cremaschi et al., 2019). Sustainability transition envisions the development of new pathways shaping future, more sustainable agricultural and food systems (Altieri 1989; Duru et al., 2015; Van der Ploeg et al., 2019; Schiller et al., 2019). New transition pathways can couple technological innovations such as agronomic practices with non-technological innovations such as cooperation between actors (Bergez et al., 2014; Meynard et al., 2017; Gaitán-Cremaschi et al., 2019). Sustainability pathways are used to create alternative agricultural and food systems in which evaluating new perspectives from agricultural practices to landscape management are key (Duru et al., 2015; Schiller et al., 2019). Landscape approaches play a central role in such a sustainability transition (Nelson & Phillips 2018; Andrieu et al., 2019) by aiming to harmonize conservation and development goals through the joint management of livelihoods and the associated ecosystems (Sayer et al., 2013).

Sustainable agroforestry practices can support landscape management and enhance forest conservation, agrobiodiversity, food production and livelihoods (Herrero-Jáuregui et al., 2019). At landscape level, tree diversity within the agroforestry systems (AFS) has an important ecological function as biological corridors and habitats and is essential to the conservation of forest-dependent biodiversity or agricultural production (Noordwijk et al., 2016; Andreotti et al., 2018). AFS play a major role in the transformation of agriculture towards sustainable landscapes (Poole & Donovan, 2014; Rapidel et al., 2015) and offers a wide range of environmental, social, and economic benefits at farm as well as landscape level. However, ways to capitalize on this potential at landscape level have not yet been fully explored (Kabaya et al., 2019, Newell 2019).

The most studied AFS connecting management practices and landscape approaches are coffee-based AFS (Tscharntke et al., 2011; Cerda et al., 2017) and cacao-based AFS (Saj et al., 2017; Andreotti et al., 2018). Coffee production in the tropics has traditionally been done in AFS with coffee being a shade tolerant species and the shade trees serving to maintain soil fertility and to create a beneficial microclimate (Sauvadet al., 2019). However, in more recent decennia, the general trend has been towards shade reduction and intensification of coffee management, leading to biodiversity losses (Moguel & Toledo 1999; Philpott et al., 2008; Jha et al., 2014). While this is true for conventional AFS, organic AFS continue to have higher shade levels and more tree strata than conventional AFS (Haggar et al., 2012), as well as more tree species richness across the landscape (Haggar et al., 2015).

Rethinking and developing management strategies agroecosystems towards more sustainable agroforested landscapes has been addressed through serious games (García-Barrios et al., 2008; 2015; Garcia et al., 2018) and action research based on local knowledge and beliefs (Bergez et al., 2014; Kishita et al., 2016). Action research allows to study and rethink the farming system as a biophysical, economic and social subject shaping scientific and local knowledge and practices (Warner 2007; Hoolohan et al., 2018). In addition, action research has been used extensively to redesign sustainable farming systems (Altieri et al., 1989; Mendez 2015; Tejedor & Segalas 2018).

A well-developed inclusive action research approach to learn about, discuss and explore the complexity of the many dimensions of contested landscapes is participatory gaming (Speelman et al., 2017; Moreau et al., 2019). The gaming approach has been increasingly used in research and development. One of the most successful examples of a gaming approach is the companion modelling approach (ComMod), which aims to facilitate collective learning about complex social-ecological system among diverse actors (Étienne 2013). By playing a game that mimics part of the real system, stakeholders explore the potential impacts of their actions, while sharing their knowledge and understanding of the functioning of the system at hand.

Most of the gaming literature aims at better understanding social-ecological systems dynamics under specific conditions and exploring what-if scenarios often in a participatory setting with stakeholders (Barnaud et al., 2010; Moreau et al., 2019). As such, these participatory gaming methods fit within the so-called forecasting approaches in which scenarios of the future are evaluated (Vergragt & Quist 2011; Hazard et al., 2018). While games taking a forecasting approach have, for example, shown to help coordinate farmers' land-use decisions at the landscape level discussing their socio-economic benefits (Speelman et al., 2014a; Hazard et al., 2018), forecasting role-playing games can also limit the player's imagination for different perspectives from the ones presented in the games (Villamor & van Noordwijk, 2011). In contrast to the forecasting approach in which future systems are explored from the current system state and under current system conditions, backcasting is an approach that focuses on what should happen in the future rather that what could happen (Vergragt & Quist 2011; Kok et al., 2011; Duru et al., 2015). Backcasting as an approach allows participants to define a desirable future from which the steps required to reach this future vision will be identified in a backwards order as so-called opportunities, and potential events that will challenge reaching the vision, which are the so-called obstacles (Kok et al., 2011; Davies 2014; Duru et al., 2015; Kishita et al., 2016).

In this paper, we present a novel approach aiming to support collective scenario evaluation towards a landscape sustainability transition. To achieve this objective, we applied an action research approach based on participatory forecasting through serious gaming and

participatory backcasting workshops. We demonstrate the method by applying it to a case study of complex coffee agroforestry systems in Nicaragua, a biodiversity hotspot where around 80% of the land is cultivated (Somarriba et al., 2017) and a major challenge in land management is the conservation of biodiversity while simultaneously securing rural livelihoods (Harvey et al., 2008; Speelman et al., 2014b; Beveridge et al., 2019). Central America is also one of the regions most exposed to climate change (Imbach et al., 2017). Nicaragua is particularly vulnerable to climate change due to its geographic, social, economic and environmental conditions (Martínez-Valle et al., 2017). Coffee is its main produce (Imbach et al., 2017; Somarriba et al., 2017) and coffee farmers face the direct and indirect impacts of climate change and land conversion (Downing et al., 1999) with predictions of substantial decreases in the total area suitable for coffee production (Laderach et al., 2011). Increasing the sustainability of coffee-based agroforestry systems in Nicaragua is key to sustaining local livelihoods (Harvey et al., 2014; Somarriba et al., 2017).

2. METHODS

2.1 Study area

The municipality Tuma-La Dalia (13°08'N 85°44' W) is situated on the border of the Matagalpa and the Jinotega departments in central Nicaragua where steep and mountainous terrain predominate (Figure 1).

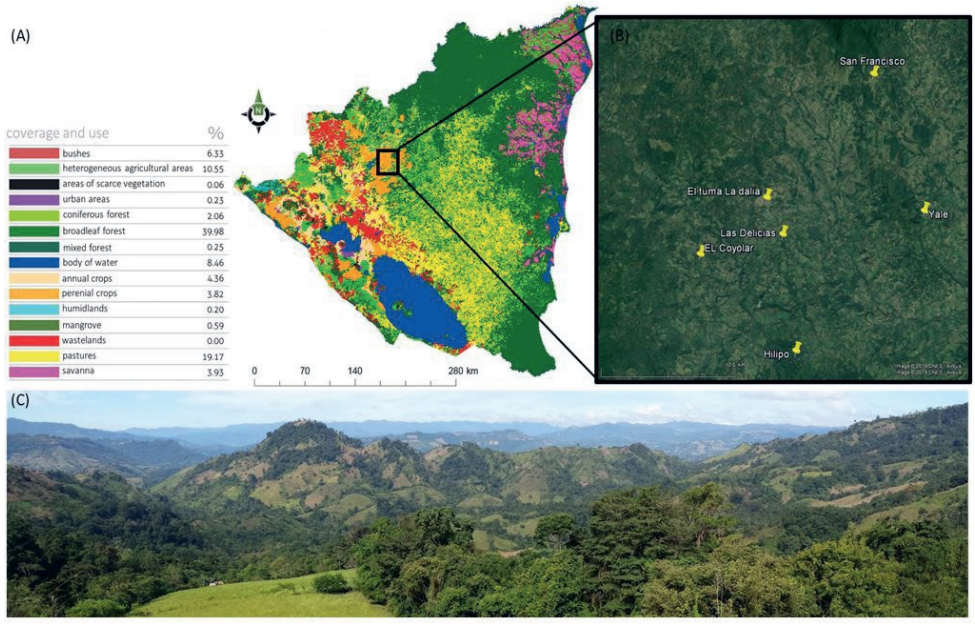

Figure 1. Map of Nicaragua land-uses (adapted from Hernández Sandoval et al., 2011): (A) location of the five studied communities around Tuma-La Dalia in the coffee area of Matagalpa department (B) and view of the landscape observed from the community of Yale (C).

The area is located at an altitude ranging from 400m to 850m (Cerda et al., 2017; 2019). The climate in Tuma-La Dalia is subtropical with temperatures ranging between 22° and 24°C (respectively daily mean temperature in the cold and in the hot months) with a distinct rainy season from May to November and an annual rainfall average of 2200mm (Montagnini 2017; Cerda et al., 2019 and Sepúlveda et al., 2020). The local landscape is fragmented with around 60% of the land characterised as low natural forest cover (Somarriba et al., 2017). Land-use consists of pastures for cattle ranching, field crops for the production of staple cereals like rice, maize and beans, home gardens and coffee-based AFS (Somarriba et al., 2017). Household income depends exclusively on these activities, and is very low with an annual average cash flow of around 134 USD ha-1 year -1 (Somarriba et al., 2017). This is in particular due to the impact of fungi (coffee rust), pests (affecting staple cereals), and the alternation of drought and excessive rainfall (Sepúlveda et al., 2018). Tuma-La Dalia is the main town within the municipality and is surrounded by several remote smallholder communities. The research presented in this paper was associated to a project entitled "System approach for the transition to biodiversified agrosystems (STRADIV)" which ran from 2015-2018. The project aimed to develop new methodological framework for the co-design and assessment of innovative biodiversified cropping systems (the authors are available for more information about the project). The research was executed in five of the communities surrounding Tuma-La Dalia, namely: Las Delicias, Yale, El Coyolar 2, Hilipo 2, San Francisco (Figure 1). These five communities are located at an altitude ranging between 600m and 800m (Las Delicias, El Coyolar 2, Hilipo 2 and Yale 600-700m; while San Francisco 700-800m).

2.2 Combining participatory forecasting games with backcasting workshops

The combination of forecasting game sessions with a backcasting workshop allowed us to develop a novel approach for envisioning sustainability transition pathways as well as to co-produce and evaluate future landscapes (Figure 2).

The role of the participants in landscape planning was explored in the games and then build upon to make a path for the future during the backcasting workshop.

Through the game sessions we were able to collect data on the current landscape scenario and on the communication and leadership of the participants. Thanks to this starting point we built up a backcasting workshop in which we invited different relevant stakeholders and the leaders from the communities selected during the game sessions. During the backcasting workshop the participants envisioned their desired future landscape starting from the current landscape scenario. Then, from the future vision the participants went backwards defining opportunities and obstacles needed to reach their ideal scenario. In sections 2.3 we encompass the detailed steps of the game sessions and in the section 2.4 the steps of the backcasting workshop.

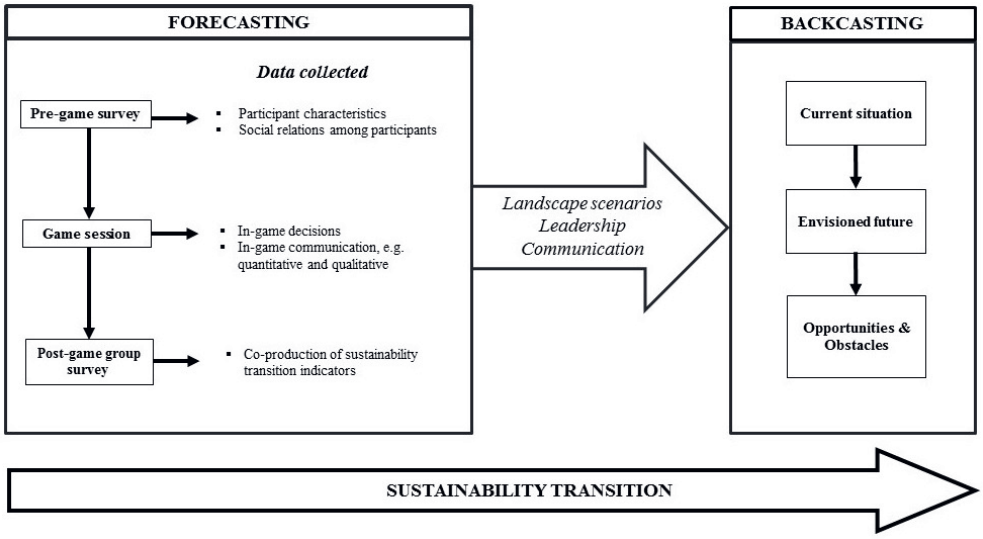

Figure 2. Sustainability transition pathways combining forecasting game sessions with backcasting workshop for co-producing desirable future landscape.

2.3 Game sessions & data analysis

As a forecasting gaming method the RESORTES board game (Speelman & Garcia-Barrios, 2010) was used. The RESORTES game facilitates agricultural and agroforestry land-use planning discussions including among stakeholders (Speelman et al., 2014a). The game revolves around individual land-use decisions and includes options for collaboration among players at the landscape level of the game. Players receive rewards based on the combination of their individual and their collective decisions. The game board represents a mountainous landscape with native forests and possibilities for agroforestry and is divided into four quadrants of nine hexagon plots each (Figure 3).

The game is played by six players who manage four hexagon fields each. The remaining hexagons represent virgin forest. In the first four rounds, players allocate their fields on the board - one field per player per round. The selected location of the fields remains unchanged throughout the game. In subsequent rounds, players select the type of land-use for each of their fields without taking turns. The game has four land-use options, of which two distinct options represent low-risk land-use types while another two distinct options represent high-risk land-use types. Players collectively decide when they are ready to end the round. At the end of each land-use selection round, players receive points based on the land-use types selected for their plots and the benefits of their participation (if any) on one or both of the collaboration schemes. Points per land-use types were determined at the end of each round by throwing two dice that reflect the range of high-risk prices

and low-risk prices. The two collaboration schemes for landscape planning that could lead to additional points reflected economic benefits from successful collaboration.

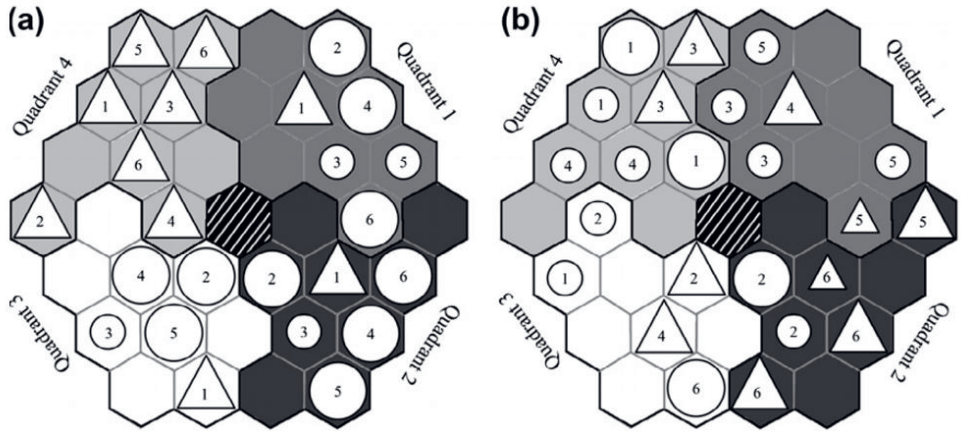

Figure 3. Schematic representation of the RESORTES game board with the field locations in four quadrants in distinct colours and the settlement in the centre of the board (striped). Two contrasting examples of participant's field and land-use allocations; (a) best possible coordination leading to maximum additional points for one individual player as well as board-wide, and (b) little coordination leading to no additional points (Source: Speelman et al., 2014a).

To better match the agroforested landscape in Nicaragua, we adapted the original RESORTES game (for a detailed description of the RESORTES game, please see Speelman et al., 2014a, and Appendix A) in three aspects to better fit the local context of coffee-based agroforestry in Nicaragua: 1) the four land-use options, 2) changing economic situations, and 3) the collaboration schemes. The adaptation of the game was developed using the expertise of the authors and by testing it with local technicians. In this RESORTES adaptation the land-use types were inspired by Moguel & Toledo (1999): a) monoculture full sun coffee, b) commercial polyculture coffee-based agroforestry system, c) highly diversified traditional coffee-based agroforestry system, and d) highly diversified traditional organic coffee-based agroforestry system (Figure 4).

Land-use types a and b were both regarded as having a higher risk than options c and d. Risk was defined as income losses in case of coffee failure due to climate change or pest and diseases (Lasco et al., 2014). Several studies pointed that this risk is higher in full sun coffee systems compared to more diversified system (Schroth et al., 2000; Avellino et al., 2012; Montagnini 2017). In addition to that, increasing tree diversity allows farmers to have more products such as timber, fodder, and fruits that can potentially create a buffer against income losses derived from pure coffee production (Lasco et al., 2014; Martínez-Valle A et al., 2017; Schiller et al., 2019).

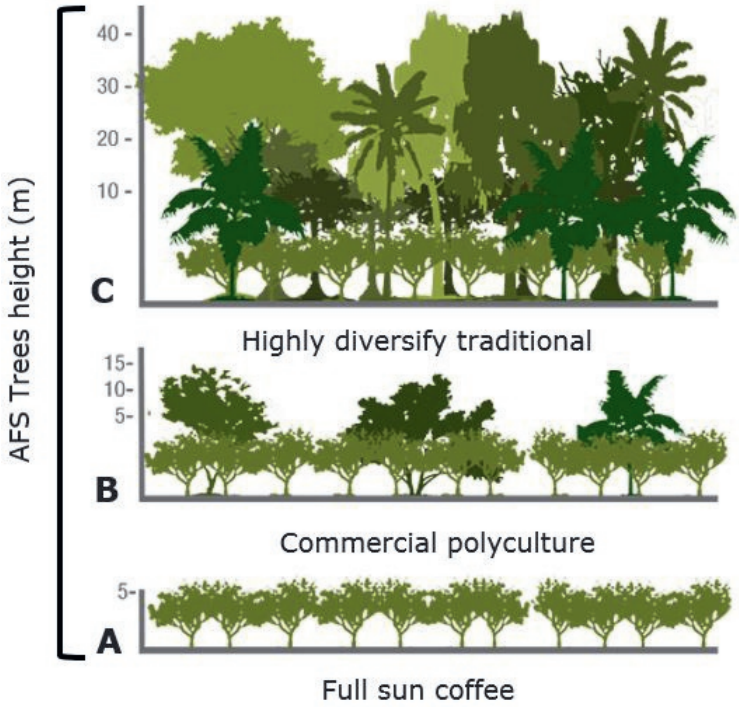

Figure 4. Land-use types used in the game sessions representing the coffee-based AFS in Nicaragua defined as: A) monoculture full sun coffee, B) commercial polyculture coffee-based agroforestry system, C) highly diversified traditional (or option D: organic) coffee-based agroforestry system (Adapted from Moguel & Toledo 1999).

Three distinct economic situations were defined to be explored in the game and these included: i) a substantially higher price for organic coffee, ii) prices being equal for conventional and organic coffee, iii) the price of chemical fertilizer being substantially lower than usual. The two collaboration schemes were based on economic benefits from successful collaboration through realistic options within the Nicaraguan landscape: forming an organic cooperative and participating in ecotourism. To meet the requirements for obtaining additional points through the cooperative scheme, eight out of the nine fields within a quadrant needed to have an organic and highly diversified traditional coffee-based AFS. If the requirements were met, all players who owned a field in the respective quadrant received five additional points per round. The ecotourism scheme requires eight fields per quadrant to be covered with highly diverse traditional conventional and/or organic coffee-based AFS and rewards all who hold a field in the respective quadrant five additional points per round. Players collectively decide how many land-use allocation rounds they play.

We employed the elaborate data collection and analysis scheme developed by Garcia-Barrios in Speelman et al., (2014a). The monitoring and analysing scheme consisted of: pre-game surveys, in-game decision registration scheme, quantitative and qualitative communication analysis during and after the game through video observation, and post-game group survey in the debriefing of the game. In the pre-game survey, we used a structure questionnaire to collect information on the participant characteristics such as age, place and farming strategy, assess the social relations and level of acquaintance among participants (self-reported relatedness). Following Speelman et al., (2014a), we performed a qualitative and quantitative analysis of the game sessions assessing: 1) individual verbal communication input, 2) leadership, both assessed as perceived. Through a post-game group survey and a general debriefing of the game each player discussed: i) his/her role during the game of the players in terms of successful collaboration, (ii) his/her choices made between the different options for land-use with a focus on organic and conventional agriculture. Later on during the post-game group survey five indicators for the sustainability transition of the landscape were chosen. The authors then compared the same indicators with their optimal values obtained by literature review. This evaluation was made in order to compare the reality of the communities studied with other communities in the same study area with similar coffee-based AFS landscapes.

All game sessions workshop took place between July and August 2017 in the different communities around the town of Tuma-la Dalia namely, Las Delicias (Group 1), Yale (Group 2), El Coyolar 2 (Group 3), Hilipo 2 (Group 4), San Francisco (Group 5) (Figure 1). In all game sessions, six local stakeholders participated in the game, five of which were farmers and one was a technician who worked as an extension officer on an NGO lead participatory project in the communities. The game facilitator was familiar with the communities and knew some of the participants. Participants were invited using the snowballing method (Goodman 1961). In each community, the contact farmer familiar to the STRADIV project was asked to invite four additional farmers who owned a coffee-based AFS to participate in the game session. Game sessions were video-taped and voice recorded for analysis purposes with participants' consent.

2.4 Backcasting workshop

As a backcasting method we adapted the participatory methodology to design agroecological transition and to support a multi-stakeholder arena presented by Duru et al., (2015). The backcasting exercise we developed aimed to support the discussion of social, economic and environmental aspects of sustainability transition at the landscape level. The exercise was divided into three steps in which the participants collectively developed their view on the: (1) the current situation, (2) their vision of the ideal situation in 2040, (3) the backwards steps (opportunities and obstacles) required to reach the ideal situation. During the presentation of the current situation we showed in the workshop

the five indicators co-produced with the participants during the post-game group survey and confirmed by literature review. Starting from the indicators of the current situation, the participants took part of a plenary discussion envisioning how these indicators could evolve in an imaginary and ideal situation in 2040. Once the consensus was reached on how the ideal future should be, they were asked to identify backwards transition pathways to reach the ideal scenario. In order to do this, the participants wrote individually on different coloured cards the opportunities and the obstacles. Then, the collected cards were placed on a board for co-producing with the participants' clusters of similar opportunities and obstacles. Therefore, once the clusters were made, we presented the results to the participants asking them for additional feedback or consensus. After all the participants agreed with the co-produced backwards transition pathway we invited the participants to a debriefing session.

Our one-day backcasting workshop was organised following the five game sessions at the end of August 2017. The participants were five community leaders as identified from the game sessions (one of each game session), three technicians who also participated to the game sessions, three researchers specialized in coffee-based AFS and two members of the municipality of Tuma-La Dalia who were involved in a development project on micro-credit and farm products diversification. The workshop was conducted by two facilitators. During the backcasting session data were collected by collective writing and voice recording with the consent of the participants.

Our study did not require an ethical approval considering the low risks involved in the process and since the familiarity that the farmers have with the STRADIV project. In fact, participants knew beforehand what was going to happen during the game sessions and the backcasting workshop. In addition, they were aware that they were free to participate, or to leave the activities when they wanted, and they knew that the data collected were anonymised.

3. RESULTS

3.1 Game outcomes: pre-game survey, game sessions & post-game survey

The pre-game survey allowed us to define the characteristics of participants per community (Table 1).

Table 1. Pre-survey games participants' characteristics from the five game sessions played in the five communities (groups): age (#), land holdings (ha), relatedness index (%), coffee production (t ha^{-1}), coffee selling price ($ t^{-1}) the average comments made per player during the game (#).

Farmers communities characteristics				
Age (years)	Group	Mean	St dev.	Range
	1	35	±13.85	18-59
	2	41	±9.98	28-53
	3	54	±16.26	20-66
	4	40	±16.68	18-62
	5	39	±4.71	30-44
Farm total land (ha)	1	2.4	±1.99	0.7-6.3
	2	10.7	±7.65	1.4-23.1
	3	3.9	±1.02	2.8-5.7
	4	4.1	±2.01	0.4-6.7
	5	2.5	±0.32	2.1-2.8
Coffee AFS (ha)	1	1.2	±0.70	0.9-2.8
	2	6.1	±2.96	1.7-10.5
	3	2.3	±1.33	0.7-4.9
	4	2.4	±1.45	0.7-4.9
	5	2.5	±0.32	2.1-2.8
Coffee Production (t ha-1)	1	2.45	±0.76	2.1-4.2
	2	2.87	±0.87	2.8-5
	3	1.52	±2.18	0.7-5.6
	4	2.98	±0.27	2.8-3.4
	5	3.74	±0.96	2.1-4.9
Coffee Selling Price ($ t-1)	1	514	±0.82	500-570
	2	700	±0.00	700
	3	580	±50.99	500-650
	4	588	±26.08	530-600
	5	530	±0.00	530
Relatedness index (%)	1	70	±25.64	20-100
	2	73	±9.21	60-80
	3	83	±13.75	60-100
	4	80	±16.33	60-100
	5	60	±20.14	20-80
Comments (#)	1	6	±5.28	1-15
	2	8	±4.20	3-16
	3	14	±8.03	4-26
	4	10	±4.24	3-16
	5	9	±2.67	5-12

Group 1 has the lowest farm total land (2.4 ha) and the lowest coffee-based AFS (1.2 ha), while Group 2 had the highest farm total land (10.7 ha) and coffee-based AFS (6.1 ha). These two groups represent also the range of the five communities concerning the

coffee selling price which is 530 $ t-1 for Group 1 and 700 $ t-1 for Group 2. Both group 1 and 2 also have no variation in coffee price as they belonged to two different small cooperatives that buy coffee at fixed price. In the case of Group 1 the price they sell it is at a minimum price, while in case of Group 2 it is a premium price justified by the high quality of the product and reliability of the producer. Group 1 had on average the youngest participants (average age of 35 years), while the oldest group was Group 3 (average age of 54 years). Group 3 has the highest relatedness index (83%).

During the game sessions most players allocated their fields in two of the board's four quadrants (QO in Table 2). This choice was justified by reproducing their own farm, which most of the time is sparing and in non-consecutive forest area. On average, only one player per game session decided to allocate the four fields into four different quadrants.

The five game sessions resulted in different outcomes in terms of landscape configurations (Table 2). In all rounds the percentage of selected of coffee-based land-use was between 0 and 100. The lowest average per round was 0 and the highest was 87.5. In Group 1, three players (players 1,3,4) always selected more than 50% of highly diversified traditional organic coffee-based AFS (option d). In Group 2 the average per game session was 39.6% for highly diversified traditional coffee-based AFS (option c) and 42.7% highly diversified traditional organic coffee-based AFS (option d). In Group 3 not a single player decided to use commercial polyculture coffee-based AFS (option b). In this group two players decided to play always with the same option: highly diversified traditional coffee-based AFS (option c, player 6) and highly diversified traditional organic coffee-based AFS (option d, player 5). Only in Group 4, all the players used the four land-use options available at least once during the four rounds. In this group the average per game session for commercial polyculture coffee-based AFS (option b) was the highest (30.2%) compared to the others groups. At the same time in Group 4 the highest average per game session was highly diversified traditional organic coffee-based AFS (option d) with 33.3%. In Group 5, four players (players 1,3,4,5,6) selected at least for two rounds 100% of highly diversified traditional coffee-based AFS (option c). In all groups the land-use option of monoculture full sun coffee (option a) was infrequently utilized: the highest average per game session was in Group 4 with 20.8% and the lowest in three groups (Groups 1, 3,5) with 8.3%.

Table 2. Outcomes of the game played in the five communities (Groups 1-5) showing the player's individual quadrant occupation (QO) and percentage and average of the selected land-use types. Each Round (R-) had one of the three possible situations: (A) Price of fertilizer is lower; (B) Same price for Organic and (C) Conventional Coffee Better price for Organic Coffee.

			Monoculture full sun coffee					Commercial polyculture coffee-based AFS					Highly diversified traditional coffee-based AFS					Highly diversified traditional organic coffee-based AFS				
Group	Player	QO	R1-A	R2-C	R3-B	R-4 A	Average	R1-A	R2-C	R3-B	R-4 A	Average	R1-A	R2-C	R3-B	R-4 A	Average	R1-A	R2-C	R3-B	R-4 A	Average
1	1	2	0	0	0	0	0.0	25	0	0	0	6.3	25	0	0	0	6.3	50	100	100	100	87.5
	2	2	25	25	25	25	25.0	25	0	0	0	6.3	25	0	0	0	6.3	25	75	75	75	62.5
	3	1	25	0	0	0	6.3	25	0	0	0	6.3	0	0	0	0	0.0	50	100	100	100	87.5
	4	4	0	0	0	0	0.0	50	50	0	0	25.0	0	0	0	0	0.0	50	50	100	100	75.0
	5	1	25	0	0	0	6.3	25	0	0	0	6.3	25	0	0	0	6.3	25	100	100	100	81.3
	6	2	0	0	25	25	12.5	25	0	0	0	6.3	50	50	25	25	37.5	25	50	50	50	43.8
	Average	2	12.5	4.2	8.3	8.3	8.3	29.2	8.3	0	0	9.4	20.8	8.3	4.2	4.2	9.4	37.5	79.2	87.5	87.5	72.9
Group	Player	QO	R1-B	R2-C	R3-A	R-4 C	Average	R1-B	R2-C	R3-A	R-4 C	Average	R1-B	R2-C	R3-A	R-4 C	Average	R1-B	R2-C	R3-A	R-4 C	Average
2	1	2	25	0	25	0	12.5	25	0	25	0	12.5	25	0	25	0	12.5	25	100	25	100	62.5
	2	2	25	25	0	0	12.5	25	0	0	0	6.3	25	50	25	50	37.5	25	25	50	50	37.5
	3	2	0	0	0	0	0.0	0	0	0	0	0.0	50	50	50	50	50.0	50	50	50	50	50.0
	4	3	25	0	0	0	6.3	0	0	0	0	0.0	25	50	50	25	37.5	50	50	50	75	56.3
	5	2	25	0	0	0	6.3	25	0	25	25	18.8	25	75	50	50	50.0	25	25	25	25	25.0
	6	2	75	0	0	0	18.8	0	0	25	0	6.3	0	75	75	50	50.0	25	25	0	50	25.0
	Average	2.2	29.2	4.2	4.2	0.0	9.4	12.5	0.0	12.5	4.2	7.3	25.0	50.0	45.8	37.5	39.6	33.3	45.8	33.3	58.3	42.7
Group	Player	QO	R1-B	R2-C	R3-A	R-4 B	Average	R1-B	R2-C	R3-A	R-4B	Average	R1-B	R2-C	R3-A	R-4 B	Average	R1-B	R2-C	R3-A	R-4 B	Average
3	1	3	0	0	0	0	0.0	0	0	0	0	0.0	100	50	50	0	50.0	0	50	50	0	25.0
	2	2	0	0	0	100	25.0	0	0	0	0	0.0	100	100	100	0	75.0	0	0	0	0	0.0
	3	3	0	0	0	100	25.0	0	0	0	0	0.0	100	50	25	0	43.8	0	50	75	0	31.3
	4	3	0	0	0	0	0.0	0	0	0	0	0.0	100	50	50	50	62.5	0	50	50	50	37.5
	5	3	0	0	0	0	0.0	0	0	0	0	0.0	0	0	0	0	0.0	100	100	100	100	100.0
	6	4	0	0	0	0	0.0	0	0	0	0	0.0	100	100	100	100	100.0	0	0	0	0	0.0
	Average	3.0	0.0	0.0	0.0	33.3	8.3	0.0	0.0	0.0	0.0	0.0	83.3	58.3	54.2	25.0	55.2	16.7	41.7	45.8	25.0	32.3
Group	Player	QO	R1-C	R2-A	R3-C	R-4 B	Average	R1-C	R2-A	R3-C	R-4B	Average	R1-C	R2-A	R3-C	R-4 B	Average	R1-C	R2-A	R3-C	R-4 B	Average
4	1	3	25	50	0	0	18.8	25	0	50	50	31.3	25	25	0	0	12.5	25	25	50	50	37.5
	2	4	50	0	0	25	18.8	50	100	50	50	62.5	0	0	25	25	12.5	0	0	25	0	6.3
	3	4	50	50	0	25	31.3	0	25	50	25	25.0	0	25	50	25	25.0	75	0	0	25	25.0
	4	3	50	50	0	25	31.3	0	0	0	25	6.3	50	50	25	25	37.5	50	25	50	50	43.8
	5	3	0	0	0	0	0.0	0	0	50	25	18.8	50	50	0	25	31.3	50	50	50	50	50.0
	6	2	0	50	25	25	25.0	75	25	25	25	37.5	0	0	25	25	12.5	25	25	25	25	25.0
	Average	3.2	29.2	33.3	4.2	16.7	20.8	25.0	25.0	37.5	33.3	30.2	20.8	25.0	20.8	20.8	21.9	37.5	20.8	33.3	33.3	31.3
Group	Player	QO	R1-C	R2-A	R3-B	R-4 A	Average	R1-C	R2-A	R3-B	R-4 A	Average	R1-C	R2-A	R3-B	R-4 A	Average	R1-C	R2-A	R3-B	R-4 A	Average
5	1	2	0	0	0	0	0.0	0	0	0	0	0.0	0	0	100	100	50.0	100	100	0	0	50.0
	2	3	0	0	0	0	0.0	0	0	0	0	0.0	0	0	100	0	25.0	100	100	0	100	75.0
	3	2	0	0	0	0	0.0	0	0	0	0	0.0	0	100	100	100	75.0	100	0	0	0	25.0
	4	1	0	0	0	0	0.0	0	0	0	0	0.0	100	100	100	100	100.0	0	0	0	0	0.0
	5	3	0	0	0	0	0.0	0	0	0	100	25.0	100	100	100	0	75.0	0	0	0	0	0.0
	6	4	0	0	100	100	50.0	0	0	0	0	0.0	100	100	0	0	50.0	0	0	0	0	0.0
	Average	2.5	0.0	0.0	16.7	16.7	8.3	0.0	0.0	0.0	16.7	4.2	50.0	66.7	83.3	50.0	62.5	50.0	33.3	0.0	16.7	25.0

Round by round, players adjusted the land-use of their fields. Most players changed the initial allocation by increasing the diversity of the land-use on the four plots (Table 2). In group 3 and 4, a total of three players switched their land-use from an initial organic to a conventional one. While in groups 1, 2, 3 and 5, seven players switched their land-use from conventional to organic. The rest of the players, who represent the majority of the players, kept their land-use during the game rounds. In Group 1 the total average percentage of selected coffee-based organic AFS land-use types was 72.9 %; 42.7% in Group 2; 32.3% in Group 3; 31.3% in Group 4 and 22.9% in Group 5.

The additional points gained by the groups of players showed diverse levels of cooperation (Table 3).

In Group 1 the total additional points gained by all the players during the game sessions was 180 additional points; 155 additional points in Group 2; 295 additional points in Group 3; 75 additional points in Group 4 and 230 additional points in Group 5.

While all players commented during the game sessions, the individual differences in quantified communication were considerable between players, ranging from 3 to 25 comments per player (Table 1). Only in group 3, a single player made 70% (26 comments) of the total number of comments. Group 3 also had the highest average comments made per player during the game (14 comments) (Table 1).

Table 3. Outcomes of the game played in the five communities (Groups 1-5) showing the additional points obtained per player and total additional points per round per group. Each Round (R-) had one of the three possible situations: (A) Price of fertilizer is lower; (B) Same price for Organic and (C) Conventional Coffee Better price for Organic Coffee.

