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RESEARCH ARTICLE

Exploring farmers' perspectives on agrobiodiversity management: future options for quinoa smallholder organizations in the Peruvian high Andes

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Abstract

The intensification of crop production is widely recognized to negatively affect the agrobiodiversity in smallholder systems. This trend can also be observed in Quinoa production systems, where few varieties are commercialized while maintaining traditional varieties of quinoa remains 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, including the development of a collective trademark. However, little is known about the opinions of smallholder farmers regarding quinoa varieties cultivation, farming practices, market choices, or the development of a collective trademark as a tool to safeguard a position in the booming international quinoa market. To address these questions, we developed our research in three villages in the Puno region of Peru, 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 sustainer*, and (Type 3) *Collaboration seeker*. Type 1 assigns importance to maintaining and promoting quinoa biodiversity through collective practices and markets. Type 2 focuses on developing export-oriented production based on certified and improved varieties, combined with efficient ways of storing quinoa. Type 3 appears 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 genetic 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 · Cultivated biodiversity · Multi-method approach · Farmers' viewpoints · Neglected and underutilized species · *Chenopodium quinoa* Willd

1 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 present on earth, only around 7000 have ever been cultivated or used for human consumption, and only 150 are commercially cultivated and marketed (Esquinas-Alcàzar 2005; Li & Siddique 2018). Hundreds of neglected and under-utilized species (NUS) mainly grown 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

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from "traditional foods" into "superfoods" that appeal to health-conscious Western consumers such as quinoa, teff, and minor millets (McDonell 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 7000 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 quinoa producer, experienced a ten-fold increase in its quinoa exports and a four-fold increase in prices (MINAGRI 2014). This production and price increment ("boom") of quinoa in Peru was followed by a rapid decrease in prices ("bust") (Alandia et al. 2020; Andreotti et al. 2022).

In 2015, quinoa prices started to decline in response to changes in national and global production (Alandia et al. 2020; McDonell 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 (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 kept in seedbanks, farms, and grown 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). 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 have tried to support smallholder farmers in their efforts to maintain this biodiversity (Fagandini et al. 2020).

Since 2011, the Peruvian high Andes region has been included in the Globally Important Agricultural Heritage Systems (GIAHS) program (Koohafkan and Cruz 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 (Koohafkan and Cruz 2011). 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 effective only at the institutional level (for example on the promotion of the Andean countries tourism). Local communities were not involved in elaborating the initial draft memorandum (GEF 2016). Drawing lessons from the Peru GIAHS pilot project, other GIAHS projects have aimed to foster the inclusion of smallholder farmers from the outset of projects (Winkel et al. 2014).

Over 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 fair-trade 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 market niche products such as traditional varieties in local and global markets (Deleixhe 2018; Cuéllar-Padilla & Ganuza-Fernandez 2018). While the development of a CT has been identified as a possible option for Andean quinoa farmers, there have been no ongoing efforts to monitor the implementation process and farmers' opinions in adopting such a label.

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) (Fig. 1). Such practices include collective crop rotations based on the community calendar (so-called *Aynokas* systems), minimum tillage, using animal manures to improve soil fertility, conserving local agrobiodiversity through community seed banks (Fagandini 2019). 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.

Fig. 1 *Aynokas* landscape in Huancarani, Puno, Peru. In the picture are shown several plots that follow collective crop rotations based on the community calendar. Credit: Federico Andreotti.

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). For collecting information on cultivated biodiversity in situ, a variety of methods can be applied. One 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 focus-group workshops 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): (i) landraces are distinguished from cultivars, (ii) and modern varieties are distinguished 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 this participatory research for studying the process of developing a CT exploring farmers' interest in adopting a CT in relation to their opinions on farm and agrobiodiversity management. In doing so, we involved smallholder farmers' organizations in the high Peruvian Andes. We also addressed the following research question:

> Which 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 3900 to 4300 m, 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 (Fig. 2). 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).

