Do community seed banks contribute to the social-ecological resilience of communities? A case-study from western Guatemala

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Abstract

Community seed banks (CSBs) are initiatives to support the conservation and use of diverse crops though locally rooted collective action. The impact of CSBs is assumed to be complex, but has not been investigated in detail. Our study addresses this gap by analysing the impact of CSBs using social-ecological resilience as theoretical framework. We focus on the western highlands of Guatemala where CSBs have been implemented since 2009. We used qualitative and quantitative methods of data collection and analysis, including focus groups, participatory workshops, and structured and semi-structured interviews conducted in the local communities with CSB members and non-members. Our results indicate that CSBs contributed to increased seed exchanges, improved access to novel crop diversity, more saving of traditional varieties, and greater information and knowledge access, use and exchange. These effects strengthened the social-ecological resilience of the local communities. The scope of action of the CSBs, however, was constrained by wider socio-economic trends, including social divisions, out-migration of youth, and a change in livelihood strategies. We conclude that for CSBs to effectively strengthen social-ecological resilience in the future, they should be continuously adapted to the local context. Conceptually, our findings call for the further evolution of the CSB concept.

Keywords: agricultural biodiversity; community seed bank; Guatemala; local seed system; social-ecological resilience

1. Crop agrobiodiversity and community seed banks

Crop agrobiodiversity is key to the livelihood strategies of smallholder farmers, as it provides the basis for agricultural diversification and further evolution of crops, which are both necessary to adapt to variable and changing ecological and socio-economic conditions (Altieri et al., 2015; Altieri & Nicholls, 2017). Smallholder farmers have been playing a pivotal role in maintaining agrobiodiversity (Brush, 1995; Jarvis et al., 2008, 2011). Recently, smallholder farmers have invested less in agrobiodiversity conservation as the socio-cultural and economic context of farming has been changing (Gepts, 2006; McLean-Rodríguez et al., 2019; Zimmerer, 2010).

As a response to the loss of agrobiodiversity, efforts have been made to conserve crop genetic diversity in gene banks (*ex situ*), on-farm and in other growing environments (*in situ*). *Ex situ* conservation is an important strategy to ensure that breeders can continue to make use of a large pool of genetic diversity (Castañeda-Álvarez et al., 2015). *In situ* conservation is important to maintain the continuous crop evolutionary processes (Bellon et al., 2017, 2018).

In situ conservation has been promoted by advocates of community biodiversity management as a means to strengthen the collective management of agrobiodiversity (Thijssen et al., 2013). In contrast to other *in situ* conservation strategies, community biodiversity management focuses on increasing decision-making power of the communities (Subedi et al., 2013). Whereas the initial debate in the 1970s positioned *ex situ* and *in situ* conservation as competing strategies, the two are increasingly seen as complementary.

Community seed banks (CSBs), growing in number and scope world-wide, are important examples of community biodiversity management (Vernooy et al., 2015). CSBs are "*local, mostly informal institutions whose core function is that of collectively managing seeds for local use*" (Vernooy et al., 2014, p. 237). CSBs hold an intermediate position between *in situ* and *ex situ* conservation, integrating concepts from both strategies. They aim to support communities in managing agrobiodiversity by securing farmers' access to diverse seeds of good quality (*in situ*) and have a physical structure where seeds are stored (*ex situ*) for short and medium duration (Vernooy et al., 2014).

Even though CSBs are increasing in number, their impact has not been documented extensively (Vernooy et al., 2015). CSBs are assumed to have a direct positive impact on agrobiodiversity management in communities and a wider impact on the livelihoods of rural families, in particular on their ability to adapt to dynamic environments. To evaluate both the direct and wider impacts of CSBs we used a systemic approach and the normative concept of social-ecological resilience – defined as "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks*" (Walker et al., 2004, p. 3). Our research question was whether and how CSBs contribute to the social-ecological resilience of communities. We addressed this question by investigating the impact of CSBs in the western highlands of Guatemala, where several CSBs have been established since 2009.

2. Conceptual framework

Agrobiodiversity dynamics are the outcome of intersecting processes happening at different spacial and temporal scales (Wittman et al., 2017). Agrobiodiversity loss has social, political, economical, and ecological drivers, such as market integration, land use changes, conventional agricultural intensification and the promotion of modern varieties, neo-liberal policies, and climate change (Chappell et al., 2013; Wittman et al., 2017).

To understand the broader context in which CSBs operate, we use the concept of social-ecological systems. Social-ecological systems include societal and ecological subsystems in mutual interaction, and can be defined at any scale (Berkes & Folke, 1998; Gallopín, 2006). Social-ecological systems are complex and continuously changing, due to external and internal drivers (Holling & Gunderson, 2002; Walker et al., 2002, 2004). We thus considered farming communities in the western highlands of Guatemala as complex social-ecological systems, and focused on external and internal drivers affecting resilience (Figure 1).

External drivers were specified as the wider social, political, economic and ecological dynamics (Figure 1). Following Vernooy et al. (2014, 2015), we assumed that CSBs can be an internal driver contributing specifically to:

- *Local agrobiodiversity conservation* in the short-term through ensuring seed availability from one cropping season to the next, and in the long-term through storing, regenerating, and distributing underutilized or rare varieties;
- *Enhancing seed access and availability*, by promoting activities that foster seed exchange among farmers, by having sufficient amount of seed in stock in case of emergency, and by linking farmers' to the formal seed system;
- *Ensuring seed and food sovereignty*, by promoting farmers' control over seed and related knowledge, supporting the local food culture, and by recognizing the key role of women farmers.

FIGURE 1 ABOUT HERE

Since our purpose was to understand the specific effect of CSBs on the social-ecological resilience of the communities, we studied how internal and external drivers of change affect resilience. We further operationalized social-ecological resilience along the four principles suggested by Folke et al. (2003):

- *Learning to live with change and uncertainty* in managing livelihoods in general and agrobiodiversity in particular;
- *Nurturing diversity for reorganization and renewal* associated with social-ecological memory to deal with disturbance and uncertainty;
- *Combining different types of knowledge for learning* to build resilience;
- *Creating opportunity for self-organization* considering the interplay between diversity and change and cross-scale dynamics.

3. Methods

3.1. Study region: Cuchumatanes, western highlands, Guatemala

Cuchumatanes is a mountain range that extends through southern Mexico and western Guatemala. The area is characterized by a complex topography of many small valleys and high-plateau formations. Altitude ranges from 1500-3000 meters above sea level. The population is mainly of Mayan origin (Richards & Macario, 2003). The Cuchumatanes has been a region of refuge where different ethnic groups would retreat when facing conflict, both before and after the Conquest (Lovell, 2005). The area is known for being rich in agrobiodiversity, especially maize, which has a central cultural role in the Mayan tradition. Maize is also vital to food security in the western highlands (Hellin et al., 2017).

In spite of its remoteness, the Cuchumatanes is connected to the wider socio-economic system. The pace of change in the region has accelerated in the last century, driven by market integration, migration, population growth, civil war, political reforms, and new technologies. Still, the environmental conditions together with the small farm-size and the difficult road access make commercial production difficult. Subsistence-based smallholdings continue to be the most common form of agriculture (Fuentes Lopez, 2013; Hellin et al., 2017). In subsistence farming, the main strategy is the milpa system – combining maize with other crops such as beans or gourds (Hellin et al., 2017).