		Additional points				
Group	Player	R1-A	R2-C	R3-B	R-4 A	Sum
1	1	5	10	10	10	35
	2	0	5	10	10	25
	3	0	5	5	5	15
	4	5	15	20	20	60
	5	0	5	5	5	15
	6	0	10	10	10	30
	Sum	10	50	60	60	180
Group	Player	R1-B	R2-C	R3-A	R-4 C	Sum
2	1	5	5	5	5	20
	2	0	10	5	5	20
	3	5	15	10	10	40
	4	5	15	10	10	40
	5	0	10	5	5	20
	6	0	5	5	5	15
	Sum	15	60	40	40	155
Group	Player	R1-B	R2-C	R3-A	R-4 B	Sum
3	1	15	20	15	5	55
	2	10	10	10	0	30
	3	15	15	15	5	50
	4	15	15	15	5	50
	5	15	15	15	0	45
	6	20	20	20	5	65
	Sum	90	95	90	20	295
Group	Player	R1-C	R2-A	R3-C	R-4 B	Sum
4	1	0	0	0	0	0
	2	5	0	5	10	20
	3	5	0	5	10	20
	4	5	0	5	10	20
	5	0	0	5	10	15
	6	0	0	0	0	0
	Sum	15	0	20	40	75
Group	Player	R1-C	R2-A	R3-B	R-4 A	Sum
5	1	10	5	10	0	25
	2	15	15	15	5	50
	3	10	5	10	0	25
	4	5	5	5	5	20
	5	15	15	15	0	45
	6	20	20	20	5	65
	Sum	75	65	75	15	230

In most of the groups the number of comments followed the same trend of the perceived leadership (Figure 5).

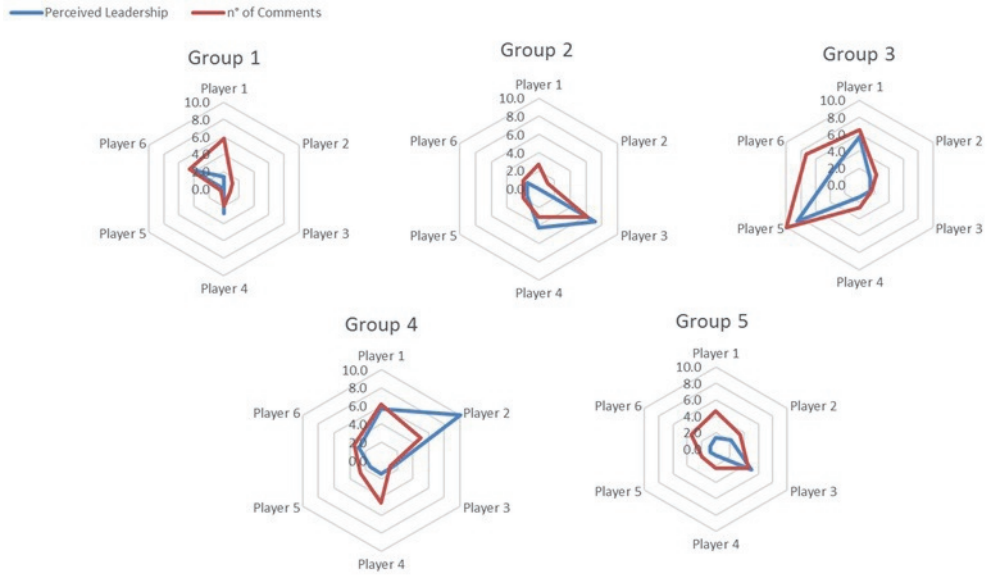

Figure 5. Overview of the perceived leadership and number of comments made by the players during the game sessions of the five pilot game groups.

In groups 2, 3 and 5 the players that made the most comments were also the ones with the highest perceived leadership (respectively players 3, 5 and 3). While, in groups 1 and 4 even though one player per group made most of the comments (in both cases player 1) they were not the perceived by the other players as leaders. In fact, they identified two different players as the leaders (respectively players 4 and 2).

During the debriefing group discussion after the game sessions five indicators were identified to describe the current situation and desired future during the backcasting workshop covering the complexity of sustainability transition encompassing socio-economic and ecological aspects, namely: (i) Productivity: the coffee yield; (ii) Soil fertility: soil organic matter content (%); (iii) Biodiversity: coffee associated trees species richness; (iv) Market: selling price of coffee ($); (v) Land-use: land expansion (ha). The five indicators collected during the post-survey were confirmed or adjusted by literature review (Fraser et al., 2013; Wilson 2013; Poole & Donovan 2014; Martínez-Valle et al., 2017; Durand-Bessart et al., 2020).

In all groups the most conflictual topic was between organic and conventional agriculture. Reasons for players adopting or not adopting organic management were collected during the game sessions (N° of comments). In the overall game sessions played in the five communities there were 11 comments in favour of organic agriculture pointing at: (i) higher selling price (3 comments); (ii) sustainable management (6 comments) and (iii)

human health (2 comments). On the other hand, there were 17 comments made against organic agriculture pointing at: (i) lack of experience (5 comments); (ii) labour intense (8 comments) and (iii) low yield (4 comments).

3.2 Backcasting workshop: developing sustainability transition pathways

At the beginning of the workshop, participants worked on describing the current situation. Therefore, the five indicators identified during the post-game discussion in all game sessions were re-introduced (Figure 6).

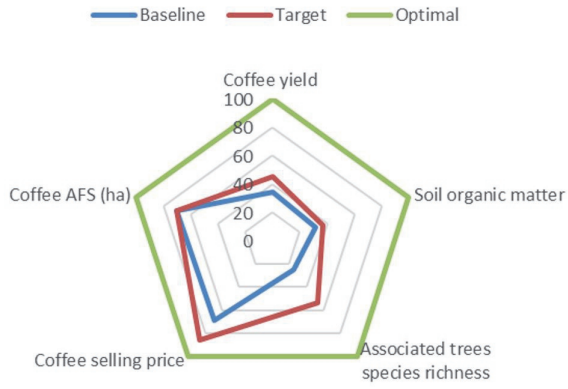

Figure 6. Current baseline and targets expressed in percentage of the envisioned future landscape for coffee AFS focused on coffee productivity, soil fertility, biodiversity, market and land-use. The optimal levels were based on literature review.

The productivity targets were discussed at length and only after two hours' discussion the participants reached consensus on the envisioned values for the indicators. Setting an ambitious productivity target for 2040 was the most important step for the participants. The discussion then moved onto organic coffee production and its currently low yields in relation to conventional coffee yields.

The participants agreed that the soil fertility targets were to be based on both the organic and conventional soil fertility values, as such the value was the average of both values.

The biodiversity targets were established by the participants starting from the current status of biodiversity in the coffee-based agroforestry systems.

The richness of the associated tree species in the agroforestry plots was evaluated in the post survey game sessions in each of the sessions. After some discussions and sharing of knowledge and practices in particular about the management of biodiversity in their coffee-based AFS, the participants expressed interest and commitment to increase the

plant diversity by continuing to share knowledge and practices of different trees species used in the communities.

Defining an envisioned market target highlighted how farmers receive different compensation when selling their coffee to local cooperatives or external companies. This difference in coffee prices in the current market system was pointed out as one of the key factors that needed to change in order to have a more equal and fair selling price for farmers. The participants proposed for the envisioned future a higher price for all organic and conventional producers. In addition to the envisioned improvements in the coffee production, participants discussed about diversifying the produce of these systems by initiating sales of associated fruits and seeds produced in the same agroforestry landscapes as a means to supplement and diversify local household income. The land-use target showed that participants were not willing nor able to expand the AFS land. Discussions on this topic included the hard-working conditions, lack of time and lack of labour.

After completing and presenting the envisioned future situation and targets, the participants of the backcasting workshop made the necessary steps to reach that future by identifying potential opportunities and obstacles (Figure 7).

For each opportunity and obstacle identified, participants discussed possible policy instruments or community-based solutions that might drive towards sustainable transition. In order to achieve a higher coffee price, the participants proposed to form a larger cooperative that would include several communities and could provide a recognized label acknowledging their sustainable production practices and fair trade (Figure 7). During the backcasting workshop, participants showed an interest to diversify their systems and produce. However, they showed little interest in further developing organic coffee production. They believed that organic production needs extensive labour requirements, considering also that more young people were leaving the countryside to find work in urban areas. As a consequence, farmers showed no interest in expanding their coffee-based AFS (Figure 6) mainly due to limited labour availability. Farmers did envision the farming practices associated with their desired future to be based on reduced external inputs, in particular, chemical inputs, that would only be used when strictly necessary.

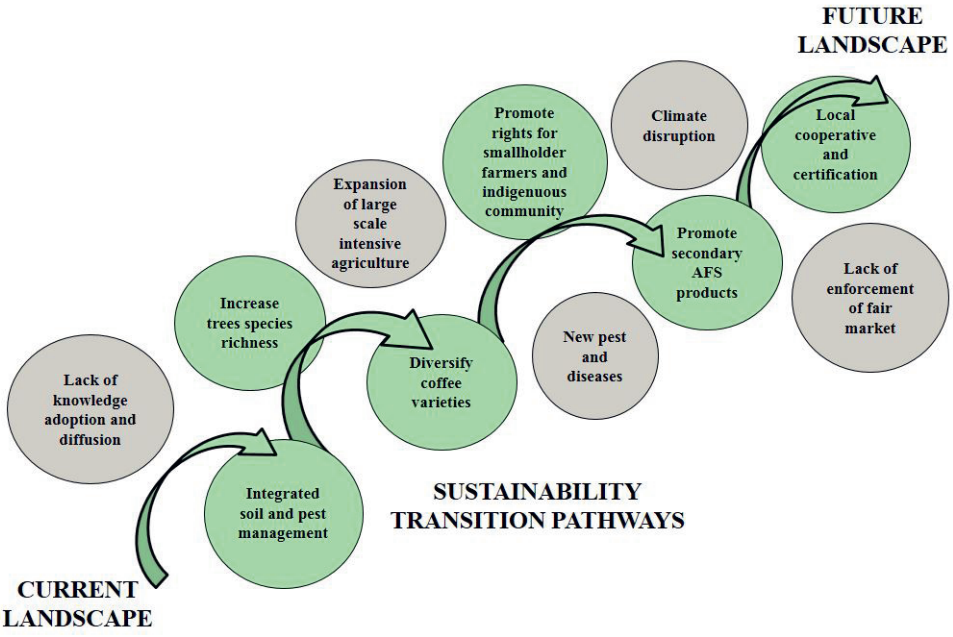

Figure 7. Policy instruments and community based solutions pathways for sustainability transition landscape through coffee-based AFS. The green circles indicate the opportunities that help to reach the future desired landscape, while the grey circles are the obstacles.

4. DISCUSSION

This study contributes to the current toolbox of methods for participatory co-production of future landscapes by combining participatory forecasting and backcasting approaches for a sustainability transition in agroforestry management. The combination of forecasting games and an interactive backcasting workshop provided new insights on farmer decision-making in these systems. In addition, it offered a unique setting for local stakeholders, farmers and technicians, to share knowledge and experiences on the management of their coffee-based AFS. New relationships and networks were established to continue further discussions on agro-forestry management at farm as well as landscape level. Five game sessions were organized with six participants each, followed by one backcasting workshop in which one participant of each game session participated to incorporate the outcomes and views of all participants from the various game sessions into the backcasting workshop. The workshop initiated discussion between farmers from different communities, technicians, researchers and the municipality, creating and/or reinforcing new networks and collaborations.

During five participatory forecasting gaming sessions, distinct agro-forested landscapes were developed with diverse combinations of the different coffee production types. Participants of the game sessions discussed at length about the different coffee production types and in particular organic vs non-organic systems when selecting their land-use types in the game landscape. This activity allowed and stimulated participants to share and discuss their knowledge, experiences and preferences related to coffee-based agroforestry landscapes. The composition of participants in each of sessions created new interactions within the safe environment of the game. Communication and leadership showed to be important pillars for collaboration among participants, both were positively related to successful collaboration among players. Through this forecasting exercise, participants jointly explored impacts of different land-use management options on income, landscape composition and collaboration. Farmers shared their interest in developing a fairer market for all coffee producers: organic and conventional. During the backcasting exercise, they built on these lessons by envisioning a desired future and identifying the steps needed to reach this future. The envisioned future was based on five pillars of sustainable coffee-based AFS as identified by the participants, namely improved coffee yields, improved soil fertility, increased biodiversity and a higher coffee price. The participants did not desire to enlarge the farmed area. Collectively the stakeholders who participated in the backcasting workshop developed a course of action for reaching the desired future (Figure 7).

Farmers in our research used the game as support for learning, sharing knowledge and practices towards opportunities and against the obstacles. The support of serious games as forecasting scenario evaluation tool for agricultural land-use planning has been presented in numerous research studies with similar results to ours: educational purpose, knowledge and management practices sharing, conflict mediation and leadership assessment (Garcia et al., 2018; Speelman et al., 2019).

Despite these convincing results obtained during the games sessions we highlighted the limitations of this approach. The limited number of options offered to the participants during the game on the one hand supported the evaluation of future scenarios, but on the other failed on elicit pathways for the desired transition. The game helped them to identify and discuss the difficulties they were facing in real life mainly related to support for production and market access. Farmers envisioned the production of coffee with different products not only for the sake of biodiversity but mainly for the market. In the study area there is a market only for coffee and not for other products (Martínez-Valle et al., 2017). This result is alarming when considering the difficulties that farmers in Tuma-La Dalia have for achieving food security (Bonilla et al., 2017). Bonilla et al., (2017) underlined how these farmers have difficulty to satisfy their food requirements between three to four months in a year as their main focus is coffee production instead of producing staple foods.

Other research studies that applied serious games also found major difficulties in adapting a unique tool for many contexts and encourage the co-production of these tools with the stakeholders mobilizing arena (Hassenforder et al., 2015) or companion modelling approach (i.e. Falardeau et al., 2019). Through the backcasting we succeeded in exploring the limitation of the four games options, engaging the discussion with the selected leaders on the indicators co-produced with the players during the post-game survey. The pathways for the desired transition included steps for allowing product diversification as developing the market for diverse products and the development of farmers' cooperative and trademark to support this desired future scenario. The scenario co-produced during the backcasting supported the collective evaluation of an optimal scenario but on the other hand only drafted the measures to achieve it. Previous studies have shown that researchers leading perspectives workshops also highlighted this weakness of the backcasting approach, but appreciated how this method is very effective for facilitating the process of co-producing scenarios involving local actors bringing local challenges to sustainability transition (Kok et al., 2011; Pedde et al., 2019; Falardeau et al., 2019).

Future research may experiment more with the methods showed in this paper to develop a common framework or protocol to be adapted for specific cases and support not only multi-level stakeholders' participation, but also a wider spatial scale which include the local landscape as well as the national and transitional levels. Applying game-changing methods as games and backcasting – taking into consideration the limitations of these methods – can be a constructive and participatory way to support local and international engagement for achieving sustainability.

5. CONCLUSIONS

The development and implementation of pathways towards sustainable tropical agroforested landscapes require an inclusive participatory approach. In these landscapes, stakeholders collectively have to address a multitude of issues including climate change, pests and diseases and prices. With suitable approaches to facilitate this co-production of sustainable landscape management still largely lacking, we presented a novel method based on the combination of forecasting game sessions and backcasting workshops. We presented a case study in the coffee-based agroforested landscapes of central Nicaragua where our approach allowed local stakeholders to define and explore distinct management strategies towards a sustainability transition in agroforestry management.

CHAPTER 2
APPENDIX A

Box 1. Detailed description of the adjusted RESORTES board game.

Basic game information

Name: RESORTES (Speelman et al., 2014a). *Objective:* To practice, discuss and evaluate the land use planning process. *Goal:* To win the game by accumulating the largest number of points. *Type:* Cooperative; non-zero-sum; goal-seeking. *Form:* Board game. *Time:* Preparation – 15 min; playing – 60 min; Debriefing – 45-90 min. *Target audience:* Smallholder farmers and technicians and/or communities that are planning their agricultural landscape. *Number of actors:* Participants – six; Facilitator – one; Assistant – one.

Resources

Game board consisting of 37 connected hexagons divided in four equally-sized quadrants; Field cards – 24; Land use cards – 4 sets of 24 cards; Dice – 3 pairs of dice (total 6 dice) with one small range and one large of numbers but with the same average. The 3 pairs of dice have lower, medium of higher values which reflect a situation in the game; Situation cards - 3 cards which represent different situation; Monopoly money; Computer.

Mechanics

A game session starts off with extensive game explanation through trial rounds. Once the facilitator has assured him or herself that all players fully understand the game, a situation is extracted randomly and field allocation starts. Players take turns and select one field location per round. When all fields have been selected, players select land use types for their fields - one land use type per field. When all players are satisfied with their selected land-use types, both dice (Different pair of dice per situation) are thrown and the facilitator and the players jointly check if any additional points through the planning schemes are earned. Then, that round's points are calculated and all players receive their points. Then, the facilitator highlights the current state for obtaining additional points through one or two of the planning schemes. The game continues for four rounds. After the game, the game debriefed in the form of group discussion.

Rules

Round situation: for each round is randomly extracted one of the three situations which affect the values of the dice, lower, medium, higher respectively representing (a) the selling price of the organic coffee is high, (b) the selling price of conventional and organic coffee is the same, (c) the price of chemical fertilizer is lower.

Turn taking: turn-taking is required when fields are allocated

Planning schemes: two incentive schemes for landscape planning can lead to additional points: 1 – economic benefits from forming an organic cooperative (OC) and 2 – ecotourism (ET). The OC scheme requires eight fields per quadrant with organic and high diversify – traditional - coffee-based AFS and rewards all who hold a field in the respective quadrant five additional points per round. The ET scheme requires eight fields per quadrant per cover with high diverse - traditional

-conventional and/or organic coffee-based AFS and rewards all who hold a field in the respective quadrant five additional points per round.
Points system: At the end of every round, players receive that round's points. Points result from standard points dependent on risk-level of current land-use choices, and additional points from one or both planning schemes.

3

Chapter 3

When neglected species gain global interest: Lessons learned from quinoa's boom and bust

Andreotti, F., Bazile, D., Biaggi, C., Callo-Concha, D., Jacquet, J., Jemal, O. M., ... & Van Noordwijk, M. (2022). When neglected species gain global interest: Lessons learned from quinoa's boom and bust for teff and minor millet. Global Food Security, 32, 100613. https://doi.org/10.1016/j.gfs.2022.100613

ABSTRACT

Until recently, many so-called neglected and underutilized species (NUS) were not present in global markets while playing a pivotal role in the local livelihoods in their places of origin. Today, some NUS receive substantial global interest and face growing global demands. Sudden increases in consumer demand trigger prices to rise; land-use change at the farm and national levels result in a rapid increase of production. This phenomenon is known as "boom" and usually it is followed by a "bust" - a rapid decrease of the prices and subsequently, production. In this review, we elaborate on the boom and bust phases of two NUS: quinoa from the Andes and teff from Ethiopia, and we explore the potential upcoming boom of minor millets in India. Our study proposes a generic framework for exploring cross-scale interactions and for rethinking sustainability pathways for future NUS booms.

Keywords: Smallholder farmers, Crop booms, Sustainability, Quinoa, Family farming, Globalization

I. Introduction

Over the last decades, dietary analysis in most of the western world welcomed the arrival of Neglected and Underutilized Species (NUS) (De Schutter 2011; Horlings & Marsden 2011; Li & Siddique 2018; Magrini et al., 2019). While previously, most NUS were produced and consumed primarily in their places of origin as subsistence agriculture, nowadays these crops receive substantial interest (Chelleri et al., 2016; Pallante et al., 2016), especially coming from health-conscious consumers attracted to their unique nutrient compositions (Li & Siddique 2018). Due to their increased popularity and swiftly developed innovative marketing, many NUS are now labelled as "superfoods" (Li & Siddique 2018) which further increased consumer demand and resulted in the rise of prices, in turn leading to the rapid and significant increase of their area of production, the so-called "boom" (Hall 2011).

Crop booms have been well documented; some emblematic examples include palm oil in Indonesia (Gilbert 2009; Sibhatu 2019), cacao in West Africa (Clough et al., 2009; Andreotti et al., 2018), coffee in Latin America (Pinilla & Willebald 2018; Beveridge et al., 2019), and shrimp in South-East Asia (Belton et al., 2017). Booms are generally triggered by rapidly increasing consumer demands from abroad (Hall, 2011), which creates the rise of market prices. Producers thus swiftly change to cultivating the booming crop (Mahanty and Milne, 2016; Ornetsmüller et al., 2018). In the medium- and long-term, the initial benefits of booms tend to negatively affect agroecosystems causing land-use to change and affecting local natural resources (McDonell 2015; Pinilla & Willebald 2018). Hence, crop booms are commonly followed by a period of production decline and finally, by a period of re-growth of crop cultivation. This process is referred to as a boom and bust cycle (Clough et al., 2009; McDonell 2015).

Today, most NUS are actively grown by smallholders in the area where they have been produced for centuries, often in marginal lands, with limited or no external inputs (Altieri et al., 1989; Wezel et al., 2017). The occurrence of crop booms can endanger local food security in these communities and sustainability of their farming systems when small holders are encouraged to expand their production rapidly, and to simplify their farming systems by adapting variety choices and agricultural practices to global standards and requirements of agroindustry (De Schutter 2011; van Noordwijk et al., 2014; McDonell 2015). In addition to these acute impacts, additional impacts include extensive land conversion, modification of rural landscapes, changes in farming practices and water management (Chelleri et al., 2016; Minten et al., 2016; van Noordwijk 2019).

In this paper, we present a literature review regarding two recent NUS booms: quinoa (*Chenopodium quinoa* Willd.) in the Peruvian and Bolivian Andes, and teff (*Eragrostis tef* (Zucc.) Trotter) in Ethiopia. Building on the knowledge from these two cases, we develop

a generic framework to explore sustainability transition in NUS boom and bust cycles. We assess the characteristics of these NUS that led to increased global demands and the resulted boom and bust cycle. In addition, we assessed the diverse governance instruments that applied in these two cases and their impacts in the cycle. Finally, we consider the upcoming minor millet boom expected to occur in India. Applying our "lessons learned" and framework to minor millets and their upcoming boom can help the actors in the value chain coordinate to learn how sustainable transitions can co-exist in a boom-bust cycle ensuring local benefits and preservation of the social-ecological environment.

2. Literature review

We operated bibliographic searches in Scopus, to explore NUS booms. First, we singled out the searching to the terms: "quinoa", "teff", "minor millets", "boom" and "neglected and underutilized species". The composite strings we developed yielded zero results for: minor millets and boom, teff and boom, neglected and underutilized species and boom (Figure 1). We conclude that no papers overlapped with NUS and boom evidencing a gap in the scientific literature. (See Appendix A for a complete overview of the search strings used in Scopus, September 2021).

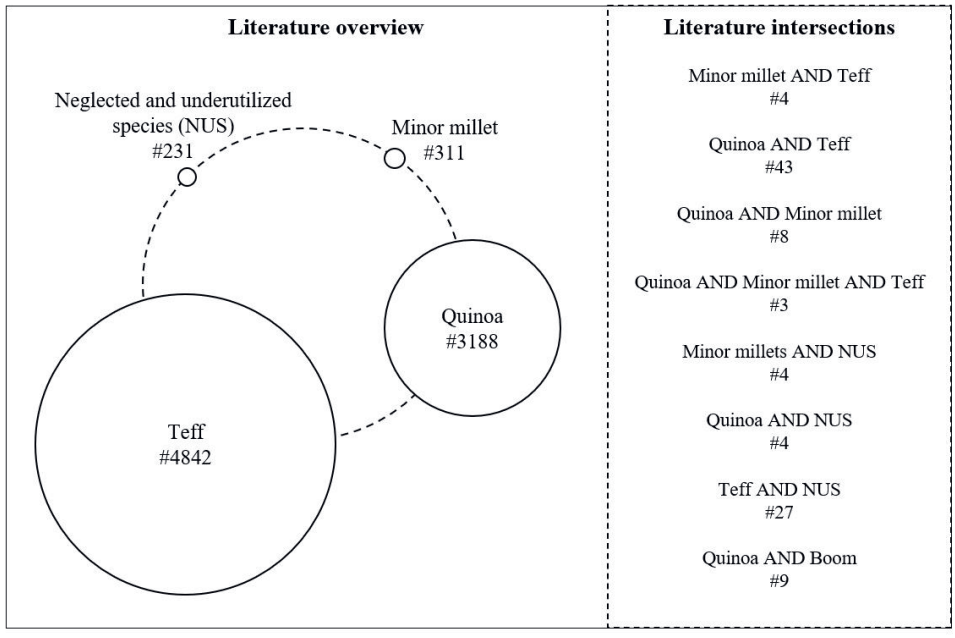

Figure 1. On the left, proportional diagrams showing the results of the literature search of the four main elements studied: "quinoa", "teff", "minor millet" and "neglected and underutilized species" (NUS). On the right the consequent list of literature intersections including "boom". The intersections that yielded zero are excluded from this figure (Scopus literature search performed in June 2020).

3. NUS boom and bust cycle

Based on the scientific articles found in our literature review, we sketch the boom and bust cycle phases which will be key to explore sustainability transition over past, current and future NUS boom and busts (Figure 2).

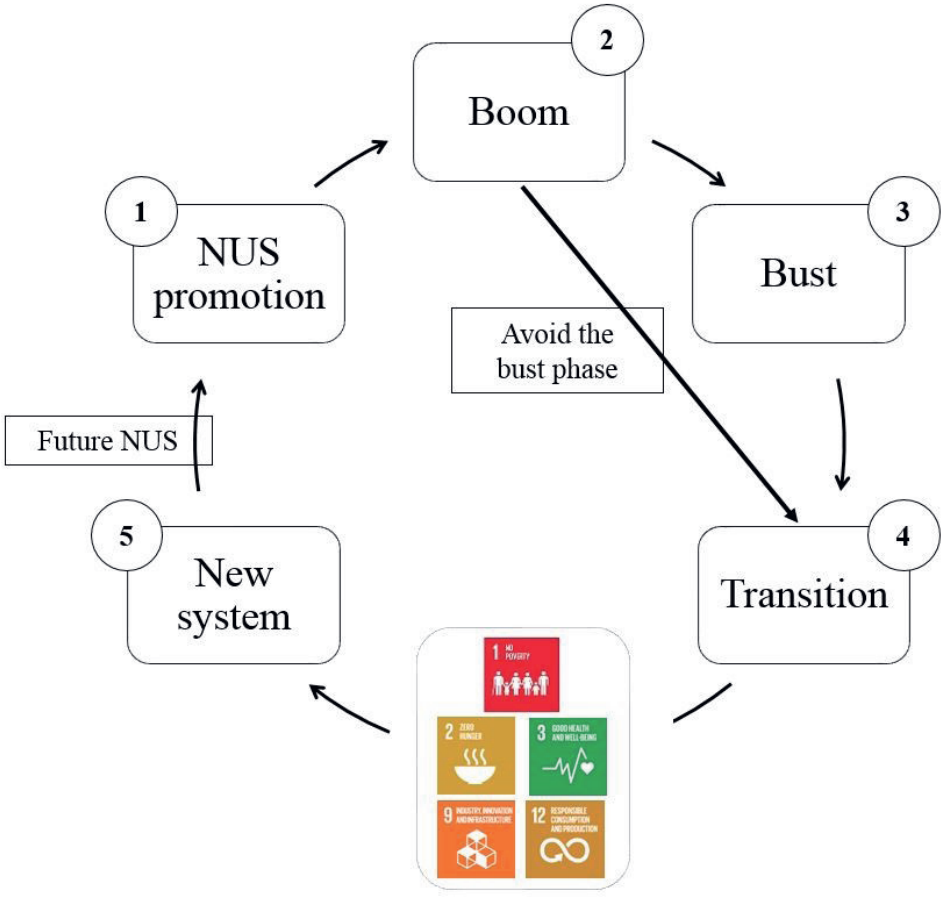

Figure 2. Phases of the NUS boom and bust cycle. Phase 4 and 5 rely on sustainability transition based on the SDGs presented by the FAO (2018) for developing sustainable food systems, namely: SDGs 1,2,3,9 and 12. These SDGs will be showed in an in depth framework for phases 4 and 5 highlighting a transition path towards sustainability (Figure 6).

Concerning the complexity and the diversity of NUS all around the world we developed a boom-and-bust cycle useful to highlight a common ground among the different case studies. Therefore, we identified five cycle phases through the literature review and the expertise of the international teams of authors of this paper. In phase 1, or NUS promotion, we point to the supply/demand relations and elasticities that have a long tradition of economic analysis. Phase 2, or the NUS boom, is a quick phase that involves

environmental effects of increased land conversion to agriculture, increasing market production for export, increase in market and farmgate rates and an increase in the area harvested. Meanwhile, government programs can try to interact with and influence the above dynamics in multiple ways, through measures which can be top down or bottom-up. In the third phase, the NUS bust, we describe the consequences on food security as well as other concerns about the way increased farm income is used and how it leads to changes in local well-being. In this phase the initial and short-term NUS boom decade in a decreasing interest among stakeholders. Of specific current interest is the degree to which growing awareness of local impacts informs and modifies global consumer behaviour, sparking response actions that may influence local dynamics and feedbacks in multiple ways. Phase 3 is the longest in terms of time, reducing the benefit obtained by local communities during the boom. As in the case of teff in Ethiopia, phase 3 can be avoided shifting from the boom phase towards a sustainability transition (Crymes 2015). In the fourth and fifth phases, new possibilities are developed by and/or for smallholders and local communities which rethink the organization of production, processing and consumption of NUS and which re-establish a connection between the different actors. This adds value to NUS local production, commercialization, and place in the global market. In phase 4 we present a common protocol for driving the sustainability transition among NUS boom and bust following the United Nations' 2030 agenda for Sustainable Development. In fact, these guidelines are not only showing the path to inclusive prosperity, but it is also drawing a common protocol to follow towards a sustainable future (Veldhuizen et al., 2020). These objectives embrace the principles of sustainability and tackle the root causes of poverty and hunger (Byerlee & Fanzo 2019; van Dijk et al., 2020). Thanks to this protocol we aim to present with phase 5 a scheme of recommendations to achieve sustainable NUS production and market. Finally, the cycle presented a continuum process framing possible future NUS boom.

3.1 Phase 1: NUS promotion

3.1.1 Nutrition characteristics of NUS

The first phase of the boom-bust cycle is the promotion of NUS as "superfoods" which attracts new consumers all over the world thanks to the crops high nutritional values (Padulosi et al., 2013; Zimmerer & Haan 2017; Pilling et al., 2020). Quinoa, teff and minor millets have an optimum amount of energy and protein compared to other common cereals (Geervani et al., 1989; Bultosa 2002; Repo-Carrasco et al., 2003; Baye 2014) (Table 1). The absence of gluten (Hopman et al., 2008; Padulosi et al., 2013) makes these three NUS valuable for preparing dietary products for gluten intolerant people. Furthermore, quinoa, teff and minor millets possess additional nutritional advantages over many common cereals such as maize, white rice and wheat. For instance, teff, due to the low glycemic index (74) and high gelatinization temperature (68-80 °C), is slow-digesting carbohydrate (Wolter et al., 2013; Baye 2014). Another example shown is that

quinoa has the ideal balance of essential amino acids for human diets (Navruz-Varli & Sanlier 2016).

Table 1. Average analysis (g 100 g^{-1} fresh weight) and mineral composition (mg 100 g^{-1} dry weight) of quinoa (Koziol et al., 1992), teff (Geremew et al., 2004), minor millets (Geervani et al., 1989) and other major staples: wheat, maize and white rice (FAO 2015).

Crops	Protein	Fat	Ash	Carbohydrate	Crude fiber	Ca	P	Mg	Fe	Zn	K
Quinoa	16,5	6,3	3,8	69	3,8	148,7	383,7	249,6	13,2	4,4	926,7
Teff	11	2,5	2,3	73	3	112,9	429	164	80,8	3,9	615
Minor millet	11,5	3,9	4	63,8	8,6	182	239	109	10,2	2,2	260,5
Wheat	10,6	1,9	1,4	61,6	10,5	108	288	126	4,3	3,5	363
White rice	7,1	0,66	1,3	80	4	28	115	25	3	2	115
Maize	9,8	4,9	1,4	60,9	9	48,3	299	107,9	3	3	324

3.1.2 *Phase 1: Quinoa*

One of the most studied NUS is *Chenopodium quinoa* Willd. (Bazile et al., 2015a). Farmers in the Andes in South America took the first steps in domesticating quinoa approximately 3,000 years ago (Planella et al., 2014). Through a multitude of selection procedures, desirable crop traits were selected from different cultures and territories in South America including parts of Peru, Bolivia, Chile, Argentina and Ecuador. Traits were selected related to the crop's cultivation (Bhargava & Srivastava 2013) and taste preferences (Bazile et al., 2016a).

The last 40 years have seen a great expansion of quinoa production and experimentation all around the world (Bazile et al., 2013; Katwal & Bazile 2020). Quinoa was promoted during the International Year of Quinoa in 2013 (IYQ-2013) by the United Nations (UN) (Bazile et al., 2016a). The main purpose of IYQ-2013 was "to focus world attention on the role that quinoa biodiversity plays, owing to the nutritional value of quinoa, in providing food security and nutrition" (Bazile et al., 2013; Murphy et al., 2016). The FAO works with national governments to help maintain and protect their quinoa agrobiodiversity, considering seed rules at global and national levels. However, the main decisions for shaping rules and laws concerning seed and plant genetic resources are developed by national institutions and governments (Bazile et al., 2016b).

Global expansion of quinoa began in the 1950s with an increased demand from North America and Europe. Producer countries quickly increased from seven in the Andean region to more than 50 before the IYQ2013. Today, quinoa is cultivated in more than 123

countries and present in every climatic zone of the planet (Bazile et al., 2016; Gardner et al., 2019).

For centuries, Andean quinoa products were denigrated and destined only for household consumption (Bazile et al., 2013). Today, quinoa has made its way into the diets of urban populations not only of Andean countries, in part due to international recognition following the IYQ-2013, but also in the United States, Europe and Asia (Bellemare et al., 2018) where a wide range of quinoa products are now available in shops: from ready-to-eat meals or breakfast cereals to healthy snacks, noodles, beverages and beers. These products are well positioned in several niche markets such as the nutraceutical, organic and fair-trade markets (Carimentrand et al., 2015). These last 50 years of quinoa expansion at a global level offer lessons for understanding what is now happening for other NUS.

3.1.3 *Phase 1: Teff*

Teff (*Eragrostis tef* (Zucc.) Trotter) is a fine grain cereal belonging to the Poaceae family, believed to have been first domesticated in its center of origin and diversity, Ethiopia, approximately 3,000 years ago (Vavilov 1951; Ketema 1997). So far, up to 4,000 varieties of teff have been identified in Ethiopia, yet locally they all are classified into three major classes: white, red and mixed (brown and white) (Ketema 1997; Gizaw 2018).

While quinoa became one of the main cultivated crops in the Andes at regional level in their main area of cultivation after their international boom, teff was already a major economical staple food grain in Ethiopia before the boom. Teff supports more than 60-75% of Ethiopia's population as a staple food (Crymes 2015; Gizaw 2018). It takes the largest share of all staple grains; 28.5% of the total cereal cultivation area and about a quarter of the total cereal production (Crymes 2015; FAO 2015). Besides its nutritional value, teff is a key cash crop, as 36% of the total national production is commercialized for local and global markets with 34% higher value than coffee (Worku et al., 2014, Minten et al., 2012)

In Ethiopia, teff is traditionally used to prepare *injera*, a thin, sour, pancake-like food, which accompanies the majority of the daily meals (Bultosa 2002; Baye 2014). Teff is also used to prepare other foods, like porridge, unleavened bread, and soup (Bultosa 2002). Teff holds a crucial role in the social, economic, cultural and political functioning and wellbeing of the country (Wolter et al., 2013).

3.2 Phase 2 and 3: NUS boom and bust

3.2.1 *Quinoa boom and bust*

After the International Year of Quinoa (2013 to 2015), 26 countries, the majority in Africa, received the FAO´s technical assistance to strengthen food security by promoting quinoa cultivation (Bazile et al., 2016b). The markets for Andean exports also underwent changes: the USA became a more important importer, concentrating 56% of the shipping from Bolivia, Ecuador, and Peru (Alandia et al., 2020). Germany, France, the Netherlands, and Japan lost relative weight as buyers, but their imports continued to increase. This occurred in the context of increased traded volumes in the global market. In fact, traditional international consumers and Importers from outside the Andes are now producing quinoa in their own countries (Bazile et al., 2016a).

One impact of the growing global interest in quinoa associated to IYQ was a rapid increase in international prices during a short period with a peak in 2014(Figure 3 and figure 4) (IICA 2018).

