Calvet-Mir, L., M. Calvet-Mir, J. Luis Molina, and V. Reyes-García. 2012. Seed exchange as an agrobiodiversity conservation mechanism. A case study in Vall Fosca, Catalan Pyrenees, Iberian Peninsula. *Ecology and Society* **17**(1): 29.
http://dx.doi.org/10.5751/ES-04682-170129

Research

Seed Exchange as an Agrobiodiversity Conservation Mechanism. A Case Study in Vall Fosca, Catalan Pyrenees, Iberian Peninsula

Laura Calvet-Mir [1], *Maria Calvet-Mir* [1], *José Luis Molina* [2], *and Victoria Reyes-García* [3]

ABSTRACT. Interest in landraces conservation has grown in the last decades with research on the topic focusing on in situ conservation of agrobiodiversity in the tropics. Researchers agree that home gardens play a key role in the maintenance of in situ agrobiodiversity, but few studies have analyzed how farmers actually maintain agrobiodiversity in home gardens and what mechanisms they use to avoid genetic erosion. We evaluate the functioning of a network of seed exchange and explore its contribution to agrobiodiversity conservation. We focus on the exchange of seeds and seedlings among 55 home garden keepers who grow a total of 62 home gardens in Vall Fosca (Catalan Pyrenees). Fieldwork included visits to gardens and surveys to register the frequency and management of local landraces. We also asked about the farmers' network of seed exchange. We identified 20 local landraces belonging to 17 species. People who were mentioned more often in the network of seed exchange (highest indegree) and who had a higher level of intermediation among other people in their personal network (highest egobetweenness) conserved more local landraces and had more local landrace knowledge than people who were less central in the network. Our findings suggest that local landrace conservation is strongly associated with individual position in the network of seed exchange.

Key Words: *Catalonia; home gardens; in situ conservation; local landraces; social network analysis; Spain; traditional ecological knowledge*

INTRODUCTION

Throughout the last few years, interest in possible ways to stop the loss of crop genetic diversity, or agrobiodiversity, has increased. In that effort, researchers and policy-makers have pointed out the importance of in situ conservation, or the conservation of species in their own habitat, as a complementary strategy to ex situ conservation, or conservation of species in genetic banks (Oldfield and Alcorn 1987, Brush 1991). Researchers have highlighted the importance of agrobiodiversity in situ conservation for four main reasons. First, in situ conservation is a dynamic mechanism by which new genetic resources are created (Louette et al. 1997), allowing the adaptation of the crops to changing environmental conditions (Altieri et al. 1987, Altieri and Merrick 1987). Second, this conservation mechanism is tied to food safety and sustainable food production, since adapted crops have low dependence on external inputs like pesticides or fertilizers (Prescott-Allen and Prescott-Allen 1982, Altieri and Merrick 1987). Third, agrobiodiversity in situ conservation ensures the maintenance of cultural information (knowledge and traditions) that can affect crop productivity (Cox 2000, Maffi 2002). Finally, agrobiodiversity in situ conservation allows for the creation and conservation of other agroecosystem active components such as social networks (Zimmerer 2003).

During the last three decades, efforts to ensure agrobiodiversity in situ conservation have also reached the policy realm. The first example of political interest in the topic is found in the 1992 Biological Diversity Convention. After the agreements in the Convention and throughout its work program on agrobiodiversity, Biodiversity International, one of the centers of the Consultative Group for International Agricultural Research, has worked on agrobiodiversity in situ maintenance and usage (Jarvis and Hodgkin 2008). Another political effort in the same line can be found in the adoption by the European Commission in June 2008 of a proposal to allow the cultivation and sale of some traditional crops that are not registered in the Common Catalogue of home garden species. This proposal aims to promote agrobiodiversity in situ conservation by reducing the impact on genetic diversity erosion caused by the rules and costs generated by the previous obligation to register commercial crop varieties in the Common Catalogue.

Despite the academic and political interest in the topic, few studies have analyzed how agrobiodiversity is actually maintained in farmers' fields. Research on the topic, mostly from South America and Asia, suggests there is a connection between the conservation of agrobiodiversity in farmers' fields and the exchange of seeds and seedlings (Zimmerer 1996, Louette et al. 1997, Thiele 1999, Zimmerer 2003, Badstue et al. 2007). For example, in a study in Peru, Ban and Coomes (2004) found that home garden agrobiodiversity was strongly tied to the number of seedlings and seed exchanges done by the gardeners, which the authors interpreted as support for the idea that seed exchange promotes the creation and preservation of genetic diversity. Following this line of

[1]Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, [2]Departament d'Antropologia Social i Cultural, Universitat Autònoma de Barcelona, [3]ICREA and Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona

thought, some researchers have stated that markets could lead to a reduction in agrobiodiversity, since local landraces, typically exchanged, would be substituted by higher yielding varieties, typically obtained through market transactions (Bellon 2004, Stromberg 2010).