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 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

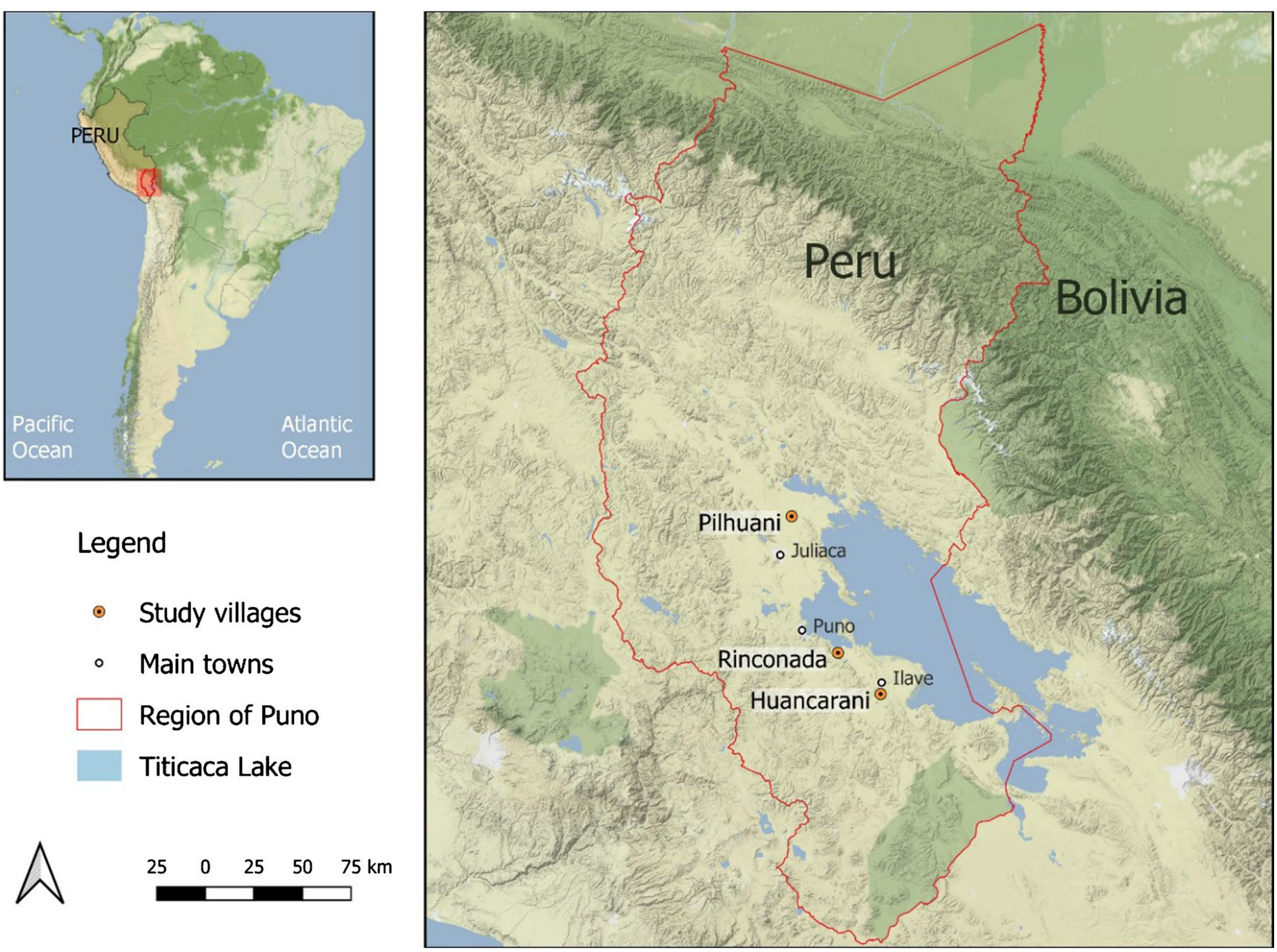

Fig. 2 Study site location: study villages (red dots); main cities (white dots); Puno region (red border).