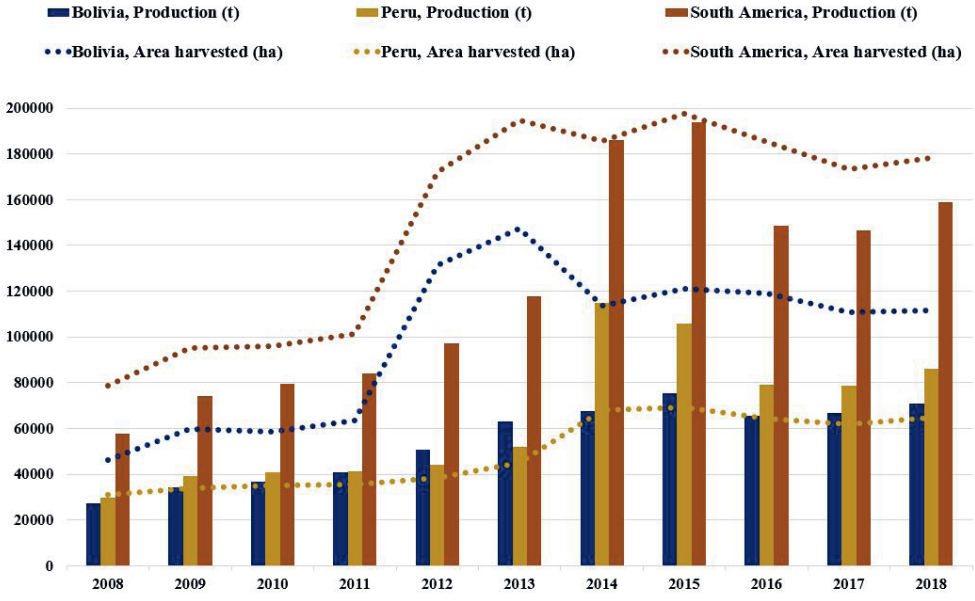

Figure 3. Harvested area (ha) and production (t) of quinoa in the Andes (Data source: FAO STAT 2018)

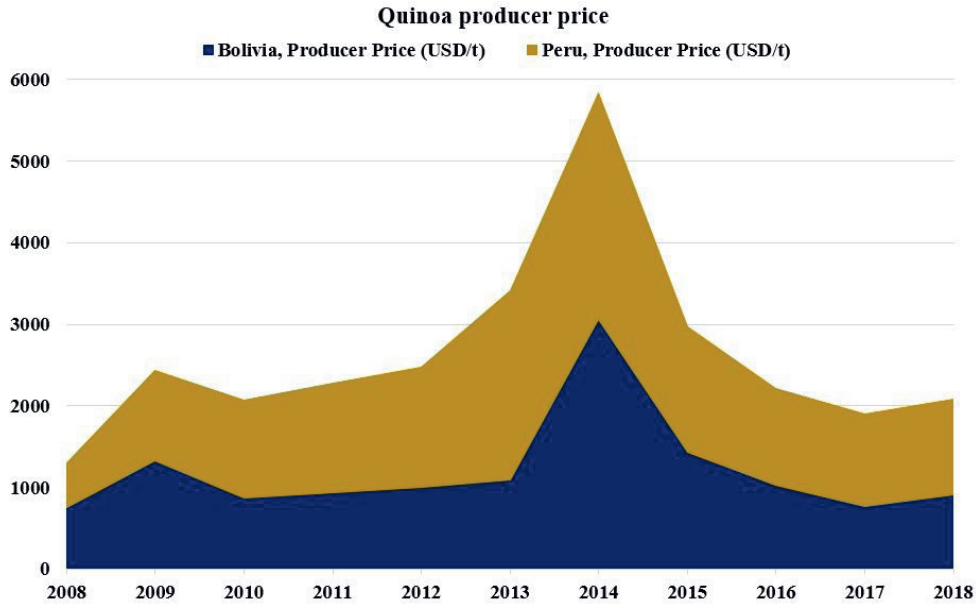

Figure 4. Producer price (USD/t)) of quinoa in Peru and Bolivia (Data source: FAO STAT 2018)

Most of the benefits of higher prices reached the farmers thanks to fair trade circuits. At the same time, many rural landowners who migrated to the cities years ago came back to their communities to grow quinoa (Risi et al., 2015; Tschopp et al., 2018; 2019). Andean countries had to rethink and update their public policies, prioritizing the sustainability of the crop and re-evaluating quinoa as a grain with global importance (Murphy et al., 2016). However, Andean countries showed an increase in per capita consumption due in part to the fact that quinoa being internationally recognized changed its status at national level and was now commercially more available for Andean local consumers in various novel consumer forms. In addition, government plans were implemented in Peru and Bolivia to favor the consumption of quinoa (Risi et al., 2015; Bellemare et al., 2018) resulting in the doubling of national quinoa consumption rates Peru as well as exported higher volumes every year (Bazile, 2015b).

Peru and Bolivia remain the two main producers of quinoa (Carimentrand et al., 2015). Recently, many countries (>117) in North America, Europe, Asia, and Africa have also expanded their quinoa production (Bazile et al., 2016b; Choukr-Allah et al., 2016; Gardner et al., 2019) while continuing to import the majority of their national quinoa consumption (Murphy et al., 2016, Bazile et al., 2021).

3.2.2 *Teff boom and bust control*

Several studies have identified the major drivers for the price escalation of teff in Ethiopia as both internal and external factors (Crymes 2015; FAO 2015; Gizaw 2018; Minten et al., 2012) (Figure 5).

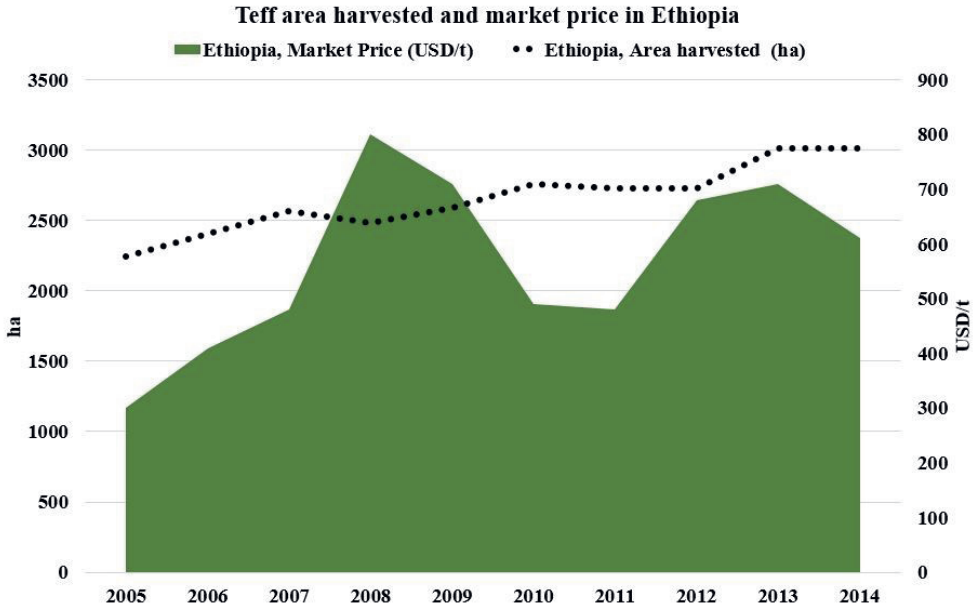

Figure 5. Harvested area and market price of teff in Ethiopia (Data source: FAO STAT 2018)

Internally, the rapidly growing non-farming population coupled with slowly improving productivity of the farming system continually widened the demand-supply gap of teff (Gizaw 2018). Externally, growing foreign demand, mainly from the African diaspora, caused the export of teff to rise significantly, which in turn negatively affected local markets (Chen et al., 2015; Minten et al., 2016).

To stabilize markets, the government banned the export of teff grain and flour in 2006. However, the measure was inefficient, as export of processed products like *injera* expanded, keeping teff rates high and increasing (Crymes 2015; Minten et al., 2012). On the other hand, the recent global recognition and promotion of teff as a gluten-free grain and as one of the superfoods of the 21st century, has caused the existing pressure of foreign demand on the local price of teff to be even stronger (Crymes 2015; Gizaw 2018; Minten et al., 2012). As a consequence, the current prices of teff have already become unaffordable for the majority of Ethiopians (Crymes 2015) and the food and nutrition security of the whole nation is now under threat (Gizaw 2018).

Ethiopia, the world's biggest producer of teff, can currently not benefit from this international trade opportunity because of the export ban (Crymes 2015; FAO 2015). Furthermore, the country is missing other opportunities to solve its crucial problems of the teff sector such as low productivity and lack of value-adding processing facilities, which could be cost-effective and faster if the involvement of international players were allowed (Di Marcantonio & Demeke 2013). Given the rapid economic progress and urbanization witnessed in previous years, as well as increased export demand, the importance of teff in food systems in Ethiopia is anticipated to increase in the coming years. Subsequently, guaranteeing appropriate efforts to meet the growing demand of teff has become a priority for agricultural and food policy in Ethiopia.

3.3 Phase 4 and 5: NUS sustainability transition to a new system

We highlight the importance of consumer social responsibility that may be needed to make NUS boom-bust cycles more manageable and supportive of food security and sustainable production practices. We show new possibilities developed by and for smallholders and local communities which rethink the organizations of production, processing, and consumption of NUS and which re-establish a connection between different actors, adding value to NUS local production and commercialization and acting in the global market.

3.3.1 *Quinoa system transition*

In the conjuncture of the IYQ 2013 (Bazile et al., 2013), the Peruvian and Bolivian governments promoted the creation of the International Quinoa Center in 2013. The center's leverage power is yet unknown as the center only developed its strategy in 2017; however, its objectives include working towards more sustainable and transparent quinoa production and sale, promoting research and stakeholder collaboration. In 2014, Andean quinoa entered international markets, Bolivia was surpassed by Peru as the world's most important quinoa producer, newly certified protected varieties were registered in the *International Union for the Protection of New Varieties* (UPOV) and small producer markets emerging across Europe and North America were all warning signs that Bolivia might lose its exclusivity on international markets (Carimentrand et al., 2015). Bolivia responded to this threat by increasing its production of highly valued varieties, like the quinoa *real* and by using denomination of origin as a branding and marketing strategy (Laguna 2003, Risi et al 2015).

In the case of quinoa, the current understanding of the agricultural boom is lacking a collective plan to ensure local benefits from the whole value chain (Tshopp et al., 2018). In fact, several different dynamics are taking place within different groups of farmers and NGOs. On one hand, these have the common objective of adding value to Andean quinoa through various niche export markets and a staple food of their diet. On the other

hand, there is a lack of coordination between these initiatives (Angeli et al., 2020). Due to a lack of stakeholders communication and organization and transformation plants, Peruvian quinoa, unlike Bolivian quinoa, does not have the necessary qualities to become a niche-market product. Bolivia is a hotspot of origin. The country maintained a large quinoa diversity. Due to a lack of understanding and action on behalf of consumers, the SDGs highlighted by the FAO (FAO 2018) are poorly implicated in the chain, in one hand, exposing the Peruvian quinoa production system as an unsustainable food system whose market is not able to sustain its context.

3.3.2 *Teff system transition*

In Ethiopia, the teff boom was quickly controlled by the national government. The Ministry of Agriculture and Natural Resources and its respective offices at the lowest administrative level, *kebele*, are the main and first responsible governmental structure of Ethiopia for improving shortcomings of teff value chains. The ministry is responsible for the promotion of improved agricultural technologies for farmers. It also facilitates and ensures the accessibility of fertilizer and improved seeds to local farmers at a fair price. As the ministry structure stretches from national to village level, it currently serves as an effective extension channel through which farmers are informed of new local technologies developed by the National Agricultural Research System of Ethiopia (FAO 2015).

In an attempt to safeguard national food security and maintain the existing role of teff as a key food and cash crop, the government of Ethiopia banned the export of teff grain and flower. As a result of this export ban, teff exports came to a total stop. However, the vastly rising local prices could not be stopped or reversed by the ban (Hauenstein 2015). There are currently two main conflicting opinions about the impact of the ban (Lee 2018). The first view argues that the policy already failed and even holds farmers back from benefitting from a new international niche market. In this view, lifting the export ban could increase farmer income from teff, thereby their access to food available on the market. In addition, it would promote the national currency reserves and enhance the state's capacity to invest in modern agricultural inputs and technologies for producing food crops. The counter-opinion sees the export ban as a way of protecting local farmers from price volatility and from the potential monopoly of multinational companies (Hauenstein 2015). Lifting the ban would reduce the availability and the affordability of teff in Ethiopia, subjecting most Ethiopians to cheaper yet less nutritious substitutes. It will also expose Ethiopians to a growing risk of a substandard teff product, ultimately harming the health and nutritional status of consumers (Crymes 2015; FAO 2015; Hauenstein 2015).

The current understanding of the agricultural boom of teff in Ethiopia and the societal willingness to act are more in line with an effective top-down coordination guided by

the government. Imposing a ban on teff regulated the market positioning of teff and *injera* as unique products, which appeal to local and global markets. On the other hand, decoupling monetary value with social and cultural value transforming teff's the purpose of cultivation from a staple food to a cash generating crop, so consumption pattern, in less than ten years. The main cause for such change is largely related to the rapid rise of teff's domestic market price which left the huge number of growers with no better option but to use their teff as a cash crop and use the cash to buy cheaper cereals like maize (Jemal et al 2018). Furthermore, the teff consumption pattern of non-farming rural and poor urban consumers has been changing as they could not afford the high prices of teff; consequently, obliged to either to blend or totally replace teff flour with cheaper flours such as sorghum, maize during the making of *injera*. Due to this change of diet, people with nutrition deficiencies are increasing in rural areas around the city of Addis Ababa (Lee 2018). In this area there has been a recent increase in health problems related to iron deficiency (Central Statistical Agency Ethiopia 2016). Replacing teff with less nutritional crops such as maize or sorghum and with less iron is going against the survival of farmers and the preservation of their socio-ecological environment (Minten et al., 2016).

3.4 Upcoming NUS boom and bust: the case of minor millets in India

In India, another traditional grain and food has been labelled as a NUS and is currently drawing the attention of political leaders, researchers, environmental activists, and urban middle-class consumers. These grains are known as millets. Millets are a family of grass-like grains commonly separated into two categories: those with a husk called minor millets, and those without a husk called major millets.

3.4.1 The evolution of minor millet production and consumption

Both major and minor millets have been eaten in India for centuries and are part of folklore and culinary traditions in many regions of the country (Chera, 2017; Bath et al., 2018; Li & Siddique 2018). Over the course of the latter half of the twentieth century, the production and consumption of millets, anf in particular of minor millets, declined across all of India (Bhalla and Singh, 2009; Shah, 2021). Several reasons explain why minor millets were negatively impacted by the changes which happened during the Green Revolution. Many authors suggest this is due to the policies of the Green Revolution which favored rice and wheat production (Shah, 2021), in addition to the drudgery involved in the processing of minor millets in order to remove their complex and heterogeneous husks (Hazereesingh, 2020).

Following the Green Revolution India achieved self-sufficiency in food like never before (Shah, 2021). However, today, India is currently facing a triple burden of malnutrition (Gomez et al., 2013). This means there is the simultaneous presence of hunger, malnutrition, and over-nutrition. Hunger is still present but overall, on the decline in

India but there is a lack of adequate micro-nutrient intake, particularly in rural areas; malnourishment affects as many as 189 million people in India which is 25% of the global rate of malnutrition (FAO et al., 2020). This can lead to stunting and many life-long health risks for children and mothers. Meanwhile, mainly in urban areas, residents experience a surplus of caloric and macro-nutrition which has resulted in an important increase in cardiovascular diseases and diabetes in the country (Shah, 2019). In this context, the Indian staples of rice and wheat, the keystone crops of the Green Revolution, have been examined with a critical eye. The low micro-nutrient qualities, low fiber, and high sugar content of rice and wheat have been highlighted (Cher, 2017).

In addition to this health and food insecurity, India is also facing an unprecedented rural and agricultural crisis which has been documented by both the press and academia (Vasavi 2009; 2012; Nagaraj et al., 2013; Shah, 2021). In the past thirty years more than three hundred thousand farmers have committed suicide (Shah 2021).

One element among many of this crisis is the depletion and pollution of the country's water resources which affects at least 60% of India's districts (Vijayshankar et al., 2011). Farmers and their families are thus vulnerable to health hazards due to numerous pollutants found in groundwater, such as fluoride, arsenic, mercury. Farmers are also struggling to obtain access to irrigation as drought frequency and severity increase. In addition, yield response to the application of increasingly more expensive chemical inputs is failing (Indoria, 2018). This has meant higher costs of cultivation without a corresponding rise in output, even as this intensified application of inputs compels farmers to draw increasing amounts of water from the ground (Shah, 2021). The Indian Council for Research on International Economic Relations (ICRIER) estimates about 78% of India's water is consumed for agriculture and that rice, wheat and sugarcane consume more than 80% of irrigation water (Sharma et al., 2018). The main reason why farmers grow such crops then, even in areas of water shortage, is the structure of incentives that exists for them, including steady markets (Shah, 2021).

India's health and food security have changed since the onset of the Green Revolution. The intensive and resource-demanding agricultural practices behind rice and wheat production are very slowly being questioned as India faces complex agricultural, environmental, and nutritional crises. The situation described above has generated concern among several categories of actors some of which see millets, the traditional and forgotten crop, as a possible solution to these complex situations.

3.4.2. The boom and the potential bust of minor millets in India

Millets have been the object of multipronged institutional campaigns aiming to increase both urban demand as well as rural production in multiple states of India like Odisha

and Karnataka. Millets are promoted as "*Good for you, good for the farmer, and good for the Earth"* by state governments (Governement of Karnataka, 2018). In contrast to rice and wheat, millets present nutritional characteristics which could help buffer both the lack of micro-nutrition and the presence of lifestyle diseases like diabetes. Millets have always been dryland crops; they grow well without irrigation, and they are drought-resistant (NAAS 2013). Their official national nomenclature was even modified in 2018, from coarse cereals to nutri-cereals, to help forget the implicit inferior status they once had (Financial Express, 2018).

Indian urban demand for minor millets has increased, especially in the upper middle classes of South Indian cities like Bengaluru, Mysuru and Chennai (Krishna et al., 2013). Trendy restaurants and shops are increasingly including millets on their menus and on their shelves and promoting them as smart foods, nutraceuticals, or as the food of the future gifted to us by our ancestors. Traditional recipes are being modified and new ones created to make millets appealing to young urban consumers (Cher, 2017).

In parallel, various national agricultural research institutions are seeking to develop high yielding and hybrid varieties as well as the appropriate machinery for the hulling, grading, and processing of millets into high-value products adapted to new urban consumption patterns and possibly for export markets (Padulosi et al., 2015).

A national year of millets was declared in 2016 and India was part of the committee to submit the proposal to the FAO for an International Year of Millets which took place in 2018. The proposal was successfully resubmitted for the year 2023 (Li & Siddique 2018). Multiple seek to create an international export market for millets, which for the meantime does not exist.

As detailed above, a multitude of actors, with different backgrounds, intentions, and values, have jumped onto the millet bandwagon. From these observations it is possible to confirm that minor millets have been and continue to be in a phase of promotion, or Phase 1 of the boom-and-bust cycle, since the mid-2000s. Minor millets are perhaps currently in Phase 2 (boom) of the boom and bust cycle.

The patterned trajectories of miracle development crops and NUS are well known (McDonell, 2020). If minor millets are currently experiencing a boom, the question is whether a bust is unavoidable? Could certain policies, a sustained consumer demand, or NGO involvement perhaps diminish the possibilities of a bust? How could the potentially beneficial effects of millet production be measured, broadened, and maintained over time? What lessons can be learned from other NUS bust experiences?

In addition, if minor millets are to experience a boom-and-bust cycle, their promise of resolving complex climatic and health issues is compromised. The value of minor millets is not only connected with their economic value, but also their ecological value which needs to be ensured and maintained over a potential boom-and-bust. Policy instruments can be used to protect local varieties and specific modes of production, which could protect millets from losing their ecological edge developed over years by local farmers and organizations (Nagarajan et al., 2009; Padulosi et al., 2015). Also, the absence of appropriate political and economic protection could lead to large-scale and intensive production destined for markets outside of rural areas and prevent the local consumption, and thus part of the potential, of millets. Long-term partnerships between governments agencies, local organisations, and farmers seem necessary to avoid the instability inherent in NUS booms.

Millets are being promoted in India because they are viewed as an alternative, even as a solution, to very specific health and environmental challenges in contemporary India. However, an increase in production and consumption of minor millets is not sufficient to resolve these complex crises which the country is experiencing. Millets could be one element of an ensemble of alternatives, perhaps even a paradigm shift (Shah, 2021).

3.5 Inclusive action decision towards sustainable NUS production and consumption

From our analysis based on our NUS study cases we evidence the poor connection that was established between producers and consumers. The gap in scientific research is also showing a lack of understanding about the role that consumers have on NUS boom and bust cycle at the place of origin (Figure 6).

More research seems needed to study the ethical issues of far-away health focused and conscious consumers. In fact, as we described, NUS boom and bust, may lead to unknown consequences for the consumers as: food insecurity in the place of production and origin, simplified local food systems, and in directly reducing the genetic diversity maintained for centuries. This challenge needs a more inclusive approaches able to promote active decision-making process and future scenario evaluation.

Inclusive active decision-making, and initiative promoted by local and international institutions may drive to a more sustainable NUS supply chain (Speelman et al., 2014; 2019; Andreotti et al., 2020; van Noordwijk et al., 2020). For instance, in Chile, a prospective by scenarios for the future of quinoa was explored with farmer organizations from three different regions, culture and practices, using a role-playing game for discussing how to enhance coordination among them and for connecting their organization to extension services and national programs (Bazile et al., 2012a; 2012b). The main result

was the creation of round-table discussions, the so-called "*Mesa nacional de la quinoa*" as an instance of the Chilean Ministry of Agriculture for debating with all actors involved in quinoa development about options for better use of public funds with local communities. A similar strategy has been adopted also by the Peruvian Ministry of Agriculture with the so-called *"Mesa de la quinoa"* fostering new opportunities and cooperation between the main quinoa producers in the Andes (Mercado & Ubillus 2017). Following up the experience of the "*Mesa nacional de la quinoa*" in Chile a more recent and ongoing PhD project presented during the *Forum Origin, Diversity and Territories* aims to involve directly Andean quinoa producers – from multiple Andean countries - for developing a collective trademark for Andean quinoa (Andreotti et al., 2020). Coordinating collective action by connecting local actors with consumers can facilitate a better understanding of NUS boom and bust cycle and open the discussion for co-designing sustainable future food systems. To achieve this, an inclusive participatory approach at the transnational value chain level is needed.

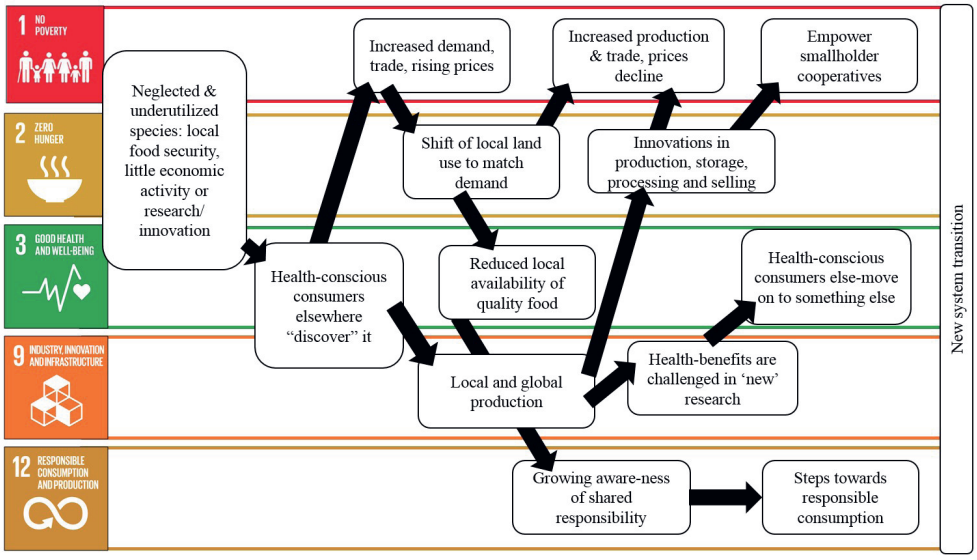

Figure 6. Sustainability transition framework highlighting processes for a new system transition (Phases 4 and 5 of Figure 2). The five SDGs presented, namely 1,2,3,9 and 12, are the grid of the processes to analyse the transformation over time.

4. Conclusions

Research shows that crop booms of neglected and underutilized species (NUS) have often resulted in negative impacts in the medium and long-term for farmers, their livelihoods and the landscapes they live in. In this paper, we reviewed the recent agricultural booms of quinoa and teff as a result of increased demand from health-conscious consumers

in the Western world. We reflected on two distinct approaches used in an attempt to manage these two booms, namely a bottom-up approach in the case of quinoa initiated by Andean farmers' organizations and a top-down approach in the case of teff supported by national government. In the case of the quinoa, a grassroots approach was used by local stakeholders to achieve positive outcomes for local landscapes and the livelihoods of quinoa farmers. In the case of the teff boom in Ethiopia a top-down approach was used to secure national food security for the country's staple food and to prevent bio-piracy of their endemic genetic resources. While in Peru and Bolivia, farmer organizations are unifying their efforts to launch a more sustainable export approach, in Ethiopia the national government imposed a temporary ban on teff exports trying to mitigate the boom-bust effect. Drawing from the lessons learnt from these two booms, we reflected upon the nascent minor millets NUS boom in India and how millets could be integrated into agricultural production and consumption in a long-term and sustainable fashion. We question if the boom-and-bust cycle is inevitable and if strong partnerships between government, researchers, and local organisations and farmer groups are not the best way to ensure that the millet potential delivers not only for urban consumers but also rural farmers and farmer families.

CHAPTER 3
APPENDIX A

Overview of the search strings including articles' title, abstract and keywords accomplished in Scopus in June 2020

- "Neglected and underutilized species" OR "NUS": 183 hits
- "Teff": 4416 hits
- "Quinoa": 2603 hits
- "Minor millet*": 269 hits
- "Minor millet*" AND "Teff": 2 hits
- "Quinoa" AND "Teff": 36 hits
- "Quinoa" AND "Minor millet*": 6 hits
- "Quinoa" AND "Minor millet*" AND "Teff": 2 hits
- "Minor millet*" AND ("Neglected and underutilized species" OR "NUS"): 4 hits
- "Quinoa" AND ("Neglected and underutilized species" OR "NUS"): 3 hits
- "Teff" AND ("Neglected and underutilized species" OR "NUS"): 25 hits
- "Quinoa" AND "Boom": 7 hits
- "Minor millet*" AND "Boom": zero hits
- "Teff" AND "Boom": zero hits
- ("Neglected and underutilized species" OR "NUS") AND "Boom": zero hits

4

Chapter 4

Exploring the future of agrobiodiversity: a multi-method approach for smallholder organizations

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This chapter is currently under review for the journal of Agronomy for Sustainable Development

Abstract

The intensification of crop production is negatively affecting the cultivated biodiversity of smallholder systems. Maintaining local landraces of quinoa is a key agricultural activity in the high-Andes landscape. In recent decades, the "boom" of quinoa production has given rise to national projects intended to ensure that farmers benefit from their agricultural heritage. This study aims to assess farmers perceptions on the importance of quinoa diversity and the associated current on-farm quinoa diversity, and the development of a collective trademark. We developed our research in three villages in the Puno region of Peru, one of the quinoa's center of origin. We applied a novel combination of participatory methods: the Q methodology to interpret the perceptions of smallholder quinoa farmers concerning the activities that are important on their farms; and the Four-Square Analysis workshops to explore quinoa biodiversity management. The results of our Q-analysis revealed three types of opinions emerging among farmers: (Type 1) *Conservationist,* (Type 2) *Intensification focus* and (Type 3) *Collaboration seeker*. Type 1 *"* assigns greater importance to maintaining and promoting quinoa biodiversity through collective practices and markets. Type 2, focus on possibilities for developing export-oriented production based on certified and improved varieties, combined with efficient ways of storing quinoa. Type 3, appear to value the collective aspects of organizations and cooperation among stakeholders. According to the results of the Four-Square Analysis, most landraces of quinoa are threatened by erosion, as they are cultivated *in situ* in small plots and on few farms. Our results are an important baseline for further project development for biodiversity conservation in situ and market inclusion engaging local communities.

Keywords**:** Agroecology, Agrobiodiversity, Multi-method approach, Farmers' viewpoints, Neglected and underutilized species, *Chenopodium quinoa* Willd.

I. Introduction

Smallholder farmers produce more than 30% of the global food supply (Ricciardi et al., 2018), while maintaining its genetic diversity (Fanzo 2017; Dardonville et al., 2020). Of the approximately 30,000 species of edible plants that are available on the planet, only around 3,000 have ever been cultivated or used for human consumption, only 150 are commercially cultivated and marketed (Planella et al., 2014). Hundreds of neglected and under-utilized species (NUS) mainly cultivated by smallholder farmers as subsistence crops, are at risk of extinction (Li & Siddique 2018; Wezel et al., 2020). In recent decades, a few NUS have attracted global interest, leading to the transformation of these crops from "traditional foods" into "superfoods" that appeal to health-conscious Western consumers such as quinoa, teff, and minor millets (McDonnell 2021; Andreotti et al., 2022). One of the most studied NUS that has generated sudden global demand is quinoa (Alandia et al., 2020).

Quinoa (*Chenopodium quinoa* Willd.) was domesticated more than 7,000 years ago on the shores of Titicaca Lake in the Peruvian and Bolivian high Andes (Bazile et al., 2016). Quinoa gained global importance due to its excellent-quality proteins and vitamins (Repo-Carrasco et al., 2003; Navruz-Varli & Sanlier 2016), as well as to its tolerance of abiotic stresses (Ruiz et al., 2014; Murphy et al., 2016) and its promotion by local and global institutions. The United Nations promoted the potential of quinoa during the International Year of Quinoa in 2013 (IYQ-2013) (Bazile et al., 2015). From 2009 to 2013, Peru the world's leading producer, experienced a ten-fold increase in quinoa exports and a four-fold increase in prices (MINAGRI 2014). This production and price increment (Named "boom") of quinoa in Peru was followed by a rapid decrease in prices (Named "bust") (Alandia et al., 2020; Andreotti et al., 2022).

Since 2015, quinoa prices have declined, in response to developments in national and global production (Alandia et al., 2020; McDonnell 2021). As a result, smallholder quinoa producers in the Peruvian high Andes increased their yield by adopting a few certified varieties of quinoa, thus abandoning their landraces (also known as "traditional varieties") for varieties that were better suited to the attributes preferred by the global market i.e., large, white grains. Traditional varieties are still available in seedbanks, farms, and in the wild in the communities around Lake Titicaca (Mujica and Jacobsen 2006; Tapia et al., 2014; Fagandini et al., 2020). Nevertheless, intensification negatively impacted the biodiversity of smallholder systems, as it reduced the number of cultivated varieties of quinoa—both certified and landraces at farm and landscape level (Huanca et al., 2015; Winkel et al., 2016). The loss of genetic diversity in quinoa has environmental and social consequences at the farm level. As environmental consequences quinoa is becoming less resilient to climate change, as well as to new pests and diseases (Mujica

and Jacobsen 2006). While as social consequences, although cultural value continues to be associated with the cultivation of quinoa and the specific roles of women and men in preserving quinoa landraces, the availability of the landraces is decreasing (Fuentes et al., 2012). Local and global projects tried to support smallholder farmers in their efforts to maintain this biodiversity (Fagandini et al., 2020).

Since 2011, the Peruvian high-Andes region is included in the Globally Important Agricultural Heritage Systems (GIAHS) program (Koohafkan et al., 2011), an official initiative of the United Nations Food and Agriculture Organization (FAO), which aims to promote public awareness and global recognition of agricultural heritage sites (Argumedo 2008). One of the program's objectives is to foster the dynamic conservation of landscapes, including the cultivation of local crops, caring for socio-cultural traditions, and ensuring the sustainability of economic goods and environmental resources. Within the GIAHS program, however, the "Andean Agriculture" pilot project was successful only at the institutional level Local communities were not involved in elaborating the initial draft memorandum (GEF 2016). Drawing lessons from the Peru GIAHS pilot project, other GIAHS projects aim to foster the inclusion of smallholder farmers from the outset of projects (Winkel et al., 2014).

In the past decade, many NGOs and research institutes have been rethinking the role of quinoa in the Andes, promoting an array of projects focusing on the organizational needs of local smallholder farmers (Winkel et al., 2014; Bazile et al., 2016). One result of these efforts is a participatory approach, which aims to foster the organization of smallholder farmers to develop a common label for quinoa, alternative to third party certification, such as fairtrade or organic labelling: the collective trademark (CT). A CT is a participatory label, for which farmers jointly decide on common rules for the production and market of quinoa. Such a label can be used for marketing niche products such as traditional varieties in local and global markets (Deleixhe 2018; Cuéllar-Padilla & Ganuza-Fernandez 2018).

Throughout the world, smallholder-farmers' organizations and the United Nations projections have envisioned CT and participatory labelling initiatives as a way for farmers' organizations to position and reaffirm their local products (Binder & Vogl 2018; Loconto & Hatanaka 2018). In the high Andes, Peruvian farmers envision the CT as a possibility for highlighting the practices, knowledge, and values that distinguish their farming systems from those of other quinoa producers around the world (Bazile et al., 2021). These distinctive aspects include the biodiversity of Andean quinoa (Argumedo 2008; Davidson-Hunt et al., 2012; Gavin et al., 2015) and the local agroecological practices that are used in its cultivation (Bedoya-Perales et al., 2018; Cotula et al., 2019) (Figure 1).

Figure 1. Quinoa plots in a small farm in Rinconada, Puno, Peru. Credit: Federico Andreotti

To date, no studies have examined the process of developing a CT in the high Andes in order to maintain quinoa biodiversity and promote market access (Argumendo 2008; Cuéllar-Padilla & Ganuza-Fernandez 2018).

Any investigation of the process of developing a CT should include the participation of smallholder-farmers' organizations (Loconto & Hatanaka 2018). Using participatory research approaches that foster inclusion can be applied to characterize the opinions of smallholder farmers and to explore local crop diversity (Lagneaux et al., 2021; Andreotti et al., 2022). The most commonly applied methods for exploring the perspectives of farmers are questionnaires and interviews. Other methods involve the application of tools for creating an interface that facilitates and fosters the inclusion of the participants. These methods include serious games (Speelman et al., 2019; Andreotti et al., 2020), backcasting workshops (van Vliet & Kok 2015), interactive design (Romera et al., 2020), and the Q methodology (Dingkuhn et al., 2020). Several methods other than questionnaires and interviews are also available for collecting information on cultivated biodiversity *in situ*. One method that has proven successful in facilitating the gathering

of such information within an inclusive setting is that of Four-Square Analysis (4SqA) (Lagneaux et al., 2021).

The visual Q methodology has been applied for the purpose of examining the opinions and values of smallholder farmers (Pereira et al., 2016; Alexander et al., 2018; Dingkuhn et al., 2020; Leonhardt et al., 2021). The method provides a representation of "opinion types" existing within a given group. A combination of qualitative and quantitative techniques, the method was first developed and applied within the discipline of psychology (Stephenson 1935). In recent decades, it has been used widely in several fields, including environmental sustainability research (Accastello et al., 2019; Sneegas et al., 2020).

The 4SqA method has been applied to a focus-group workshop conducted for the purpose of exploring the knowledge and management practices of smallholder farmers concerning crop and varietal diversity among smallholder farmers with an *in-situ* conservation perspective (Grum et al., 2003; Legneaux et al., 2021). This method also entails both quantitative and qualitative components. It has been widely used by researchers and NGOs to generate inventories of crops—including specific species and landraces—in developing countries (Grum et al., 2003; Kilwinger et al., 2019). A landrace is a taxonomic rank used to define groups of organisms of the same species that share similar characteristics (Zeven 1998). A landrace is a domesticated, locally adapted traditional variety of a species of plant that has been developed over time, through adaptation to its natural and cultural environment of agriculture. The quinoa landraces of the farmers participating in our study are considered traditional varieties, as the farmers manage their seed lots each year, passing them from generation to generation. These landraces do not possess the characteristic of homogeneity, which is the main criterion for the certification of varieties based on national and international seed legislation (Bazile et al., 2016): landraces are generally distinguished from cultivars, and modern varieties from conventional plant breeding.