Some areas in the western highlands, such as Panajachel, Sololá and Aguacatan have specialized in commercial crop production of "traditional" vegetables, such as onions and garlic. Other farmers have increasingly taken up growing "non-traditional" vegetables and fruits for the export market, including broccoli, cauliflower, and snow peas (Hamilton & Fischer, 2003; Von Braun et al., 1989). Seasonal migration has been common since the emergence of the coffee economy from the middle of the 19th century. More recently, migration to Mexico and the United States has become prominent. As a result, the importance of remittances has increased (Taylor et al., 2006). Furthermore, the rural labour market has profoundly changed: the absence of (often male) migrants has increased the reliance on hired labour and off-farm employment. The resulting transformation of household economies has decreased the availability of labour and land for traditional crops (van Etten, 2006b).

The effects of the armed conflict (1960-1996) were particularly severe in the western highlands, damaging social organization (Carmack, 1988; McAllister, 2009). The advancement of evangelical Christianity among indigenous groups created new sectarian divides in the communities (Copeland, 2011). Changes in the traditional community arrangements (process of 'aldeización' – the emergence of sub-municipality units) and interventions from development organizations most likely also contributed to the increased division and power inequalities within local communities (van Etten, 2006b). Some studies in the western highlands suggest that the loss of social cohesion hinders local agrobiodiversity conservation (Steinberg & Taylor, 2002; van Etten, 2006a). Such an eroded social fabric and deep social and political divisions are a challenge for the promotion of collective action, such as CSBs (Hellin et al., 2018).

3.2. Research site

The research site is located in the Huehuetenango department in western Guatemala. In an initial exploratory phase, ten CSBs in the study-area were visited. Of these CSBs, we selected two diverse cases for an in-depth case study (Yin 2009) (Figure 2).

FIGURE 2 ABOUT HERE

The two selected CSBs are located in Quilinco and Secheu communities respectively (Table 1). The main criteria for CSB selection comprised: year of establishment of the CSB, agrobiodiversity preserved, number of members, and women participation.

In both communities, farming is the main livelihood activity and maize is produced mostly for household consumption. Farmers cultivate crops on small plots at different altitudes with varying timing and intensity of use. The two communities focus on different cash crops, which has implications for the milpa cultivation. In Secheu, the main cash crop is grown on lower-altitude plots separate from maize whereas in Quilinco the cash crops are generally grown in rotation with maize, which requires shorter production cycles and a higher intensity of milpa cultivation than in Secheu. For traditional crops, farmers produce their own seed and only exceptionally source seed off-farm, mostly within the same community or neighbouring village.

TABLE 1 ABOUT HERE

3.3. Data collection

Before collecting the data, we obtained free prior and informed consent from each community and individual who participated in our research. We collected data between March and July 2017. The research methods used were both individual-based and group-based. Individual-based methods included structured and semi-structured interviews, complemented by seed network maps and timelines. Group-based methods comprised focus group discussions (FGDs) and validation workshops (Table 2). To gain in-depth knowledge, the first author also lived in the local communities over a period of 5 months and used participatory observation and key-informant interviews as another input into the study.

TABLE 2 ABOUT HERE

In each of the research sites, we followed two different sampling strategies: (1) for the group-based methods, we selected participants following purposive sampling. We specifically targeted elders and local experts who took part in CSB activities. The call for participants was done in cooperation with the local NGO; (2) for the individual-based methods we followed quota sampling in order to capture the variability across households and farmers' individual characteristics. We created a grid of locally relevant socio-demographic categories (i.e. gender, ethnic group, age, CSB membership and dedication to farming). We defined as CSB members all those farmers who stored seed in the CSB from one crop cycle to the next, independent from their level of involvement in any other CSB activities. The sample size was guided by saturation.

To build the research instruments we referred to the dimensions of the conceptual framework and further specified categories of data relevant to address the research question (Table 2).

With consent of the participants, the interviews and discussions were recorded with a voice recorder and the visual material (i.e. timelines and seed network maps) was documented with a digital camera.

3.4. Data analysis

We used R statistical software (v. 2018) to run univariate and bivariate tests on quantitative data, Lilliefors test to test for normality and Mann-Whitney-Wilcoxon test to test for the significance of bivariate relations.

The qualitative data were transcribed and coded using ATLAS.ti (7.0). The codes were developed based on the analytical framework and the research questions, and continuously complemented with inductively developed codes emerging during the analysis. To allow for comparison, the seed network maps and timelines were transferred to a standardized spreadsheet format and quantitatively/qualitatively analysed.

4. Characteristics of the community seed banks in the research site

The establishment of CSBs in the western highlands was mostly led by a local NGO in the framework of several national and international development projects. The 10 CSBs visited had a similar infrastructure, organization and management system, and used the same methods of seed management (e.g. seed storage, documentation, etc.). All CSBs owned a central building to store the seed, which was administered by CSB members (see SM2 for a photo, supplementary material). Farmer members could make use of this facility to store their private seed (for free). In case an emergency affected seed production, farmers could take out 75% of the stored seed leaving the remaining 25% for the next planting seasons, thus ensuring family supply in emergency situations. Moreover, some of the CSBs also conserved, managed and used the diversity that resulted from participatory plant breeding (PPB) activities.

CSBs in the research site stored mostly maize and bean varieties, since the focus was "*on those crops that are culturally relevant and important in terms of food security*" (key informant, local NGO). Other common crops stored in the CSB included milpa companion crops (e.g. gourd), herbs and some medicinal plants (Table 1; Table SM1, supplementary material).

Both CSBs studied in detail had experienced an increase in size in the last five years (see Table 1 for a quantification). However, only a small percentage of community dwellers were CSB members. Respondents mentioned the difficulties in mobilizing farmers to join, in particular youth. The lower involvement of youth was seen as caused by migration and interest in off-farm work. One key informant confirmed that CSBs are "*closely related to the milpa system, a system associated with food security and subsistence farming, which entails a way of life that is not being absorbed by the newer generations. Young people look for more profitable alternatives. Another factor that plays against it is the lack of incentives and mechanisms to help young people have access to more profitable productive processes*" (key informant, local NGO). Women participation was high, but mostly restricted to non-leadership positions. This was attributed to the traditional gender roles.

Respondents in Secheu and Quilinco gave similar reasons for not joining the CSB, which mostly related to social barriers such as religious beliefs, class, traditionalism, mistrust, and the perceived closed nature of the CSB. Other reasons mentioned included having other interests or priorities (e.g. due to a strong market orientation), time-investment not paying off, and the lack of awareness about the roles of a CSB.

5. Results

We report the results following the categories introduced in the conceptual framework: agrobiodiversity conservation, access to and availability of local crop diversity, and seed and food sovereignty. For each category, external and internal drivers are documented.