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)
Agroecological zone	Puna	Id	Id
Altitude	3900 m	Id	Id
Average annual temperature	5–8 °C	Id	Id
Precipitation	700–1000 mm	Id	Id
Wet season	One single rainy season, September–April/May	Id	Id
Dry season	May–September	Id	Id
Growing season quinoa	September–April	Id	Id
Harvest season quinoa	April–June	Id	Id
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
Organization	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.

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.

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 (Fig. 3). 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.

2.3 Assessing the perspectives of the farmers

The visual *Q* methodology was used to assess farmers' opinions about the future of their farming systems. This semi-quantitative method allowed us to identify different "opinion types" comparing individual perspectives (Zabala et al. 2018). We evaluated those perspectives by analyzing how farmers ranked pictures and keywords (so-called items) in relation to their farming systems. The results of QM therefore allowed us to highlight agreements or disagreements of opinions among the farmers of the three smallholder organizations that participate to this research.

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" (Fig. 4). 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).

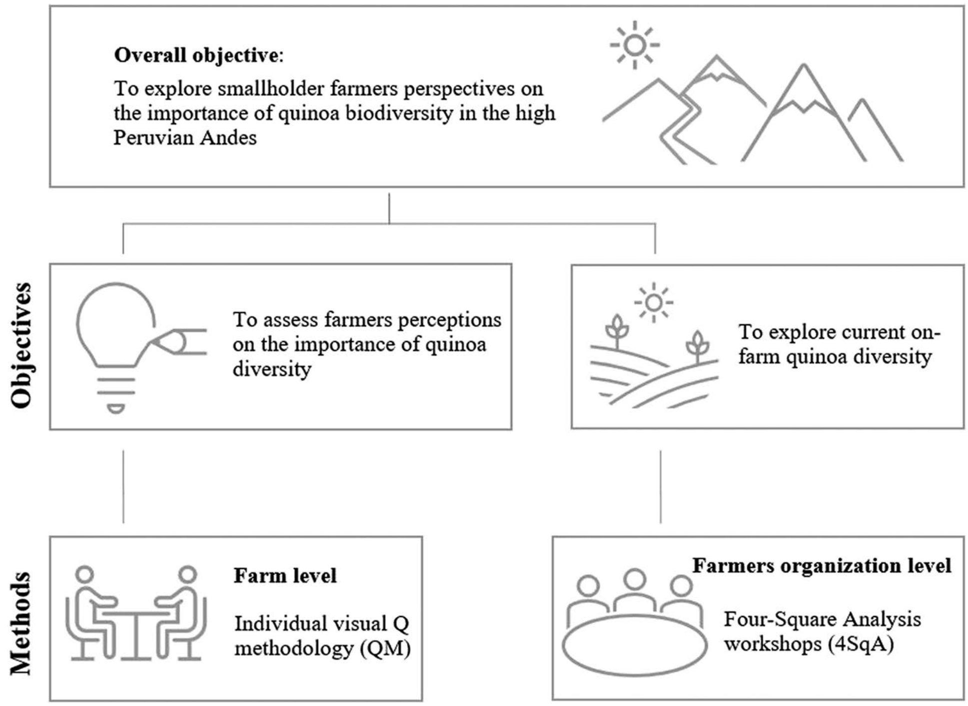

Fig. 3 Overview of research objectives and methods.