In this study, we explored farmers perceptions on the importance of quinoa diversity and the associated current on-farm quinoa diversity management. We applied participatory approaches to foster the inclusion of a broad range of actors and to characterize the opinions of smallholder farmers on agricultural practices and the market. We initiated a participatory research for studying the process of developing a CT. In doing so, we involved smallholder-farmers' organizations in the high Peruvian Andes. We addressed the following research question:

What are the opinions of smallholder farmers regarding quinoa varieties cultivation, farming practices, market choices, and the development of a collective trademark?

2. Materials and methods

2.1 The study site: The Puno region in the high Andes

The Puno region in the "Altiplano" area of Peru was selected as a case study. It is located in the center of the area where quinoa originated (Vavilov et al., 1992), and it is characterized by high, diverse production of quinoa (Fagandini 2019). In this region, more than 120 quinoa landraces are regularly cultivated as subsistence crops by smallholder farmers (Fagandini et al., 2020). Referred to as "desert *puna*," this agroecological zone is located at an altitude of 3,900 to 4,300 meters, and it is covered by grass and steppes (Morlon 1992; Fries & Tapia 2007; Mazoyer & Roudart 2017).

Within the desert *puna* in the Puno region, we selected three quinoa-growing areas surrounding the three main cities and markets of the region: Puno, Ilave, and Juliaca (Figure 2).

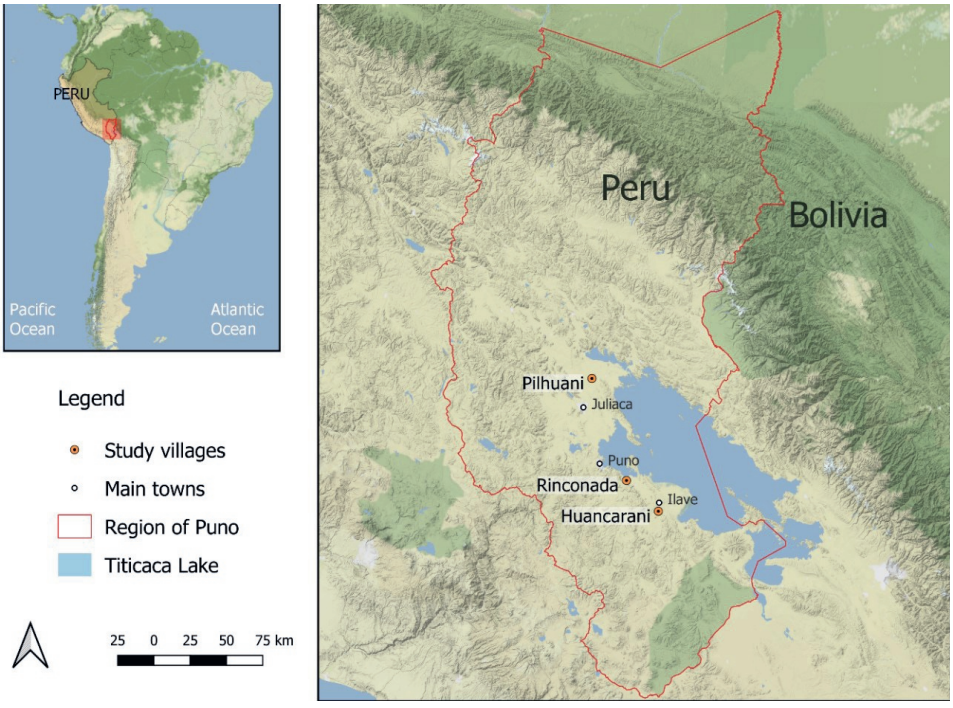

Figure 2. Study site location: Study villages (red dots); Main cities (white dots); Puno region (red border).

With the help of local institutions and researchers, we subsequently selected three villages in which smallholder-farmers' organizations were actively facilitating the production of and market for quinoa: Huancarani (Village A), Rinconada (Village B), and Pilhuani

(Village C). We participated in general assemblies with the smallholder-farmers' organizations in each of the three villages, during which we presented and discussed our research project and objectives. The farmers' organizations approved our project, and we were welcome to proceed with the research.

All three villages are located in desert *puna* zones, which are characterized by an arid environment (Table 1). Rainfall is seasonal, and most of the annual rainfall (90%) is spread over a single wet season, which usually starts in September and ends in April or May, followed by a dry season follows with little or no rainfall (Lavado Casimiro et al., 2013). Knowledge and local technologies concerning the maintenance and management of water is currently deteriorating or fading away (Verzijl & Quispe, 2013). Each of the villages has a smallholder-farmers' organization with fewer than 30 household members. In Village A, there is an association of farmers within a traditional farmers' collective known as an *Aynoka*. The association provides agronomic and marketing support from farmer to farmer, in addition to the collective ownership of a tractor. The *Aynoka* promotes communal labor in the village and organizes collective planning concerning land-use and crop-rotation choices, with varieties being maintained at the individual level. Village B has an active community of farmers based on individual households, with a primary focus on producing crops for the subsistence and a secondary objective of selling on the market. Village C is part of a larger farmers' cooperative, which promotes the processing of quinoa at the local level. Compared to the other two villages, it has a more direct link to the national market and the associated possibilities to commercialize quinoa for exports.

In each of the three villages, the agricultural work cycle is divided into stages, starting with plowing the field to prepare the soil for good seed germination and plant establishment (supplementary information about the farming systems is provided in Appendix A). Although plowing was traditionally done with animals, it is now commonly done with tractors for agricultural plots that are located in the plains. In addition to plowing, other agricultural activities include the sowing, weeding, and terracing of plots. Most of the quinoa landraces are harvested between April and June (Fagandini et al., 2020). In general, quinoa harvesting consists of three processes: swathing, threshing, and storing (which involves drying and cleaning) (Aguilar & Jacobsen, 2003). Each of the three villages also has a variety of animals, including alpacas, llamas, donkeys, sheep, cows, chickens, and pigs, some of which are kept mainly for meat and wool production. The animals' manure is applied to the soil when rotating crops in order to maintain the fertility of the soil. The most widely cultivated crops in the villages are quinoa, alfalfa, amaranth, barley, fava beans, oats, maize, and potatoes.

Table 1. Characteristics of the villages, including location, climate, agricultural seasons, and the ethnicity and organization of the households.

	Huancarani, Village A	**Rinconada, Village B**	**Pilhuani, Village C**
Location	(16°08'S 69°38'W)	(15°56'S 69°51'W)	(15°18'S 70°04'W)
Agro-ecological zone	Puna		
Altitude	3900 m		
Average annual temperature		5 - 8 °C	
Precipitation		700-1000 mm	
Wet season		One single rainy season, September - April/May	
Dry Season		May-September	
Growing season quinoa		September – April	
Harvest season quinoa		April - June	
Distance from the city	8.4 km from Ilave	26.3 km from Puno	24.3 km from Juliaca
Total number of households	78 households	56 households	62 households
Ethnicity	Aymara	Aymara	Quechua
Language(s)	Aymara and Spanish	Aymara and Spanish	Quechua and Spanish
Organisation	Farmers' organisation and traditional farmers' collective (Aynokas)	Farmers community: Family agricultural systems	Farmers' cooperative (in-situ product processing and market orientation).
Total number of households	25 households participate in the farmers' association.	27 households are quinoa producers	29 households participate in the cooperative.

2.2 Methods

We employed two participatory methods, one at the individual and the other on the collective level to answer our research questions: visual Q methodology (QM) for individual representations and Four-Square Analysis (4SqA), based on a focus-group approach (Figure 3).

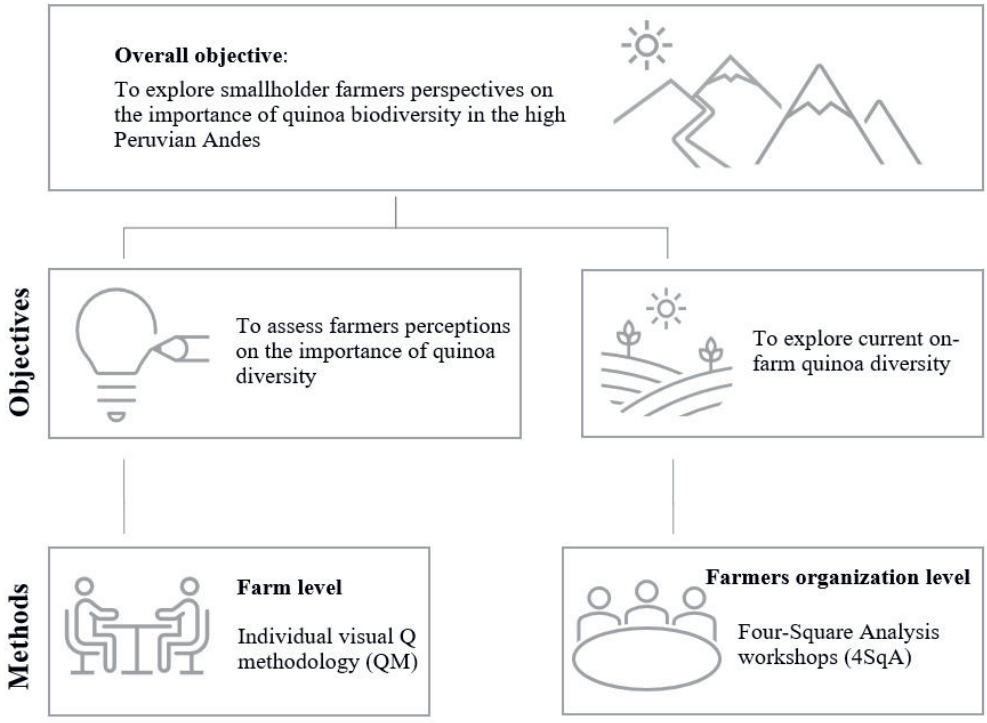

Figure 3. Overview of research objectives and methods.

We applied the QM to explore the perspectives of individual farmers with regard to farming practices, quinoa market choices, and the development of a collective trademark. The 4SqA was used to identify the quinoa landraces and improved and certified varieties that are cultivated by the farmers. The QM focused on the farm level, engaging farmers individually in sharing their own perspectives. While the 4SqA focused at the farmers organization level, connecting multiple farmers, and providing an overall illustration of the state of quinoa biodiversity.

2.2.1 *Assessing the perspectives of the farmers*

The visual Q methodology is used to assess people's opinions about a given topic (Zabala et al., 2018). This semi-quantitative method allows the identification of "opinion types" by clustering together people with similar perspectives (Watts and Stenner 2005). The

opinion types represent the collective perspectives of a group, and they do not represent the opinion of any individual., The results of QM therefore highlight agreements or disagreements of opinions within a group of people.

In QM, the items in a given set (i.e., a "Q-set") are ranked in order of importance or agreement. The items in the Q-set (i.e., statements, keywords, and/or pictures) depict the opinions of the participants with regard to a specific issue. The ranking operation (i.e., the "Q-sort") follows a semi-normal distribution, in which most of the items are ranked as "neutral," with a few items ranked as "most important" or "least important" (Figure 4).

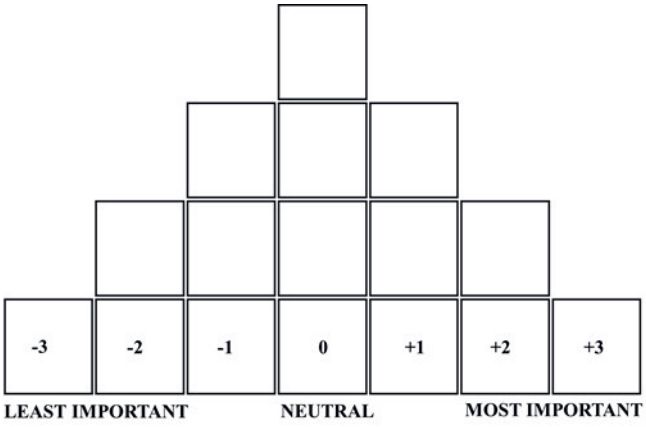

Figure 4. Q-sort semi-normal distribution

The statistical interpretation of the level of importance is based on the associated value of the quasi-normal distribution, with different values in each column. Starting from the right, the values are distributed as follows: +3 ("most important;" one item), +2 (two items), +1 (five items), 0 ("neutral;" five items), -1 (three items), -2 (two items), and -3 ("least important;" one item).

We used a visual Q-set consisting of pictures and keywords to facilitate the inclusion of Andean Peruvian farmers with abroad range of literacy. In all, 16 pictures and keywords were first tested for clarity and possible interpretations with local stakeholders and farmers, and then further employed to illustrate different farming practices and market choices that the smallholder famers used to improve their farming systems (Figure 5).

The overall question presented in Spanish, and here translated in English to initiate the exercise was "How important is this activity/component for the future of your farm?". Thanks to this question we collected individual opinion ranking on what is important or not for the future of the farm, focusing on quinoa varieties cultivation, farming practices,

market choices, and the development of a collective trademark. Such a "Learning from the future" approach has been shown to foster the exploration of transition pathway when re-thinking current challenges in the food system (Valencia et al., 2022).

Figure 5. Q-set keywords and corresponding pictures. Picture 5 was adapted from Latorre Farfàn (2014). Picture 15 displays the logos of USDA organic and the European Organic Certification. The rest of the pictures were taken by the first author.

The selection of keywords and pictures used to build the Q-set was based of recent studies of rural development conducted with Andean smallholder farmers in the Puno region (Carimentrand et al., 2015; Bedoya-Perales et al., 2018; Bellemare et al., 2018). After we identified the key words for the Q-set, the first author took the pictures while conducting fieldwork in the Puno region (September–October 2019) and picture found in the literature (i.e., Farfàn 2017). Keywords and pictures were combined to create the first Q-set. The keywords were translated from English into Spanish with support

from a local translator. A trial was conducted with local and international researchers, technicians, students, NGO members, and farmer leaders to establish whether the Q-set was representative of and comprehensible to farmers.

The participants were individually invited to rank the keywords and pictures (16 items in total) in a three-step process. In the first step, they were asked to sort the items into three piles: i) most important, ii) least important, and iii) neutral. Second, they were asked to place the items onto the pyramid board (Figure 4), starting with the most and least important items, and only then proceeding to place the neutral items in the empty spots. Third, if needed, they were asked to re-consider the level of importance of the items and reposition them to fill all of the spots available in the pyramid. Once a participant confirmed the position of each item, the results were noted. The process ended with a debriefing session focusing on the participant's reasoning for the choices and feedback on the experience. On average, the Q-sort and debriefing session took one hour per participant.

The researcher conducted the Q-sorts in Spanish with individual farmers in the Spanish language in October and November 2019. For each village, the leader provided a list of households belonging to a farmers' organizations that were active in quinoa production: a farmers' association in Huancarani, a farmers' community in Rinconada, and a farmers' cooperative in Pilhuani. In all, 36 farmers agreed to participate in the Q-sort and to take part in our study (Table 2).

Table 2. Descriptive information on the smallholder farmers participating in the Q-sort: Number of participants, age, use of organic or conventional quinoa-production practices, and whether they sold quinoa to the local market or to retailers.

	Huancarani, Village A	**Rinconada, Village B**	**Pilhuani, Village C**
Total number of participants	12	12	12
Men (number of people)	8	4	8
Women (number of people)	4	8	4
Average age (years)	50.6	57.8	54.8
Youngest (years)	19	39	42
Oldest (years)	77	78	68
Quinoa organic production (number of people)	12	6	12
Quinoa conventional production (number of people)	0	6	0
Quinoa sold to the local market (number of people)	9	12	7
Quinoa sold to retailers (number of people)	10	0	12

The outcomes of the Q-sort from the three villages were analysed using the Q-method function in the R software package (Zabala 2014). Throughout the analysis, we assessed three types of opinions. These types were based on significantly similar item rankings. We confirmed the three opinion types based on our own judgments and understanding of the topic, as well as on relevant literature. We analyzed the three opinion types using varimax factor rotation (Zabala 2014). Each participant was assigned to one of the three types according to a significant loading ($p < 0.05$). With these results, we further assessed the items that pointed to consensus or disagreement among the participants and explored trends in the opinions. Following Accastello et al., (2019), we present our results using a spider diagram highlighting the preferences of the participants with regard to the Q-set items.

2.2.2 *Exploring the cultivation of quinoa biodiversity*

Four-Square Analysis (4SqA) was used to explore the knowledge and management of crop diversity among a group of farmers located in the same landscape at the village level (Grum et al., 2014). The analysis took the form of participatory focus-group workshops, in which participants listed all crops (species and varieties) known to them and provided collective answers to specific questions related to them. In our case study, we asked the participants which quinoa varieties (cultivars and landraces for covering all quinoa biodiversity) were cultivated at the farm level. The farmers were further asked to locate each of the quinoa varieties on a two-dimensional plane. One axis representing the approximate combined surface area over which a specific quinoa variety was grown (Small plots *versus* Large plots) and the other axis representing an estimation of the number of households cultivating that variety (Few farms *versus* Many farms) (Figure 6).

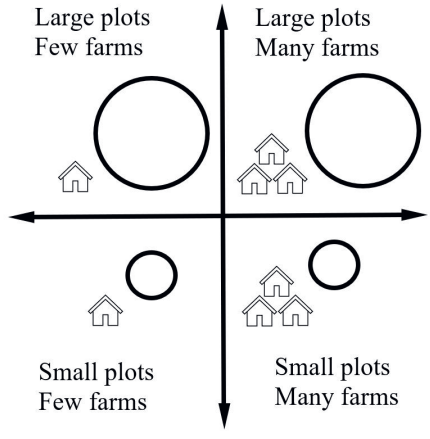

Figure 6. Representation of the Four-Square Analysis: The horizontal axis represents the size of the area on which a crop is cultivated (Small plots *versus* Large plots), and the vertical axis represents the number of households cultivating it (Few farms *versus* Many farms).

By doing so we established which varieties were at risk of genetic erosion, if placed in small plots and few farms or if they were common in the community if cultivated in small or large plots in many farms.

We applied this method to gain insight into how farmers manage and assign value to quinoa biodiversity. In each village, one 4SqA focus-group workshop was organized, with a minimum of six farmers, representing the biodiversity of the farms in the village (Table 3). The leader of the farmer organization was asked to invite people in the village to participate in the focus groups. The number of participants varied according to the availability of the farmers.

Table 3. Distribution of participants in the 4SqA focus-group workshops in the three villages studied.

	Huancarani, Village A	**Rinconada, Village B**	**Pilhuani, Village C**
Total number of participants	6	10	17
Men (number of people)	3	8	7
Women (number of people)	3	2	10

The focus groups were organized between late October 2019 and mid-December 2019. All of the workshops were conducted in Spanish and held at a location chosen by the participants (e.g., a school or another common meeting place). Each workshop lasted an average of 1.5 hours. First, the participants were asked to list all the quinoa varieties that they knew and that were currently cultivated in the village. Second, they provided collective answers to questions relating to the characteristics of the quinoa varieties, including the traditional names of the landraces or commercial name for cultivars and certified, and the main attributes for its cultivation and uses. They subsequently answered questions related to the management and value of the quinoa varieties. Third, the participants were asked to group the varieties that were cultivated in their village along the 4SqA axes.

3. Results

3.1 Assessment of the farmers perspectives

We used the QM results to explore the perceptions of smallholder farmers with regard to farming practices, market choices, and the development of a collective trademark. Based on the results of this analysis, our own judgements and understanding of the topic, and relevant literature, we developed three archetypes, which are defined as follows:

1. *Conservationist:* Farmers within this archetype value the biocultural heritage aspects of maintaining and promoting quinoa biodiversity over export market outcomes.
2. *Intensification focus:* Farmers within this archetype assigned importance to concrete aspects of technology (production and market), encompassing the use of certified and improved varieties and of efficient systems for storing quinoa for market export. Being prepared to fulfill market requirements (in terms of both quantity and quality) is apparently a priority for them.
3. *Collaboration seeker:* Farmers within this archetype value the collective aspects of organization (social and professional) over the concrete aspects of quinoa cultivation and production. They apparently assign the greatest importance to social organization and reliance on other stakeholders.

Of the 36 total participants, 14 showed to belong within the cluster for Opinion Type 1, with 11 belonging to Opinion Type 2, and three belonging to Opinion Type 3. The opinions of three participants did not fit into any of the three opinion types (additional information about the participants is presented in Appendix B).

The cluster for Opinion Type 1 had the highest number of men (10), with the highest number of women (6) being in the cluster for Opinion Type 2. The smallest cluster was for Opinion Type 3, which consisted of four women and one man. On average, the age of the participants in the three groups were similar (54–57 years), with both the youngest (28 years) and oldest (78 years) participants in Cluster 2. For all three clusters, the highest level of education completed was secondary school, with the smallest share of each cluster not having had access to school (e.g., four participants in Cluster 1 had not had access to school). The majority of farmers in all three clusters used organic practices to produce quinoa. The participants in Cluster 1 sold quinoa to retailers (10) and local markets (12), while those in the other clusters sold only to local markets.

The three clusters clearly reflected the various opinions with regard to the most important items. The participants in the cluster reflecting Opinion Type 1 expressed the strongest agreement concerning the importance of the cultivation of quinoa biodiversity (Item 8; factor array score: +3). For those in the cluster reflecting Opinion Type 2, the most important aspect was the possibility of storing quinoa (Item 9; +3), with Opinion Type 3 assigning the greatest importance to the export of quinoa (Item 10; +3). The three clusters also shared similar opinions concerning the utilization of pesticide (Item 5). This practice was considered of least importance in Opinion Types 1 and 2 (-3), sharing seeds (Item 4) was of least importance in Opinion Type 3 (-3; see Figure 7).

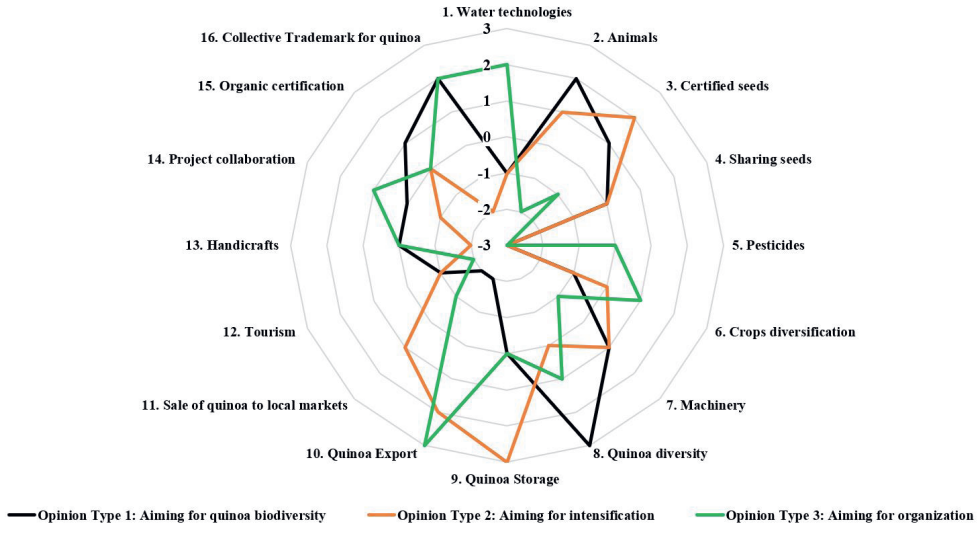

Figure 7. Spider diagram of item rankings for each opinion type. The black line indicates Opinion Type 1, the green line indicates Opinion Type 2), and the orange line indicates Opinion Type 3. Each ring of the diagram represents the importance value (from -3 to +3) assigned to each item.

3.2 Exploring quinoa biodiversity

In all, the participating farmers listed 21 quinoa varieties during the 4SqA workshops (additional information on the names of the varieties collected during the workshops is presented in Appendix C). The farmers in Village A (Huancarani) identified 12 varieties, including many local varieties: *Kankolla, REAL Salcedo INIA, Koito, Vitulla, Choclito, Pasankalla, Misa Misa, Hara, Ayrampu, Chulpi,* and *Janki.* They also classified *cañihua* as a quinoa variety, even though it is another species from the same family identified by botanists as *Chenopodium pallidicaule* Aellen. Most of the farmers in Village A reported having grown the modern variety *REAL Salcedo INIA* from National Public Research (first introduced by the local university) for many years. According to the respondents, this variety is more resistant to changing climatic conditions. The farmers' openness to newer varieties does not mean that they neglected the more indigenous varieties. On the contrary, indigenous varieties are now being reintroduced more than in previous years. In Village B (Rinconada), the farmers listed 10 different varieties of quinoa: *Quinoa Blanca, Cheveka, Vitulla, Sajama, Blanca de July, Kankolla Rosada, Kancolla Blanca, Hara,* and *Koito*. These farmers also classified *cañihua* as a quinoa variety. The participating farmers classified all of the varieties as local varieties or landraces, which had been cultivated "since ancient times." They did not classify any of the varieties as having been introduced more recently. In Village C (Pilhuani), the farmers identified 13 varieties of quinoa that they cultivated, including two landraces of *cañihua*: *Koito, REAL Salcedo INIA,*

Kankolla, Sajama, Rosada, Cañihua, Cañihua Amarilla, Cañihua Plomo, Pasankalla, Chulpi, Ayrampu, Amarilla, and *Choclo Taraquiña* (Appendix B).

Our results showed strong usage of certified and improved varieties, that are cultivated in large plots by many farmers, as in Village C. Based on the information we gathered, most of the local quinoa landraces are threatened by genetic erosion, as they are cultivated *in situ* in small plots and on few farms. This was the case in all three villages (Figure 8). The names of the landraces differ somewhat across the village, as each village used different names to designate traditional varieties of quinoa.

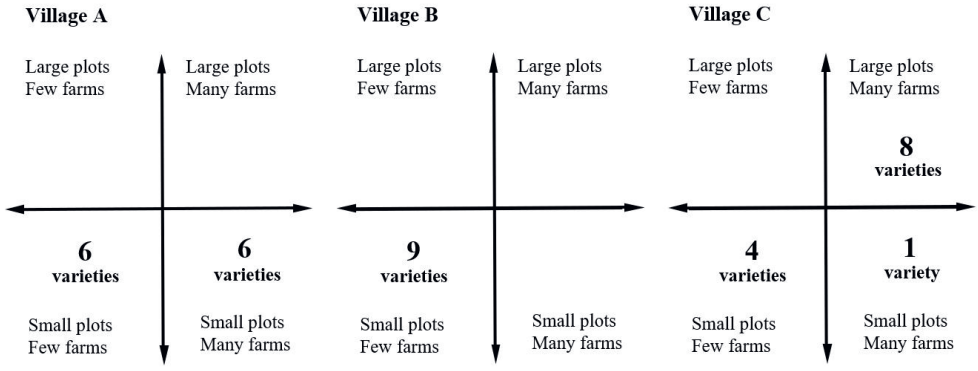

Figure 8. Overall results of the Four-Square Analysis workshops in each village. Each value shows in the squares express the number of quinoa varieties cultivated in a given village. No quinoa varieties were listed under the Four-Square category of "Large plots/Few farms".

4. Discussion

4.1 Reflection and perspectives on the Q methodology

As indicated in previous studies (Hamadou et al., 2016; Pereira et al., 2016; Alexander et al., 2018), the Q methodology can be a powerful tool for interpreting the perspectives of local communities that are facing the dynamics of complex socioecological systems.

The total number of participants in the current study was 36. Our sample provided a good reflection of the diversity of farmers' organizations in the Puno region, as it included a farmers' association, a farmers' community, and a farmers' cooperative. Several previous studies have generated relevant typologies with a similar range of participants. Examples include Hamadou et al., (2016) with 20 participants, Pereira et al., (2016) with 26 participants, Langston et al., (2019) with 34 participants, and Alexander et al., (2018) with 35 participants. With a total of 36 participants, our sample is thus within the acceptable parameters for QM.

In our study, we applied QM with farmers individually, in order to guarantee their active participation. We combine this with the 4SqA workshops to explore the biodiversity cultivated within the community. Similar approaches have been applied effectively within other research contexts for small-group collective activities (e.g., educational activities; see Pruslow et al., 2012) or for democratic endeavors (Billard 1999). Reflecting on our own experience, we agree with Berthet et al., (2016) that a proper understanding of local perspectives is likely to require the involvement of multiple stakeholders.

4.2 Opinion types

The findings of our study point to three perspectives on quinoa biodiversity emerging among the farmers (as producers of quinoa): *Conservationist* (Opinion Type 1), *Intensification focus* (Opinion Type 2), and *Collaboration seeker* (Opinion Type 3). Farmers adhering to Opinion Type 1 assign greater importance to maintaining and promoting quinoa biodiversity through collective practices and markets than they do to the export of quinoa. This is in contrast to those adhering to Opinion Type 2, who focus on possibilities for developing export-oriented production based on certified and improved varieties, combined with efficient ways of storing quinoa in order to fulfill the quality and quantity demands of retailers. Farmers adhering to Opinion Type 3 appear to value the collective aspects of organizations and cooperation among stakeholders more highly than they do the concrete agronomic aspects of quinoa cultivation and production. Despite the differences between these three emergent viewpoints, they share similarities as well, which point to potential common ground for establishing cooperation among farming communities (Hamadou et al., 2016; Tschopp et al., 2018; Tomich et al., 2019).

4.2.1 Agricultural practices

Agroecological and organic agriculture practices aim to be self-sustaining, reducing external inputs and managing soil as a living organism, while encouraging optimum yield (as opposed to maximum yield), crop diversification, and biological and environmental measures for controlling pests, diseases, and weeds, along with the use of slow-release fertilizers, such as manure (Altieri et al., 1989; Wezel 2020). These principles reflect the perspectives of all three opinion types with regard to pesticide utilization, and those of Opinion Types 1 and 2 with regard to the integration of animals within the agricultural system.

Most of the participants were not particularly interested in the use of pesticides, and this aspect was identified as being of the least importance for Opinion Types 1 and 2. In contrast to Bedoya-Perales et al., (2018), who describe "the emergence of difficult-to-control pests" due to the expansion of land acreage in traditional systems in the Puno region after the quinoa boom, our results hint to the potential for valorization of more

traditional knowledge in order to achieve a more agroecological and organic method of production.

The farmers adhering to Opinion Types 1 and 2 regarded the integration of animals within the farming system as important for the activities relating to their livelihood. The value of animal manure, meat, and fiber has previously been highlighted by Kerssen (2015) as essential to the ecological balance between crops and animals. Animal husbandry (including sheep, alpacas, cows, llamas, poultry, and pigs) is also a way to achieve food security and to diversify products (e.g., meat and dairy) designated for the local market (Agüero García 2014).

4.2.2 *Quinoa biodiversity and breeding programs*

We observed common ground between farmers adhering to Opinion Types 1 and 2 with regard to the importance of certified and improved quinoa seeds. This result echoes the findings of Carimentrand et al., (2015), who demonstrate that the international and urban demand for large, uniform grains encourages producers to sow improved quinoa varieties. The results of our 4SqA workshops point to a strong usage of certified and improved varieties, which are cultivated in large areas by many households in Village C, which correspond to Opinion Type 2. On the other hand, most quinoa landraces are produced in small areas by few households. This result provides a clear signal for the risk of biodiversity loss due to climatic conditions and/or neglect by farmers. These results are corroborated by those previous studies, including one by Fuentes et al., (2012), who report that households with larger areas tend to ignore more traditional varieties in favor of certified and improved varieties.

Several participatory breeding programs, some of which require payments to a local conservation group (Scott et al., 2018), have been developed with the objective of using *in-situ* cultivation and the creation of local community seed banks to bridging these two perspectives (Salazar-Tortosa et al., 2019; Ceccarelli & Grando 2020). As reported by Galluzzi and López Noriega (2014), a breeding program for five under-utilized crops to improve performance and promote their continued conservation and use in local communities of the Peruvian Andes. Their results highlight the important role that the participatory breeding program played in achieving a balance between improving yield and maintaining genetic diversity, thus clearing the path for the development of a new model of agrobiodiversity conservation (Murphy et al, 2016).

4.2.3 *Perspectives on a collective trademark and market choices*

In addition to its importance to plant-breeding activities, participation can play a crucial role in realizing the potential market innovation highlighted by Opinion Types 1 and 2: the collective trademark. This initiative is in line with UN projects fostering collective

trademarks and participatory labelling to position and reaffirm traditional products within local and international markets (Binder & Vogl 2018; Loconto & Hatanaka 2018). With this objective, the FAO launched an initiative during the *Fifth Quinoa World Congress* in 2015, involving producers' associations from Ecuador, Bolivia, Chile, Argentina, and Peru. The initiative aimed to assemble the Andean Network of Quinoa Producers, which was launched in 2016 within the Ecuadorean Ministry of Agriculture, with all of the 28 farmers' organizations involved (Chevarria Lazo & Bazile 2017). In addition to opening up the dialogue between the main producers of quinoa in South America, this professional network aims to identify ways to improve the regulation system in order to optimize the management of genetic resources. The process of improving this regulation system will entail in-depth dialogue among all stakeholders involved in managing the genetic resources of quinoa. As highlighted by Chevarria et al., (2015), no single solution is adapted to all situations from which the creation of collective trademarks might arise, thus suggesting the need to develop a new framework aimed at integrating the diverse perspectives concerning the management of quinoa's genetic resources (Bazile 2021).

5. Conclusions

In this article, we present the results of a study in which we applied two participatory methods to foster inclusion and to characterize the perspectives of smallholder farmers with regard to farming practices, market choices, and the development of a collective trademark. The study further involved an exploration of the genetic resources that are cultivated *in situ* by smallholder farmers. We developed our research focusing on three villages in the Puno region of Peru. We applied visual Q methodology to interpret the opinions of smallholder quinoa farmers concerning the relative importance of specific activities within the context of their farms, and we conducted Four-Square Analysis workshops to explore quinoa biodiversity. We identified three types of opinion emerging among the farmers: (Type 1) *Conservationist,* (Type 2) *Intensification focus* and (Type 3) *Collaboration seeker*. Farmers adhering to Opinion Type 1 assign greater importance to maintaining and promoting quinoa biodiversity through collective practices and markets are of high importance than they do to the export of quinoa. This is in contrast to those adhering to Opinion Type 2, who focus on possibilities for developing export-oriented production based on certified and improved varieties, combined with efficient ways of storing quinoa in order to fulfill the quality and quantity demands of retailers. Farmers adhering to Opinion Type 3 appear to value the collective aspects of organizations and cooperation among stakeholders more highly than they do the concrete agronomic aspects of quinoa cultivation and production. According to the 4SqA results, most quinoa landraces are threatened by erosion as they are only cultivated in small plot and on a few farms.

We further concluded that the two participatory research methods applied in this study facilitated the inclusion of smallholder farmers in the research process. In particular, the usage of visual support (e.g., the pictures used in the QM) facilitated the participation of smallholder farmers during our research. As we have demonstrated, engaging smallholder farmers through participatory research methods can generate helpful information and insightful perspectives. Acknowledging the efforts of international and national projects aiming to promote and maintain quinoa biodiversity, we therefore recommend to start by exploring these possibilities directly with farmers' organizations.

CHAPTER 4
APPENDIX A

Overview of farm characteristics, agricultural practices, and land management.

	Huancarani, Village A	**Rinconada, Village B**	**Pilhuani, Village C**
Farm size		Smallscale 0.1 - 2 ha	
Land ownership	Community-owned and individually owned	Individually owned	Individually owned
Rotation system	Crop-rotation system. Continuous rotation dependent on the Aynoka system: discussed with community	Crop-rotation system. Dependent on the farmer.	Crop-rotation system. Dependent on the farmer.
Land preparation		Plowing	
Other crops cultivated	Alfalfa, amaranth, barley, fava beans, oats, maize, potatoes	Barley, fava beans, oats, maize, potatoes	Alfalfa, amaranth, barley, fava beans, oats, lupins, maize, potatoes
Access to a tractor	Yes: One shared amongst the entire village. Owned by the farmers' association.	No: Privatised. Three community members own a tractor. Can be borrowed in terms of payment.	No: Borrowed from other communities surrounding the municipality of Pilhuani.
Animals in the village	Alpacas, llamas, donkeys, sheep, cows, chickens, and pigs		
Household tasks	Responsibility is shared; everyone contributes		

APPENDIX B

Overview of the characteristics and opinion types of participants, including age, study level, use of organic farming practices, and the sale of quinoa to retailers and/or local markets.