We contribute to this line of research by evaluating the functioning of a seed exchange network, a type of social network. A social network is a measure of the social world based on a tie definition among a set of actors, in this case, spontaneous socialization among people owning a home garden. Specifically, we (1) assess the structure of the seed exchange network, and (2) estimate the association between an individual's centrality on the seed exchange network and (i) local landrace in situ conservation and (ii) local landrace knowledge. For the empirical analysis, we use data from high-mountain home gardens in an under studied region: the Vall Fosca, Catalan Pyrenees. Based on previous research that suggests that the exchange of knowledge and information is crucial for the effective governance of natural resources (Bodin and Crona 2009), we hypothesize that informal networks of seed exchange can play an important role in agrobiodiversity in situ conservation. Based on previous studies (Vogl and Vogl-Lukasser 2003, Acosta-Naranjo and Díaz-Diego 2008), we also assume that seed and knowledge are transmitted together. We use the term "home garden" to refer to small, fenced plots relatively close to the gardener's homestead, where annual, biennial, and perennial cultivated species are grown in beds (Vogl and Vogl-Lukasser 2003). We focus on home gardens because previous research has highlighted the importance of home gardens in the maintenance of plant genetic resources (Agelet et al. 2000, Sunwar et al. 2006, Perrault-Archambault and Coomes 2008, Calvet-Mir et al. 2011) and has underlined the link between agrobiodiversity in situ conservation and seed exchange in home gardens (Ban and Coomes 2004). We adapt previous definitions of "local landrace" (Brown 1978, Cleveland et al. 1994, Guzmán-Casado et al. 2000, Louette and Smale 2000) and use the term to refer to annual and biennial crops that have been continuously reproduced by gardeners for more than one generation (30 years or more) in the geographic area of study. For perennial crops and crops with vegetative reproduction, we use the term local landrace when a specific crop has been cultivated and reproduced in the area for more than 60 years. Gardeners have selected these crops from among domesticated or wild species and have adapted them to the local environmental conditions and to the local agrarian culture, uses, and management. Finally, we use the term "local landrace knowledge" to refer to the cumulative body of knowledge, practice, and belief related to local landraces that have evolved by adaptive processes and been handed down through generations by cultural transmission (adapted from Berkes et al. 2000).

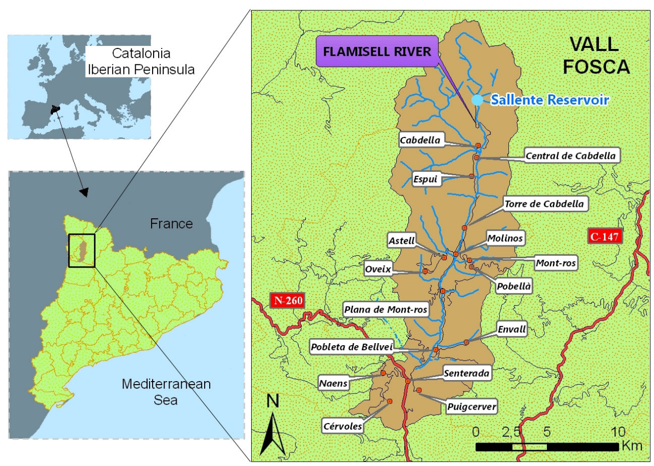
METHODS

This study is part of a larger research project on home gardens in three rural areas of the Iberian Peninsula (Aceituno-Mata 2010, Calvet-Mir et al. 2010, Reyes-García et al. 2010, Calvet-Mir et al. 2011). We collected data on the Vall Fosca (Northern Catalonia) between March and September 2008 and between July and September 2009. Data collection included participant observation, garden inventories, and semi-structured and structured interviews.

Study site

Vall Fosca is a 200 km^2 Pyrenean valley of glacial formation lying along the Flamisell River (Fig. 1), and has about 1000 inhabitants. At the administrative level, it is constituted mainly by the municipality of La Torre de Capdella and partially by the municipality of Senterada. The altitude in the region varies from 729 masl to nearly 3000 masl. Annual precipitation ranges from 800 to 1200 mm, depending on the altitude. The altitudinal vegetation gradient varies from Mediterranean to alpine communities.

Fig. 1. Map of the study area.



Peasants who worked as cattle dealers were the main inhabitants in the valley. However, over recent years, local inhabitants have started to combine traditional activities, such as cattle ranching, with tourist services by offering accommodation and food for urban visitors. High altitudes and the presence of slopes make it difficult to engage in intensive agriculture, which explains why the area lacks a strong agricultural sector. Furthermore, the most characteristic form of agriculture in the area is home gardens. Home garden products are grown mainly for household needs, and normally are not sold. As part of their household activities, women customarily managed home gardens because the men spent much of their time outside the house in charge of the cattle.

Nowadays, retired men manage home gardens as a hobby. Because of the absence of shops and the difficult access to the market town, especially in winter, home gardens traditionally included a wide diversity of species and varieties. For the same reasons, most seeds were kept or exchanged. According to our informants, before the 1970s, when accessibility to the market town improved, seed storage and exchange were the most common ways to acquire seeds. Conversely, previous studies have shown that nowadays as much as 80% of plants in the studied gardens have a commercial origin (Calvet-Mir et al. 2011). However, local landraces are out of the market and can be acquired only via exchange. We have also found that women, retired people, people who manage an organic garden, and experienced gardeners conserve more local landraces than do other people (Calvet-Mir et al. 2011). Additionally, in an effort to strengthen in situ agrobiodiversity conservation, in 2005, a local seed bank was established in the area with the goal of conserving local landraces of two neighboring valleys based on the participation of local gardeners. Gardeners are provided local landraces to sow in their gardens and are asked to return part of the seeds to the local seed bank. However, less than 10% of the gardeners in Vall Fosca are active collaborators in the local seed bank, mainly due to accessibility issues for people who are too old to drive a car.

Sampling

Research was conducted in 16 of the 23 villages that are geographically within the Vall Fosca. We excluded villages without permanent residents or without home gardens. Villages in the sample varied in altitude, population size, and composition. Altitude ranged from 729 to 1422 masl, and the number of permanent residents ranged from five to 156. In three villages, there was only one permanent household. Only three of the villages had a grocery shop, although an itinerant trader who sells fruits and vegetables visits all the villages once a week. Most households owned a car, and all the villages had a weekly public transport service to the nearest market town, La Pobla de Segur.

Structured data collection included the inventory of 62 home gardens belonging to 55 households, and a survey conducted with primary garden keepers (55). Since we surveyed almost 70% of the villages in Vall Fosca and all of the available gardens in those villages, our sample captured almost all of the potential gardeners in the area.