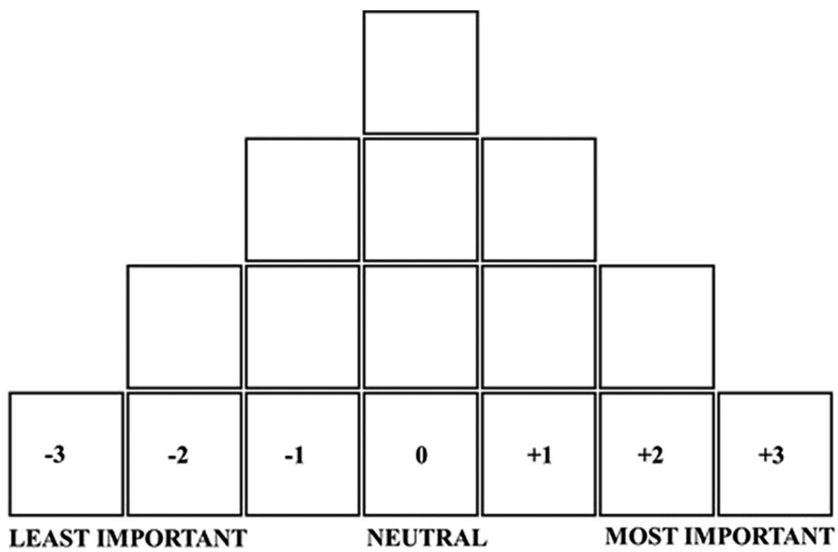

Fig. 4 *Q*-sort semi-normal distribution.

We used a visual *Q*-set consisting of pictures and keywords to facilitate the inclusion of Andean Peruvian farmers with a broad 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 (Fig. 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 for the future of the farm and what is not, focusing on quinoa varieties cultivation, farming practices, market choices, and the development of a collective trademark. Such a "learning from the future" approach has shown to enlighten transition pathway when re-thinking current challenges in the food system (Valencia et al. 2022).

The selection of keywords and pictures used to build the *Q*-set was based on recent studies on 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

Fig. 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.

conducting fieldwork in the Puno region (September–October 2019) and picture found in the literature (i.e., Farfán et al. 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 (Fig. 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 Spanish 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).

The outcomes of the *Q*-sort from the three villages were analyzed 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.

2.3.1 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. 2003). 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 to cover 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) (Fig. 6). 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 participatory method as a focus group exercise to facilitate the exchange among the participants. Allowing such a horizontal space for

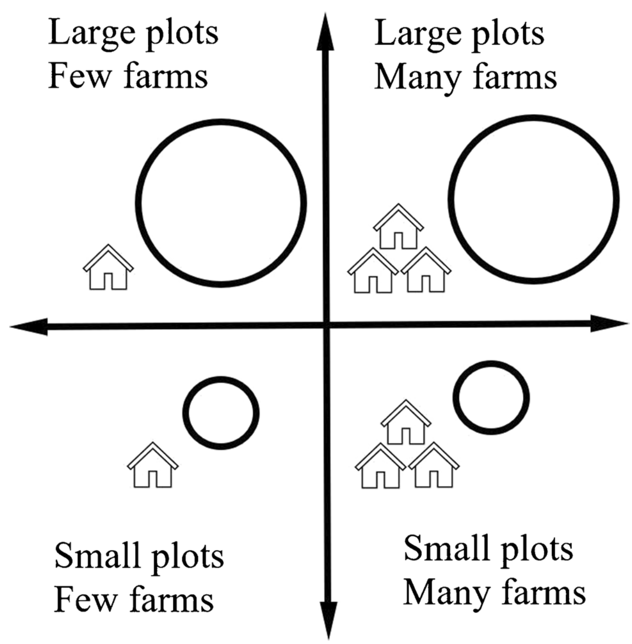

Fig. 6 Representation of the Four-Square Analysis: The horizontal axis represents the size of the area on which a crop is cultivated (small plots *versus* large plots), and the vertical axis represents the number of households cultivating it (few farms *versus* many farms).

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

dialogue fostered the exchange concerning farmers' knowledge and values on the different quinoa varieties.

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.

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 h. 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 certified cultivars, 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 farmer 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 judgement 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 sustainer*: Farmers within this archetype assign 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.

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

Out of a total of 36 participants, 14 belong to Opinion Type 1, 11 to Opinion Type 2, and three 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 Fig. 7).