	Q-sort ID	Age	Gender	Highest level of education completed	Production practices: Organic	Quinoa sold to: Retailers	Quinoa sold to: Local market	Opinion type
Village A	1	58	M	Secondary	X	X	X	1
	2	60	M	Secondary	X	X	X	1
	3	62	M	Secondary	X		X	1
	4	49	M	Secondary	X	X	X	1
	5	36	F	Primary	X	X	X	1
	6	77	M	Primary	X	X	X	2
	7	73	F	None	X		X	1
	8	53	M	Secondary	X	X	X	1
	9	28	F	Primary	X	X	X	2
	10	65	F	None	X			2
	11	27	M	Secondary	X	X	X	1
	12	19	M	Secondary	X	X	X	1
Village B	13	35	F	Secondary	X		X	NA
	14	53	F	Primary	X		X	3
	15	45	F	Secondary	X		X	2
	16	39	F	Secondary			X	2
	17	69	F	Primary			X	3
	18	60	M	Secondary			X	3
	19	78	M	None	X		X	2
	20	73	M	None	X		X	NA
	21	43	F	Secondary			X	3
	22	58	F	Primary			X	3
	23	70	F	None			X	1
	24	71	M	Primary	X		X	1
Village C	25	60	M	Secondary	X	X		2
	26	64	M	Primary	X	X	X	1
	27	55	F	Secondary	X	X		1
	28	45	F	Primary	X	X	X	1
	29	62	M	Secondary	X	X		1
	30	68	F	Primary	X	X	X	2
	31	51	M	Prmary	X	X	X	2
	32	46	M	Secondary	X	X		2
	33	57	M	Secondary	X	X	X	NA
	34	51	F	Primary	X	X	X	2
	35	42	M	Secondary	X	X	X	2
	36	57	M	Secondary	X	X		2

APPENDIX C

Four-Square Analysis workshops of the villages Huancarani (A); Huancarani (B); Pilhuani (C). Each row shows the names of the quinoa variety selected by the participants and whether a variety is cultivated in large or small plots, and the number of farms cultivating it (few or many). "Not available" (NA) indicates that a quinoa landrace was not mentioned during the workshop. Names of the landraces may differ across villages, as each community uses different names to indicate specific quinoa landraces.

Quinoa varieties	Huancarani, Village A	
Amarilla	*NA*	*NA*
Ayrampu	*Small plots*	*Few farms*
Blanca de July	*NA*	*NA*
Canihua	*Small plots*	*Few farms*
Canihua (a) amarilla; (b) plomo	*NA*	*NA*
Cheveka	*NA*	*NA*
Choclo taraquina	*NA*	*NA*
Chulpi	*Small plots*	*Few farms*
Hara	*Small plots*	*Few farms*
Janko	*Small plots*	*Many farms*
Kankolla	*Small plots*	*Many farms*
Kankolla (a) blanca; (b) rosada	*NA*	*NA*
Koito	*Small plots*	*Many farms*
Misa Misa	*Small plots*	*Few farms*
Pasankalla	*Small plots*	*Many farms*
Real Salcedo INIA	*Small plots*	*Many farms*
Rosada Taraco	*NA*	*NA*
Sajama	*NA*	*NA*
Vitulla	*Small plots*	*Many farms*

Quinoa varieties	Rinconada, Village B	
Amarilla	*NA*	*NA*
Ayrampu	*NA*	*NA*
Blanca de July	*Small plots*	*Few farms*
Canihua	*Small plots*	*Few farms*
Canihua (a) amarilla; (b) plomo	*NA*	*NA*
Cheveka	*Small plots*	*Few farms*
Choclo taraquina	*NA*	*NA*
Chulpi	*NA*	*NA*
Hara	*Small plots*	*Few farms*
Janko	*NA*	*NA*
Kankolla	*NA*	*NA*
Kankolla (a) blanca; (b) rosada	*Small plots*	*Few farms*

Koito	*Small plots*	*Few farms*
Misa Misa	*NA*	*NA*
Pasankalla	*NA*	*NA*
Real Salcedo INIA	*NA*	*NA*
Rosada Taraco	*NA*	*NA*
Sajama	*Small plots*	*Few farms*
Vitulla	*NA*	*NA*

Quinoa varieties	**Pilhuani, Village C**	
Amarilla	*Small plots*	*Few farms*
Ayrampu	*Small plots*	*Few farms*
Blanca de July	*NA*	*NA*
Canihua	*Large plots*	*Many farms*
Canihua (a) amarilla; (b) plomo	*Large plots*	*Many farms*
Cheveka	*NA*	*NA*
Choclo taraquina	*Small plots*	*Few farms*
Chulpi	*Small plots*	*Few farms*
Hara	*NA*	*NA*
Janko	*NA*	*NA*
Kankolla	*Large plots*	*Many farms*
Kankolla (a) blanca; (b) rosada	*NA*	*NA*
Koito	*Large plots*	*Many farms*
Misa Misa	*NA*	*NA*
Pasankalla	*Small plots*	*Many farms*
Real Salcedo INIA	*Large plots*	*Many farms*
Rosada Taraco	*Large plots*	*Many farms*
Sajama	*Large plots*	*Many farms*
Vitulla	*NA*	*NA*

5

Chapter 5

Narrative games for social learning: game development and application on transforming fairtrade rules for smallholder organizations

Andreotti, F., Speelman E.N., Bregt A.K, Bazile D. (2022) Narrative games for social learning: game development and application on transforming fairtrade rules for smallholder organizations

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Abstract

In the Global South, export-oriented food market has often coincided with crop production intensification, reducing the cultivated biodiversity of smallholder farmer systems. While the environmental benefits of maintaining a diversity of local crop species are well known, there is a need to support smallholder organizations to transition towards a sustainable production for varieties & species-diverse supply chains. Learning and understanding the challenges that smallholders face is needed to address sustainability transition in the food system. Participatory research approaches have shown the potential to be a catalyst for social learning and foster collective action. Participatory methods, serious games are used successfully as a facilitation tool to foster social learning. The different types of serious games, narrative games have shown their potential to discuss complex problems with a broad audience through their fast, democratic, and smart game designs. The potential of narrative game has not been tested yet for collective decision-making processes and social learning. Our research presents the development, testing, application and assessment of our narrative game named SCENE. In doing so, we present the iterative developing methods for designing the narrative game including: (1) narratives development and testing; (2) online game development in the open-source platform Twine; (3) game illustration development; (4) game test and assessment methods development; (5) game application. Our application consists of three game-based workshops. Each included a preparation phase in which group leaders were interviewed using a backcasting method; and a follow-up interview reflecting on the participants' social learning, positionality and agency. Further, the impact of the game on social learning was assessed using Q methodology before and after the game sessions. In the game application, we focused on renewing fairtrade certification schemes and quinoa smallholder organizations and agrobiodiversity in the high Andes. The game-based research method presented and its assessment, highlighted new certification scheme ideas for promoting local agrobiodiversity for export. Further, we assessed the shift in understanding, before and after the game sessions. We highlighted how some participants valued local agrobiodiversity more, while another opinion group valorised local governance initiatives such as collective trademark more. Our approach and method could be applied to foster social learning about complex social-ecological systems. Further, such a remote approach can nurture collective action connecting multiple actors involved in the supply chain and consumers to re-imagine a sustainable and fair market.

Keywords: Role-playing gaming, decision-making process, transformative process, agrobiodiversity, smallholder organizations, quinoa, Andes

I. Introduction

In the Global South, export-oriented food market has coincided with crop production intensification, thereby often reducing the cultivated biodiversity of smallholder farmer systems (Fanzo 2017; Dardonville et al., 2020). The performativity paradigm spread in the Global South promoted the production of a few selected and improved varieties instead of traditional and local wild species (Fagandini et al., 2020; McGreevy et al., 2022). Therefore, current research addresses the importance of maintaining the so-called Neglected and Underutilized Species (NUS) to avoid biodiversity erosion (Li & Siddique, 2018) and foster crop resilience (Padulosi et al., 2013). While the environmental benefits of maintaining these species are well known, there is a need to support smallholder farmers and organizations to transition towards a sustainable production and varieties & species-diverse supply chain (Bene et al., 2019; Zimmerer et al., 2017).

Societal learning and understanding about the challenges that smallholders face is needed to address sustainability transition in the food system (Alves Zanella et al., 2018; Bächtiger & Parkinson, 2019). In doing so, participatory research approaches have shown the potential to be a catalyst for social learning and foster collective action (Blackstock et al., 2007; Barreteau et al., 2013). While sustainability transition through transformative approach is a long-term process that is impossible to frame completely in short-term project durations, social learning is a significant step to possibly achieve a step of those long-term processes. Social learning has been defined in several ways, sometimes in contrast (Den Haan & Van der Voort 2018). Reed et al., (2010) reviewed this concept and rephrased the most important components of social learning. They defined it as a result of a participatory process that fosters social interactions in a social network and in which the individual participant and the collective group have a shift in understanding. Among these participatory methods, serious games can facilitate dialogue, reducing social distance among players and creating a playful environment (Stern, 2005). In participatory research, serious games are applied for envisioning future scenarios (Andreotti et al., 2020), making collective decisions (Speelman et al., 2014a; Duffy & O'Rourke, 2015) and for fostering social learning (Mochizuki et al., 2021).

Within the different types of serious games, narrative games have shown their potential as fast, democratic, and smart game designs able to discuss complex problems with a broad audience (McCoy et al., 2010; Wouters et al., 2011; Callahan et al., 2019). Narrative games combine interactivity and storytelling, allowing players to decide the course of a story (Gordon & Manosevitch, 2011; Strobel & Idan, 2006; Torsi et al., 2020; Veloso & Prada, 2021). Usually, such a story is non-linear and offers branches that focus on key processes leading to different scenarios and final outcomes (Callahan et al., 2019). Furthermore, narrative games are user-friendly online tools to be played remotely and

easy to adapt and improve (Wouters et al., 2011; Friedhoff 2013). These online games have the potential to reduce social distancing, engaging participants in collective activities remotely (Bleakley et al., 2022).

No previous research applied narrative games for studying social learning, collective scenario evaluation and decision-making among actors addressing problems in socio-ecological systems. Also, applying these methods requires data analysis to analyse the discourse and assess the potential impact of the game sessions. Therefore, in this paper, the overall aim is to demonstrate and evaluate the potential of narrative games for social learning. This overall aim is addressed by the following objectives:

1. Develop a narrative game in an iterative process that includes co-creating the narratives, and co-designing and testing the game;

2. Apply the narrative game developed for drawing new fairtrade rules for including smallholder organization perspectives and challenges;

3. Assess the impact of the game sessions on participants' social learning, collective decision making, and scenario evaluation.

For addressing these objectives, we present a case based on smallholder organizations' potential to produce and market a diversity of crops. In particular, we worked on one neglected species that gained global recognition: quinoa. Quinoa (*Chenopodium quinoa* Willd.) cultivated by smallholder farmer communities in the high Andes is one of the most studied NUS (Alandia et al., 2020; Andreotti et al., 2022). Maintaining and marketing local landraces of quinoa is a key activity for smallholder organizations in the high Andes (Alandia, 2020; Bazile et al., 2021). To address the growing demand of quinoa from consumers from around the global, smallholders assembled into cooperatives, focusing on a few quinoa varieties and selling mainly through fairtrade and organic retailers (Carimentrand et al., 2015; Li & Siddique, 2018; Tschopp et al., 2018; Andreotti et al., 2022).

Fairtrade retailers are the most active stakeholders involved in fostering a sustainable, fair and environmentally friendly production and market for smallholder cooperatives (Tschoop et al., 218). In fact, while research and development projects have limited duration linked to the funds available, fairtrade retailers have built long-term relations with smallholder cooperatives, mostly in the Global South, working both from the producers' and consumers' sides (Malik et al., 2022). This collaboration, on the one hand, has created market opportunities but, on the other, has imposed a top-down code of practice (Lyon 2021). These rules are challenging for smallholder cooperatives in the

Global South that are not involved with well-established supply chains such as cacao and coffee (Malik et al., 2022). Furthermore, such an approach does not include local perspectives (Alexander et al., 2018) and traditional practices in relation to cultivated biodiversity (Li & Siddique 2018) and climate change challenges (De Schutter 2011).

2. Methods

In this section, we address our first objective: develop a narrative game in an iterative process that includes co-creating the narratives, and co-designing and testing the game. The narrative game presented is named SCENE game, which stands for "Supporting Collective Evaluation of NarrativEs" game. We first describe the narrative game design, including the creation of the narratives and the game design and test; and secondly, we present the game-based workshop design and assessment.

2.1 Narrative game design process and testing

The narrative game design was realized through an iterative process which includes the co-creation of the narratives and further the game co-design and testing (Figure 1).

The iterative process for co-developing the narratives, game design and test include nine phases. First, we performed a literature review on the impact of the quinoa "boom" on Andean smallholder organizations, and the possible sustainability transition pathways for rethinking local governance and markets (the complete review article has been published by Andreotti et al., (2022) in combination with an opinion paper Bazile et al., 2021).

Second, the knowledge and results gained from the review were compared with local stakeholder perspectives. The perspectives of quinoa smallholder organizations in the Peruvian Andes were explored highlighting the futures of quinoa production and market. We further, developed a typology analysis of the different perspectives. (Andreotti et al., under review, Andreotti et al., 2022). The different perspective types supported our first draft of the narratives.

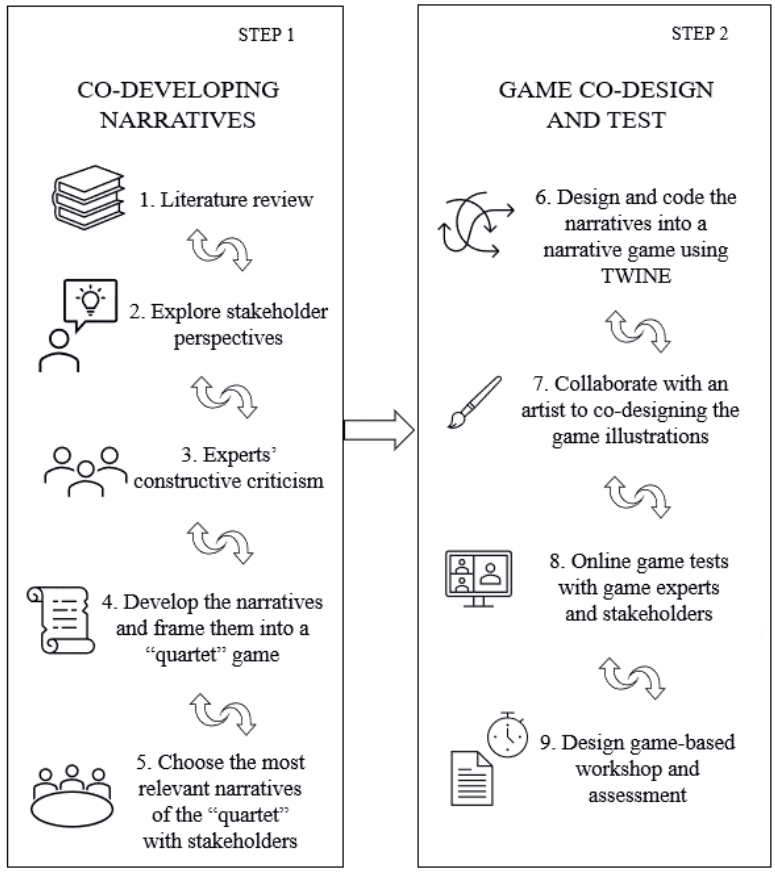

Figure 1. Narrative game iterative development process in two steps: co-developing the narratives (Step 1); and game co-design and test (Step 2). The process presented is inspired by the companion modelling approach (Étienne 2013).

Third, we interviewed quinoa experts, involving smallholders, NGO members, international organization officers, researchers, and retailers questioning about the most relevant narratives of Andean quinoa production, and market.

Fourth, we selected the most relevant narratives according to the narratives highlighted by the stakeholders in phase three. Further, we developed a "quartet" game framing eight narratives. Eight narratives were selected in order to fit the dynamics and mechanics of the quartet game. Quartet is a card game, to be played by three participants or more, composed traditionally of 32 cards, divided into eight groups of four cards. Each card has a letter and a number (i.e., A1, A2, A3, A4) and contains one-fourth of one narrative in the form of a short story. The entire deck is shuffled and equally distributed face-down to the participants. The game starts with one player asking another player for a card. For example, if the requesting player has two cards from group "A", the player will ask

for another "A" card to complete this quartet. If the player who has been asked for the card has it, then the player must hand it; otherwise, if the player doesn't have that card, the player will start a new round by asking a participant for a card. To win the game the participants must complete most of the quartet narratives. Quartet game has proved its potential as a facilitation tool for learning and applied in several disciplines, such as biology and economics (Hakim et al., 2015; Ayriza et al., 2021). In using the quartet, we tested eight narratives (Our quartet game, named "AYNI", is available in Appendix A). We played our quartet with six groups of five to eight players with the participants of the *Forum Origin, Diversity and Territories* (Val Poschiavo, Switzerland, 2021) of the thematic workshop: *Rethink the preservation of natural resources and heritage of food systems.* Once the game was over, we asked the participants for feedback on the quartet method itself, and on the selection of the most urgent narratives.

Fifth, using the feedback on the quartet sessions, we selected the three most relevant narratives according to the participant preferences, namely: (1) climate risk effects, the quinoa "boom" and "bust"; (2) pandemic crisis effects on their farming systems and community; and (3) local issues: biodiversity conservation, the development of quinoa trademark, and the abandonment of the rural villages by the young generations. We selected three narratives, as we aimed to develop our narrative game into three parts. We made this choice based on common knowledge on creating engaging storytelling (Aelius Donatus 4th century BC). Dividing a fiction or non-fiction story into three parts is one of the most effective and popular ways of constructing engaging storytelling (Field, 1979). Therefore, for combining our narratives we used these three steps that are usually represented as (a) setup, (b) confrontation, (c) resolution (Field 1979). Once, we finalized the three narratives we developed one script for the narrative game.

Sixth, we translated and coded the three narratives into a narrative game using the online open-source tool Twine (Twine v. 2.4., the program is downloadable in the link available at Appendix B). Twine is used for developing interactive and nonlinear story games (Rasmusson et al., 2017). For more information about the game structure and development on Twine please check Appendix B.

Seventh, we collaborated with an artist, familiar with the context to add a visual appearance to the narratives.

Eighth, we tested the narrative game online and the illustrations with researchers specialized in serious games of the *ComMod* association (Montpellier, France), and of the *WUR Game Hub* (Wageningen, the Netherlands). This process was made to improve the game and illustrations through an iterative process, obtaining the final version to be applied to our case study.

Ninth, based on the narrative game test, we finalized the game-based workshop design including, timing, online platform, facilitation process, and its assessment through a combination of methods presented in the following sections.

2.2 Game-based application workshop design

The application of the SCENE game had the objective to foster social learning and facilitate collective scenario evaluation of fairtrade retailers on smallholders' perspectives. We developed our game application on the major fair trade retailer organizations that link Andean quinoa farmer cooperatives with consumers in Europe. The network built during the game design process allowed us to identify over ten candidates of fairtrade organization that work on quinoa to participate in our research. Only, three were able to participate actively throughout the process. Two of the three organizations were based in Europe and one in the Andean countries: Peru, Bolivia, and Ecuador. From each organization, a contact person and group leader invited five to six colleagues to join our workshop. In doing so, we focused on renewing fairtrade certification schemes and quinoa smallholder organizations in the high Andes. Three game sessions were realized. Each included a preparation phase in which each entry point and group leader was interviewed using a backcasting framework, and a follow-up interview. We assessed participants' social learning of the game sessions using the Q methodology (Brown 2009). We, therefore, prepared and assessed our research together with the participants by exploring future perspectives, decision-making processes, social learning, and reflecting on the participants' positionality and agency (Figure 2).

Before and after the workshop, three contact persons and leaders were engaged in an interview process: two weeks before the workshop a backcasting interview was conducted, and one month after the game session, a follow-up interview was conducted. During the backcasting interview, we asked the participant to envision a desirable future of the Andean quinoa supply chain in five years, including opportunities and challenges (also called roadblocks) to reach those futures. While in the follow-up interview, we asked them about the aspect they enjoyed or did not during the research process and how they reflect on the experience highlighting social learning, their positionality and agency in changing the current system towards a more sustainable, fair, and biodiverse future.

The game sessions included the leader and four or five colleagues from the same organizations. We ran three sessions of one hour each of the SCENE online game. The game sessions were held online via Zoom. The workshop was facilitated by the first author or in combination with a professional facilitator. An observer joined each workshop online, only critically observing the process. According to the group participants, the game was developed and played in French or Spanish.

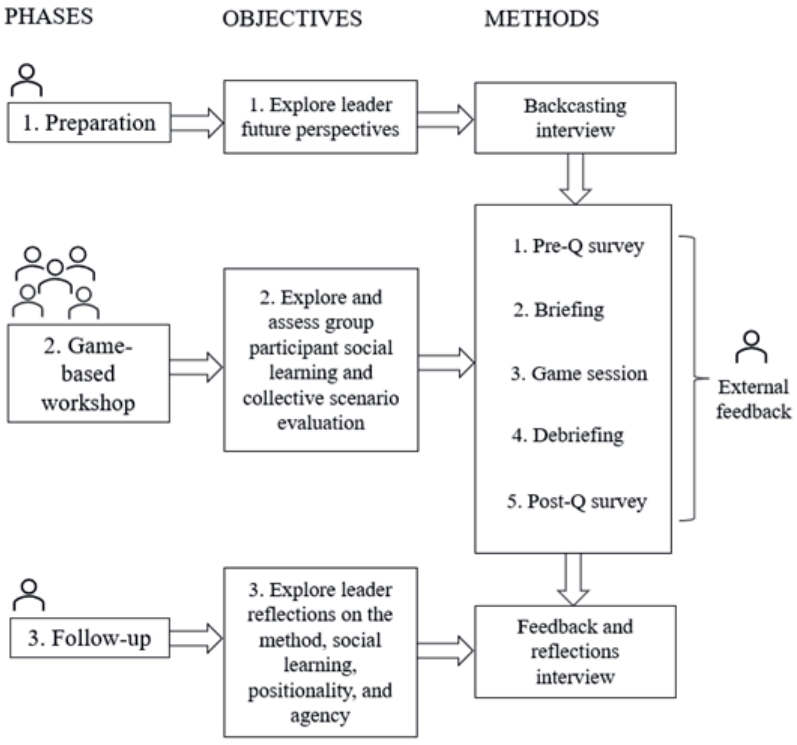

Figure 2. Overview of the research objectives and methodological process in three phases: preparation, game-based workshop, and follow-up.

To start the game session, the facilitator gave the context of the game and explained the rules. During the game sessions the participants played the role of a smallholder farmers family and explored the three selected narratives (The complete game is available in Appendix B, for playing the game, download the open-source software Twine).

2.3 Social learning assessment

Before the game started, we introduced the goal of the workshop and asked the participants to introduce themselves. Then we invited the participants to complete a quick Q-survey of 16 statements, following the Q methodology. The Q methodology has been successfully applied for the purpose of examining the opinions and values of research participants (Pereira et al., 2016; Dingkuhn et al., 2020; Leonhardt et al., 2021). This socio-analytic method provides a representation of "opinion types" existing within a given group. In recent decades, it has been used broadly in various fields, including sustainability science (Sneegas et al., 2020).

This methodology was applied to understand a potential shift of opinions immediately before and after the game. Using this method, the impact of the game on social learning

was assessed. During a Q-survey, participants individually ranked a set of statements based on agreement or disagreement (Brown et al., 2009). The statements were developed and tested during the game design process with several stakeholders involved in this research. We specifically asked the participants to first read all the statements placing them in three piles: agree, neutral, and disagree. After that, the participants placed the statements in order from most agree to most disagree in a pyramid. This setup allowed us to obtain a statistical interpretation based on the associated value of quasi-normal distribution according to the value assigned per each statement: most agree (+3, one item), agree (+2, two items; +1, three items), neutral (+0, four items), disagree (-1, three items; -2, two items) most disagree (-3, one item) (Figure 3).

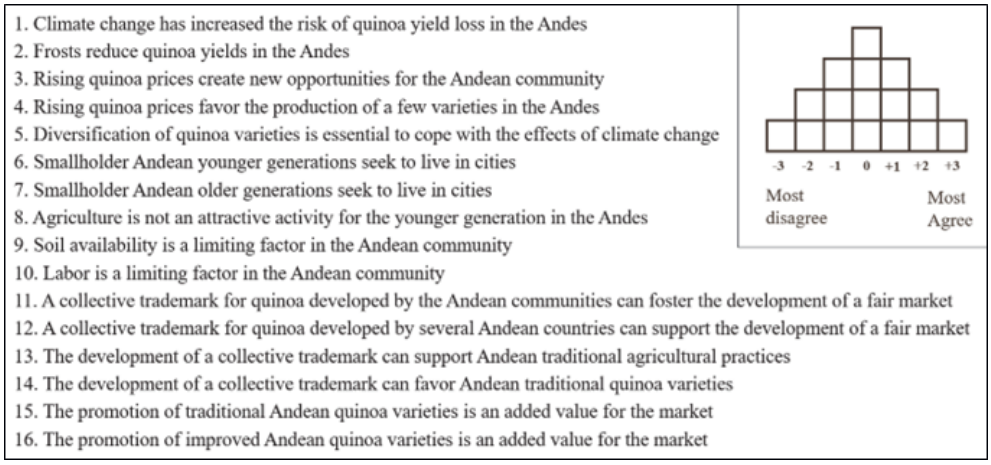

Figure 3. Q statements and related number; and pyramid indicating the different ranks between most agree (+3) and most disagree (-3).

During the game, the participants teamed up to collectively decide their preference of the narrative by choosing step by step an illustrated vignette with explanatory text and diagrams to create their group-personalized story. Each branch gave two alternatives to the participants. Each group decision was taken within five minutes. A timer with a countdown was displayed during the game sessions. Once they reached the end of the game with a specific outcome, the facilitator introduces the debriefing. During the debriefing the participants shared their feedback about the games, and how they enjoyed or not the session. Further, the participants collectively reflected on the decision-making process by (a) Individually highlighting the choice that the player regretted the most; (b) the one with which the player agreed the most; (c) revealing only one path that the group did not cross, this last decision was collective. To conclude a collective reflection on the social learning process was facilitated before assessing it individually with the post-Q survey.

Interviews and game sessions were videotaped, and voice recorded for analysis purposes with participants' consent. The names of the participants and the organization were anonymized. In addition to the Q-survey before and after the game sessions, we analysed the discourse and decision-making process during the game sessions. We transcribed and translated the recorded conversations in English of the three game sessions. We inferred the themes from the discourse analysis, and we clustered the different themes in a hierarchy. To do so, we used the qualitative data analysis software QSR Nvivo (V. 12). The analysis was conducted by the first author multiple times to test the reproducibility of the coding. Further, we adapted two data visualization tools for presenting the most important themes and sub-themes using the Sankey diagram (Sankey 1896).

3. Results

3.1 Game-based workshop application

3.1.1 Exploring sustainable future through backcasting

Before the game sessions the group leader of three workshops participated individually in a backcasting interview sharing their vision for a desirable future for developing a fair and sustainable market and production for Andean quinoa (Figure 4). These futuring exercises allowed the participants to reflect on their position as fairtrade retailers and on their impact or potential impact in improving the living condition of smallholder farmers.

All the three participants aimed in their future vision to reach marginalized smallholders by co-developing a new code of practice, based on environmental practices, fairness, and workers' rights. One participant highlighted a future in which there exists an Andean network to connect several smallholder organizations, developing stronger communication with consumers in Europe.

Within this vision, the roadblocks identified were related to the lack of knowledge that fairtrade retailers have on smallholder organizations' perspectives and challenges. Further, it was mentioned by one participant how the current fairtrade code of practice is not suitable for smallholder farmer organizations as it only facilitates larger quinoa cooperatives. Such an inequality generated quinoa smuggling and corruption among the different production countries and geographical areas and negatively impacted the transparency of organic and fairtrade production.

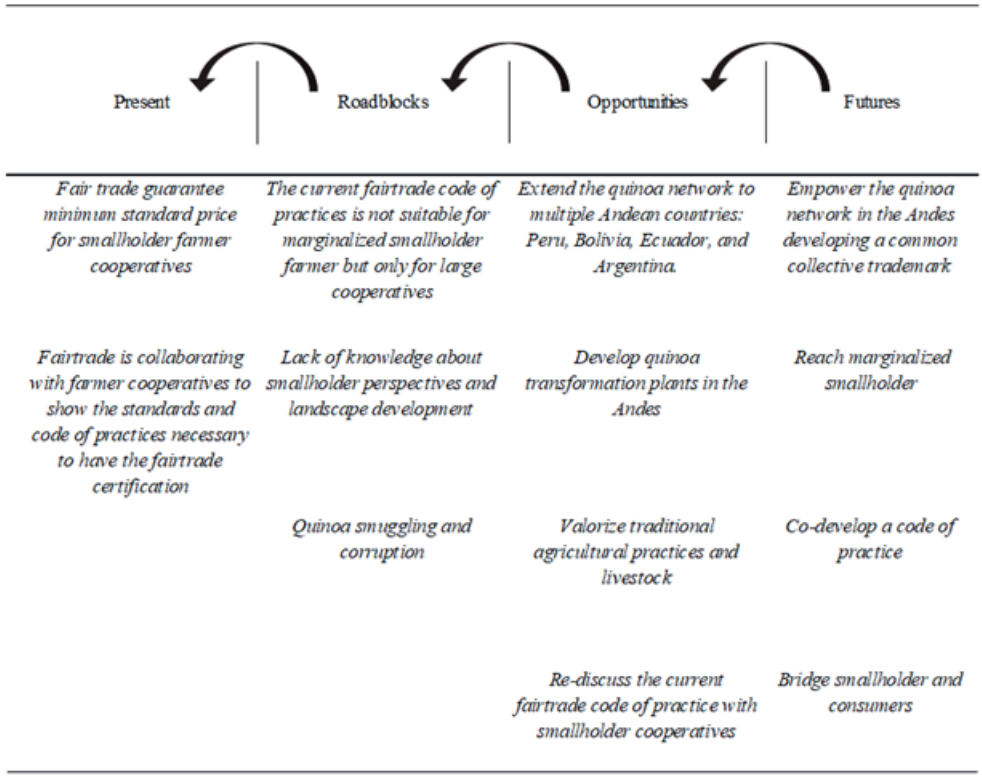

Figure 4. Summary of the most relevant quotes collected during the backcasting interviews conducted with the three entry points of workshops A, B and C in preparation for the game-based workshop. The participants shared their desirable future for developing a fair and sustainable market and production for Andean quinoa. Starting from the future vision they highlighted opportunities and roadblocks bridging with the present situation.

Contrasting these roadblocks, the three participants individually shared several opportunities in which it would be possible to reach the future vision. In doing so, they imagined re-discussing internally in the organization the certification scheme. They aimed to connect different fairtrade organizations re-discussing the code of practices, adapting it more to smallholder perspectives, and initiating a participatory development with farmers establishing the new criteria for obtaining the fairtrade label and guaranteeing a fair price. Further, they also mentioned organizational innovation such as fostering the quinoa network and technological innovation, for instance, building quinoa transformation plants in strategic points in the Andean regions.

The participants believed that those activities may transform the present of fairtrade. As currently, the main task in their work for fairtrade is to verify and promote two main activities directly with producers. They guarantee a minimum price for smallholder farmer cooperatives and work with them for explaining fair trade code of practices.

3.1.2 *Narrative game applications*

In this section we present the overall results of the social learning, scenario evaluation and decision-making processes of the game sessions. We present the results following the three narratives played in the game and encompassing the themes highlighted through the discourse analysis. Four themes were coded on the overall three game session transcripts: (a) advantages and risks for traditional varieties and practices; (b) Andean agricultural challenges, (c) pandemic crisis and rural exodus, (d) perspectives on developing sustainable, fair and biodiverse market (Table 1).

Table 1. Game sessions thematic chart. Four themes are presented for the three game sessions. The values in the table are the number of times that each theme was mentioned per game session expressed in percentage.

Themes	Advantages and risks for traditional varieties and practices	Andean agricultural challenges	Pandemic crisis and rural exodus	Perspectives on developing sustainable, fair and biodiverse markets
Game Session A	*44,5*	*33,3*	*22,2*	*0*
Game Session B	*57,1*	*19,1*	*0*	*23,8*
Game Session C	*0*	*46,8*	*18,7*	*34,5*

Further, starting from the four main themes we highlighted the sub-themes per each game session. In the Sankey diagram, we show the flow of the discourse analyzed starting from the transcription of the three game sessions, passing through four themes, and highlighting nine sub-themes (Figure 5).

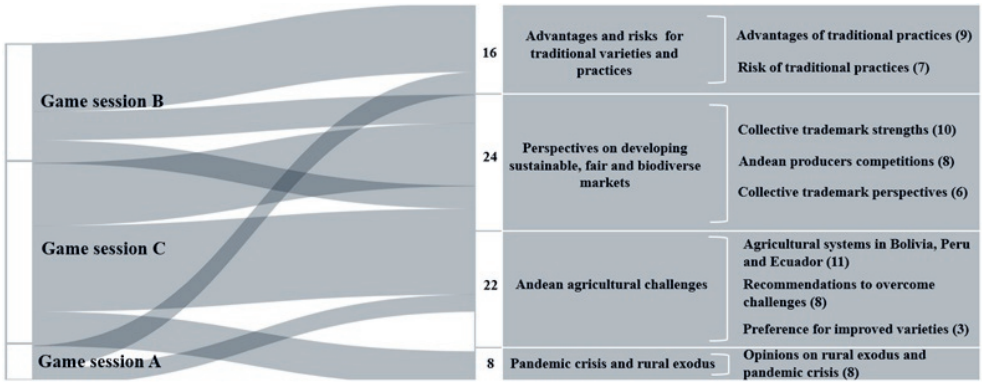

Figure 5. Sankey style diagram of the main results of the discourse analysis. The flow shows four coded themes per game session. Per each theme, we highlighted and ranked the discussed sub-themes. The values shown in the graph are the overall recurrence of these themes and sub-themes in the three game sessions. While the width of the flow lines is proportional to the rate of the flow. Each of the themes and sub-themes and related quotes were presented and discussed for the three game narratives in the following paragraphs.

3.2.1 *Quinoa Boom and Climate risks*

During the first game narrative, the participants decided collectively about cultivating traditional varieties on the slopes or cultivating improved varieties on the low land or not. In workshops "A" and "B" all the participants agreed to cultivate traditional varieties on the slopes. In workshop "B", two participants, the minority, voted for the opposite option, mentioning how limited resources and labour would have made it necessary to work using machinery, indicating that the community should invest in collectively buying a tractor. The same approach was indicated by the participants of workshop "C", who collectively preferred to cultivate improved varieties on the low land. "A" and "C" also pointed at this option considering the year this decision took place. In fact, in 2013, the quinoa boom raised the quinoa price for producers from around 3000 USD/t in 2012 to more than 4000 USD/t in 2013 (Andreotti et al., 2022). The consequences of this decision in the game brought an extreme climatic event, in which the communities that cultivated quinoa using machinery lost around 70% of their quinoa yield due to frost. In comparison, the community that cultivated on the slopes did not have any losses due to frost. This mechanism was explained as the cold air reaching the lowland at night, causing plants, in particular, quinoa to freeze. While participants of workshops "A" and "B" were satisfied with their choice, participants of workshop "C" highlighted possible ways in which a more intensive production of quinoa in the low land is possible in the Andes. They specifically mentioned how planting trees, around the plots as a windbreak band could limit the flow of cold air at night. The narrative ended by showing the price of quinoa reaching its peak in 2014, reaching around 6000 USD/t paid to the producers, and the following bust in 2015, when the price paid to the producers went down to less than 3000 USD/t. The participants were well aware of this boom and bust reality. They

discussed the possible consequences related to food security in workshops "A" and "B". In contrast, in group "C", they mainly discussed the risk they took by investing money in buying machinery when the price of quinoa was higher.