5.1. Local agrobiodiversity conservation

> *"Our grandparents believed maize was sacred. I remember my grandmother would never allow the chicken to step on the maize seeds because that would mean a bad harvest. She would also not allow to burn the maize in the fire. She had this belief that if the maize burns in the fire, the seed would rot in the field."* (Focus group 8, woman farmer)

Respondents attributed the observed agrobiodiversity loss to a number of interrelated trends, specifically: 1) a decrease in land-availability, 2) a shift in maize and bean variety preferences, and 3) a general change of livelihood strategies away from subsistence farming.

Due to a growing population and the traditional inheritance system and despite the massive migration movement, farmers reported that landholdings are increasingly fragmented.

At the same time, farmers' preferences are changing towards short-cycle maize varieties, particularly in Quilinco, where farmers grow vegetables in rotation with the milpa system. In Secheu, most of the farmers still preferred long-cycle varieties, dividing their cropland into coffee plantations and the milpa system. For beans, which in the milpa system are planted to climb on maize, farmers' preference is changing towards bush beans to reduce the risk of maize lodging. In addition to practical reasons, respondents also stated that cultural norms and rituals associated with traditional varieties lose importance, for example, the use of Salpor maize to bake bread during Lent.

On a more fundamental level, we found that the importance of subsistence farming as a livelihood strategy is decreasing. More cash crops are grown and maize is bought on the market, many of the younger generation are migrating to the United States, dietary habits are changing, and traditional knowledge and values are eroding.

> *"Before there was respect. Respect for Mother Earth. Before harvesting the maize, I always pray. I thank the holy Mother Earth that gave us the maize. Many don't appreciate it. But, if it weren't for her, from where would we get our food? (…) Maize is our food. We all eat maize. The chickens eat maize, the pigs eat maize, the dogs eat maize, even the birds eat maize! What would we eat without maize?"* (Focus group 9, man farmer)

The establishment of CSBs provided farmers with new options to store their seeds from one crop season to the next (short-term conservation) and to exchange and use local traditional varieties and PPB-improved local varieties (long-term conservation).

The findings also indicated a positive association between CSB membership and varietal diversity of maize and beans grown on farm. CSB-members cultivated a greater diversity of maize and bean varieties than non-members (Table 3). The respondents stated that the CSBs had provided access to new varieties, including short-cycle maize varieties and bush-bean varieties through PPB activities supported by the local NGO and national and international agricultural research organizations.

TABLE 3 ABOUT HERE

While farmers in Secheu had added new varieties to their existing crop portfolio, farmers in Quilinco had partly replaced traditional with new shorter cycle varieties that they considered more convenient to grow. Simultaneously, some farmers in Quilinco continued to plant bean traditional varieties in smaller areas, since they preferred their taste for use in traditional dishes. Access to improved seeds could potentially stabilize or increase yield quantity and quality. While respondents considered this an incentive to participate in the CSB and to maintain broader agrobiodiversity on-farm, we could not obtain verifiable data on this.

5.2. Seed availability and access

The respondents identified two general challenges to agricultural production in the region that affected seed availability: a change in weather patterns and increasing pest infestations. Both changes were considered to compromise farmers' capacity to save enough seed from one crop season to the next.

> *"What happens is that the weather went crazy. This is what changed. We have more mishaps, more exceptional events. A strong wind comes and drops all the maize. A hailstorm comes and damages all the harvest. If these mishaps come when the maize is already mature, we can't harvest seed and the seed is lost."* (Focus group 9, man farmer)

Agriculture in the region is rain-fed and thus highly affected by changes in climate variability. While farmers rely on their experience to plan cultivation in the milpa system (i.e. planting, weeding, harvesting), erratic weather patterns have increasingly limited their capability to do this. Respondents reported that the rainy season is starting later, delaying sowing time, but also making it less predictable. The farmers also found it ever more difficult to anticipate drought, frost and hailstorm periods, and therefore felt more vulnerable to these events. A particular concern were stronger winds, which cause maize lodging and seed losses.

> *"Before there were no pests in the milpa (...) what happens now is that the land is tired. Daily, daily it has to give. (...) Our parents, our grandparents, they farmed to the will of God and harvested good maize!"* (Focus group 6, man farmer)

The respondents reported that pest infestations increasingly affected seed production and seed storage particularly in maize and beans. In production, they attributed this trend to the over-use of chemical fertilizers, the abandonment of intercropping in the milpa system and to the unintended effects of pesticides used on non-traditional vegetable crops. Regarding home seed storage, most farmers mentioned that particularly moth (*Sitotroga cerealella* O.) and weevil (*Sitophilus zeamais* Motsch, *Acanthoscelides obtectus* Say) caused seed loss. Traditionally, maize seeds had been stored in the "troja"[1] next to the house or at higher altitudes in the mountains or "en mancuerna[2]", below the roof, hanging from the beams. The respondents assumed that storing the seed at home and changing from traditional straw and clay-tiled to metal roofing had increased the storage temperature and made the environment more favourable for pests.

According to the respondents, establishing the CSBs had increased seed access substantially. In general, the exchange of seeds did not take place freely within the community due to the "celo por la semilla" – "seed jealousy":

> *"Someone arrives and asks 'Please, do me the favour of giving me some seeds'. 'No, I don't have any,' they will say. But they have seeds. There are people who will not give you their seed even if you begged or paid."* (Focus group 1, man farmer)

The CSB and the interventions of NGOs and other organizations were considered to have changed this mentality to some extent, providing an institutional framework for seed sourcing and

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[1] '*troja*' is a type of barn used to protect harvested maize from touching the ground. In the study area, they mostly consist of a frame of wooden sticks covered with wire (see SM3a for a photograph, supplementary material)

[2] '*en mancuerna*' is the traditional way of storing seed in the research site. Seed is stored under the roof, hanging from the beams (see SM3b for a photograph, supplementary material)

seed exchange. In the past, to recover seed after a loss, most respondents (members and non-members) recalled mobilizing their existing network, social relations or the market to solve the problem. Our findings suggest that CSBs diversify seed sourcing options, especially for CSB members. Whereas most members would mobilize the CSB if confronted with a complete seed loss in the future, this was only the case for a minority of non-members, who mostly did not consider the CSB as an option (Table 4).

TABLE 4 ABOUT HERE

At the technical level, the main contribution CSBs had made to seed access and availability were considered to be (1) a reduction of seed production losses through a change in seed selection practices; and (2) a reduction of post-harvest seed losses through improved seed storage practices.

CSB members were significantly more likely to practice systematic seed selection in the form of stratified mass selection[3] (Table 4). Traditionally, farmers selected maize seeds from harvested ears. In stratified mass selection, the selection starts in the field, which allows selecting not only for traits observable in ears, but also for plant traits. Farmers who applied this technique complemented their traditional selection criteria (e.g. large cob, healthy grains) with other agronomic criteria (e.g. plant height). Respondents stated that this practice had contributed to achieving higher yields, reduced plant height, and earlier flowering. For storing seeds, some CSB members dried and de-grained the cobs before storage, which was not common among non-members. In the CSBs, seeds are stored kernelled in plastic jars with a double lid. Room temperature and humidity are regularly controlled and seed quality regularly monitored. CSB members had thus adopted some of the practices used in the CSBs for storing seed at home, while traditionally ears were only kernelled before sowing. Most respondents stated that the improved technique allowed for longer storage and enhanced the protection against pests.