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

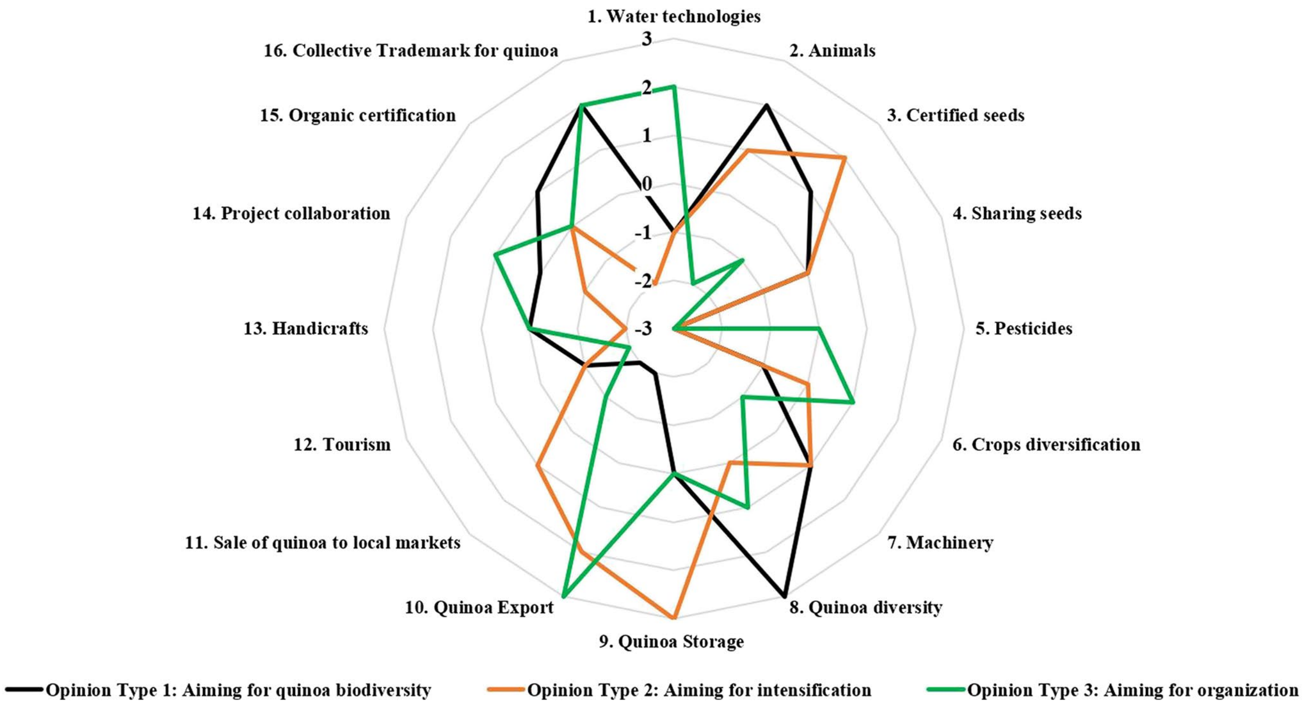

Fig. 7 Spider diagram of item rankings for each opinion type. The black line indicates Opinion Type 1, the green line indicates Opinion Type 2, and the orange line indicates Opinion Type 3. Each ring of the diagram represents the importance value (from −3 to +3) assigned to each item.

(Huancarani) identified 12 varieties, including many local varieties: *Kankolla*, *REAL Salcedo INIA*, *Koito*, *Vitulla*, *Choclito*, *Pasankalla*, *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 (Fig. 8). The names of the landraces differ somewhat across the village, as each village used different names to designate traditional varieties of quinoa.