Methods of data collection

Participant observation: We used participant observation to achieve a better understanding of home gardening in the area. During fieldwork, we worked with garden keepers and observed their work. For example, we helped them when planting and accompanied them during harvest time. Living in the village gave us ample opportunities—other than during the formal interviews—to interact with gardeners and to discuss the gardens' progress and many other issues.

Semi-structured interviews: We conducted semi-structured interviews with a sample of 28 elderly men and women who owned a home garden. We asked about the management of home gardens and the presence and management of local landraces over the last 70 years.

Inventory: We visited each home garden three times. In the first visit, we asked the main keeper to accompany us to the home garden and to identify all the plants cultivated in it. In the two subsequent visits, we inquired about the presence of other plants that had not been planted during the first visit. The lead author determined which species were being grown based on the vernacular name and took photos of each variety to compare the information with that used by botanists from Universitat de Barcelona, Universidad Autónoma de Madrid, and Universidad de Oviedo. Vouchers of all local landraces were deposited in the herbarium of the Centre de Documentació de Biodiversitat Vegetal, Universitat de Barcelona.

Survey: We conducted a questionnaire with the 55 home garden primary keepers. In Vall Fosca, the primary garden tender is the person who mainly performs the activities related to the home garden management. Other members of the family act only as secondary managers. The questionnaire was divided into five sections: (1) socioeconomic characteristics of the gardener, (2) home garden management practices, (3) seed and propagule origin and management, (4) seed exchange network, and (5) local landrace knowledge. In the first section, we compiled information about the socioeconomic characteristics of the main home garden keeper, including age, gender, and number of years gardening. In the second section, we asked about fertilization and pest management techniques used in the home garden. In the third section, we asked about the origin of the seeds and propagules of all the plants in each garden. We also asked about the number of years that a crop had been grown from seeds kept from previous years. In the fourth section, we asked keepers about their seed exchange network. Specifically, we asked, "Could you please list the name of all the people to whom you have ever given seeds or any other type of propagule?" Once the person stopped listing names, we asked, "Could you please list the name of all the people who had ever given you seeds or any other type of propagule?" After all the names were listed, we asked informants the sex, age, and place of residence of all the people listed. In the last section, as a proxy for gardeners' local landrace knowledge, we asked them to identify seeds and pictures of local landraces and to respond to questions about their management and usage (Calvet-Mir et al. 2010). The questionnaire included six questions on three local landraces (6*3 = 18 questions): one of the landraces was well known in the valley, one was quite well known, and one was rare. The six questions for each local landrace were similar and included (a) the identification of the seed by its local name, (b) the presence of the local landrace in the informant's garden at the time of the interview, (c) the presence of the local landrace in the informant's garden during previous years, (d) having the local landrace in storage, (e) a question on landrace management, and (f) a question on landrace use.

Methods of data analysis

Social network analysis: We used information on section four of the survey to (1) explore the network of seed exchange and (2) calculate two individual centrality network measures (indegree and egobetweenness). Information was analyzed with the program UCINET6-Netdraw for Windows (Borgatti et al. 2010).

In order to identify the network of seed exchange, we used two name generators consecutively as stated above: "to whom you have ever given seeds or any other type of propagule" and "who had ever given you seeds or any other type of propagule". The response of one informant to the first name generator fills one row in the first matrix (thus, the responses of all informants to the first name generator fill all the rows of the first matrix), and the response of one informant to the second name generator fills one column of the second matrix (thus, the responses of all informants to the second name generator fill all the columns of the second matrix). The two matrices were joined following the UnionGraph procedure from UCINET6. This procedure sums up the edges that relate dyads taken from the 55 gardeners interviewed, resulting in cells with values that range from 0 to 2. The former value implies that any edge was present in the matrices, the value of 1 indicates that only one edge was present in one of the two matrices, and the latter value indicates that the edge was present in both of the matrices, meaning that both actors agree on the direction of the seed exchange. Finally, if one of the alters was not part of the gardeners interviewed, a corresponding column was added. Some of the procedures used in this work dichotomize automatically the matrix (i.e., egobetweenness). In the case of indegree, we computed the weighted indegree (reciprocated nominations have a value of 2, and simple nominations have a value of 1).

By joining information from the two networks, we reduced the number of missing ties that occurred as a consequence of recall bias (Brewer 2000, Feld and Carter 2002), so the resulting matrix more accurately represented the actual network of seed exchange in the valley than one of the two original matrices. Based on Borgatti et al. (2010), we then calculated four network measures: (1) size, or number of actors in the network; we differentiated between actors living within and outside the studied villages; (2) number of components, or the number of connected subgraphs in which all actors were directly or indirectly in contact; (3) density, or the number of links in the network, expressed as a proportion (from 0 to 1) of the maximum possible number of links; and (4) network centralization index, or the tendency of a few actors in the network to have many links (expressed in percentage).

Using the sum of responses to the two name generating questions, we also calculated two individual centrality measures (Borgatti et al. 2010): (1) indegree refers to the number of nominations that a person received on other people's lists. For example, if nine people mentioned one informant when asked to list the name of seed givers or receivers, then the informant would have an indegree of nine; and (2) egobetweenness measures how many alters are connected to each other through the person (ego), and it indicates the importance of each person connecting his/her personal network. It is a measure of the proportion of times that ego lies in the shortest path between each pair of alters.