At the institutional level, the CSBs contributed to seed access and availability through two mechanisms. First, CSBs distributed improved local maize and bean varieties, which were mainly accessed by CSB members (Table 4). Non-members mostly accessed improved varieties through seed exchanges in the community and during events organized by the CSBs. The second mechanism through which CSBs contributed to seed access was by promoting activities to enhance seed exchanges among farmers (e.g. seed and agrobiodiversity fairs). CSB members were significantly more likely to be involved in seed transactions than non-members (Table 4).

5.3. Seed and food sovereignty

> *"Before everybody cultivated their own maize. It is hard to earn money from maize. Here what helps us are the vegetables. Now we grow vegetables and buy the maize. Those that have family in the North, they don't grow, they just buy."* (Focus group 2, man farmer)

The respondents agreed that there is a tendency away from subsistence farming to market-oriented livelihood strategies. While in the past households managed to cover their maize need for the whole year, the self-sufficiency in maize was mostly below 6 months at the time of the study. Most of the households did not have enough land and labour to be self-sufficient and did not produce enough cash crops to maintain their livelihoods. Non-farming and off-farm income sources and remittances were increasingly important for livelihoods.

The respondents expressed concern about the loss of seed sovereignty: although maize and bean traditional varieties are still preferred, the respondents reported a tendency to buy bean seeds

[3] '*Stratified mass selection*' is a seed selection method to improve maize agronomic traits. Prior to the selection of individuals (mass selection) the field is divided into smaller selection units (field stratification). In the study area, the adoption of this technique was initially promoted by the national agricultural research organization (ICTA) in the 1970s and in the 1990s motivated by the Collaborative Program of Participatory Plant Breeding in Mesoamerica.

in the local market. Maize seed sovereignty was declining as well, and farmers stated that traditional varieties had already been lost:

> *"I remember that before, when my father sowed maize, he used to have five different colours. (...) Sometimes we do not manage to find enough land to sow the five colours. We only sow two or three colours and then, the following year, there is no seed, or the seed doesn't germinate. This is how we lost the seeds and the colours."* (Focus group 3, man farmer)

According to the respondents, the CSBs made an explicit effort to address questions of food and seed sovereignty. In general, by benefitting from increased yields due to the use of improved varieties, the respondents observed that food self-sufficiency had increased. Some women farmers reported that the trainings and seed programme of the CSB motivated them to begin cultivating maize and beans. However, our survey results did not reflect differences in terms of food and seed self-sufficiency between CSB members and non-members (Table 5).

The CSBs helped to link *in situ* and *ex situ* conservation efforts through repatriation and distribution of maize germplasm from the gene bank of the International Maize and Wheat Improvement Center (CIMMYT). The link with CIMMYT brought seeds from the formal seed sector closer to the farmers. However, seed flows between the case-study CSBs and gene banks were occasional. According to key-informants, this link contributed to create a successful institutional context for seed sovereignty.

Through the CSBs, farmers had access to a wide range of trainings and other group activities, which were considered helpful for strengthening knowledge and social capital. By organizing workshops about farmers' rights, respondents reported CSBs increased their awareness and responsibility to choose the food they want to grow and eat, and how. Respondents in both case-study communities also acknowledged that collaboration and management skills were strengthened by the CSB. This change was mentioned in particular by women, for whom the participation in a group, specially related to farming, had been limited in the past. Some women indicated that being part of the CSB group also strengthened their position in the household, particularly regarding farming decisions and activities. This tendency was only supported by our survey results in Quilinco, where women in CSBs were more likely to participate in seed selection (Table 5). In Secheu, a respondent explained the lower involvement of women by the gender roles associated with the dominating ethnic group. There were also substantial differences regarding women's membership and leadership in the case-study CSBs. Women membership was higher in Quilinco, where the local NGO had worked for longer time promoting the fulfillment of gender quotas. Still, higher membership numbers did not directly translate into higher decision-making power. In both CSBs women were a minority in the CSB management committees and tended to participate less from the discussion than their male counterparts.

Considering sovereignty as an expression of the capacity for self-organization, the respondents identified leadership and technical challenges as main constraints to CSBs realizing their full potential. The CSBs remained rather dependent on external support, and developing internal leadership was particularly difficult. Some respondents reported that members had accepted leading roles due to a feeling of obligation rather than genuine interest and commitment. The local NGO filled the gaps when the CSB members fell short of commitment or technical and operational capacities.

TABLE 5 ABOUT HERE

6. Discussion

6.1. *Learning to live with change and uncertainty*

Numerous studies have highlighted that spreading risk is the key mechanism that households use to cope with environmental, social and economic shocks (e.g. Agrawal (2008); Reyes-García et al. (2013)). Our results showed that in the western highlands of Guatemala, seed recovery after a crisis was mostly based on pooling and sharing, thus spreading risk across households and communities. All respondents mobilized their personal social networks to deal with seed shortages. In the future, however, the described changes in the production system, including the reduction of maize cultivation, could weaken the opportunities for farmers to obtain seeds through their social network. Some research suggests that sharing and pooling as a risk reduction strategy is more effective when only a few are affected. When many or all households are affected, the network cannot cope very well with shocks (Kurosaki & Fafchamps, 2002). CSBs could, as an additional safety net, provide a back-up option to obtain seeds.

Given that extreme events particularly related to climate change and variability are more likely to occur in the study area, and that the reliance on cash cropping and remittances reduces the amount of crop seeds farmers store, our findings support that CSBs can play an important role in complementing informal risk-spreading strategies by diversifying seed sourcing options.

6.2. Nurturing diversity for reorganization and renewal

Crop diversity is central to traditional risk management practices. Relying on a diversity of crop varieties, for their different traits and tolerances, provides response diversity to disturbance (e.g. weather, pests, market shocks) (Altieri & Nicholls, 2017; Meldrum et al., 2017). The role of diversity is also to have more possible alternatives for reorganization after a disturbance (Folke et al., 2003). On-farm agrobiodiversity conservation of local varieties contributes to their adaptation to changing conditions (Vigouroux et al., 2011). Our findings highlight the instrumental role of CSBs for the recovery of traditional varieties and their role as catalyser for the introduction of new varieties in the agricultural system. Furthermore, CSBs create direct incentives (e.g. yield and quality improvements) for farmers to continue maintaining diversity in their fields.

At the same time, having access to new varieties did not necessarily lead to an increase of the crop diversity maintained on-farm, as farmers replaced traditional with new varieties. Bellon (2004, p. 160) argued that planting a diverse set of varieties "*does not necessarily mean that more genetic diversity is maintained or that there is higher evolutionary potential among them, as these varieties may not all be genetically different or contribute equally to crop evolution*". However, improved local varieties in the study area can be expected to retain much of the diversity of the traditional varieties. Breeding and distribution of such varieties can thus be a key contribution of CSBs to diversity.