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 number of participants. Examples

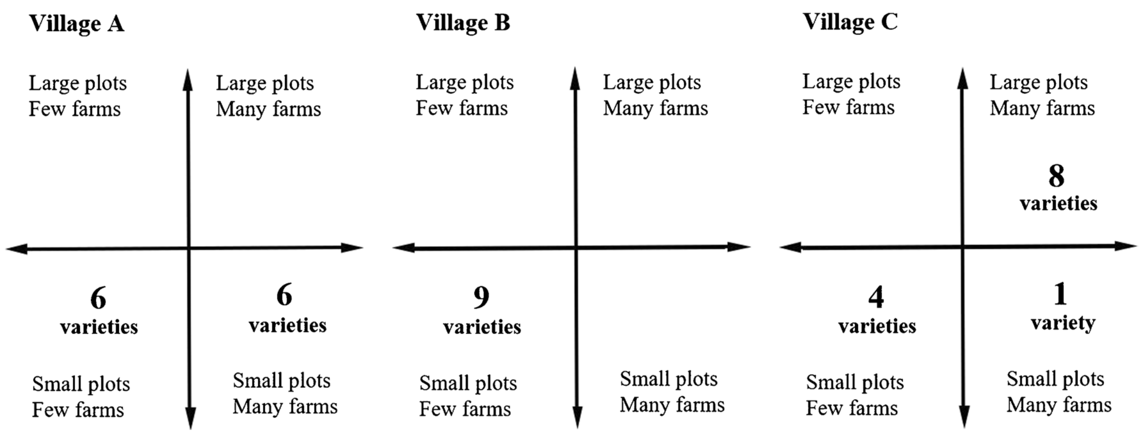

Fig. 8 Overall results of the Four-Square Analysis workshops in each village. Each value shows in the squares express the number of quinoa varieties cultivated in a given village. No quinoa varieties were listed under the Four-Square category of "large plots/few farms".

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 was 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 sustainer* (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 demands for large, uniform grains encourage 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 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 was developed 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

Within the context of maintaining agrobiodiversity, smallholder farmer organizations play a pivotal role for cultivating local varieties through traditional practices; exploring farmers' perspectives on the future can reveal winning and disruptive strategies to maintain agrobiodiversity encompassing novel farming and market practices. In this article, we present the results of a study in which we applied two participatory methods 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 a 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 sustainer*, and (Type 3) *Collaboration seeker*. Farmers adhering to Opinion Type 1 assign greater importance to maintaining and promoting quinoa biodiversity through collective practices and local markets. This contrasts with 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 genetic erosion as they are only cultivated in small plots and on a few farms. The novel combination of methods presented allows to develop opinion types based on individual and collective perspectives concerning practices for maintaining agrobiodiversity. Such an approach has the potential to be used in other cases where smallholder farmer organizations need to explore pathways to foster agrobiodiverse futures. 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 a visual support (e.g., the pictures used in the Q methodology) facilitated the participation of smallholder farmers during our research. As we have demonstrated, engaging smallholder farmers through participatory research methods can generate insightful perspectives on exploring farmers' perspectives on the future. Our approach and results contribute to the literature by monitoring the implementation process and farmers' opinions in adopting a collective trademark in relation to farm and agrobiodiversity management.

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Authors' contributions Conceptualization: A. F., S. E., B. D., and N. C. M.; methodology: A. F., and N. C. M.; data analysis: A. F.; investigation: A. F., and N. C. M.; writing original draft, A. F.; writing-review and editing: A. F.; S. E., B. D., and N. C. M.; visuals: A. F.

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Data availability The integrity of the data used in this study are included in it and in the appendix.

Code availability The software used for the *Q* analysis is "Ken-Q Analysis," an open source web application for Q Methodology (Version 1.0.7).

Declarations

Ethical approval This research was conducted according to the Netherlands Code of Conduct for Research Integrity 2018 and its later amendments.

Consent to participate All the research participants gave their informed consent to participate in this study.

Consent for publication The authors confirm that all the participants gave their informed consent to participate in the study.

Conflict of interest The authors declare no competing interests.

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