Generation of outcome and control variables: We used answers to survey questions to generate additional variables for statistical analysis. Outcome variables included local landrace conservation and local landrace knowledge. We used the questions on seed and propagule origin and management to identify local landraces, and generated a variable, local landrace conservation, which captured the number of local landraces kept by each gardener. We also generated a variable that served as a proxy for individual knowledge of local landraces, local landrace knowledge, by adding responses to all the knowledge questions related to local landraces. Since questions on local landraces were coded as correct (1) or incorrect (0), the scores for local landrace knowledge ranged from 0 to 18 (18 = 3 local landraces*6 questions).

Finally, we created four binary variables to use as controls in multivariate regression models. Male was coded as 1 if the main keeper of the garden was a man; otherwise, the code was 0. Retired was coded as 1 if the person was 65 years or older, since 65 is the usual age of retirement in Spain; otherwise, the code was 0. Experienced was coded as 1 if the person had continuously been gardening for 25 years or longer; otherwise, the code was 0. We used information on garden management techniques to classify gardens as organic or nonorganic. A garden was classified as organic if the gardener reported the use of manure or organic products as the main fertilization management technique and the use of manual, organic, or not-treatment methods as the main management techniques to control weeds and pests. We coded the variable organic as 0 if the gardener used chemical fertilizers or agrochemical pests and weed control as primary management methods.

Statistical analysis: We ran Spearman correlations and a set of multiple regressions to examine the association between the person's centrality in the seed exchange network (explanatory variables) and (1) local landrace conservation and (2) local landrace knowledge (outcome variables) while using the proxy variables for the socio-demographic characteristics of the person as the control. Regression models were Poisson with clustering by village of residency. For the statistical analysis, we used STATA 9 for Windows.

Table 1. Local landraces in Vall Fosca home gardens. Type of reproduction refers to the main way that gardeners reproduce the local landraces in the valley.

Vernacular name (Catalan)	Scientific name	Family	Voucher	Life cycle	Type of reproduction
Bleda del país	*Beta vulgaris* L. subsp. *vulgaris* var. *vulgaris*	Chenopodiaceae	BCN-S 1653	Annual/Biennial	Sexual
Col berrugada	*Brassica oleracea* L. var. *capitata* (L.) Alef.	Brassicaceae	BCN-S 1660	Biennial	Sexual
Col de lluc	*Brassica oleracea* L. var. *capitata* (L.) Alef.	Brassicaceae	BCN-S 1671	Biennial	Sexual
Col de ruc	*Brassica oleracea* L. var. *oleracea*	Brassicaceae	BCN-S 1661	Biennial	Sexual
Carbassa de rabequet	*Cucurbita maxima* Duch.	Cucurbitaceae	BCN-S 1659	Annual	Sexual
Carbassa de cabell d'àngel	*Cucurbita ficifolia* C.D. Bouché	Cucurbitaceae	BCN-S 1665	Annual	Sexual
Enciam de carxofeta de la Maria	*Lactuca sativa* L. var. *capitata* L.	Asteraceae	BCN-S 1672	Annual	Sexual
Tomata rosa de la Paquita	*Lycopersicum esculentum* Mill.	Solanaceae	BCN-S 1666	Annual	Sexual
Julivert	*Petroselinum crispum* (Mill.) Hill	Apiaceae	BCN-S 1654	Biennial	Sexual
Fesol afartapobres	*Phaseolus coccineus* L.	Fabaceae	BCN-S 1664	Annual	Sexual
Fesol perona de mata alta	*Phaseolus vulgaris* L. var. *vulgaris*	Fabaceae	BCN-S 1657	Annual	Sexual
Ceba de paret/escalunya	*Allium ascalonicum* L.	Liliaceae	BCN 62717	Biennial	Vegetative
All	*Allium sativum* L.	Liliaceae	BCN 60897	Biennial	Vegetative
Espàrrecs	*Asparagus officinalis* L.	Liliaceae	BCN 62710	Perennial	Vegetative
Safrà	*Crocus sativus* L.	Iridaceae		Perennial	Vegetative
Codonyer	*Cydonia oblonga* Mill.	Rosaceae	BCN 62712	Perennial	Vegetative
Maduixera	*Fragaria* x *ananassa* (Weston) Duchesne ex Rozier	Rosaceae	BCN 62708	Perennial	Vegetative
Patatera	*Helianthus tuberosus* L.	Asteraceae	BCN 62706	Perennial	Vegetative
Prinyoner d'agost	*Prunus domestica* subsp. *insititia* (L.) Bonnier et Layens	Rosaceae	BCN 62714	Perennial	Vegetative
Herbacol	*Cynara cardunculus* L.	Asteraceae		Perennial	Vegetative

RESULTS

Descriptive analysis

We found 20 varieties from 17 species that fitted with our definition of local landrace (Table 1). On average, each gardener kept 2.6 local landraces (SD = 2.4) (Table 2). One gardener had 8 local landraces, but 14 gardeners (25.45%) did not have any. From a range of 0 to 18, the average score of local landrace knowledge was 8.0 (SD = 4.5). Two gardeners obtained the maximum score, while four gardeners (7.27%) scored 0. About half (45.5%) of the people in the sample were men, half (50.9%) were experienced gardeners, and 52.7% were retired people. Organic home gardens represented 74.6% of the sample. On average, each gardener nominated 2.03 people as seed givers or receivers (SD = 1.6).

Gardeners had an average indegree of 2.5 (SD = 1.9) and an average egobetweenness of 3.8 (SD = 5.5) (Table 2). Analysis (not shown) suggested that both measures were collinear, and that on average, women had a higher indegree (3.1) than men (1.8; $p = 0.01$). Women also had a higher egobetweenness than men (5.1 versus 2.2; $p = 0.04$), although the two centrality measures did not vary according to the other control variables analyzed.

Network of seed exchange in Vall Fosca

The network of seed exchange in Vall Fosca was composed of 111 actors or people nominated by the 55 local gardeners when asked about seed exchanges. Those actors included 76 gardeners in Vall Fosca and 35 living outside the research area. The 21 gardeners within the Vall Fosca that were not part of our study population were mainly people who had recently given up managing a home garden due to their advanced age.