The importance of farmer-to-farmer seed flows for diversity in the agricultural system is well acknowledged in the literature (Calvet-Mir et al., 2012; Coomes et al., 2015). Our research confirmed that CSB members were involved in more seed transactions than non-members, underlining that CSBs can be a central node in farmers' local seed systems (Vernooy et al., 2014). Accordingly, CSBs not only promote *in-situ* conservation, but also the processes and mechanisms (i.e. seed exchange) that help to maintain agrobiodiversity (Altieri & Nicholls, 2017; Vernooy et al., 2014).

Diversity can substantially contribute to the ability for renewal when it is linked with social-ecological memory (Folke et al., 2003) – the pool of accumulated experiences retained in local institutions and local knowledge (Barthel et al., 2010). We found that CSBs reinforce social-ecological memory by enhancing the exchange of seeds and associated experiences and knowledge through trainings, workshops and common workdays. CSBs can be seen as "*pockets of social-ecological memory"* (Barthel et al., 2010), where agrobiodiversity and associated knowledge and practices are collectively generated, maintained and transmitted.

Despite the adaptive importance of social-ecological memory to cope with environmental and social disturbances (Reyes-García et al., 2014), respondents in the local communities shared the concern that local knowledge related to agrobiodiversity, together with more traditional values and forms of cultural identity, were not being adopted by the younger generations. Among others, market integration, modernization and the out-migration of youth seem to be playing an important role. These patterns were also reflected in the low participation of youth in the CSBs, limiting CSBs contribution to social-ecological resilience.

Findings from research in other parts of the world portray similar socio-economic and political transformations, which are leading to an "agrarian transition": subsistence-farming does not always fulfill the aspirations of the younger generations that look for more economically viable alternatives (Agarwal, 2014). This raises important questions for CSBs on how to make agriculture an attractive livelihood option for the youth. Specifically, how to converge the global vision of CSBs – with its emphasis on agrobiodiversity, local knowledge, food sovereignty, non-chemical farming and cultivation of food crops – with the needs and aspirations of the youth – that might prefer commercial crops, high-input farming, and for whom resilience and food security might not come from cultivating their own food, but from having economic access to it.

6.3. Combining different types of knowledge for learning

Learning is central to adaptation in complex social-ecological systems, increasing the options of response when facing a challenge (Folke et al., 2003). We found that access to new information and knowledge through CSBs strengthened the capacity of local knowledge systems to develop and adapt by combining scientific experimental knowledge and local experiential knowledge. The integration of new seed selection and storage techniques with existing practices in the western highlands is a good example of how different epistemologies can merge. This resonates with earlier studies on how traditional knowledge systems hybridize with other knowledge systems (Gómez-Baggethun & Reyes-García, 2013; Reyes-García et al., 2014). Folke et al. (2003, p. 372), however, underlined that interventions "*should not dilute, homogenize, or diminish the diversity of experiential knowledge systems"*. Further research could explore whether CSBs contribute to the epistemicide of local knowledge or in fact create space for local knowledge to thrive.

6.4. Creating opportunity for self-organization

By definition, CSBs are intended to work as a community biodiversity management strategy, in which local groups act collectively to take control of and improve their biodiversity-based resources (Vernooy et al., 2014).

Earlier studies reported that CSBs promote linkages among a diversity of stakeholders and across multiple scales (Vernooy et al., 2014). An illustrative example of such linkages found in our case-study communities were the connections between farmers, CSBs and national and international gene banks and breeding programmes, which enhanced seed and information flows. When such linkages lead to systemic self-organization, they can reduce vulnerability to external trends and influences and increase the social-ecological resilience of the local communities (Folke et al., 2003). Furthermore, by strengthening social networks and information and agrobiodiversity flows and by offering spaces for dialogue and collective action, CSBs are expected to contribute to food sovereignty (Vernooy et al., 2014), which accounts for the social and political dimensions of resilience (Wittman, 2011).

As largely discussed in literature, local power asymmetries and trust geographies can be a major constraint to building social-ecological resilience (Pelling & Manuel-Navarrete, 2011; Portes, 1998). According to our results, whether CSBs potential to enhance the self-organization capacity of the local communities can be realized depends to a large extent on the capacity of CSBs to overcome structural gender inequalities, social fragmentation and mistrust.

Gender inclusion is considered key for successful environmental collective action (Agarwal, 2000; Wittman, 2011). Looking at community biodiversity management strategies without a gendered lens can lead to biased conclusions regarding their impact and performance (Agarwal, 2000). Along these lines and despite the big steps that local CSBs have already made in this regard, we consider the low participation of women in leadership positions in the case-study CSBs a symptom of the latent structural inequalities that still prevail in the local communities and a limiting factor for CSB contribution to social-ecological resilience.

In general, social barriers were one of the main constraints to seed access in the western highlands. In theory, CSBs could help to overcome these constraints by providing a more formal community mechanism that makes seed available to all. Our data show that this potential was not fully realized. CSBs mainly provided services to its members, but membership did not reflect the diversity of religious groups, ethnicities and socio-economic status present in the case-study communities. Instead, most members were closely related to the small group of community members directly involved in establishing the CSB. Other studies in the western highlands documented that increasing social barriers have led to an increasingly fragmented distribution of knowledge about agrobiodiversity (van Etten, 2006b).

Social capital literature regards social relations as multidimensional (Portes, 1998) and distinguishes three main types of social capital: *bonding*, which refers to relations between the members of a network that share the same identity; *bridging*, which refers to relations between people with distinctive identities (e.g. driven by differences in age, ethnic group, gender, class, socio-economic level, religion, etc.), and *linking*, which refers to relations between people with different power levels (Szreter & Woolcock, 2004; Verweij, 2007). Following this line of argument, CSBs contribute to social-ecological resilience by enhancing seed and information flows among CSB members (*bonding*) and between CSB members, NGO workers, and national and international gene-banks (*linking*). However, CSB contribution to social-ecological resilience is constrained by their inability to cross social boundaries in terms of membership (*bridging*). Other authors working in the western highlands have encountered similar challenges when wanting to promote collective action and attributed them to the deep social divisions, the armed conflict and its aftermath (Hellin et al., 2018).

Our findings raise the question of how far CSBs could help cross these social boundaries and whether CSBs do not cross these social boundaries because of their group-based nature. In such case, could there be other more 'loose network' types of interactions that make seeds change hands? New approaches that aim for inclusiveness in CSB membership and for more dynamic and effective networking are therefore called for.

7. Looking ahead: what role can CSBs play in the future in the western highlands?

Our research demonstrate that CSBs have the potential to act as "*pockets of social-ecological memory*", sustaining agrobiodiversity and associated knowledge and thus contributing to social-ecological resilience. However, not all community members could equally access and benefit from CSB activities, which stresses the need to consider local power dynamics in all stages of CSB implementation and operation.

Future developments would also benefit from looking at gender both in terms of membership and leadership, acknowledging the value of women's specific knowledge. This could be realized, for example, by promoting the purposeful inclusion of crops from women production spaces (i.e. home-gardens) in the CSB and consistently encouraging women to take (over) leadership positions.

Agriculture and livelihoods in the western highlands are undergoing rapid transformation. The importance of maize cultivation and farming in general diminishes, agricultural activities become more market-oriented and a large proportion of the youth migrate to the US. Traditionally, being self-sufficient in maize production has been an indicator of social-ecological resilience. Today, however, remittances and a diversified household economy are dominant factors shaping resilience.