3.1.2 *Rural Exodus and Pandemic Crisis*

In the second game narrative, we introduced the migration flow from the countryside to the city and vice versa before and after the pandemic crisis. Collectively the participants decided where to stay during these times, whether staying in the cities and looking for alternatives or going back/staying in the community in the countryside. In the three workshops, the participants collectively decided on going back/staying in the community and demanding their right to the land, which led to conflicts in the community. In workshop "B," they discussed the issue of the available land no longer suited to family size and/or business ambitions. They collectively found it difficult to reach the local market and export to the world market. In the cities, people lost their jobs, and schools and universities were closed. In workshop "C", they collected a higher debt and decided to move to the city in 2018, mentioning how quinoa has variable prices and that such an investment in time and money was not reliable. A participant specifically mentioned, "The city is the salvation of farmers. Here we can find other jobs to supplement the inadequate income given by farming." The narrative ended with a discussion related to the fact that the pandemic crisis in 2020 hasn't stopped yet. Returning to the community meant facing conflicts related to land rights and the difficulty of having enough food and access to the local and global markets. Participants initiated a discussion that continued in the last narrative of the game. They questioned the strength of traditional smallholder organizations and communities and how to set new rules of coexistence.

3.2.3 *Re-design fairtrade rules*

In the third game narrative, the participants were asked to (a) first imagine playing the role of a smallholder organization and reflect on possible common rules of living together and design a code of practice for a collective trademark; and after (b) we invited the participants to play their own role as fair trade retailers, re-discussing their current code of practice, reframing new rules for fairtrade.

Group "A" highlighted the importance of developing both local and global markets. They also underlined the need to study more traditional varieties concerning market access and production to reach national and global standards. In group "B," they mentioned the need to tailor fairtrade certification to smallholder producers bridging smallholder perspectives and consumers' demands, including a range of different quinoa varieties, and explaining the landscape origin and traditional practices. In this group, a final discussion highlighted the fact that currently, one of the larger organic and fairtrade distributors in France decided to limit products outside France. In this case, the quinoa produced in

France became a direct competitor of quinoa produced in the high Andes. The challenge presented was related to explaining the added values of supporting smallholder farmers in the Andes and supporting how both quinoa production sites can be partners instead of competitors. In group "C", the participants mentioned the need to develop a transnational quinoa collective governance and brand connecting the major quinoa producers in the high Andes: Peru, Bolivia, and Ecuador. The Red Quinoa (translated: Quinoa Network, also known as Red Andina de Productores de Quinua) effort did not bring the results imagined and did not create cohesion between the different nations. A participant specifically mentioned, "There is a lack of organization. Different organizations have different markets and prices. There is a need for social responsibility and common rights. […] We need to guarantee a minimum fair price."

3.2 Social learning assessment

3.3.1 *External auditor feedback*

The discussion between the facilitator and the external auditor highlighted the validity, pro and cons of our methodology. It was specifically emphasized how groups "A" and "B" lacked the knowledge and experience in quinoa production, and agronomic and environmental competencies compared to group "C". The auditors mentioned the ability of the facilitator to create a comfortable environment for the participants online, and the rich conversation that was developed during the one-hour workshop. Furthermore, the auditors mentioned how the individual Q-survey before and after the game sessions, slow down the energy and engagement in the three game-based workshops. Reflecting on that, they mentioned the possibility of adding an energizer or imagining novel, quicker, and engaging ways for assessing social learning. Lastly, in workshop "C", the internet connection was the main challenge even though the facilitator managed to successfully finalize the workshop. In this last workshop two participants experienced difficulties establishing a stable connection.

3.3.2 Q *method: assessing social learning before and after the game sessions*

The application of the Q-survey before and after the game session highlighted a shift in the perception of two different opinion groups (Figure 6).

Based on the result of the Q analysis two archetypes were obtained. Further we named those according to our knowledge of the case study, and literature review. For both Q-survey, before and after the game sessions, two archetypes were defined as follows:

- Factor 1 named "Pro-climate and biodiversity": Fairtrade retailers represented by this archetype are aware of climate risks effect on quinoa production in the high Andes in both, before and after the game sessions. After the game

sessions, their opinion remains strong on this aspect, but in addition, they seek quinoa diversity as a resource to face climate risk challenges.

- Factor 2 named "Pro-collective trademark": Fairtrade retailers represented by this archetype believe that having a transnational collective trademark among different Andean countries can favour a fair and biodiverse quinoa market. Their opinions shift before and after the game session regarding their opinion on the impact that a collective trademark can have on the local system promoting diverse quinoa varieties for the market.

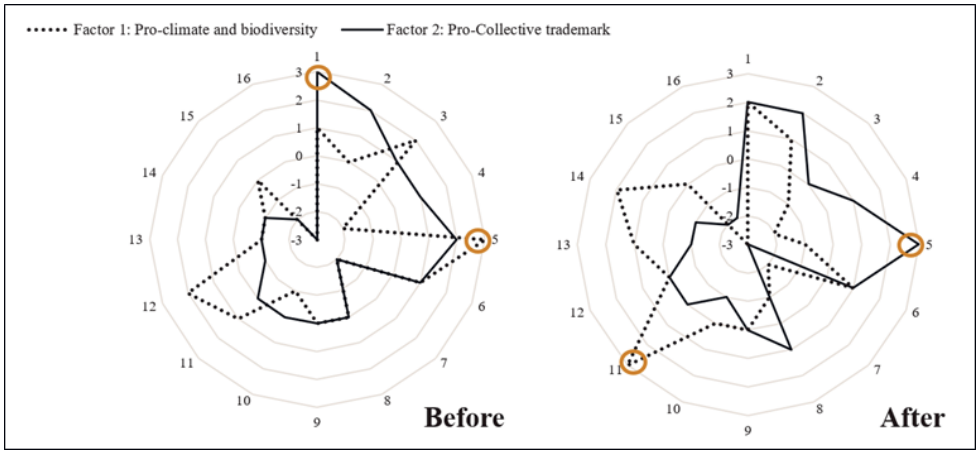

Figure 6. Spider diagrams summarizing the Q-survey and related statements ranking (1-16) of the workshop's "A" and "B": before the game sessions (on the left) and after the game sessions (on the right). In both diagrams factor 1 "Pro-climate and biodiversity" is a black line, while factor 2 "Pro-collective trademark" is the dotted black line. The statements with the highest ranking (+3) are highlighted with an orange circle for both factors.

In the Q-survey before the game sessions, of the 10 participants, five were clustered in factor 1 and five in factor 2. While for the Q-survey after the game sessions, six participants were clustered in factor 1 and four in factor 2. Comparing the two Q-survey before and after the game sessions, we found that three participants remained in factor 1, and three participants remain in factor 2. While two participants shift from factor 1 to factor 2 before and after the game sessions, and three participants shift from factor 2 to factor 1 after the game session.

3.3.3 *Follow-up interviews*

One month after the game session, we re-invited the entry points leader participants of the three workshops for an individual in-depth interview where we explored what they like, and what they did not like about the game session; their positionality in the

research process, and their agency for changing the current fairtrade label code of practice (Figure 7). This follow-up allowed us to maintain a strong and long-term connection with the participants. They appreciated that the collaboration was transparent and clear on reciprocal expectations and roles.

The participants appreciated different aspects of the game sessions such as understanding smallholder organization challenges at the farm and at the landscape level. Also, it was remarked that the simplicity and effectiveness of the game stimulated collective reflection and learning. Further, they all mentioned that it would be interesting to further develop the game by including more media and playful components and bring it to consumers to increase societal knowledge on the challenges that smallholder organization are facing.

Like	Dislike	Positionality	Agency
This game helped to understand smallholder perspectives at different levels: farm and landscape.	*Would have been interesting to mix other media with it, such as videos or pictures.*	*I had knowledge on fairtrade labelling, but I learned about mechanism and problems adopting the point of view of producers.*	*We don't have the power to decide. The fairtrade label doesn't match with most of the marginalized smallholders. We should prioritize more the environment and look more at farmer autonomy and at their ecological principles.*
It is a simple and effective game to stimulate collective reflection.	*The game should include also different key actors, such as European quinoa producers.*	*I was playing the role of farmers in the first two chapters, while in chapter 3 I was jumping from being a farmer and being myself, a fairtrade retailer.*	*It's very complex and frustrating to work with smallholder farmers. Building network between different countries that produce the same goods is very challenging. Farmer communities are distrustful towards us, and we have limited funds for it.*
It has high potential for consumer communication	*The game could have been more fun and playful.*	*I felt comfortable participating in a research process. Would be interesting to adapt the game also for consumers.*	*We have the role to connect farmers and consumers creating awareness about fair products. But today, in France, one of the largest fairtrade supermarkets stop to buy our Andean quinoa, preferring only French quinoa.*

Figure 7. Summary of the most relevant quotes shared by the three group leader participants of workshop "A", "B" and "C" concerning (i) what they liked and (ii) did not liked of the game sessions, (iii) key statements about their positionality in the research process, and (iv) their agency for changing the current fairtrade label code of practice.

The participants also highlighted what they did not like about the game. They were expecting the game to have more playful mechanics. To improve the "gamification" around narrative games, they suggested using other media in combination with illustration, for

instance, visual media, such as sounds and/or videos. Also, considering the opportunity to bring this game to consumers, as an online game, they pointed out that would be interesting to represent more key actors in the game, such as for instance European quinoa producers, to explore global competition.

We analysed the role of the leading participants in the research process. The participants shared their role as positionality and agency (Figure 8). Regarding their positionality, they were able to embrace the role-playing game shifting by playing the role of the farmer in the first two narratives and fairtrade retailers in the third one. In doing that they experience the lack of knowledge that they have about smallholder perspectives and appreciated the mechanism of the games to experience it.

The participants shared their frustration when questioned about their agency for changing the current fairtrade label rules. As mentioned in the backcasting interview, they shared how the fairtrade code of practice is not suitable for most of the marginalized smallholders. Also, they mentioned the need for funds to make a change and reach those farmers and re-discuss with them the current rules and labeling expectations. Further, the global competition around quinoa is becoming stronger, considering for instance that in France, one of the largest fairtrade and organic supermarkets decided to limit the product that comes outside Europe, including quinoa.

4. Discussion

4.2 Narrative game development and application

Our study introduced the development, testing, application, and assessment of our narrative game named SCENE. We delivered a facilitation tool for social learning with quick and high re-usability. These main results were highlighted by the participants and external auditor feedback. Further, the high re-usability of narrative game using Twine has been highlighted in the process of developing serious games (Stark et al., 2016) and for addressing different disciplines, such as education (Rasmusson et al., 2017); and societal challenges, such as depression (Tao et al., 2021) or societal engagement, such as activism (Vivienne & Burgess 2012).

The iterative game design process presented is in line with other game development processes in research like the ones presented by Barreteau et al., (2003) or Mochizuki et al., (2021). Our process mainly differs with the introduction of the quartet game for assessing the different game narratives. Gamifying the co-design process of games has been successfully used mainly in education research (Stark et al., 2016; Rasmusson et al., 2017). Further, the process of selecting the most relevant narratives has its limitations. Due to

project time limitations, participants availability and game mechanics, few narratives can be discussed and played. Future applications of this method may consider including several interactive narrative game sessions for exploring and testing most of the narratives developed in the quartet game. Such an implementation will reduce the marginalization of narratives and related key actor challenges (Pascual et al., 2021).

The online game application presented, provides abridge to participants from different countries, but lacks in engagement mainly in the collective decision making, as mentioned by some of the participants. Such a limitation can be tackled by developing in-person workshops, using SCENE as a foundation of board serious games (Stark 2016) or theatre forums (Jankowski et al., 2020), which can be both based on the development of a narrative.

4.2 Game impact on social learning

The narrative game-based workshop presented gave us the opportunity to nurture social learning among key actors who may foster collective actions toward a sustainable transition. Our results are in line with other research (Haan & Van der Voort 2018) that applied serious games to catalyze social learning. In our application, we made the effort to assess social learning before and after the game sessions by performing discourse analysis, using the Q methodology, and doing in-depth interviews. For instance, Mochizuki et al., (2021) focused their serious games on social learning, performing a qualitative assessment only after the game sessions. In their study, a shift in perception was not highlighted, as there was not a comparison with the initial state of being. Further, the qualitative analysis presented in their paper was based on a thematic analysis, using the themes of the project, rather than running a discourse analysis and coding tailored themes. We presented this example to display how currently in game research is more important to develop a complex framework on social learning rather than assessing it. This issue was partly presented by the review paper on evaluating social learning outcomes of serious games, by Den Haan & Van der Voort (2018), but without calling the need for a common protocol for assessing social learning in serious games. A common protocol for game assessment is needed to prevent credibility and "seriousness" loss of this research method (Speelman et al., 2021). We hope to engage the game research communities to reflect on this issue.

Reflecting on our game session assessment, groups "A" and "B" groups finalized the Q-survey before and after the game sessions. While with group "C" it was not possible to finalize the Q-survey as the participant found this activity not engaging in comparison with the game session. Further, we assessed a shift in understanding, before and after the game session, as an essential component for social learning and we highlighted how some participants valorised more local agrobiodiversity, while another group valorised more local governance initiatives such as collective trademark. The Q method has a great

potential in revealing change in understanding, on the other hand, it adds many steps in a workshop for the participants that may results in repetitive and less engaging compared to the game sessions. Using the Q-survey with "A" and "B" allowed us to explore the impact that the game sessions had in relation to social learning. Using the Q methodology as a step for assessing a shift in understanding has been use for workshop (Webler et al., 2009), and experience participatory modelling (Doody et al., 2009), but never for serious game (Mayer et al., 2013). The illustration we provided in this paper using the Q-method may have a limited pull of participants, but it could inspire other researchers to try to assess in a more structured and semi-quantitative way the impact of serious games on social learning. Group "C" took different paths compared to "A" and "B". Group "C" was more interested in having improved varieties and novel agricultural practices to reduce yield loss due to freezing. Also, it seemed to have a better understanding of the system and the complexity of the problems approached in the game narrative. Our game application and assessment are an illustration that needs to be performed in different and larger case studies to be improved and potentially be introduced as a possible step of a common protocol for assessing social learning in serious games. Further, as some of the participants suggested, another potential opportunity to improve the SCENE game is to combine the game illustration with other media as short videos for fostering a more engaging and playful workshop.

4.3 Fairtrade and smallholder organizations toward sustainability transition

Our results from the preparation phase and backckasting interviews showed the need to include smallholder perspectives in developing future fairtrade certification schemes. Further, the participants highlighted the importance of valorizing local initiatives that promote a product for the national market, such as collective trademarks. This result is in line with Tschoop et al., (2018)., who showed how smallholder organizations such as cooperatives have the potential to guide sustainability transition, specifically for quinoa production in the Andes. The participants also highlighted, the importance of creating a transnational network, among the high Andean countries, Peru, Bolivia, Ecuador, and Argentina, for assembling the effort and communication to the global market. This idea has been launched by Fairtrade and CLAC in 2013. This initiative, also followed up by a FAO development project (Chevarria et al., 2015) remained a top-down project that only found collaboration by the larger quinoa cooperatives. As result, most of the small organizations remained marginalized and not supported by regional and national plans. This challenge is also connected to the high level of corruption and smuggling around Quinoa in the Andes. This seems one of the main roadblocks to the sustainability transition of quinoa production and market. According to Lakkala et al., (2019) an advisable future state for quinoa production would make more transparency in budget investment and allocation from private and public investments. Further, they pointed

out the need to re-enforcing anti-corruption policies against illegal quinoa imports and smuggling and mixing of certified (i.e. organic, fairtrade) quinoa with non-certified. Such complex aspects highlighted during the backcasting interviews were explored also in our game sessions, rising the complexity of the current state of fairtrade scheme that currently only guarantees a minimum standard price for smallholder organizations.

During game sessions, we co-designed a novel code of practice with the participants. Novel criteria for the certification scheme were imagined, such as: agrobiodiversity, valorizing local varieties; and including territorial criteria of a specific "origin of place" as in the case of the high Andes. On the one hand, the current lack of organization at the regional, national, and, therefore, transnational levels make these changes challenging. On the other hand, smallholder organization initiatives are imagining and developing more inclusive certification scheme such as collective trademark, and participatory guarantee systems (Binder & Vogl 2018). As suggested by Chevarria et al., (2015) learning more from such bottom-up initiatives could help to understand how fostering sustainability transitions for novel labelling rules and collective governance initiatives.

The need to rethink certification schemes has been proposed by many researchers and institutions. We are confident that our method, including the SCENE narrative game, could support several organizations in re-designing their rules including smallholder perspectives, practices and agrobiodiversity. Also, as suggested by the participants, our online tool may be used to connect consumers and producers and understanding the environmental and sustainability challenges that smallholder organizations are facing. Further, we foresee great potential for our method to create connection, sharing knowledge and collaboration online with connecting and sharing worldwide smallholder perspectives. We aim for this method to be adapted to several other case studies, though online and in-person settings.

5. Conclusions

Fostering social learning though iterative and participatory research process requires simple, quick, and playful methods to engage stakeholders in the transition towards sustainable futures. Our research presented the development, testing, application, and assessment of a narrative game named SCENE. We presented an application of the game to foster social learning and facilitate collective scenario evaluation of fairtrade retailers on smallholders' perspectives. Three game sessions were realized. Each included a preparation phase in which each entry point and leader was interviewed using a backcasting framework and a follow-up interview reflecting on the participants' social learning, positionality and agency. Further, the impact of the game on social learning

was assessed using Q methodology before and after the game session. The game-based workshop presented has the potential to be adapted for other case studies and online or in-person settings. This research method and its assessment highlighted new certification schemes for promoting local agrobiodiversity for export and acknowledging and sharing with the consumers the development of traditional practices and perspectives. Further, we assessed a shift in understanding, before and after the game session, as an essential component for social learning and we highlighted how some participants valorised more local agrobiodiversity, while another group valorised more local governance initiatives such as collective trademark. Our approach and method could be applied to several products marketed from the global south, where smallholder farmer organizations maintain traditional varieties and practices. Further, such a remote approach can foster the dialogue among several actors involved in the supply chain and consumers to re-imagine a sustainable and fair market.

CHAPTER 5
APPENDIX A AND B are available by scanning the QR code, or at this link: https://bit.ly/3REVwwY

Scan this QR code to have access to the AYINI quartet game, and the SCENE narrative game trial.

6

Chapter 6

General discussion

GENERAL DISCUSSION

1. Main findings

The main objective of this thesis is to explore the potential of serious games and future approaches to studying the sustainability transition of agrobiodiversity and smallholder organizations. This chapter presents a reflection on the main results of this research and an outlook on future avenues for the research and methods used. Furthermore, I provided an illustration and reflection of the final, short fieldwork, in which I shared the results of chapters 3, 4, and 5 with smallholder organizations, NGOs, and regional governments, through interviews and serious games in the high Andes of Peru. In doing so, the main objective was addressed by tackling these objectives:

1. Test the potential of games and future approaches for exploring sustainability transition for agrobiodiversity and smallholder organizations;

2. Explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations;

3. Explore smallholder organizations' future perspectives on agrobiodiversity conservation and sustainable use;

4. Develop and apply an online narrative game as a facilitation tool for social learning and collective scenario evaluation.

In Table 1, I summarize the overall approaches, case studies, methods, and results of each of the objectives presented. While the following sections provide a reflection on each separate objective.

Table 1. Summary of the objectives, case studies, actors and locations, agrobiodiversity studied, methods and approaches, and outcomes represented as sustainable futures in each chapter of this thesis.

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Objectives	1. Test the potential of games and future approaches for exploring sustainability transition for agrobiodiversity and smallholder organizations	2. Explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations	3. Explore smallholder organizations' future perspectives on agrobiodiversity and sustainable use	4. Develop and apply an online narrative game as a facilitation tool for social learning and collective scenario evaluation
Case study	Nicaragua	Peru, Ethiopia, and India	Peru	Peru, Bolivia, and Ecuador
Actors and locations	Coffee smallholder organizations in Matagalpa, Nicaragua	Multiple stakeholders and smallholder organizations are involved in quinoa supply chain in Peru, teff in Ethiopia, and millet in India	Quinoa smallholder organizations in the Puno region, Peru	Andean quinoa international retailers
Agrobiodiversity	Complex agroforestry system with high diversity of tree species	Quinoa landraces, teff and millet	Quinoa landraces, and local crop varieties	Quinoa landraces
Methods and approaches	Combine serious games and backcasting workshop	Literature review and framework design	Combine Q methodology and focus groups	Development and application of an online narrative game; and before and after assessment through in-depth interviews and Q methodology
Sustainable futures	Foster social learning and collective decision making for managing agrobiodiversity in agroforested landscape	Design a framework and potential sustainability pathways exploring governance tools for smallholder organizations and agrobiodiversity	Identify smallholder organizations perspectives, practices, market choices and governance tools typology on the future of quinoa diversity	Foster social learning, decision-making process, and future scenario evaluation on developing novel certification schemes for agrobiodiversity and smallholder organizations

1.1 Test the potential of games and future approaches for exploring sustainability transition for agrobiodiversity and smallholder organizations

Researchers involved in long-term participatory research projects (5-10 years), not only have the opportunity to establish experiments on the farms and decide research objectives together with smallholders but also – and mainly – establish relationships based on trust and reciprocity. Therefore, once the project ends, researchers must share the research results to trigger collective reflection and validation. In addition, this step in the research brings together different knowledge and perspectives and also provides an opportunity to "celebrate" together the end of the research journey. In chapter 2, I presented the way I decided to "celebrate" such a project by doing serious game sessions and a backcasting workshop. After spending months living, working, and collecting data from different coffee smallholder farms scattered across the mountain landscape of Tuma-La Dalia, in Central Nicaragua, I adapted the serious game RESORTES (Speelman et al., 2014) based on what I experienced and discussed. Learning about the project and learning by participating in local management practices gave me the opportunity not only develop an adapted version of the game but also to facilitate a meaningful discussion during and after the workshops.

This study contributes to the current toolbox of methods for participatory co-production of future landscapes by combining games and backcasting workshops for exploring sustainability transition in agrobiodiversity management. Five game sessions were organized, followed by one backcasting workshop in which one participant of each

game session participated to incorporate the outcomes and views of all participants from the various game sessions. The workshop initiated a discussion between farmers from different communities, technicians, researchers, and the municipality, creating and/or reinforcing networks and collaborations at the farm as well as landscape and organization level. This research offered a setting for local stakeholders, farmers and technicians to share knowledge and experiences on the management of their coffee-based agroforestry system. The game supported the participants to identify and discuss the difficulties they were facing in real life, mainly related to supporting for production and market access. Smallholders envisioned the production of coffee with different products not only for the sake of agrobiodiversity but also for the market. In the study area, there is a market only for coffee and not for other products. This has important consequences when considering the difficulties farmers in Tuma-La Dalia have in achieving food security (Bonilla et al., 2017). Bonilla et al., (2017) underlined how these farmers have difficulty satisfying their food requirements between three to four months in a year as their focus is coffee production instead of producing staple foods.

Through the backcasting, I succeeded in exploring the limits of the four-game decision-making options and discussing pathways for the desired transition including steps for allowing product diversification, such as developing the market for diverse products and developing farmers' cooperatives and trademarks to support this desired future scenario. On the one hand, the scenario co-produced during the backcasting supported the collective evaluation of an optimal scenario but, on the other hand, it only drafted possible measures to achieve it. Previous studies (Kanter et al., 2016) have shown that perspective workshops are effective facilitation tools for co-producing scenarios. Therefore, the combination of multiple methods and assessments is recommended when researchers are leading a participatory research approach that aim to develop multiple interactions fostering not only social learning but also collective actions.

I.2 Exploring sustainable pathways in developing agrobiodiversity markets and governance tools for smallholder organizations

In chapter 3, we initiated a research project that continued in chapters 4 and 5, which focused on exploring the sustainability transition of quinoa agrobiodiversity and smallholder organizations in the Peruvian high Andes by using games and future approaches. As a first step, we developed a literature review and designed a framework to explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations by studying three different case studies: quinoa in Peru, teff in Ethiopia, and millet in India. These crops, also known as Neglected and Underutilized Species (NUS), receive substantial global interest and face growing global demands. Sudden increases in consumer demand trigger prices to rise; land-use change at the farm and national levels result in a rapid increase in production. This phenomenon

is known as a "boom," and usually, it is followed by a "bust" - a rapid decrease in prices and, subsequently, production. We showed how NUS booms have often resulted in negative impacts in the medium and long term for farmers, their livelihoods, and the landscapes they live in.

In this chapter, we reviewed the recent agricultural booms of quinoa and teff as a result of increased demand from health-conscious consumers in the Western world. We reflected on two distinct approaches used in an attempt to manage these two booms, namely, a bottom-up approach in the case of quinoa initiated by Andean farmers' organizations and a top-down approach in the case of teff supported by the national government. In the case of quinoa, a grassroots approach was used by local stakeholders to achieve positive outcomes for local landscapes and the livelihoods of quinoa farmers. In the case of the teff boom in Ethiopia, a top-down approach was used to secure national food security for the country's staple food and to prevent bio-piracy of their endemic genetic resources. In Peru and Bolivia, farmers' organizations are unifying their efforts to launch a more sustainable export approach, while in Ethiopia, the national government imposed a temporary ban on teff exports trying to mitigate the boom-bust effect. Drawing from the lessons learnt from these two booms, we reflected upon the nascent minor millets NUS boom in India and how millets could be integrated into agricultural production and consumption. by urban consumers but also to rural farmers and smallholder families. The framework developed highlight possible futures scenario by following the Sustainable Development Goals, could be applied and tested on other cases fostering common reflections on how face trade-off challenges related to food security, access to market, marginalization of smallholders and national and international unfair competition. In doing so, we highlighted the importance of consumer social responsibility that is needed to make NUS boom-bust cycles more manageable and supportive of food security and sustainable production practices. We showed new possibilities developed by and for smallholders and local communities which rethink the organizations of production, processing, and consumption of NUS and which re-establish a connection between different actors, adding value to NUS local production and commercialization and acting in the global market.

1.3 Exploring agrobiodiversity and smallholder organizations futures: farmer perceptions for Peruvian quinoa

Building on the knowledge of chapter 2, we developed a participatory research approach for exploring smallholder organizations' future perspectives on agrobiodiversity in three contrasted quinoa smallholder organizations, from traditional to modern, in the Puno region in Peru. In this chapter, we presented the results of the fieldwork in which we applied two participatory research methods to foster inclusion and characterize the perspectives of smallholder farmers with regard to farming practices, market choices, and the development of a collective trademark. This study further involved an exploration of

the genetic resources of plants cultivated *in situ* by smallholder farmers. We applied the visual Q methodology to interpret the opinions of smallholder quinoa farmers concerning the relative importance of specific activities within the context of their farms, and we conducted Four-Square Analysis workshops (4SqA) to explore quinoa biodiversity perceptions. We identified three types of opinions emerging among the farmers: (Type 1) Conservationist, (Type 2) Intensification focus, and (Type 3) Collaboration seeker. Farmers adhering to Type 1 opinion assign greater importance to maintaining and promoting quinoa biodiversity through collective practices and markets than they do to the export of quinoa. This is in contrast to those adhering to Type 2 opinion, who focus on possibilities for developing export-oriented production based on certified and improved varieties, combined with efficient quinoa storage methods in order to fulfil the quality and quantity demands of retailers. Farmers adhering to Type 3 opinion appear to value the collective aspects of organizations and cooperation among stakeholders. According to the 4SqA results, most quinoa landraces are threatened by erosion as they are only cultivated on small plots by few farms. We further concluded that the two participatory research methods applied in this study successfully facilitated the inclusion of smallholder farmers in the research process. In particular, the usage of visual support (e.g., the pictures used in the QM) facilitated the participation of smallholder farmers during our research. As we have demonstrated, engaging smallholders through participatory research methods can generate helpful information and insightful perspectives. Acknowledging the efforts of international and national projects to promote and maintain quinoa biodiversity, I, recommend starting by exploring these possibilities directly with farmers' organizations.

Participation can play a crucial role in realizing the potential market innovation highlighted by Types 1 and 2 opinions: the collective trademark. This initiative is in line with UN projects fostering collective trademarks and participatory labelling to position and reaffirms traditional products within local and international markets (Binder & Vogl, 2018; Loconto & Hatanaka, 2018). With this objective, the FAO launched an initiative during the Fifth Quinoa World Congress in 2015, involving producers' associations from Ecuador, Bolivia, Chile, Argentina, and Peru. The initiative aimed to assemble the Andean Network of Quinoa Producers "RAPQUINUA", which was launched in July 2016 by the Ecuadorean Ministry of Agriculture, with all of the 28 smallholder organizations involved (Chevarria Lazo & Bazile, 2017). In addition to opening up the dialogue between the main quinoa producers in South America, this professional network aims to identify ways to improve the regulatory system in order to optimize the management of genetic resources. The process of improving this regulatory system will entail in-depth dialogue among all stakeholders involved in managing quinoa's genetic resources. As highlighted by Chevarria et al., (2015), no single solution is adapted to all situations from which the creation of collective trademarks might arise, thus suggesting the need to develop a new framework aimed at integrating the diverse perspectives concerning the management of

quinoa's genetic resources (Bazile, 2021). We recommend that those frameworks, to be successful and relevant, needs to come from smallholder realities and perspectives instead of international or national agendas and strategies.

1.4 Develop and apply a narrative game as a facilitation tool for social learning: exploring new rules for fairtrade and smallholder organizations

In chapter 5, we developed and apply an original narrative game, named SCENE game, for facilitating social learning and collective scenario evaluation.

Concerning the development, firstly, we presented the iterative developing methods for designing a narrative game including narratives development and test; secondly, we developed the selected narratives on the online open-source platform TWINE for narrative game design and we collaborated with an illustrator artist to add a visual appearance to the narratives. Thirdly, we tested the game and illustrations with game research experts improving the game through an iterative process, obtaining the final version to be applied to my case study.

The application had the objective to foster social learning and facilitate collective scenario evaluation of fairtrade retailers on smallholders' perspectives. In doing so, we focused on renewing fairtrade certification schemes and quinoa smallholder organizations in the high Andes. Three game sessions were realized. Each included a preparation phase in which each group leader was interviewed using a backcasting framework and a follow-up interview. We were able to prepare and assess our research together with the participants by exploring future perspectives, decision-making processes, social learning, and reflecting on the participants' positionality and agency.

The need to rethink certification schemes as been promoted by many researchers and institutions (Haggar et al., 2012; Meemken 2020). Our method, including the SCENE narrative game, could support several kinds of organizations for re-designing their rules including smallholder perspectives, practices and agrobiodiversity. Also, as suggested by the participants, our online tool may be used to connect consumers and producers and understanding the environmental and sustainability challenges that smallholder organizations are facing. Further, we foresight a great potential for our method to create connection, sharing knowledge and collaboration online with connecting and sharing worldwide smallholder perspectives. We aim for this method to be adapted to several other case studies, but also to in-person workshops, using SCENE as a foundation of board serious games (Stark 2016) or theatre forums (Jankowski et al., 2020), which can be both based on the development of a narrative.

2. Perspectives

Developing and applying participatory research methods such as games and future approaches can support sustainability transition by facilitating the evaluation of future scenarios, supporting collective decision-making and fostering social learning. In this thesis, I highlighted how smallholder organizations have the potential to lead to sustainability transition if supported by local, national, and international organizations and identified as governance tools by novel or renewed certification schemes. Further, I explore the potential of agrobiodiversity as a lever to support the transition. Therefore, smallholder organizations' perspectives must influence the initial step when studying or developing new projects as they may differ from institutional and international actors' views. Supporting local governance tools, such as collective trademark initiatives and participatory guarantee systems, seems to be the key to unlocking local organizations to facilitate collaboration and organization for food security and markets. The following paragraphs share my reflections on the methods presented by highlighting strengths and limits, and further I developed a broader outlook on the role of smallholder organizations that have on maintaining and promoting agrobiodiversity for achieving sustainable futures. Further I present complementary applications on how games and participatory workshop can be used to foster collective reflection towards sustainable futures. I present a follow-up in-person game session in the Peruvian Andes to foster social learning with multiple stakeholders (Chapter 6, Section 2.1), and we present a game follow-up workshop based on a backcasting process to design novel agroforestry systems including the perspectives of multiple stakeholders (Chapter 6, section 2.3). While these workshops were not presented in the previous chapters, they are crucial in the iterative participatory research process. These follow-up workshop outcomes and tools have the potential to be used by local organizations to further explore sustainable futures, also once the research project is completed.

2.1 Games as a facilitation tool for social learning

Our game research approach, development, and application showed how serious games are effective tools to foster collective decision-making and social learning, framed in this research as the result of social interaction and a change in understanding (Reed et al., 2010). Therefore, by encompassing different case studies and actors, I provided several illustrations that display the potential of such methods in fostering social learning on agrobiodiversity for smallholder organizations and other stakeholders. Additionally, in chapter 2, I adapted an existing game, while in chapter 5, I developed and applied a new game that can be adapted in the future. Therefore, here is a reflection on the potential that adapting games can have on research when it comes to sharing the research results with a larger number and diverse stakeholders.

In addition to the research work presented in the chapters, I was able to test another time, the potential of adapting existing research games for agrobiodiversity and smallholders. In particular, once I was allowed to travel again to Peru. I organized workshops and visited local smallholder organizations, local NGOs, and regional officers for sharing the overall results of my research using game-based workshop. While the game online will be used as a starting point for bridging smallholder organizations, fairtrade retailers and consumers (SCENE game, chapter 5), I had the chance to use an adaptation of the RESORTES game on quinoa for the Peruvian high Andes smallholder organizations co-developed together with the MSc student Pauline Hohnel who did her MSc thesis under my co-supervision. I used this adapted game for sharing the results of my research and assessing its impact on social learning with in-depth interview and by using the Q methodology. I played three RESORTES game sessions in different communities (Figure 1).

Figure 1. Pictures of the game sessions played in the high Peruvian Andes. Adaptation of the RESORTES game in a local event on agrobiodiversity and education in the Peruvian Andes (Farmers organization in Molino, Ilave, Peru. Credit: Federico Andreotti).

In addition to these game sessions, I had the chance to facilitate another workshop with around 20 participants coming from different smallholder organizations and technicians the in the "PluriveristyPark", in the Peruvian Andes (Figure 2). This workshop was done in collaboration with the Peruvian NGO named "ANDES". in. In this case, I adapted the game REHAB (Le Page et al., 2016) and test and implement it together with the NGO members and technicians before the workshop with the smallholders. Through the REHAB game session, I explored the potential of a quick adaptation of existing

games on agrobiodiversity dynamics. While a single session and related data collection through recordings and game decision-making process did not reveal scientific insights, it highlighted the potential of being an effective facilitation tool to foster collective discussion on agrobiodiversity conservations. In addition, these game-based workshops were essential steps in the participatory research approach for sharing and discussing the results. Further, the online game presented in chapter 5, the SCENE game; and the adaptations of RESORTES and REHAB games, were shared with local researchers, NGOs and governmental officers for being further utilization as a facilitation tool in their projects and workshops on agrobiodiversity with smallholder organizations.

Figure 2. Pictures of the game sessions played in the high Peruvian Andes. Adaptation of the REHAB game in an event in collaboration with the NGO Andes in the "Pluriveristy" Park, Peruvian Andes (Left side three pictures credit: Federico Andreotti; right side picture credit: Paulina Rosero).

While these methods are very effective as a facilitation tool, there are questions in the game research on assessing the impact not only on social learning but also on the decision-making processes and agency in the real life. Further researchers study social learning and decision making because these are proxies for possible future collective action or change in individual behaviour towards transition. My recommendation is that games have to be assessed not as a single method, but as part of an iterative and long-term research process. Collective action or changing behaviour may not happen in one single session but on the long-term effort and energy shared by researchers and participants. Further developing common protocols on the usability of games in research is still a challenge. In Chapter 5, learning from the experience of chapter 2 (RESORTES game adaptation), I developed a draft of a potential protocol for developing and assessing the SCENE game.

Such an approach may be useful for developing and adapting this game in different contexts. Social learning is an outcome that can be fostered indeed by serious games, but most of all, by the collaboration and iterative process among researchers and participants. Therefore, this thesis added to the body of literature that empowers these approaches and applications towards the sustainability transitions.