The network had a centralization index of 4.91%. The measure was low relative to that of a pure star network, which will have a centralization index of 100%, thus indicating that the degree of concentration in the distribution of degree centralities among the actors was fairly low. The network had five independent components (Fig. 2). That is, gardeners who could potentially be connected were in fact organized in five disconnected networks. The largest component included 76.6% of the actors, the second largest included 10.8%, and each of the other three components included less than 5% of the actors. The analyzed network had a low density (0.018), indicating that there were few ties even between the actors that belonged to the same component.

Centrality and local landrace conservation and knowledge

The bivariate and multivariate analyses of the relation between centrality and local landrace conservation and knowledge was conducted with the subset of actors from which we had complete information on the outcome variables ($n = 55$). In Spearman correlation analysis, we found a positive association between our two measures of an individual's centrality in the

Table 2. Definition and descriptive statistics of the variables used (*n* = 55).

	Definition	Mean	SD	Min.	Max.
Dependent variables					
Local landrace conservation	Number of species continuously cultivated by the gardener for more that 30 years (sexual reproduction) or 60 years (vegetative or perennial reproduction)	2.6	2.4	0	8
Local landrace knowledge	Score in the local landrace knowledge test	8.0	4.5	0	18
Explanatory variables					
Indegree	Number of nominations in the seeds exchange network	2.5	1.9	0	7
Egobetweenness	Grade of intermediation among people with which each person is directly connected	3.8	5.5	0	26.5

network of seed exchange and local landrace conservation and local landrace knowledge (Table 3). Specifically, people with a higher indegree (i.e., mentioned more often) conserved more local landraces ($p = 0.006$) and had more knowledge ($p = 0.03$) than people with lower indegree. Figure 3 provides a visual representation of the association between a gardener's indegree (size of the node) and local landrace conservation (color of the node). We also found that people with higher egobetweenness (i.e., with more brokerage in her/his personal network) also conserved more local landraces ($p = 0.004$) and had higher knowledge ($p = 0.07$) than people with lower egobetweenness (Table 3).

Table 3. Spearman correlations between individual centrality measures (indegree and egobetweenness) and local landrace conservation and knowledge (*n* = 55). For definition of variables, see Table 2.

	Local landrace conservation	Local landrace knowledge
Indegree	0.37***	0.30**
Egobetweenness	0.38***	0.24*

* Significant at p ≤ 10%, ** Significant at p ≤ 5%, *** Significant at p ≤ 1%

We tested the associations using multivariate analysis. Table 4, columns [1] and [2], shows the results of a set of Poisson multivariate regressions of local landrace conservation (outcome variable) against our two measures of centrality in the network of seed exchange. Gardeners with high indegree (column [1] $p = 0.002$) or high egobetweenness (column [2] $p = 0.007$) were more likely to conserve local landraces than less central gardeners. We conducted a similar analysis using local landrace knowledge as the outcome variable (columns [3] and [4]). People with higher indegree had more local landrace knowledge ($p = 0.01$) than people with lower indegree (column [3]). Likewise, people with higher egobetweenness (column [4]) had more local landrace knowledge than people with lower egobetweenness ($p = 0.003$).

In additional analyses (not shown), we tested the robustness of the results in two different ways. First, we changed the control variables in the model (including retired and organic, and different combinations of the control variables). We included them in separate models since our sample size was small and we could not include many control variables in our model. Second, we ran the regressions using the variables indegree and egobetweenness with the information on nominations as seed giver and seed receiver separately. Results from our robustness models did not significantly vary from results in Table 4. We also conducted additional analyses (not shown) bynarizing the matrix we used to construct the variable indegree. Bynarizing the matrix produced an unweighted measure of indegree. We used this measure in our multivariate analysis and found similar results in magnitude and significance as when using the weighted measure.