Folke et al. (2003) stress the importance of actively adapting to change. This requires a change of perspective and demands that stakeholders explore how these trends can be leveraged to strengthen local agrobiodiversity and social-ecological resilience. The new PPB improved short-cycle maize varieties are an example of integrating emerging preferences while safeguarding diversity. The CSBs could take better advantage of new opportunities that occur in an increasingly commercial economy, for example, through enhancing market channels for local products with added value made from traditional varieties or by including in the CSB a wider range of crops important for income or nutrition. These measures could serve as incentives to make the CSB concept more attractive to the younger generations and local communities in general.

Some CSBs in other parts of the world have a revolving fund that CSB members can use to finance income-generating activities – this is known as the 'community biodiversity management fund' (Shrestha, Sthapit et al., 2013). Others produce and market seeds of local varieties, generating economic incentives for its members and/or the CSB. In the western highlands, if applied, these measures should consider the strong symbolic, spiritual, and cultural value of maize and the possible underlying tensions between local notions around seed and maize as money maker.

Reversing the trend of agrobiodiversity loss and knowledge fragmentation and reconnecting agrobiodiversity and its associated knowledge with younger generations also requires crossing epistemological boundaries. In other parts of the world, indigenous story-telling, forum theater and rural poetry and drama have led to higher engagement in (agro)biodiversity conservation (Fernández-Llamazares & Cabeza, 2018; Shrestha, Subedi et al., 2013). Promoting agrobiodiversity-related activities based on local and scientific knowledge and expertise in schools or other (informal) learning spaces in the local communities can enhance the interest of younger generations in agrobiodiversity – see McCarter et al., (2014) for an example. The use of information and communication technologies can facilitate new channels and structures for local knowledge to thrive (Benyei et al., 2019). In the western highlands, including similar tools and initiatives in the repertoire of CSB activities could foster local participation in agrobiodiversity conservation, and revitalize and enhance the transmission of local knowledge between generations and across social divides by creating new contexts for its use.

Furthermore, standard records of seeds in CSBs, which typically include the date, location of the site, name of the collector, vernacular name, and length of the cycle, could be complemented with cultural information (e.g. uses, management practices, local valuation, etc.). This could help safeguard for future use not only the seeds, but also their associated knowledge. Examples are the 'memory banking' in Nazarea (2006), the 'people's biodiversity register' in Gadgil et al., (2000) and the use of community biodiversity registers in CSBs described by Gómez-César et al. (2016).

Standardizing the information collected in these registers and sharing it in a decentralized network system between farmers, CSBs, and national-level institutions such as gene-banks could enhance the already existing complementariness between *in-situ* and *ex-situ* agrobiodiversity conservation. As an example, 'Seeds for Needs' is an initiative that connects gene banks with farmers' organizations to mobilize agrobiodiversity for climate change adaptation (Bioversity International, n.d.).

Van Etten describes how such configuration could look by drawing the analogy with the management of renewable energies, guided by a 'smart grid' of demand and supply: "*(...) in the same way, gene banks cease to be the equivalent of long-term stocks of fossil resources and become the 'batteries' or 'supercapacitators' in a 'smart grid' for agrobiodiversity that would also connect with CSBs*" (van Etten, 2019, p. 161). Through this network, all farmers could rapidly and timely access varieties and reliable information related to seed and diversity management, regardless of the persistent social divisions. Following a similar logic, breeders would also have access to a broader base of genetic resources for evolutionary/participatory breeding. Such coordinated network could provide the scientific community with a solid baseline to monitor agrobiodiversity conservation dynamics (in line with the global monitoring effort suggested in Mercer et al., (2019)) and guide public/private support for agrobiodiversity conservation.

Building on principles of crowdsourcing, information technologies, and citizen science could make this network more participatory and the information more accessible, contributing to creating synergies and spaces for knowledge co-production among stakeholders. However, for this to be achieved, the network should be relevant and accessible for the local communities. In the western highlands, the limited experience of (mostly elderly) farmers in the use of digital technologies could be a challenge.

Such an open system places at the forefront of the debate power asymmetries, agrobiodiversity governance and intellectual property rights. A wider-adoption of open-access polices and licenses, such as the digital commons approach could help overcome this problem, contributing to break the knowledge divide and enhancing the power and control of farmers and local communities over their agrobiodiversity and associated knowledge.

8. Conclusions

The purpose of this study was to investigate whether and how CSBs contribute to the social-ecological resilience of communities in the western highlands of Guatemala.

We found that the CSBs supported the use of traditional agro-ecological practices while stimulating a certain degree of innovation. CSB members improved seed management practices and strengthened local seed dynamics by adopting new selection and storage methods, participating in seed exchanges and accessing new varieties. The access to, use and exchange of information and knowledge improved, and gender roles and organizational and leadership skills evolved. These effects, in turn, strengthened the social-ecological resilience of the local communities. At the same time, however, the region is undergoing fundamental changes that are having an impact on the very foundation of agriculture and livelihood strategies. This challenges CSB implementation, functions and scope. Being built on established social relations, the CSBs seem to have difficulties to bridge existing social divides. While CSBs contributed to *bonding* and *linking* social capital, *bridging* existing social divisions remained a challenge. Moreover, the structural gender inequalities in the local communities limited women leadership in the case-study CSBs.

Our research points to the key role that trust, community dynamics and customary practices play in the effectiveness of CSBs. More context-specific adaptations of the general CSB concept seem warranted. Theories underpinning CSB conceptualization should create space for such nuances. In the context of the larger socio-economic and environmental change processes, CSBs will need to acquire new meanings in order to keep promoting conservation and wider use of agrobiodiversity and its associated knowledge. We suggest the CSB concept to shift from being individual "standing reserves" to being "the gateway" into an open, decentralized, coordinated network of agrobiodiversity and related knowledge.

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Figure captions

Figure 1: Conceptual framework.

Figure 2: Location of the study-sites. (X) CSBs visited during the exploratory phase; (*) Case-study CSBs.

Table captions

Table 1: Selected characteristics of the case-study CSBs and respective communities.

Table 2: Overview of research's methodological design and characteristics of study participants by research tool

Table 3: Indicators used to measure the contribution of CSBs to local agrobiodiversity conservation. Varieties are defined as variants within species locally identified and named by farmers, which include local varieties as well as introduced varieties released by official channels. Significance codes: *p<0.05, **p<0.01, ***p<0.001

Table 4: Indicators used to measure the contribution of CSBs to seed access and availability. Significance codes: *p<0.05, **p<0.01, ***p<0.001

Table 5: Indicators used to measure the contribution of CSBs to seed and food sovereignty. Significance codes: *p<0.05, **p<0.01, ***p<0.001

Supplementary material (SM) captions

SM1: Characteristics of selected CSBs in the moment of the first field visit (March-April 2017)

SM2: Outdoor (a) and indoor (b) of a CSB in the research area. Credit: Anna Porcuna-Ferrer

SM3: Traditional way of storing maize seed in the case-study communities. Seed stored (a) in the "troja" and (b) "en mancuerna". Credit: Anna Porcuna-Ferrer

Figure 1: Conceptual framework.