2.2 Participatory research approaches need to be transdisciplinary

Developing a long-term iterative participatory research approach seems key to developing sustainable futures. While, for specific problems mono-disciplinary research is still very effective, when it comes to exploring futures for complex social-ecological systems, inter and transdisciplinary research are a must. To do so, it is needed to combine different disciplines and local knowledge and perspectives into the elaboration of research objectives. Nowadays, several funding and project calls are promoting transdisciplinary research, but no common definition has been provided (von Wehrden et al., 2019). Further, as an additional roadblock, there is a lack of trust among natural and social scientists, and researchers give different values to quantitative and qualitative data (Sandbrook et al., 2013). This lack of trust is "clipping the wings" of potential transdisciplinary research, preventing connection and knowledge sharing among different scientists and actors (Turnhout et al., 2021). Transdisciplinary research is lacking a common protocol that would strengthen this approach and make it real for both participants and researchers. Further, giving more value to the work of participants, inviting them as co-researchers, and sharing impactful results, could lead to real transdisciplinary research. To tackle this issue, in chapter 5 and in combination with the game sessions, I performed in-depth interviews focusing on the importance of the positionality of researchers and participants in the participatory research process. Further, I explored their agency for changing the current system toward sustainable futures. Through this approach, the participants gave important insights as for instance to develop more engaging methods for assessing social learning and give the opportunity to participants to have those workshop online and in person. Further, participants highlighted on how such methods and tools can work in understating our own and each other's roles in the research for managing expectations and fostering a more effective collaboration.

2.3 Smallholder organizations lead sustainability transition

Developing a participatory research process allows understanding of existing bottom-up initiatives that have the potential to lead transitions (Chambers et al., 1994). By developing and testing this approach, I analysed and valorised smallholder organizations' perspectives and agrobiodiversity toward sustainable futures. Thanks to this approach, I realized that researchers must enter into studying transition and agrobiodiversity with smallholder organizations through "small doors" of local initiatives and NGOs instead of passing through the "big doors" of research institutes, national governments, and

international NGOs. Starting with a bottom-up perspective instead of a top-down perspective is an effective way of providing meaningful action research, valorising local initiatives, and being critical of ambitious and large-scale projects that came from the mind of foreign officers. Believing blindly in these top-down projects is an additional social and environmental crisis threatening smallholder organizations and agrobiodiversity (Brush et al., 1995; Pascual et al 2021). Valorising bottom-up perspectives may foster a more horizontal and fair dialogue among stakeholders towards transitions.

For instance, in chapter 3, I focused on how the opportunity of bringing agrobiodiversity into the market could be a double-edged sword for smallholder organizations and their environment. If, in one hand it fostered a more economically viable alternative, on the other it created strong competition among Andean countries and worldwide quinoa producers promoting mechanization instead of agroecological principles. From my analysis based on our NUS study cases, I evidenced the poor connection that was established between local producers and global consumers. The gap in scientific research also shows a lack of understanding of consumers' role in the NUS boom and bust cycle at their places of origin. More research is needed to study the ethical issues of international health-focused and conscious consumers and their impact on local producers. In fact, as I described, the NUS boom and bust may lead to unknown consequences for the consumers: food insecurity in the place of production and origin, simplified local food systems, and a direct reduction in the genetic diversity maintained for centuries. This challenge needs more inclusive approaches to promote active decision-making processes and future scenario evaluation. Inclusive, active decision-making and initiatives promoted by local and international institutions may drive a more sustainable NUS supply chain.

Exploring and studying how these initiatives work and what is needed for success is key. Such initiatives are collective trademarks development or participatory guarantee systems. Top-down projects aiming for agrobiodiversity conservation, such as payment for ecosystem services, have failed their development in Latin America, while bottom-up initiatives which engage horizontally with multiple actors are becoming more mainstream thanks to the strong agroecological movements. Such a narrative of development and paying for maintaining systems in the way they were functioning in the previous generation is not effective.

Besides, during the pandemic crisis, smallholder organizations showed not only their resilience but also proved the need to develop novel systems to fight against health, agricultural and food crises. In a common reflection paper with quinoa expert, in which I participated (Bazile, Andreotti et al., 2021), I highlighted the need to question the current food systems and imagine new solidarities by empowering current initiatives such as collective trademark and participatory guarantee systems and including local

perspectives in regional, national, and international schemes by using participatory tools. Such a reflection highlighted, even more, the need to involve multiple actors in exploring sustainable futures for agrobiodiversity conservation and smallholder farmer organizations

Multiple actors are encouraging sustainability transition for agricultural systems but understanding how studying this subject and how research can support the transition is still a challenge (McGreevy et al., 2022). Through the different chapters of this thesis, I co-developed possible different futures for achieving sustainability through agrobiodiversity based on smallholder organizations' perspectives. While it is encouraging to see the results that are attainable in the short term, what is lacking currently is constant support for this research and projects. This is due to a lack of long-term project funds, time, and resources and environmental and political disruption. Here, I introducetwo research applications, not presented in the thesis chapters, but complementary to those, in exploring future application co-design for agrobiodiversity, and in understanding other smallholder organization initiatives.

In Chapter 2, I explored different scenarios of how to include agrobiodiversity in the design of a novel agroforestry system with coffee smallholder organizations. This approach was valorised by an additional outcome, not documented inChapter 2, in which the participants of the backcasting workshop collectively realized and discussed a novel agroforestry design (Figure 3).

The next step would have been to test some of its elements on a real farm. Funding was available for continuing the research. But, unfortunately, the smallholders involved in the research had to face the political crisis and riots that caused many of those to abandon their farms and find security for themselves and their families elsewhere. Designing transition towards sustainability may not be only related to agriculture but also to the need to establish a safe and fair environment for research participants.

The second research application was in Peru. During the first year of my PhD, I had the chance to visit other fieldwork areas and actors in Peru, as the cacao smallholder in the Puerto Maldonado area, Madre de Dios. Here I tested the focus group method presented in Chapter 3. Thanks to these methods test and application I was able to explore multiple initiatives that promote agrobiodiversity led by smallholder organizations, as in the case of local-seed sharing networks and events (Lagneaux, Andreotti, et al., 2021). Here, I explored how another crop "boom," as cacao in the region of Madre de Dios, Peru, affected the perspectives of smallholder organizations on agrobiodiversity. In this area, international NGOs foster the production of a few industrial cacao varieties against the high cacao diversity produced by smallholder organizations. In this research application, I highlighted the importance of these events and that the expansion of these initiatives,

such as local seed-sharing networks and events, can open a market and attract benefits in producing diverse cacao varieties for sustainable futures. This is another example of how local initiatives led to more change than heavy and top-down projects with high research academic impact and low actual impact on the field. Promoting grassroots initiatives is key for sustainable futures for smallholder organizations and agrobiodiversity. Smallholder grassroots initiatives for agrobiodiversity as local-seed sharing networks, or collective trademarks, are also crucial components of more complex organization schemes as participatory guarantee systems (PGS) (Niederle et al., 2020). Understanding what could foster these bottom-up initiatives is still a gap in research (McGreevy et a. 2022).

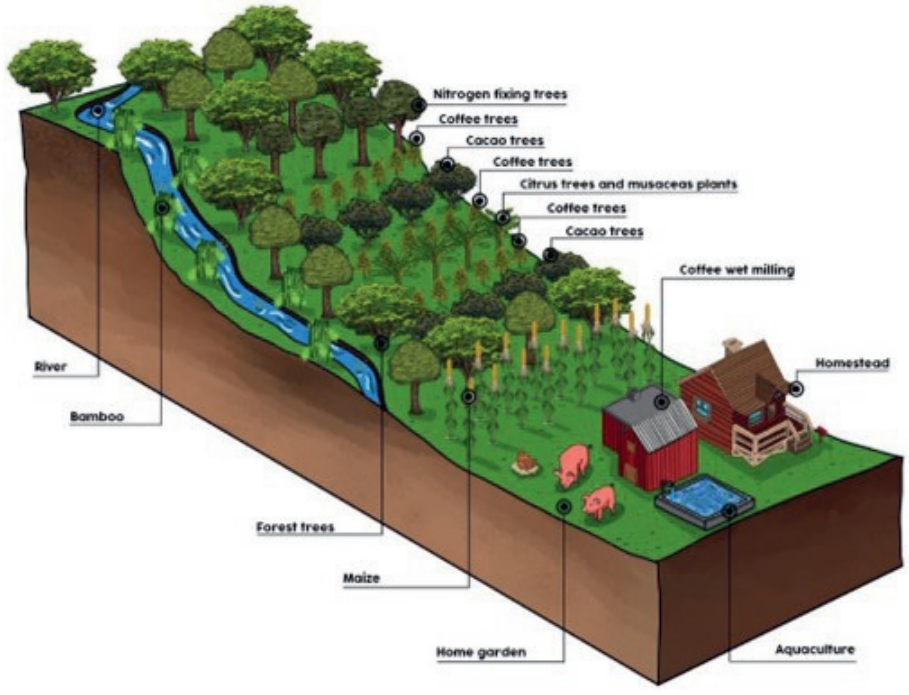

Figure 3. Sketch of a future coffee-agroforestry farm design in the landscape of Tuma-La Dalia, Nicaragua. This sketch is the final outcome of the backcasting workshop, presented in Chapter 2. After the backcasting workshop, the participants draw a future desired farm design per group. Further by presenting and giving feedback to each other, they co-developed one design, including several agrobiodiversity managements, as: nitrogen fixing trees, coffee trees, cacao trees, citrus trees and musaceas plants, bamboo, forest trees, and maize field. It also includes the homestead, home garden, aquaculture and coffee wet milling. The spatial design was framed by the participants while the design illustration was then finalized by a professional illustrator and reviewed by local technicians.

3. Future avenues of research

This thesis contributes to the field of serious games and participatory research towards sustainable futures for agrobiodiversity and smallholder organizations. It also identified further research gaps or approaches to be investigated. Here are the three most important topics that need urgent investigation towards more effective and meaningful research in the field of games, smallholder organization and agrobiodiversity.

Firstly, future participatory research projects must be developed in transdisciplinary research schemes. Funding and research institutes should not allow these approaches without the collaboration of natural, and social scientists, and co-researchers based on the field of study. Only in this way it will be possible to foster research impact and allow researchers to assess the effectiveness of participatory methodologies. By doing so, it will be possible to tackle the following challenges that the different categories of actors (and not only researchers) are facing in game research and participatory processes: (1) having internal and external validity of their legitimacy in the participatory research process; (2) assessing during all the process of the project the level of participation, while exploring positionality and agencies of participants and researchers (3) developing a standard protocol when working with transdisciplinary research and games for analysing method, process, results and assessing the impacts.

Secondly, tap the research potential of meaningful serious games to connect science and society to foster social learning on complex social-ecological challenges. This future research objective opens the following questions: (1) What are the most effective tools or methods (i.e. serious games) to bridge science and society (2) How these tools or methods foster social learning and/or collective action? These questions invite researchers to explore and assess the effectiveness of several tools (i.e. card games, or augmented reality games) for facilitating social learning, scenario evaluations, or decision-making process in different contexts and with several stakeholders. For instance, future research may assess the impact of novel games that directly connect smallholder organizations and consumers. This future research may increase the consumers' understanding on the consequences of their choices on agriculture sustainability, and it would potentially generate new dialogues towards sustainable futures.

Thirdly, identify the mechanism that allows/empowers existing collective governance tools of smallholder organizations, such as collective trademark and participatory guarantee systems. Comparing these initiatives around the world may highlight lessons on these system mechanisms, and potential improvements. Further understanding on which scale these initiatives can operate would reveal possible sustainability leading experience at the local, national and transnational levels. Research should explore the driver that fosters this

type of social innovation and the creation of alternative markets and certification schemes that allow solidarity and agrobiodiversity as added values for smallholder organizations and diversity of consumers.

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Summary

Smallholder farmer organizations are crucial stakeholders in the development of fair and biodiverse crop markets. Therefore, incorporating their perspectives and needs is as critical to developing and supporting their practices as cultivating agrobiodiversity and creating sustainable agricultural landscapes. Incorporating smallholder perspectives requires action, research approaches, and interactive methodologies. In this thesis, I explored the potential of serious games and methods for exploring futures for smallholder farmer organizations and other key actors in the food system for fostering sustainable use and conservation of agrobiodiversity. In this thesis the following objectives were explored: (1) Test the potential of games and future approaches for exploring sustainability transition for agrobiodiversity and smallholder organizations; (2) Explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations; (3) Explore smallholder organizations' future perspectives on agrobiodiversity conservation and sustainable use; (4) Develop and apply an online narrative game as a facilitation tool for social learning and collective scenario evaluation. I explored the practices and perspectives of smallholder farmers' organizations with a focus on collective governance tools and labelling by applying participatory research methods such as serious games and backcasting. I worked with quinoa producers in the high Andes of Peru, and coffee producers in Nicaragua as case studies. Further, also teff producers in Ethiopia and millet producers in India were studied as complementary cases for a literature review. This research highlighted new transition pathways and agendas for including quinoa landraces and agrobiodiversity for local-global markets. Furthermore, through my research, I highlighted the need for acknowledging and sharing with the local-global consumers the development of traditional practices and cultures. Our approach and method could be applied to foster social learning about complex social-ecological systems. Further, our method can nurture collective action connecting multiple actors involved in the supply chain and consumers to re-imagine a sustainable and fair market.

Chapter 2 presents an illustration of adapting a serious game, the RESORTES game (Speelman et al., 2014a), for coffee-based smallholder organizations in Nicaragua. A combination of games and methods for exploring futures were used for exploring sustainability transition for agrobiodiversity and smallholder organizations. We presented a novel approach to explore pathways for the sustainability transition of agroforestry systems. By combining participatory forecasting and backcasting approaches based on serious games and future vision development, we explored relevant agroforestry management strategies for reaching sustainable future coffee-based agroforestry landscapes in relation to agrobiodiversity. We focused on the challenges faced in the main coffee-producing area in Nicaragua. Five participatory game sessions were organized to explore farmer decision-making processes and farming strategies to develop new networks and

stimulate social learning among farmers. In the associated backcasting workshop, the most influential game session participants joined such as technicians, researchers, and municipality officials to collectively envision sustainable future landscape management. In all game sessions, farmers developed diversified coffee-based agroforest landscapes characterized by increased density and diversity of shade trees for the purpose of income diversification as well as forest conservation. During the backcasting workshop, the participants identified governance instruments and community-based solutions for the transition to sustainable landscapes. This participatory approach facilitated discussion on landscape and agrobiodiversity planning among farmers and other stakeholders and allowed the outline of a pathway towards the collective envisioned future landscape. The combination of participatory forecasting and backcasting proved to be a helpful tool to support multi-stakeholder processes towards sustainable landscape management in this and other complex landscapes.

In chapter 3, a literature review and framework were developed to explore sustainability pathways in developing agrobiodiversity markets and governance tools for smallholder organizations. The literature review focussed on two recent Neglected and Underutilized Species booms (NUS): quinoa (*Chenopodium quinoa* Willd.) in the Peruvian and Bolivian Andes and teff (*Eragrostis tef* Zucc. Trotter) in Ethiopia. Building on the knowledge from these two cases, we developed a generic framework to explore sustainability transition in NUS boom and bust cycles. We assessed the characteristics of these NUS that led to increased global demands and the resulting boom and bust cycle. In addition, we assessed the diverse governance tools that were applied in these two cases and their impacts on the boom and bust cycle. Finally, we considered the upcoming minor millet boom as expected to occur in India. Applying our "lessons learned" and framework to minor millets and their upcoming boom can help the actors in the value chain coordinate to learn how sustainable transitions can co-exist in a boom-bust cycle ensuring local benefits and preservation of the social-ecological environment.

In chapter 4, we compared the knowledge gained in the previous chapter with quinoa smallholder organizations in the high Peruvian Andes, exploring their future perspectives on agrobiodiversity in relation to agricultural practices, market choices, and governance tools. We explored farmers' perceptions on the future of quinoa diversity and the associated current on-farm quinoa diversity management. The research was conducted in three villages in the Puno region of Peru, one of the quinoa's centers of origin. A combination of participatory methods was applied: the Q methodology to interpret the future perspectives of smallholder quinoa organizations concerning the important activities on their farms and the Four-Square Analysis to explore quinoa biodiversity management. Our results are an important baseline for further project development for *in situ* agrobiodiversity conservation and market inclusion engaging local communities.

The participatory approach continues in chapter 5, in which an online narrative game was developed and applied as a facilitation tool for social learning and collective scenario evaluation. We assembled the different quinoa smallholder organizations' perspectives into a game to be played with European fairtrade retailers. Such an approach was necessitated by the covid restriction and the impossibility of engaging the fieldwork. Additionally, through this chapter, we fostered the inclusion of smallholder organizations' perspectives on fair and sustainability certification schemes for agrobiodiversity and sustainability transition. We co-developed an online narrative game to explore the collective scenario evaluation and decision-making process. Furthermore, we tested such an approach and showed an illustration based on the case of quinoa production in the high Andes. In addition, perspectives, positionality, and agency when rethinking the fairtrade code of practice were studied. We focussed on a well-studied traditional crop, quinoa (*Chenopodium quinoa* Willd.) in the high Andes, involving specialized local smallholder organizations and international fairtrade retailers. This research method and its impact assessment – on social learning - highlighted new label criteria important such as promoting local cultivated biodiversity for export and acknowledging and sharing the development of traditional practices and cultures with consumers. Our approach and method could be applied to several products marketed from the global south, where smallholder farmers' organizations maintain traditional varieties and agricultural practices. Besides, such a remote approach can foster the dialogue among several actors involved in the supply chain and consumers to re-imagine a sustainable production and a fairtrade market.

Lastly, in chapter 6, I present a general discussion of the main findings, reflecting on the results and proposing future avenues for the research and methods used. I present a reflection on (a) games as a facilitation tool for social learning, in which I give recommendations on how games have to be assessed not as a single method, but as part of an iterative and long-term research process; (b) the need of participatory research approaches to be transdisciplinary, in which I reflect on the fact that transdisciplinary research is lacking a common protocol that would strengthen this approach and make it real for both participants and researchers; and (c) on how smallholder organizations perspectives should lead sustainability transition, in which I reflect on how smallholder organizations' perspectives have to influence the initial step when studying or developing new projects as they may differ from institutional and international actors' views. Furthermore, I provided an outlook and results of the final short fieldwork, in which I shared the results of chapters 3, 4, and 5 with smallholder organizations, NGOs, and regional governments, through interviews and serious games in the high Andes of Peru. Concluding in this chapter, I point at future research topics including: (I) the need for future participatory research projects to be developed in transdisciplinary research schemes; (II) tapping the research potential of meaningful serious games to connect

science and society to foster social learning on complex social-ecological challenges; (III) identify the mechanism that allows/empowers existing collective governance tools of smallholder organizations.

Resumen

Las organizaciones de pequeños agricultores son actores cruciales en el desarrollo de mercados de cultivos justos y biodiversos. Por lo tanto, incorporar sus perspectivas y necesidades es tan crítico para desarrollar y apoyar sus prácticas como cultivar la agrobiodiversidad y crear paisajes agrícolas sostenibles. La incorporación de las perspectivas de los pequeños agricultores requiere enfoques de acción, investigación y metodologías interactivas. En esta tesis, exploré el potencial de los juegos serios y los métodos para explorar el futuro de las organizaciones de pequeños agricultores y otros actores clave del sistema alimentario para fomentar el uso sostenible y la conservación de la agrobiodiversidad. En esta tesis se exploraron los siguientes objetivos: (1) Probar el potencial de los juegos y los enfoques de futuro para explorar la transición de la sostenibilidad para la agrobiodiversidad y las organizaciones de pequeños agricultores; (2) Explorar las vías de sostenibilidad en el desarrollo de los mercados de agrobiodiversidad y las herramientas de gobernanza para las organizaciones de pequeños agricultores; (3) Explorar las perspectivas de futuro de las organizaciones de pequeños agricultores sobre la conservación y el uso sostenible de la agrobiodiversidad; (4) Desarrollar y aplicar un juego narrativo en línea como herramienta de facilitación para el aprendizaje social y la evaluación colectiva de escenarios. Exploré las prácticas y perspectivas de las organizaciones de pequeños agricultores centrándome en las herramientas de gobernanza colectiva y el etiquetado, aplicando métodos de investigación participativa como los juegos serios y el backcasting. Trabajé con productores de quinua en los altos Andes de Perú y con productores de café en Nicaragua como estudios de caso. Además, también se estudiaron los productores de tef en Etiopía y de mijo en la India como casos complementarios para una revisión bibliográfica. Esta investigación puso de manifiesto nuevas vías de transición y agendas para incluir las variedades locales de quinua y la agrobiodiversidad para los mercados locales y globales. Además, a través de mi investigación, destaqué la necesidad de reconocer y compartir con los consumidores locales-globales el desarrollo de las prácticas y culturas tradicionales. Nuestro enfoque y método podrían aplicarse para fomentar el aprendizaje social sobre sistemas socioecológicos complejos. Además, nuestro método puede alimentar la acción colectiva conectando a múltiples actores implicados en la cadena de suministro y a los consumidores para reimaginar un mercado sostenible y justo.

El capítulo 2 presenta una ilustración de la adaptación de un juego serio, el juego RESORTES (Speelman et al., 2014a), para las organizaciones de pequeños productores de café en Nicaragua. Se utilizó una combinación de juegos y métodos para explorar futuros para explorar la transición de la sostenibilidad para la agrobiodiversidad y las organizaciones de pequeños agricultores. Presentamos un enfoque novedoso para explorar caminos para la transición de la sostenibilidad de los sistemas agroforestales. Combinando enfoques participativos de previsión y backcasting basados en juegos

serios y desarrollo de visión de futuro, exploramos estrategias de gestión agroforestal relevantes para alcanzar paisajes agroforestales sostenibles en el futuro basados en el café en relación con la agrobiodiversidad. Nos centramos en los retos a los que se enfrenta la principal zona productora de café de Nicaragua. Se organizaron cinco sesiones de juegos participativos para explorar los procesos de toma de decisiones de los agricultores y las estrategias agrícolas para desarrollar nuevas redes y estimular el aprendizaje social entre los agricultores. En el taller de backcasting asociado, los participantes más influyentes de las sesiones de juego se unieron a técnicos, investigadores y funcionarios municipales para imaginar colectivamente una gestión sostenible del paisaje en el futuro. En todas las sesiones de juego, los agricultores desarrollaron paisajes agroforestales diversificados basados en el café y caracterizados por una mayor densidad y diversidad de árboles de sombra con el fin de diversificar los ingresos y conservar los bosques. Durante el taller de backcasting, los participantes identificaron instrumentos de gobernanza y soluciones comunitarias para la transición a paisajes sostenibles. Este enfoque participativo facilitó el debate sobre la planificación del paisaje y la agrobiodiversidad entre los agricultores y otras partes interesadas y permitió esbozar un camino hacia el paisaje futuro previsto colectivamente. La combinación de previsión participativa y backcasting demostró ser una herramienta útil para apoyar los procesos de múltiples partes interesadas hacia la gestión sostenible del paisaje en este y otros paisajes complejos.

En el capítulo 3, se elaboró una revisión bibliográfica y un marco para explorar las vías de sostenibilidad en el desarrollo de mercados de agrobiodiversidad y herramientas de gobernanza para las organizaciones de pequeños agricultores. La revisión bibliográfica se centró en dos recientes auges de especies olvidadas e infrautilizadas (NUS): la quinoa (Chenopodium quinoa Willd.) en los Andes peruanos y bolivianos y el tef (Eragrostis tef Zucc. Trotter) en Etiopía. A partir de los conocimientos de estos dos casos, desarrollamos un marco genérico para explorar la transición hacia la sostenibilidad en los ciclos de auge y caída de los NUS. Evaluamos las características de estos NUS que condujeron al aumento de la demanda global y al consiguiente ciclo de auge y caída. Además, evaluamos las diversas herramientas de gobernanza que se aplicaron en estos dos casos y su impacto en el ciclo de auge y caída. Por último, examinamos el próximo auge del mijo menor que se espera que se produzca en la India. La aplicación de nuestras "lecciones aprendidas" y de nuestro marco a los mijos menores y a su próximo boom puede ayudar a los actores de la cadena de valor a coordinarse para aprender cómo pueden coexistir las transiciones sostenibles en un ciclo de auge y caída que garantice los beneficios locales y la preservación del entorno socioecológico.

En el capítulo 4, comparamos los conocimientos adquiridos en el capítulo anterior con organizaciones de pequeños agricultores de quinua en los altos Andes peruanos, explorando sus perspectivas futuras sobre la agrobiodiversidad en relación con las prácticas

agrícolas, las opciones de mercado y las herramientas de gobernanza. Exploramos las percepciones de los agricultores sobre el futuro de la diversidad de la quinua y la gestión actual de la diversidad de la quinua asociada. La investigación se llevó a cabo en tres pueblos de la región peruana de Puno, uno de los centros de origen de la quinua. Se aplicó una combinación de métodos participativos: la metodología Q para interpretar las perspectivas futuras de las organizaciones de pequeños productores de quinua en relación con las actividades importantes en sus fincas y el Análisis de Cuatro Cuadrados para explorar la gestión de la biodiversidad de la quinua. Nuestros resultados son una base importante para el desarrollo de nuevos proyectos de conservación de la agrobiodiversidad in situ y la inclusión en el mercado con la participación de las comunidades locales.

El enfoque participativo continúa en el capítulo 5, en el que se desarrolló y aplicó un juego narrativo en línea como herramienta de facilitación para el aprendizaje social y la evaluación colectiva de escenarios. Reunimos los puntos de vista de las diferentes organizaciones de pequeños productores de quinua en un juego para ser jugado con minoristas europeos de comercio justo. Este enfoque fue necesario debido a la restricción del covid y a la imposibilidad de realizar el trabajo de campo. Además, a través de este capítulo, fomentamos la inclusión de las perspectivas de las organizaciones de pequeños agricultores sobre los esquemas de certificación justa y de sostenibilidad para la transición de la agrobiodiversidad y la sostenibilidad. Desarrollamos conjuntamente un juego narrativo en línea para explorar la evaluación de escenarios colectivos y el proceso de toma de decisiones. Además, probamos dicho enfoque y mostramos una ilustración basada en el caso de la producción de quinua en los altos Andes. Además, se estudiaron las perspectivas, la posicionalidad y la agencia a la hora de repensar el código de prácticas del comercio justo. Nos centramos en un cultivo tradicional bien estudiado, la quinua (Chenopodium quinoa Willd.) en los altos Andes, con la participación de organizaciones locales especializadas de pequeños agricultores y minoristas internacionales de comercio justo. Este método de investigación y su evaluación de impacto -sobre el aprendizaje social- puso de manifiesto nuevos criterios de etiquetado importantes, como la promoción de la biodiversidad cultivada localmente para la exportación y el reconocimiento y la puesta en común del desarrollo de las prácticas y culturas tradicionales con los consumidores. Nuestro enfoque y método podrían aplicarse a varios productos comercializados desde el sur global, donde las organizaciones de pequeños agricultores mantienen variedades y prácticas agrícolas tradicionales. Además, este enfoque a distancia puede fomentar el diálogo entre varios actores implicados en la cadena de suministro y los consumidores para reimaginar una producción sostenible y un mercado de comercio justo.

Por último, en el capítulo 6, presento una discusión general de las principales conclusiones, reflexionando sobre los resultados y proponiendo futuras vías para la investigación y los métodos utilizados. Presento una reflexión sobre (a) los juegos como herramienta

de facilitación del aprendizaje social, en la que doy recomendaciones sobre cómo los juegos tienen que ser evaluados no como un método único, sino como parte de un proceso de investigación iterativo y a largo plazo; (b) la necesidad de que los enfoques de investigación participativa sean transdisciplinarios, en la que reflexiono sobre el hecho de que la investigación transdisciplinaria carece de un protocolo común que fortalezca este enfoque y lo haga real tanto para los participantes como para los investigadores; y (c) sobre cómo las perspectivas de las organizaciones de pequeños agricultores deberían liderar la transición hacia la sostenibilidad, en la que reflexiono sobre cómo las perspectivas de las organizaciones de pequeños agricultores tienen que influir en el paso inicial cuando se estudian o desarrollan nuevos proyectos, ya que pueden diferir de los puntos de vista de los actores institucionales e internacionales. Además, proporcioné una perspectiva y los resultados del breve trabajo de campo final, en el que compartí los resultados de los capítulos 3, 4 y 5 con las organizaciones de pequeños agricultores, las ONG y los gobiernos regionales, mediante entrevistas y juegos serios en los altos Andes de Perú. Concluyendo en este capítulo, apunto a futuros temas de investigación, incluyendo: (I) la necesidad de que los futuros proyectos de investigación participativa se desarrollen en esquemas de investigación transdisciplinarios; (II) aprovechar el potencial de investigación de los juegos serios significativos para conectar la ciencia y la sociedad para fomentar el aprendizaje social sobre los complejos desafíos socio-ecológicos; (III) identificar el mecanismo que permite/empodera las herramientas de gobernanza colectiva existentes de las organizaciones de pequeños agricultores.

Samenvatting

Organisaties van kleine boeren zijn cruciale belanghebbenden bij de ontwikkeling van eerlijke en bio diverse markten voor gewassen. Daarom is het voor de ontwikkeling en ondersteuning van hun praktijken net zo belangrijk dat rekening wordt gehouden met hun perspectieven en behoeften als met het cultiveren van agrobiodiversiteit en het creëren van duurzame agrarische landschappen. Het integreren van de perspectieven van kleine boeren vereist actie, onderzoek benaderingen en interactieve methodologieën. In dit proefschrift heb ik het potentieel onderzocht van serious games en methoden voor het verkennen van toekomstperspectieven voor organisaties van kleine boeren en andere belangrijke actoren in het voedselsysteem om duurzaam gebruik en behoud van agrobiodiversiteit te bevorderen. In dit proefschrift werden de volgende doelstellingen verkend: (1) Het potentieel van games en toekomstige benaderingen testen voor het verkennen van duurzaamheidstransities voor agrobiodiversiteit en kleine boerenorganisaties; (2) Duurzaamheidspaden verkennen in de ontwikkeling van agrobiodiversiteitsmarkten en governance-instrumenten voor kleine boerenorganisaties; (3) Toekomstperspectieven van kleine boerenorganisaties verkennen op het behoud en het duurzame gebruik van agrobiodiversiteit; (4) Een online verhalend spel ontwikkelen en toepassen als een faciliterend instrument voor sociaal leren en collectieve scenario-evaluatie. Ik onderzocht de praktijken en perspectieven van organisaties van kleine boeren met een focus op collectieve bestuursinstrumenten en etikettering door participatieve onderzoeksmethoden zoals serious games en backcasting toe te passen. Ik werkte met quinoa producenten in de hoge Andes van Peru, en koffieproducenten in Nicaragua als casestudies. Verder werden ook teffproducenten in Ethiopië en gierstproducenten in India bestudeerd als aanvullende cases voor een literatuurstudie. Dit onderzoek belichtte nieuwe overgangstrajecten en agenda's voor het opnemen van quinoa-landrassen en agrobiodiversiteit voor lokale-mondiale markten. Bovendien heb ik door mijn onderzoek de noodzaak benadrukt om de ontwikkeling van traditionele praktijken en culturen te erkennen en te delen met de lokaal-mondiale consumenten. Onze benadering en methode kunnen worden toegepast om sociaal leren over complexe sociaal-ecologische systemen te bevorderen. Verder kan onze methode collectieve actie stimuleren die meerdere actoren in de toeleveringsketen en consumenten verbindt om een duurzame en eerlijke markt opnieuw te bedenken.

Hoofdstuk 2 presenteert een illustratie van het aanpassen van een serious game, de RESORTES game (Speelman et al., 2014a), voor organisaties van kleine koffieboeren in Nicaragua. Een combinatie van games en methoden voor het verkennen van toekomsten werd gebruikt voor het verkennen van duurzaamheidstransities voor agrobiodiversiteit en kleine boerenorganisaties. We presenteerden een nieuwe aanpak om paden voor de duurzaamheidstransitie van agroforestrysystemen te verkennen. Door het combineren van participatieve voorspellingen en backcasting benaderingen op basis van serious games

en toekomstvisieontwikkeling, onderzochten we relevante agroforestry management strategieën voor het bereiken van duurzame toekomstige op koffie gebaseerde agroforestry landschappen in relatie tot agrobiodiversiteit. We richtten ons op de uitdagingen in het belangrijkste koffieproducerende gebied in Nicaragua. Er werden vijf participatieve spelsessies georganiseerd om besluitvormingsprocessen en landbouwstrategieën van boeren te onderzoeken om nieuwe netwerken te ontwikkelen en sociaal leren onder boeren te stimuleren. In de bijbehorende backcastingworkshop sloten de deelnemers aan de spelsessies met de meeste invloed, zoals technici, onderzoekers en gemeenteambtenaren, zich aan om zich gezamenlijk een duurzaam toekomstig landschapsbeheer voor te stellen. In alle spelsessies ontwikkelden de boeren gediversifieerde agroboslandschappen op basis van koffie, gekenmerkt door een grotere dichtheid en diversiteit van schaduwbomen met het oog op inkomstendiversificatie en bosbehoud. Tijdens de backcasting workshop identificeerden de deelnemers bestuursinstrumenten en op de gemeenschap gebaseerde oplossingen voor de overgang naar duurzame landschappen. Deze participatieve aanpak vergemakkelijkte de discussie over landschaps- en agrobiodiversiteitsplanning tussen boeren en andere belanghebbenden en maakte het mogelijk een pad uit te stippelen naar het collectieve toekomstige landschap. De combinatie van participatieve prognoses en backcasting bleek een nuttig instrument om processen met meerdere belanghebbenden op weg naar duurzaam landschapsbeheer in dit en andere complexe landschappen te ondersteunen.

In hoofdstuk 3 werden een literatuurstudie en een kader ontwikkeld om duurzaamheidstrajecten te verkennen bij de ontwikkeling van agro-biodiversiteitsmarkten en bestuursinstrumenten voor kleine boerenorganisaties. Het literatuuronderzoek richtte zich op twee recente hausses van verwaarloosde en onderbenutte soorten (NUS): quinoa (*Chenopodium quinoa* Willd.) in de Peruaanse en Boliviaanse Andes en teff (*Eragrostis tef* Zucc. Trotter) in Ethiopië. Op basis van de kennis van deze twee gevallen hebben wij een generiek kader ontwikkeld om de duurzaamheidstransitie in de hoog- en laagconjunctuur van NUS te onderzoeken. Wij evalueerden de kenmerken van deze NUS die leidden tot de toegenomen wereldwijde vraag en de daaruit voortvloeiende boom- en bustecyclus. Daarnaast beoordeelden we de verschillende bestuursinstrumenten die in deze twee gevallen werden toegepast en hun effecten op de hausse- en baissecyclus. Ten slotte hebben wij de komende hausse van kleine gierst in India onderzocht. De toepassing van onze "geleerde lessen" en ons kader op minor millets en de aanstaande hausse daarvan kan de actoren in de waardeketen helpen bij het coördineren om te leren hoe duurzame overgangen kunnen bestaan in een boom-bustcyclus die lokale voordelen en het behoud van de sociaal-ecologische omgeving garandeert.

In hoofdstuk 4 hebben we de in het vorige hoofdstuk opgedane kennis vergeleken met organisaties van kleine quinoa-boeren in de hoge Peruaanse Andes, waarbij we hun

toekomstperspectieven op agrobiodiversiteit in relatie tot landbouwpraktijken, marktkeuzes en bestuursinstrumenten hebben onderzocht. We onderzochten de perceptie van boeren over de toekomst van quinoadiversiteit en het huidige beheer van quinoadiversiteit op de boerderij. Het onderzoek werd uitgevoerd in drie dorpen in de Puno regio van Peru, een van de centra van oorsprong van quinoa. Een combinatie van participatieve methoden werd toegepast: de Q-methodologie om de toekomstperspectieven van kleine quinoa-boeren te interpreteren met betrekking tot de belangrijke activiteiten op hun boerderijen en de vierkantsanalyse om het quinoa biodiversiteitsbeheer te onderzoeken. Onze resultaten vormen een belangrijke basis voor verdere projectontwikkeling voor het behoud van agrobiodiversiteit *in situ* en marktintegratie waarbij lokale gemeenschappen worden betrokken.