DISCUSSION AND CONCLUSION

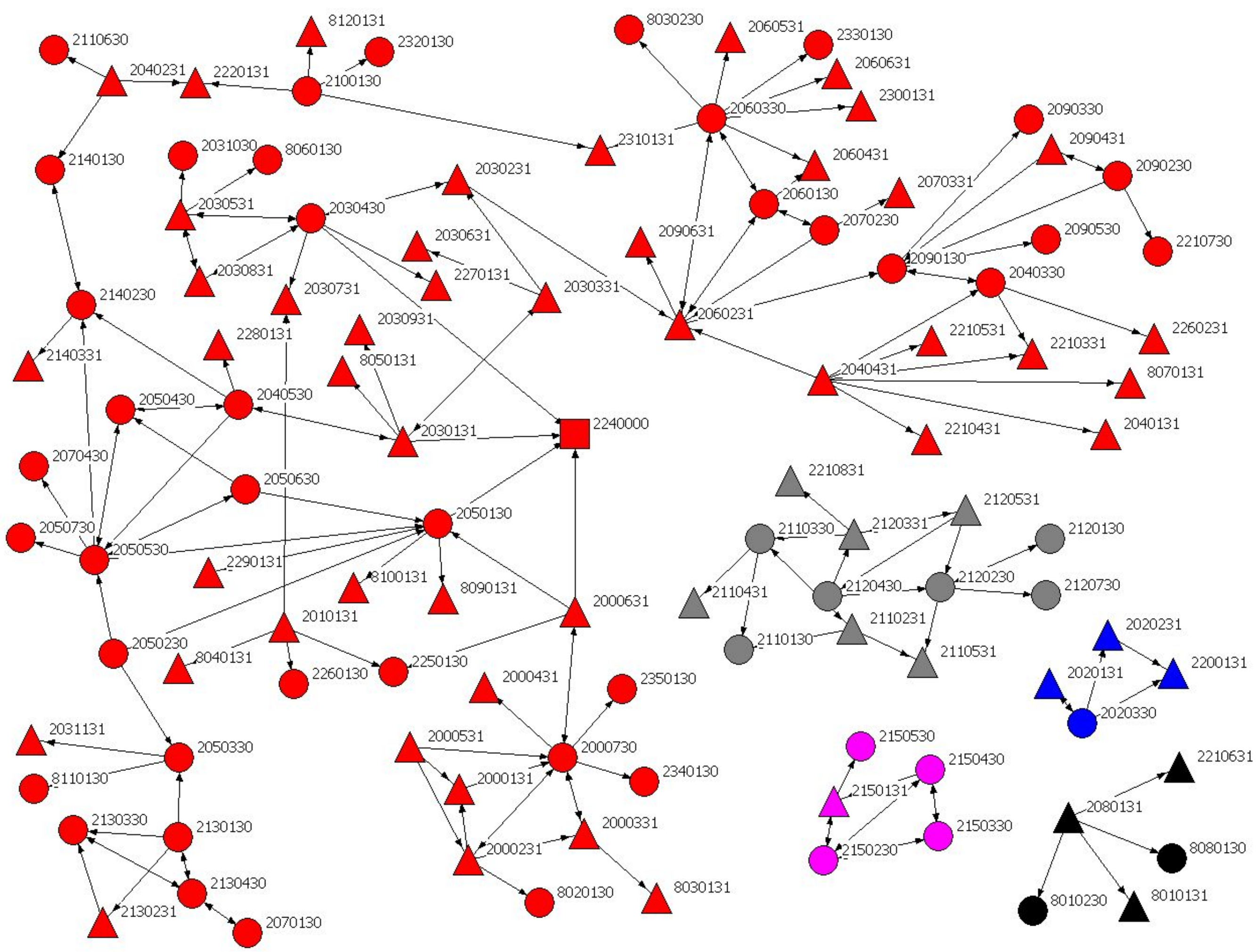
Two main findings emerged from our work: (1) the seed exchange network in Vall Fosca is active but fragmented, decentralized, and has a low density of exchanges, and (2) centrality on the network of seed exchange is associated with local landrace conservation and knowledge.

The structure of the Vall Fosca seed exchange network

Several studies have suggested that seed exchange is not the main mechanism for seed acquisition since gardeners exchange seeds only occasionally (Badstue et al. 2007, Stromberg et al. 2010). Our previous research suggested that as much as 80% of plants in the studied gardens have a commercial origin (Calvet-Mir et al. 2011). In that context, it is not surprising that, although active, the Vall Fosca network of seed exchange is fragmented, decentralized, and has a low density of exchanges.

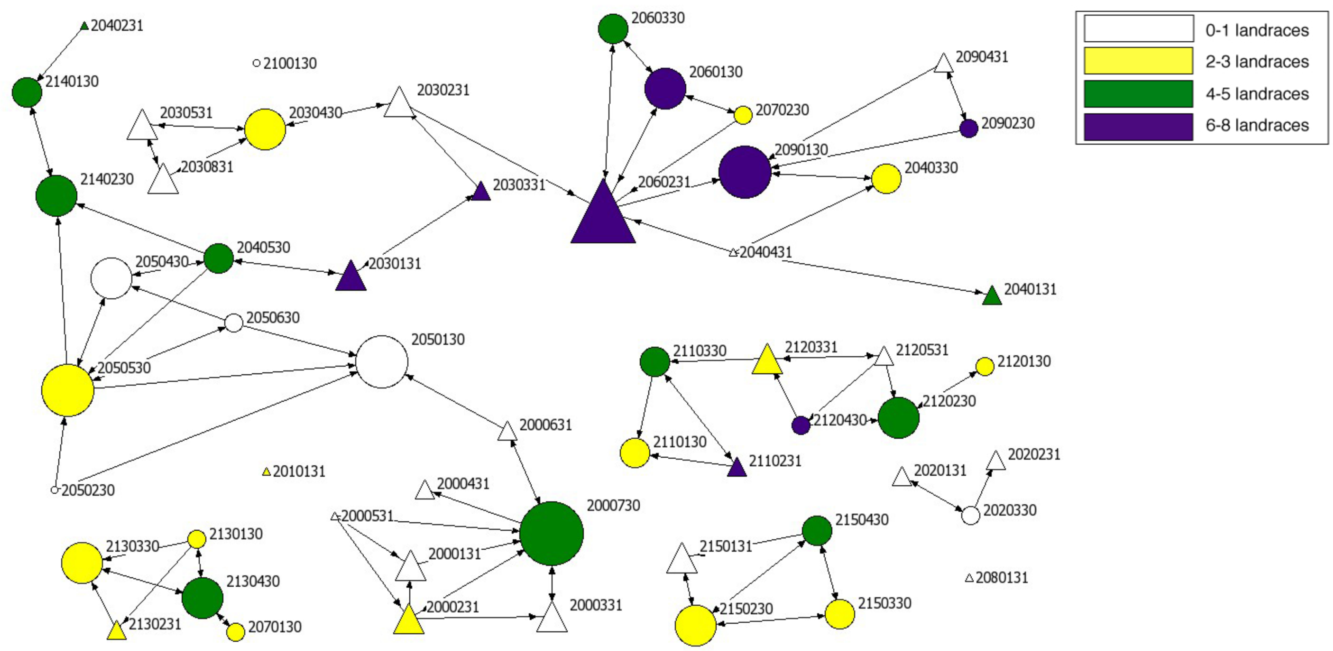
We found that the network is fragmented into five small networks that correspond mostly to subgroups of seed exchanges among people from the same or neighboring