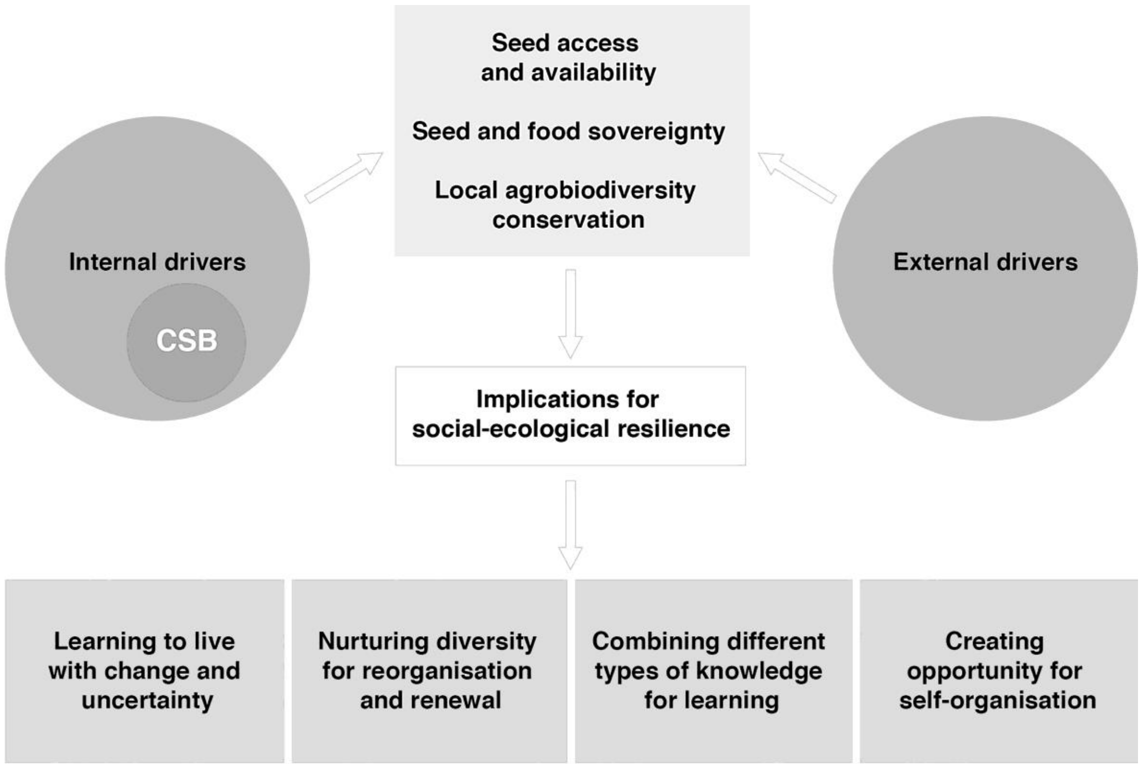

Figure 2: Location of the study-sites. (X) CSBs visited during the exploratory phase; (*) Case-study CSBs.

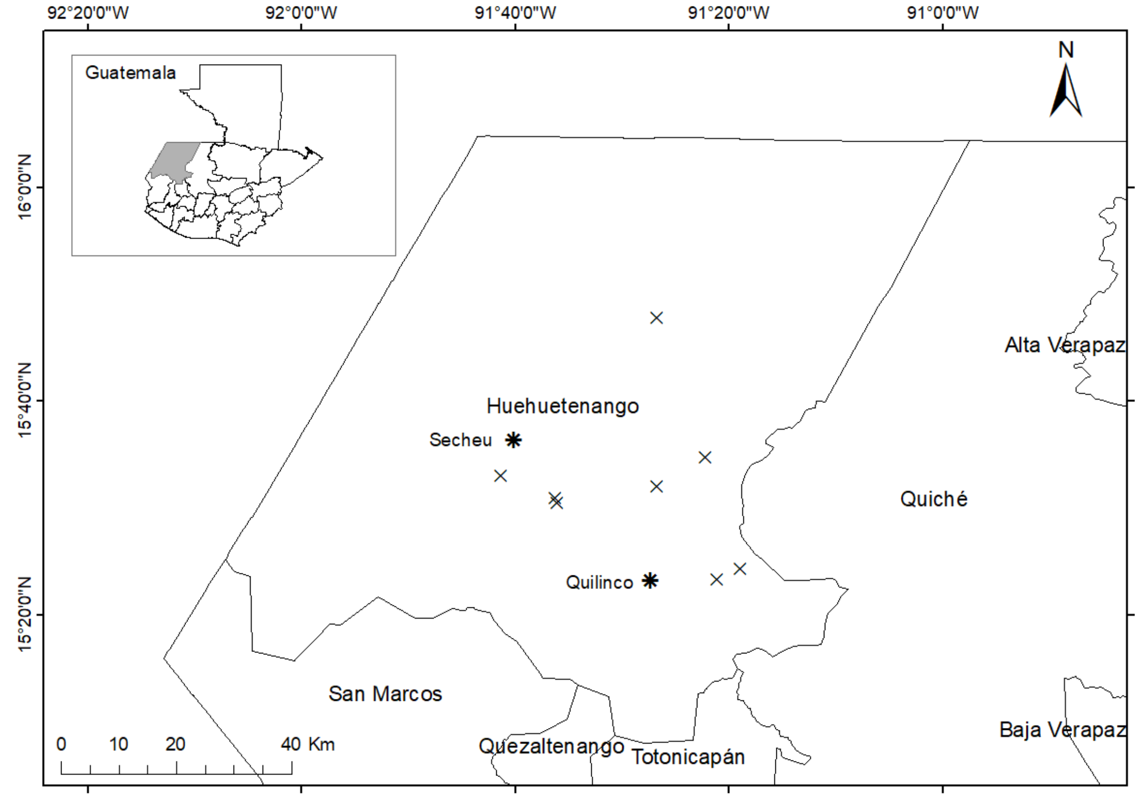

Table 1: Selected characteristics of the case-study CSBs and respective communities.

	Quilinco	Secheu
Local community		
Department	Huehuetenango	Huehuetenango
Municipality	Chiantla	Concepción Huista
Number of inhabitants	2119	840
Number of households	353	126
Meters above sea level	2500	2078
Main livelihood activity	Farming	Farming
Main cash-crop	Vegetables (garlic, broccoli, cauliflower, snow peas)	Coffee
Community seed bank		
Year of establishment	2009	2011
Crops conserved	Maize, bean, fava bean, gourd, wheat, barley, oats, chamomile	Maize, bean, gourd, turnip, coriander, radish, carrot, cabbage, beetroot
Number of collections	Maize (122), beans (10), others (12)	Maize (43), beans (20)
Number of CSB members		
In 2017	96	44
When the CSB was established	15	20
% Women	57	41

Table 2: Overview of research's methodological design and characteristics of study participants by research tool.