De participatieve aanpak wordt voortgezet in hoofdstuk 5, waarin een online verhalend spel werd ontwikkeld en toegepast als faciliterend instrument voor sociaal leren en collectieve scenario-evaluatie. We brachten de perspectieven van de verschillende organisaties van kleine quinoa-boeren samen in een spel dat we speelden met de Europese fairtrade retailers. Een dergelijke aanpak was noodzakelijk door de coviduele beperking en de onmogelijkheid om het veldwerk te betrekken. Bovendien bevorderden we met dit hoofdstuk de opname van de perspectieven van kleine boerenorganisaties op eerlijke en duurzame certificeringsprogramma's voor agrobiodiversiteit en duurzaamheidstransitie. We ontwikkelden samen een online verhalend spel om het collectieve scenario-evaluatie- en besluitvormingsproces te verkennen. Verder hebben we een dergelijke aanpak getest en een illustratie getoond aan de hand van de casus van de quinoaproductie in de hoge Andes. Daarnaast werden perspectieven, positionaliteit en agency bij het herdenken van de fairtrade praktijkcode bestudeerd. We richtten ons op een goed bestudeerd traditioneel gewas, quinoa (*Chenopodium quinoa* Willd.) in de hoge Andes, waarbij gespecialiseerde lokale organisaties van kleine boeren en internationale fairtradehandelaars betrokken zijn. Deze onderzoeksmethode en de effectbeoordeling ervan - over sociaal leren - bracht nieuwe belangrijke labelcriteria aan het licht, zoals het bevorderen van de lokale geteelde biodiversiteit voor de export en het erkennen en delen van de ontwikkeling van traditionele praktijken en culturen met de consumenten. Onze aanpak en methode kunnen worden toegepast op verschillende producten die op de markt worden gebracht vanuit het Zuiden, waar organisaties van kleine boeren traditionele variëteiten en landbouwpraktijken in stand houden. Bovendien kan een dergelijke aanpak op afstand de dialoog bevorderen tussen verschillende actoren in de toeleveringsketen en consumenten om een nieuwe visie te ontwikkelen op duurzame productie en een fairtrade markt.

Ten slotte geef ik in hoofdstuk 6 een algemene bespreking van de belangrijkste bevindingen, waarbij ik reflecteer op de resultaten en voorstellen doe voor toekomstige wegen voor het onderzoek en de gebruikte methoden. Ik presenteer een reflectie over

(a) games als een faciliteringsinstrument voor sociaal leren, waarin ik aanbevelingen doe over hoe games niet als een enkele methode moeten worden beoordeeld, maar als onderdeel van een iteratief onderzoeksproces op lange termijn; (b) de noodzaak dat participatieve onderzoeksbenaderingen transdisciplinair zijn, waarin ik reflecteer over het feit dat transdisciplinair onderzoek een gemeenschappelijk protocol ontbeert dat deze aanpak zou versterken en reëel zou maken voor zowel deelnemers als onderzoekers; en (c) over hoe de perspectieven van kleine boerenorganisaties de overgang naar duurzaamheid moeten leiden, waarin ik nadenk over hoe de perspectieven van kleine boerenorganisaties de eerste stap bij het bestuderen of ontwikkelen van nieuwe projecten moeten beïnvloeden, aangezien zij kunnen verschillen van de visie van institutionele en internationale actoren. Verder geef ik een vooruitblik en de resultaten van het laatste korte veldwerk, waarin ik de resultaten van de hoofdstukken 3, 4 en 5 heb gedeeld met kleine boerenorganisaties, NGO's en regionale overheden, door middel van interviews en serious games in de hoge Andes van Peru. Ter afsluiting van dit hoofdstuk wijs ik op toekomstige onderzoeksonderwerpen, waaronder: (I) de noodzaak om toekomstige participatieve onderzoeksprojecten te ontwikkelen in transdisciplinaire onderzoeksschema's; (II) het aanboren van het onderzoekspotentieel van zinvolle serious games om wetenschap en maatschappij met elkaar te verbinden om sociaal leren over complexe sociaal-ecologische uitdagingen te bevorderen; (III) het identificeren van het mechanisme dat bestaande collectieve bestuursinstrumenten van kleine boerenorganisaties mogelijk maakt/versterkt.

Résumé

Les organisations de petits exploitants agricoles sont des acteurs indispensables au développement de marchés agricoles équitables et biodiversifiés. Par conséquent, la prise en compte de leurs points de vue et de leurs besoins est aussi essentielle pour développer et soutenir leurs pratiques que la culture de l'agrobiodiversité et la création de paysages agricoles durables. L'intégration des perspectives des petits exploitants nécessite des actions, des approches de recherche et des méthodologies interactives. Dans cette thèse, j'ai exploré le potentiel des jeux sérieux et des méthodes pour explorer les futurs des organisations de petits exploitants agricoles et d'autres acteurs clés du système alimentaire pour favoriser l'utilisation durable et la conservation de l'agrobiodiversité. Dans cette thèse, les objectifs suivants ont été explorés : (1) Tester le potentiel des jeux et des approches futures pour explorer la transition vers la durabilité pour l'agrobiodiversité et les organisations de petits exploitants ; (2) Explorer les voies de la durabilité dans le développement des marchés de l'agrobiodiversité et des outils de gouvernance pour les organisations de petits exploitants ; (3) Explorer les perspectives futures des organisations de petits exploitants sur la conservation et l'utilisation durable de l'agrobiodiversité ; (4) Développer et appliquer un jeu narratif en ligne comme outil de facilitation pour l'apprentissage social et l'évaluation collective des scénarios. J'ai exploré les pratiques et les perspectives des organisations de petits exploitants agricoles en mettant l'accent sur les outils de gouvernance collective et l'étiquetage en appliquant des méthodes de recherche participative telles que les jeux sérieux et le backcasting. J'ai travaillé avec des producteurs de quinoa dans les hautes Andes du Pérou, et des producteurs de café au Nicaragua comme études de cas. En outre, des producteurs de teff en Éthiopie et des producteurs de millet en Inde ont également été étudiés comme cas complémentaires pour une revue de la littérature. Cette recherche a mis en évidence de nouvelles voies de transition et de nouveaux agendas pour inclure les variétés de quinoa et l'agrobiodiversité dans les marchés locaux et mondiaux. En outre, grâce à mes recherches, j'ai mis en évidence la nécessité de reconnaître et de partager avec les consommateurs locaux et mondiaux le développement des pratiques et des cultures traditionnelles. Notre approche et notre méthode pourraient être appliquées pour favoriser l'apprentissage social de systèmes socio-écologiques complexes. En outre, notre méthode peut favoriser l'action collective en reliant les multiples acteurs impliqués dans la chaîne d'approvisionnement et les consommateurs afin de réimaginer un marché durable et équitable.

Le chapitre 2 présente une illustration de l'adaptation d'un jeu sérieux, le jeu RESORTES (Speelman et al., 2014a), pour les organisations de petits exploitants basés sur le café au Nicaragua. Une combinaison de jeux et de méthodes d'exploration des futurs a été utilisée pour explorer la transition vers la durabilité pour l'agrobiodiversité et les organisations de petits exploitants. Nous avons présenté une nouvelle approche pour explorer les

voies de la transition vers la durabilité des systèmes agroforestiers. En combinant des approches participatives de prévision et de rétrospection basées sur des jeux sérieux et le développement de visions du futur, nous avons exploré des stratégies de gestion agroforestière pertinentes pour atteindre des paysages agroforestiers durables à base de café en relation avec l'agrobiodiversité. Nous nous sommes concentrés sur les défis rencontrés dans la principale région productrice de café du Nicaragua. Cinq sessions de jeux participatifs ont été organisées pour explorer les processus de prise de décision des agriculteurs et les stratégies agricoles afin de développer de nouveaux réseaux et de stimuler l'apprentissage social entre les agriculteurs. Lors de l'atelier de rétrospective associé, les participants aux sessions de jeu les plus influents se sont joints à des techniciens, des chercheurs et des fonctionnaires municipaux pour envisager collectivement une gestion durable du paysage. Dans toutes les sessions de jeu, les agriculteurs ont développé des paysages agroforestiers diversifiés à base de café, caractérisés par une densité et une diversité accrues d'arbres d'ombrage dans le but de diversifier les revenus et de préserver la forêt. Au cours de l'atelier de rétrospective, les participants ont identifié des instruments de gouvernance et des solutions communautaires pour la transition vers des paysages durables. Cette approche participative a facilité la discussion sur la planification du paysage et de l'agrobiodiversité entre les agriculteurs et les autres parties prenantes et a permis d'esquisser un chemin vers le paysage futur envisagé collectivement. La combinaison de la prévision participative et du backcasting s'est avérée être un outil utile pour soutenir les processus multi-acteurs vers une gestion durable du paysage dans ce paysage et d'autres paysages complexes.

Dans le chapitre 3, une revue de la littérature et un cadre ont été développés pour explorer les voies de la durabilité dans le développement des marchés de l'agrobiodiversité et des outils de gouvernance pour les organisations de petits exploitants. La revue de la littérature s'est concentrée sur deux récentes booms d'espèces négligées et sous-utilisées (NUS) : le quinoa (Chenopodium quinoa Willd.) dans les Andes péruviennes et boliviennes et le teff (Eragrostis tef Zucc. Trotter) en Ethiopie. En nous appuyant sur les connaissances tirées de ces deux cas, nous avons développé un cadre générique pour explorer la transition vers la durabilité dans les cycles d'expansion et de ralentissement des NUS. Nous avons évalué les caractéristiques de ces NUS qui ont conduit à une augmentation de la demande mondiale et au cycle d'expansion et de ralentissement qui en a résulté. En outre, nous avons évalué les divers outils de gouvernance qui ont été appliqués dans ces deux cas et leurs impacts sur le cycle d'expansion et de ralentissement. Enfin, nous avons examiné le prochain boom du millet mineur qui devrait se produire en Inde. L'application de nos «leçons apprises» et de notre cadre au millet mineur et à son prochain boom peut aider les acteurs de la chaîne de valeur à se coordonner pour apprendre comment des transitions durables peuvent coexister dans un cycle d'expansion et de ralentissement garantissant des bénéfices locaux et la préservation de l'environnement socio-écologique.

Dans le chapitre 4, nous avons comparé les connaissances acquises dans le chapitre précédent avec les organisations de petits exploitants de quinoa dans les hautes Andes péruviennes, en explorant leurs perspectives futures sur l'agrobiodiversité en relation avec les pratiques agricoles, les choix de marché et les outils de gouvernance. Nous avons exploré les perceptions des agriculteurs sur l'avenir de la diversité du quinoa et la gestion actuelle associée de la diversité du quinoa à la ferme. La recherche a été menée dans trois villages de la région de Puno au Pérou, l'un des centres d'origine du quinoa. Une combinaison de méthodes participatives a été appliquée : la méthode Q pour interpréter les perspectives d'avenir des petits exploitants de quinoa concernant les activités importantes sur leurs exploitations et l'analyse à quatre carrés pour explorer la gestion de la biodiversité du quinoa. Nos résultats constituent une base de référence importante pour le développement de nouveaux projets de conservation in situ de l'agrobiodiversité et d'inclusion du marché impliquant les communautés locales..

L'approche participative se poursuit au chapitre 5, dans lequel un jeu narratif en ligne a été développé et appliqué comme outil de facilitation pour l'apprentissage social et l'évaluation collective de scénarios. Nous avons rassemblé les perspectives des différentes organisations de petits exploitants de quinoa dans un jeu destiné à être joué avec des détaillants européens du commerce équitable. Une telle approche était rendue nécessaire par la restriction du covidage et l'impossibilité d'engager le travail de terrain. De plus, à travers ce chapitre, nous avons encouragé l'inclusion des perspectives des organisations de petits exploitants sur les systèmes de certification équitable et durable pour la transition vers l'agrobiodiversité et la durabilité. Nous avons co-développé un jeu narratif en ligne pour explorer l'évaluation collective des scénarios et le processus de prise de décision. En outre, nous avons testé une telle approche et montré une illustration basée sur le cas de la production de quinoa dans les hautes Andes. En outre, nous avons étudié les perspectives, la positionnalité et l'agence lors du réexamen du code de pratique du commerce équitable. Nous nous sommes concentrés sur une culture traditionnelle bien étudiée, le quinoa (*Chenopodium quinoa Willd.*) dans les hautes Andes, impliquant des organisations locales spécialisées de petits exploitants et des détaillants internationaux de commerce équitable. Cette méthode de recherche et son évaluation d'impact - sur l'apprentissage social - ont mis en évidence de nouveaux critères de labellisation importants tels que la promotion de la biodiversité cultivée localement pour l'exportation et la reconnaissance et le partage du développement des pratiques et cultures traditionnelles avec les consommateurs. Notre approche et notre méthode pourraient être appliquées à plusieurs produits commercialisés dans le sud du monde, où les organisations de petits exploitants agricoles maintiennent des variétés et des pratiques agricoles traditionnelles. En outre, une telle approche à distance peut favoriser le dialogue entre plusieurs acteurs impliqués dans la chaîne d'approvisionnement et les consommateurs pour réimaginer une production durable et un marché équitable.

Enfin, dans le chapitre 6, je présente une discussion générale des principaux résultats, en réfléchissant aux résultats et en proposant des pistes futures pour la recherche et les méthodes utilisées. Je présente une réflexion sur (a) les jeux en tant qu'outil de facilitation de l'apprentissage social, dans laquelle je donne des recommandations sur la façon dont les jeux doivent être évalués non pas comme une méthode unique, mais comme une partie d'un processus de recherche itératif et à long terme ; (b) la nécessité pour les approches de recherche participative d'être transdisciplinaires, dans laquelle je réfléchis sur le fait que la recherche transdisciplinaire manque d'un protocole commun qui renforcerait cette approche et la rendrait réelle pour les participants et les chercheurs ; et (c) sur la façon dont les perspectives des organisations de petits exploitants devraient conduire la transition vers la durabilité, dans laquelle je réfléchis à la façon dont les perspectives des organisations de petits exploitants doivent influencer l'étape initiale lors de l'étude ou du développement de nouveaux projets, car elles peuvent différer des vues des acteurs institutionnels et internationaux. En outre, j'ai fourni une perspective et les résultats du court travail de terrain final, dans lequel j'ai partagé les résultats des chapitres 3, 4 et 5 avec les organisations de petits exploitants, les ONG et les gouvernements régionaux, par le biais d'entretiens et de jeux sérieux dans les hautes Andes du Pérou. En conclusion de ce chapitre, j'indique des sujets de recherche futurs, notamment : (I) la nécessité de développer de futurs projets de recherche participative dans des schémas de recherche transdisciplinaires ; (II) l'exploitation du potentiel de recherche de jeux sérieux significatifs pour relier la science et la société afin de favoriser l'apprentissage social sur des défis socio-écologiques complexes ; (III) l'identification du mécanisme qui permet/renforce les outils de gouvernance collective existants des organisations de petits exploitants agricoles.

Sommario

Le organizzazioni di piccoli agricoltori sono attori cruciali nello sviluppo di mercati di colture eque e biodiverse. Pertanto, incorporare le loro prospettive e i loro bisogni è fondamentale per sviluppare e sostenere le loro pratiche, così come coltivare l'agrobiodiversità e creare paesaggi agricoli sostenibili. Incorporare le prospettive dei piccoli agricoltori richiede approcci orientati all'azione, alla ricerca e a metodologie interattive. In questa tesi ho esplorato il potenziale dei giochi e dei metodi seri per esplorare il futuro delle organizzazioni di piccoli agricoltori e di altri attori chiave del sistema alimentare per promuovere l'uso sostenibile e la conservazione dell'agrobiodiversità. In questa tesi sono stati esplorati i seguenti obiettivi: (1) Testare il potenziale dei giochi e degli approcci futuristici per esplorare la transizione verso la sostenibilità per l'agrobiodiversità e le organizzazioni di piccoli agricoltori; (2) Esplorare i percorsi di sostenibilità nello sviluppo dei mercati dell'agrobiodiversità e degli strumenti di governance per le organizzazioni di piccoli agricoltori; (3) Esplorare le prospettive future delle organizzazioni di piccoli agricoltori sulla conservazione e l'uso sostenibile dell'agrobiodiversità; (4) Sviluppare e applicare un gioco narrativo online come strumento di facilitazione per l'apprendimento sociale e la valutazione collettiva degli scenari. Ho esplorato le pratiche e le prospettive delle organizzazioni di piccoli agricoltori concentrandomi sugli strumenti di governance collettiva e sull'etichettatura, applicando metodi di ricerca partecipativa come i serious games e il backcasting. Ho lavorato con i coltivatori di quinoa nelle alte Ande del Perù e con i coltivatori di caffè in Nicaragua come casi di studio. Inoltre, i produttori di teff in Etiopia e di miglio in India sono stati studiati come casi complementari per una revisione della letteratura. Questa ricerca ha evidenziato nuovi percorsi di transizione e agende per includere le varietà locali di quinoa e l'agrobiodiversità per i mercati locali e globali. Inoltre, attraverso la mia ricerca, ho evidenziato la necessità di riconoscere e condividere con i consumatori locali e globali lo sviluppo di pratiche e culture tradizionali. Il nostro approccio e il nostro metodo potrebbero essere applicati per favorire l'apprendimento sociale di sistemi socio-ecologici complessi. Inoltre, il nostro metodo può alimentare l'azione collettiva mettendo in contatto più attori coinvolti nella catena di approvvigionamento e i consumatori per ripensare un mercato sostenibile ed equo.

Il capitolo 2 illustra l'adattamento di un serious game, il gioco RESORTES (Speelman et al., 2014a), per le organizzazioni di piccoli produttori di caffè in Nicaragua. Una combinazione di giochi e metodi di esplorazione del futuro è stata utilizzata per esplorare la transizione verso la sostenibilità per l'agrobiodiversità e le organizzazioni di piccoli agricoltori. Presentiamo un approccio innovativo per esplorare i percorsi di transizione verso la sostenibilità dei sistemi agroforestali. Combinando approcci partecipativi di foresight e backcasting basati su serious games e visioning development, esploriamo le strategie di gestione agroforestale rilevanti per ottenere un futuro sostenibile dei paesaggi

agroforestali a base di caffè in relazione all'agrobiodiversità. Ci siamo concentrati sulle sfide che deve affrontare la principale area di produzione di caffè del Nicaragua. Sono state organizzate cinque sessioni di gioco partecipativo per esplorare i processi decisionali e le strategie agricole degli agricoltori, per sviluppare nuove reti e stimolare l'apprendimento sociale tra gli agricoltori. Nel workshop associato di backcasting, i partecipanti più influenti delle sessioni di gioco si sono uniti a tecnici, ricercatori e funzionari comunali per immaginare collettivamente una gestione sostenibile del paesaggio nel futuro. In tutte le sessioni di gioco, gli agricoltori hanno sviluppato paesaggi agroforestali diversificati basati sul caffè, caratterizzati da una maggiore densità e diversità di alberi da ombra, al fine di diversificare i redditi e conservare le foreste. Durante il workshop di backcasting, i partecipanti hanno individuato strumenti di governance e soluzioni comunitarie per la transizione verso paesaggi sostenibili. Questo approccio partecipativo ha facilitato la discussione sulla pianificazione del paesaggio e sull'agrobiodiversità tra gli agricoltori e le altre parti interessate e ha permesso di delineare un percorso verso il paesaggio futuro immaginato collettivamente. La combinazione di previsione partecipativa e backcasting si è rivelata uno strumento utile per sostenere i processi multi-stakeholder verso una gestione sostenibile del paesaggio in questo e in altri paesaggi complessi.

Nel capitolo 3, è stata sviluppata una revisione della letteratura e un quadro di riferimento per esplorare i percorsi di sostenibilità nello sviluppo dei mercati dell'agrobiodiversità e degli strumenti di governance per le organizzazioni di piccoli agricoltori. La revisione della letteratura si è concentrata su due recenti boom di specie trascurate e sottoutilizzate (NUS): la quinoa (Chenopodium quinoa Willd.) nelle Ande peruviane e boliviane e il teff (Eragrostis tef Zucc. Trotter) in Etiopia. Basandoci sulle intuizioni di questi due casi, sviluppiamo un quadro generico per esplorare la transizione verso la sostenibilità nei cicli di boom e bust del NUS. Valutiamo le caratteristiche di questi NUS che hanno portato all'aumento della domanda globale e al successivo ciclo di boom e bust. Inoltre, valutiamo i vari strumenti di governance applicati in questi due casi e il loro impatto sul ciclo boom-bust. Infine, esaminiamo l'imminente boom del miglio minore che si prevede in India. Applicare le nostre «lezioni apprese» e il nostro quadro di riferimento ai miglio minori e al loro prossimo boom può aiutare gli attori della catena del valore a coordinarsi per imparare come le transizioni sostenibili possano coesistere in un ciclo boom-bust che garantisca benefici locali e la conservazione dell'ambiente socio-ecologico.

Nel capitolo 4, confrontiamo le conoscenze acquisite nel capitolo precedente con le organizzazioni di piccoli coltivatori di quinoa delle Ande peruviane, esplorando le loro prospettive future sull'agrobiodiversità in relazione alle pratiche agricole, alle opzioni di mercato e agli strumenti di governance. Abbiamo esplorato le percezioni degli agricoltori sul futuro della diversità della quinoa e sulla gestione attuale della diversità della quinoa associata. La ricerca è stata condotta in tre villaggi della regione peruviana di Puno, uno dei

centri di origine della quinoa. È stata applicata una combinazione di metodi partecipativi: la metodologia Q per interpretare le prospettive future delle organizzazioni di piccoli proprietari di quinoa in relazione alle attività importanti nelle loro aziende agricole e l'analisi quadratica per esplorare la gestione della biodiversità della quinoa. I nostri risultati sono una base importante per lo sviluppo di nuovi progetti di conservazione in situ dell'agrobiodiversità e di inclusione nel mercato con la partecipazione delle comunità locali.

L'approccio partecipativo prosegue nel capitolo 5, dove è stato sviluppato e applicato un gioco narrativo online come strumento di facilitazione per l'apprendimento sociale e la valutazione collettiva degli scenari. Abbiamo riunito i punti di vista delle diverse organizzazioni di piccoli produttori di quinoa in una partita da giocare con i rivenditori europei del commercio equo e solidale. Questo approccio si è reso necessario a causa della limitazione di covid e dell'impossibilità di condurre un lavoro sul campo. Inoltre, attraverso questo capitolo, abbiamo incoraggiato l'inclusione delle prospettive delle organizzazioni di piccoli agricoltori sui sistemi di certificazione e sostenibilità per la transizione e la sostenibilità dell'agrobiodiversità. Abbiamo sviluppato insieme un gioco narrativo online per esplorare la valutazione collettiva degli scenari e il processo decisionale. Inoltre, abbiamo testato l'approccio e mostrato un'illustrazione basata sul caso della produzione di quinoa nelle alte Ande. Inoltre, sono state esplorate le prospettive, la posizionalità e l'agency nel ripensare il codice di condotta del commercio equo e solidale. Ci siamo concentrati su una coltura tradizionale ben studiata, la quinoa (Chenopodium quinoa Willd.) nelle Ande alte, con il coinvolgimento di organizzazioni locali di piccoli proprietari specializzati e di rivenditori internazionali del commercio equo e solidale. Questo metodo di ricerca e la sua valutazione d'impatto - sull'apprendimento sociale - hanno rivelato nuovi importanti criteri di etichettatura, come la promozione della biodiversità coltivata localmente per l'esportazione e il riconoscimento e la condivisione dello sviluppo di pratiche e culture tradizionali con i consumatori. Il nostro approccio e il nostro metodo potrebbero essere applicati a una serie di prodotti commercializzati nel Sud del mondo, dove le piccole organizzazioni di agricoltori mantengono varietà e pratiche agricole tradizionali. Inoltre, questo approccio distanziato può favorire il dialogo tra i vari attori coinvolti nella filiera e i consumatori per reimmaginare una produzione sostenibile e un mercato equo e solidale.

Infine, nel capitolo 6, presento una discussione generale dei risultati principali, riflettendo sui risultati e proponendo strade future per la ricerca e i metodi utilizzati. Presento una riflessione su (a) i giochi come strumento per facilitare l'apprendimento sociale, in cui fornisco raccomandazioni su come i giochi debbano essere valutati non come un singolo metodo, ma come parte di un processo di ricerca iterativo e a lungo termine; (b) la necessità che gli approcci di ricerca partecipativa siano transdisciplinari, in cui rifletto sul

fatto che la ricerca transdisciplinare manca di un protocollo comune che rafforzerebbe questo approccio e lo renderebbe reale sia per i partecipanti che per i ricercatori; e (c) come le prospettive delle organizzazioni di piccoli agricoltori dovrebbero guidare la transizione verso la sostenibilità, in cui rifletto su come le prospettive delle organizzazioni di piccoli agricoltori debbano influenzare il passo iniziale quando si studiano o si sviluppano nuovi progetti, in quanto possono differire dai punti di vista degli attori istituzionali e internazionali. Inoltre, ho fornito una panoramica e i risultati del breve lavoro sul campo finale, in cui ho condiviso i risultati dei capitoli 3, 4 e 5 con le organizzazioni di piccoli agricoltori, le ONG e i governi regionali, attraverso interviste e giochi seri nelle alte Ande del Perù. In conclusione di questo capitolo, indico i temi di ricerca futuri, tra cui: (I) la necessità che i futuri progetti di ricerca partecipativa siano sviluppati nell'ambito di schemi di ricerca transdisciplinari; (II) lo sfruttamento del potenziale di ricerca dei giochi seri significativi per collegare la scienza e la società e promuovere l'apprendimento sociale su sfide socio-ecologiche complesse; (III) l'identificazione del meccanismo che abilita/potenzia gli strumenti di governance collettiva esistenti delle organizzazioni di piccoli agricoltori.

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Thanks to everyone who accompanies me on this journey and thanks also to those I did not thank.

About the author

Federico Andreotti was born in Milan, Italy, in the spring of 1992. After spending his childhood in the countryside of the province of Como, he and his family moved to Milan. During his high school he became passionate about agriculture and food working for different restaurants in the city discovering different cultures, tastes and hospitalities. In 2012 he enrolled in the University of Agriculture in Milan. During his bachelor degree, he had the opportunity to work as a consultant to the Olona Valley Agricultural District developing projects at the territorial level in rural areas near the city of Milan. The last year of the bachelor he did an Erasmus in the city of Porto in Portugal with the CIIMAR research center working on soil regeneration applying nature-based solutions.

In 2015 he enrolled at Wageningen University, for the MSc on Organic Agriculture, with specialization in Agroecology. Thanks to this master's degree he had the opportunity to develop his interest on smallholder farmer organizations, agrobiodiversity and participatory research. He did his MSc thesis in collaboration with CIRAD, on the management of cacao-based agroforestry systems in Cameroon. During his visit at CIRAD in France he developed a great interest on participatory research and learn new methodologies such as serious games. In Montpellier, France he co-founded the Non-Conference, a French association specialized in organizing science-society events and participatory research project using art-based methods on agroecology projects. This experience decreed the beginning of a long collaboration with the French research centre, continuing in a research project on coffee-based agroforestry systems in Costa Rica and Nicaragua with CATIE. Here Federico applied serious games and action research approaches studying sustainability transition.

After completing his MSc in 2017 he came back to Milan working as an agronomist on urban agroforestry projects and collaborating with the University of Milan and the Water Museum of Milan, organizing participatory events on open science.

In 2019 he started his PhD in collaboration with CIRAD and Wageningen University in the frame of the SESAM project, specializing himself on collective governance, smallholder organizations and serious games. During this year he co-initiated the WUR Game Hub, at Wageningen University, connecting multiple researchers that use games to bridge science and society. Throughout the last years at Wageningen University he has been teaching as a guest lecturer in different disciplines focusing on food systems and participatory methods.

Today Federico is a lecturer at Farming System Ecology group and researcher for the SESAM project at the Geo Information Science and Remote Sensing group at

Wageningen University. Future Federico aims to dive into transdisciplinary science by being an “unusual collaborator” in education and research projects.

Pictures by: Caspar Schoevaars – Centre for of Unusual Collaboration, Autumn 2022

Scientific publications

- **Andreotti F.**, Bazile D., Biaggi C., Callo-Concha D. Jacquet J. … Speelman E. van Noordwijk M. (2022). When neglected species gain global interest: Lessons learned from quinoa's boom and bust for teff and minor millet. Global Food Security, 32, 100613 (JCR: Q1, IF: 9.0). https://doi.org/10.1016/j.gfs.2022.100613

- Bazile, D., **Andreotti, F.**, Biaggi, C., Murillo, A. C., Chevarria-Lazo, M., Chura, E., ... & Tapia-Nuñez, M. E. (2021). Le Quinoa au temps de la Covid-19: vers de nouvelles coordinations entre les producteurs des différents pays andins. Cahiers Agricultures, 30, 28. (JCR: Q3, IF :1.1). https://doi.org/10.1051/cagri/2021016

- Lagneaux, E., **Andreotti, F.**, & Neher, C. M. (2021). Cacao, copoazu and macambo: Exploring Theobroma diversity in smallholder agroforestry systems of the Peruvian Amazon. Agroforestry Systems, 1-1. (JCR: Q2, IF: 2.4). https://doi.org/10.1007/s10457-021-00642-6

- Zanzi, A., **Andreotti, F.**, Vaglia, V., Alali, S., Orlando, F., & Bocchi, S. (2021). Forecasting agroforestry ecosystem services provision in urban regeneration projects: Experiences and perspectives from Milan. Sustainability, 13(5), 2434. (JCR: Q2, IF: 3.9). https://doi.org/10.3390/su13052434

- **Andreotti, F.**, Speelman, E. N., Van den Meersche, K., & Allinne, C. (2020). Combining participatory games and backcasting to support collective scenario evaluation: an action research approach for sustainable agroforestry landscape management. Sustainability Science, 15(5), 1383-1399. (JCR: Q1, IF: 7.2). https://doi.org/10.1007/s11625-020-00829-3

- van Noordwijk, M., Speelman, E., Hofstede, G. J., Farida, A., Abdurrahim, A. Y., Miccolis, A., ... **Andreotti, F.**,… & Teuling, A. J. (2020). Sustainable agroforestry landscape management: Changing the game. Land, 9(8), 243. (JCR: Q2, IF: 3.9). https://doi.org/10.3390/land9080243

- Durand-Bessart, C., Tixier, P., Quinteros, A., **Andreotti, F.**, Rapidel, B., Tauvel, C., & Allinne, C. (2020). Analysis of interactions amongst shade trees, coffee foliar diseases and coffee yield in multistrata agroforestry systems. Crop Protection, 105137. (JCR: Q1, IF: 3.0). https://doi.org/10.1016/j.cropro.2020.105137

- **Andreotti, F.**, Mao, Z., Jagoret, P., Speelman, E. N., Gary, C., & Saj, S. (2018). Exploring management strategies to enhance the provision of ecosystem services in complex smallholder agroforestry systems. Ecological indicators, 94, 257-265. (JCR: Q1, IF: 6.3). https://doi.org/10.1016/j.ecolind.2018.06.048

- Fernandes, J. P., Almeida, C. M. R., **Andreotti, F.**, Barros, L., Almeida, T., & Mucha, A. P. (2017). Response of microbial communities colonizing salt marsh plants rhizosphere to copper oxide nanoparticles contamination and its implications for phytoremediation processes. Science of The Total Environment, 581, 801-810. (JCR: Q1, IF: 10.8). https://doi.org/10.1016/j.scitotenv.2017.01.015

- **Andreotti, F.**, Mucha, A. P., Caetano, C., Rodrigues, P., Gomes, C. R., & Almeida, C. M. R. (2015). Interactions between salt marsh plants and Cu nanoparticles–effects on metal uptake and phytoremediation processes. Ecotoxicology and environmental safety, 120, 303-309. (JCR: Q1, IF: 7.1). https://doi.org/10.1016/j.ecoenv.2015.06.017

Media publications

- **Andreotti F**. & Sacchi A. Weekly Seeds podcast on sustainability project related to agriculture. Food Systems Summit 2021, May-August 2021.

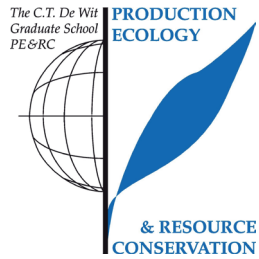
- **Andreotti F**. & Pirovano L. Quinoa is a beacon of hope for the Andean communities in a time of global crisis. The Conversation, September 2020

- **Andreotti F**. & Pirovano L. Reportage: Cacao frees former gold diggers in the Peruvian Amazon. Altreconomia, April 2020

- **Andreotti F.** & Pirovano L. Reportage: On the Andes in Peru, where quinoa farmers defend biodiversity. Altreconomia, July 2020

- **Andreotti F.** & Pirovano L. Reportage: Tales of agriculture that protects history. Altreconomia, September 2021

PE&RC Training and Education Statement



With the training and education activities listed below the PhD candidate has complied with the requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Title of review / title project proposal (6 ECTS)

- when neglected species gain global interest: lessons learned from quinoa's boom and bust for teff and minor millet
- proposal development and defense were required to win the CIRAD PhD grant

Post-graduate courses (16.7 ECTS)

- Agent-based modelling; Behave, University of Milan, Italy (2019)
- Companion modelling; PE&RC (2020)
- Research design and methodology for the study of social phenomena relevant for research on serious games & organizing culture; SESAM project, WUR (2020)
- Visual research methods; WASS (2019)
- Q-methodology & fuzzy cognitive map; SESAM (2020)
- Multivariate analysis; PE&RC (2020)
- Research methodology, from topic to proposal; WASS (2021)
- Analysing discourse: theories and methods; WASS (2021)

Invited review of journal manuscripts (2 ECTS)

- Ecological indicators: agricultural practices and landscape change (2019)
- Agronomy for sustainable development: participatory and action research approaches for agricultural sustainability transition (2022)

Competence strengthening / skills courses (2.4 ECTS)

- Scientific writing; WUR (2019)
- Storytelling and communication; Holden University, Turin, Italy (2021)
- The essentials of scientific writing & presenting; WUR (2021)
- Journalism and podcasting scientific communication; ilPost, Peccioli, Italy (2021)

Scientific integrity / ethics in science activities (1.1 ECTS)

- Ethics for social sciences research; WUR (2020)
- Research integrity; WUR (2020)

PE&RC Annual meetings, seminars and the PE&RC weekend (1.2 ECTS)

- Midterm years PE&RC retreat (2018)
- Last years PE&RC retreat (2021)

Discussion groups / local seminars or scientific meetings (11.7 ECTS)

- ESSA Summer school in social simulation; WUR (2019)
- EIR-A seminars; French Universities Network (2019, 2021)
- SESAM Discussion group; WUR (2020-2021)
- Game hub; WUR (2021-2022)
- 5th World congress on agroforestry; Quebec, Canada (2022)

International symposia, workshops and conferences (6.3 ECTS)

- 4th World congress on agroforestry; poster presentation; Montpellier, France (2019)
- Origin, diversity and territories forum; oral presentation; Eurre, France (2020)
- Conference sustainability through art; oral presentation; Geneva, Switzerland (2020)
- Origin, diversity and territories forum; oral presentation; Poschiavo, Switzerland (2021)
- Landscape conference; oral presentation; Zalf, Leibniz, Germany (2021)

Societally relevant exposure (1.5 ECTS)

- Wiki City at the Water Museum of Milan, Italy (2019)
- Seeds on sustainability projects related to food and agricultural systems (2020)
- Quinoa is a beacon of hope for the Andean communities in a time of global crisis (2020)
- Cacao frees former gold diggers in the Peruvian Amazon (2020)
- On the Andes in Peru, where quinoa farmers defend biodiversity (2020)

Lecturing / supervision of practicals / tutorials (3 ECTS)

- Origin food: a market for identity (2019-2021)
- Ethnobotany (2019-2021)
- Geo-information science in context (2021-2022)
- Agroforestry (2022)
- Forest & nature conservation planning (2022)

BSc/MSc thesis supervision (9 ECTS)

- Development and rural innovation, seeds, livelihoods and the market the inclusion and exclusion of Peruvian farmers and quinoa seed in the market
- Including farmers perspectives in sustainability assessment tools

- Exploring consumers' understanding of land use decisions in quinoa cultivation in the Andes, Peru a serious gaming approach

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