Fig. 2. Seed exchange network in Vall Fosca (Catalan Pyrenees). Note: Nodes (111 gardeners who participated in seed exchanges) are shaped by the sex of the node (triangle for men, circle for women, and a square for a local seed bank), and colored to indicate different network components. The number next to the node corresponds to the identification number of the primary garden tender (the first three numbers for village of residency). Edges arrow represents the direction of the nomination.



villages. Three of the smallest networks correspond to exchanges among people from the most geographically isolated villages, who exchange seeds mainly among themselves. In one of these villages, elders told us that they do not exchange seeds with people from other villages because, due to their age, they rarely visit those other villages, and it is easier for them to ask their relatives or friends to bring them seeds or seedlings from the market town. The smallest network corresponds to one person who exchanged seeds only with people from outside the valley. The network is not only fragmented, but also fragile, because some of the people within the groups are connected by only one tie. Fragmentation constitutes a clear limitation on seed exchange networks as an effective mechanism for the conservation of agrobiodiversity and its associated knowledge at the local level since it hampers the possibility of an individual to access all the local landraces and knowledge within the network. As in other situations (Borgatti and Foster 2003), fragmentation might undermine the development of trust between people, further affecting the exchange of seeds and knowledge. Bodin et al. (2006) have also suggested that fragmentation reduces the social memory and the learning and adaptive capacities of the network. Our results provide an example of how those processes might occur. Elders mentioned that in the past, when there were no markets for seeds, everybody had many seeds and there were many exchanges. Since the establishment of a seed market in the area, most people prefer to buy seeds and seedlings to avoid problems of seed degeneration and to evade the extra work

Fig. 3. Local landrace conservation in relation to the number of seed exchanges. Note: Nodes (55 gardeners who where surveyed) are sized by the number of nominations that a person received on other people's list (indegree), shaped by the sex of the node (triangle for men, circle for women), and colored to indicate the number of landraces kept by each gardener. The number next to the node corresponds to the identification number of the primary garden tender (the first three numbers for village of residency). Edges arrow represents the direction of the nomination.



that comes with the seed bank preparation. As a consequence, the number of seed exchanges and associated social interactions between gardeners has decreased.

We also found that the network is decentralized, meaning there is not a tendency for a few actors to have many links. Surprisingly, not even the local seed bank, which was created to improve the circulation of information on local landraces, has a central role in the network. Centralization can play a double role in the conservation of agrobiodiversity and its associated knowledge. On the one side, a low degree of centralization can increase the opportunities for learning because it increases the access of individual actors to multiple sources of information (Abrahamson and Rosenkopf 1997). For example, an informant who actively collaborates with the local seed bank pointed out that maintaining links with gardeners outside his village increased their access to several local landraces that they did not know. On the other side, a low degree of centralization can hamper the process of solving simple problems, such as seed degeneration, because relevant information cannot be relayed to and synthesized by a few actors who can make a decision and take action (Leavitt 1951, quoted in Bodin et al. 2006).

Lastly, we found that the network had a low density of exchanges. Like decentralization, low network density might also have unclear effects on agrobiodiversity conservation. On the one side, a low level of density can provide a multiple set of experiences and knowledge (Bodin and Norberg 2005) that can be useful to maintain the maximum number of local landraces and knowledge. On the other side, low density may debilitate the trust between individuals and groups and consequently increase the risk and cost of collaborating with others (Ostrom 1990), a prerequisite for maintaining the seed exchange network.

In summary, our results also suggest that, although fragmented and with a low density, the informal network of seed exchange is still alive in the area, and like in other contexts (Thiele 1999, Bodin and Crona 2009), this informal network represents a more important mechanism of seed exchanges than the local seed bank. In a sense, in the studied context, our results can help conceptualize social networks as human biologic corridors that facilitate the conservation of agrobiodiversity by social interactions between actors.

Centrality, local landrace conservation, and knowledge

Based on previous studies (Vogl and Vogl-Lukasser 2003, Acosta-Naranjo and Díaz-Diego 2008), in this work we considered conservation of local landraces and associated knowledge as parts of agrobiodiversity conservation. Our results suggest that, indeed, at the individual level, measures

Table 4. Poisson multivariable regressions between individual centrality in the network of seed exchange (indegree and egobetweenness) and local landrace conservation and knowledge (outcome) (n = 55). The regressions are Poisson with the standard error (in parentheses). Regressions include clusters depending on the village of residence and constant (not shown). For definition of variables see Table 2.

	Local landrace conservation		Local landrace knowledge	
	[1]	[2]	[3]	[4]
Indegree	0.14 (0.00)***	^	0.06 (0.01)***	^
Egobetweenness	^	0.04 (0.01)***	^	0.02 (0.00)***
Male	-0.19 (0.48)	-0.26 (0.36)	-0.21 (0.04)**	-0.23 (0.02)**
Experienced	0.53 (0.01)***	0.62 (0.00)***	0.42 (0.00)***	0.47 (0.00)***

^ Variable deliberately omitted
* Significant at p ≤ 10%, ** Significant at p ≤ 5%, *** Significant at p ≤ 1%

of network centrality are associated with those two aspects of agrobiodiversity conservation. The finding that centrality in the seed exchange network is associated with local landrace conservation and knowledge reinforces previous findings on the importance of seed exchanges in ensuring the maintenance of local agrobiodiversity (Thiele 1999, Zeven 1999). Farmers have traditionally used informal networks to acquire seeds (Vogl and Vogl-Lukasser 2003, Acosta-Naranjo and Díaz-Diego 2008), especially those only locally available (Ban and Coomes 2004, Badstue et al. 2007, Stromberg et al. 2010).