Objectives	Data collection method	Number of participants	Variable	Descriptive statistics			
To get a community perspective of perceived changes regarding: agrobiodiversity conservation; seed access and availability; seed and food sovereignty	Focus group discussions (n=10)	87	Age	mean	SD	*min*	*max*
				40	12	18	68
			Sex	54 men			
				33 women			
			Community	10 communities, 7-13 participants per community			
			CSB membership	82 members			
				5 non-members			
To understand the effects of CSBs on local communities by: (i) exploring perceived CSB-induced changes; (ii) comparing CSB members and non-members according to selected indicators of on-farm agrobiodiversity conservation, seed access and availability, and seed and food sovereignty; (iii) understanding the reasons for membership / non-membership	Structured and semi-structured interviews (n=48)	48	Age	mean	SD	*min*	*max*
				47	14	21	87
			Sex	32 men			
				16 women			
			Community	21 Quilinco			
				27 Secheu			
			CSB membership	28 members			
				20 non-members			
To validate the CSB-induced changes collected with the previously mentioned methods	Validation workshops (n=2)	29	Age	mean	SD	*min*	*max*
				47	15	27	87
			Sex	22 men			
				7 women			
			Community	15 Quilinco			
				14 Secheu			
			CSB membership	29 members			
				0 non-members			

Table 3: Indicators used to measure CSB contribution to local agrobiodiversity conservation. Varieties are defined as variants within species locally identified and named by farmers, which include local varieties as well as introduced varieties released by official channels. Significance codes: *p<0.05, **p<0.01, ***p<0.001

Indicator	**Crop**	**Community**	**Membership**		**P-values**	
			Members	**Non-members**		
			Median (IQR)	Median (IQR)		
Number of varieties grown on-farm last cropping season	Maize	Quilinco	2.5 (2-3.25)	2 (2-4)	0.97	
		Secheu	3 (2-3)	1 (1-1.75)	0.003	**
		Together			0.046	*
	Beans	Quilinco	3.5 (2.75-4.25)	3 (2-3)	0.13	
		Secheu	4 (3-7)	1 (1-3.25)	0.01	*
		Together			0.003	**

Table 4: Indicators used to measure CSB contribution to seed access and availability.
Significance codes: *p<0.05, **p<0.01, ***p<0.001

Indicator	Crop	Community	Variety	Source	Membership: Members	Membership: Non-members	*P*-values	
					Median (IQR)	Median (IQR)		
Number of seed transactions last cropping season	Maize	Quilinco			2 (1-5)	2 (0-2)	0.23	
		Secheu			1 (1-3)	0 (0-0)	0.005	**
		Together					0.006	**
	Beans	Quilinco			2 (2-3)	1 (0-1)	0.001	**
		Secheu			0 (0-1.5)	0.5 (0-1)	1	
		Together					0.03	*
			Variety	**Source**	%	%		
Source of new seed used in the past	Maize	Quilinco	Long growing cycle	CSB	-	-		
				Others	-	-		
			Short growing cycle	CSB	38	19		
				Others	62	81		
		Secheu	Long growing cycle	CSB	0	0		
				Others	100	100		
			Short growing cycle	CSB	12	0		
				Others	88	100		
	Beans	Quilinco	Bush	CSB	52	10		
				Others	48	90		
			Climbing traditional	CSB	5	0		
				Others	95	100		
			Climbing others	CSB	33	0		
				Others	67	100		
		Secheu	Bush	CSB	32	0		
				Others	68	100		
			Climbing traditional	CSB	0	0		
				Others	100	100		
			Climbing others	CSB	0	0		
				Others	100	100		
Seed source in case of future loss	Maize	Quilinco		CSB	73	25		
				Others	27	75		
		Secheu		CSB	59	11		
				Others	41	89		
	Beans	Quilinco		CSB	65	18		
				Others	35	82		
		Secheu		CSB	56	13		
				Others	44	87		
				Method	%	%		
Seed selection method	Maize	Quilinco		Stratified mass selection	75	0		
				Post-harvest selection	25	100		
		Secheu		Stratified mass selection	81	18		
				Post-harvest selection	19	82		

Table 5: Indicators used to measure CSB contribution to seed and food sovereignty. Significance codes: *p<0.05, **p<0.01, ***p<0.001

Indicator	Crop	Community		Membership		
				Members	**Non-members**	***P*-values**
				%	**%**	
Seed self-sufficiency last cropping season	Maize	Quilinco		100	89	
		Secheu		87	100	
		Together		93	95	
	Beans	Quilinco		100	89	
		Secheu		80	80	
		Together		89	84	
				Median (IQR)	**Median (IQR)**	
Number of months of food self-sufficiency per year	Maize	Quilinco		6.5 (5.0 - 8.0)	6.5 (5.4 -10.5)	0.468
		Secheu		6 (4.5 - 7.0)	4.3 (2.5 - 6.8)	0.388
		Together				0.919
				%	**%**	
Women participation in seed and crop management practices	Maize	Quilinco	Seed selection	75	33	
			Seed storage	75	89	
			Sowing	25	22	
			Harvesting	83	89	
		Secheu	Seed selection	33	40	
			Seed storage	40	40	
			Sowing	13	10	
			Harvesting	47	30	

Supplementary material. SM1: Characteristics of selected CSBs in the moment of the first field visit (March-April 2017)

	CSB 1	CSB 2	CSB 3	CSB 4	CSB 5	CSB 6	CSB 7	CSB 8	CSB 9	CSB 10
Basic information										
Nº communities served	5	1	1	4	4	2	3	4	5	1
Year of establishment	2009	2010	2010	2011	2011	2011	2012	2015	2015	2016
Membership										
N° members	96	14	18	31	44	23	15	37	34	21
% women	57	0	0	23	41	9	33	86	62	5
Actors involved										
Farmers	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Local NGOs	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
National and international NGOs and development agencies	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Researchers	✔	✗	✗	✔	✗	✗	✗	✗	✗	✗
National and international gene-banks	✔	✗	✗	✔	✗	✗	✗	✗	✗	✗
National or local government	✗	✔	✗	✗	✗	✗	✗	✗	✗	✗
Organization and regulation										
Operational management committee	✔	✗	✗	✔	✔	✔	✗	✔	✔	✔
Internal regulation	✔	✗	✗	✔	✔	✔	✔	✔	✗	✔
Agrobiodiversity										
Restoration of lost or rare varieties	✔	✗	✗	✔	✔	✗	✗	✗	✗	✗
Crops conserved										
Maize	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Beans	✔	✔	✔	✔	✔	✔	✔	✗	✔	✔
Others	✔	✗	✗	✔	✔	✔	✗	✗	✔	✔
Seed management										
Proper seed storage conditions	✔	✗	✔	✔	✔	✔	✔	✔	✔	✔
Seed register	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Regular seed monitoring	✔	✗	✗	✔	✔	✔	✔	✔	✔	✔
Regular seed renewal	✔	✗	✗	✔	✔	✔	✗	✗	✔	✗

Supplementary material. SM2: Outdoor (A) and indoor (B) of a CSB in the research area. Credit: Anna Porcuna-Ferrer

Supplementary material . SM3: Traditional way of storing maize seed in the case-study communities. Seed stored in the “troja” (A) and “en mancuerna” (B). Credit: Anna Porcuna-Ferrer