A potential explanation of why individual centrality on the network of seed exchange is associated with local landrace conservation and knowledge is the role of seed exchange as an agrobiodiversity conservation mechanism. As suggested for other regions (Thiele 1999, Ban and Coomes 2004, Badstue et al. 2007, Stromberg et al. 2010), it is likely that in Vall Fosca, the exchange of seeds favors local landrace conservation since local landraces are out of the market in a context where the main way of propagules acquisition is the market (Calvet-Mir et al. 2011).

It is also worthy to note that the exchange of local landraces might be a marker of cultural identity. As Stromberg et al. (2010) noted, the significance of gifts as a source of seeds, although rare, indicates the social significance of varietal exchange as a contributor to maintaining agrobiodiversity. For example, we observed that gardeners in Vall Fosca plant large seed banks with local landraces so they can offer seeds to friends and relatives. Gifts of local landraces are locally highly appreciated.

Finally, social network analysis shows how gardeners mingle with each other and allows their role in the network to be identified. As other authors have pointed out (Prell et al. 2007), social network analysis, combined with other tools as stakeholder analysis, could be used to select stakeholders for participation in natural resource management initiatives. Results from our analysis could therefore be used to strengthen seed exchange networks by practitioners aiming to strengthen the networks of seed exchange. For example, after identifying the different roles in a network, practitioners could put the main intermediaries in the network in touch with the main local landraces and local landrace knowledge keepers in order to spread the seed and knowledge throughout the network.

In conclusion, our study suggests that social network analysis can provide many insights in the analysis of networks of seed exchanges, and could support projects for agrobiodiversity conservation.

Limitations

Results from this study should be taken with caution due to some methodological limitations. First, since we did not conduct genetic analyses of local landraces, it is possible that we over or underestimated the number of total local landraces. Second, our measure of local landrace knowledge might be biased since we asked about only three local landraces, and they might capture only a reduced spectrum of all local landrace knowledge within the valley. Third, our sample size (n = 55) was small for multivariate statistical analysis that would allow us to estimate the relative weight of the different variables. Fourth, we assumed that seed and knowledge are transmitted together; however, it is possible that people engage in knowledge exchange without exchanging seeds, or vice versa. Lastly, we had to rely on gardeners' information to construct the network of seed exchange. Previous authors have noted that seed exchanges are difficult to record because gardeners do not remember them well (Badstue et al. 2007). Reports of interactions can also be affected by a number of other factors (e.g., informants' recall capacity, frequency of the interaction, time since last interaction), so relying on reported data might have biased our results in an unknown magnitude and direction.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol17/iss1/art29/responses/

Acknowledgments:

Research was funded by the Programa de Ciencias Sociales y Humanidades del Ministerio de Educación y Ciencia (MEC-España, SEJ2007-60873/SOCI), the Secretaría de Estado de Investigación, Desarrollo e Innovación del Ministerio de Economía y Competitividad (MICINN-España, CSO2009-07057), the Agència de Gestió d'Ajuts Universitaris i de Recerca (AGAUR) and the Centre de Promoció de la Cultura Popular i Tradicional Catalana (CPCTC) (Generalitat de Catalunya). L. Calvet-Mir acknowledges financial support from a FPU grant (MEC-España, AP-2006-01849). We thank all the tenders who collaborated in the project. We also thank Laura Aceituno, Teresa Garnatje, Juan José Lastra, Montserrat Parada, Manuel Pardo, Montserrat Rigat, Joan Vallès, and Sara Vila for help in the identification of species and comments to previous versions of this work. Thanks also go to Neus Costa-Llesuy for editorial help and to Daniel Corbacho-Monné and Laia Echániz-Pou for help in the fieldwork and in the elaboration of the figures. We finally thank three anonymous reviewers for providing useful comments to improve the article.

LITERATURE CITED

Abrahamson, E., and L. Rosenkopf. 1997. Social network effects on the extent of innovation diffusion: a computer simulation. *Organization Science* 8(3):289–309. http://dx.doi.org/10.1287/orsc.8.3.289

Aceituno-Mata, L. 2010. *Estudio etnobotánico y agroecológico de la Sierra Norte de Madrid.* Dissertation, Universidad Autónoma de Madrid, Madrid, Spain.

Acosta-Naranjo, R., and J. Díaz-Diego. 2008. *Y en sus manos la vida. Los cultivadores de las variedades locales de Tentudía.* First edition. Centro de Desarrollo Comarcal de Tentudía, Tentudía-Extremadura, Spain.

Agelet, A., M. À. Bonet, and J. Vallès. 2000. Homegardens and their role as a main source of medicinal plants in mountain regions of Catalonia (Iberian Peninsula). *Economic Botany* 54:295–309. http://dx.doi.org/10.1007/BF02864783

Altieri, M. A., M. K. Anderson, and L. Merrick. 1987. Peasant agriculture and the conservation of crop and wild plant resources. *Conservation Biology* 1:49–58. http://dx.doi.org/10.1111/j.1523-1739.1987.tb00008.x

Altieri, M. A., and L. Merrick. 1987. In situ conservation of crop genetic resources through maintenance of traditional farming systems. *Economic Botany* 41:86–98. http://dx.doi.org/10.1007/BF02859354

Badstue L. B., M. R. Bellon, J. Berthaud, A. Ramírez , D. Flores, and X. Juárez. 2007. The dynamics of gardeners' maize seed supply practices in the Central Valleys of Oaxaca, Mexico. *World Development* 35(9):1579–1593. http://dx.doi.org/http://dx.doi.org/10.1016/j.worlddev.2006.05.023

Ban, N., and O. T. Coomes. 2004. Home gardens in Amazonian Peru: diversity and exchange of planting material. *Geographical Review* 94(3):348–367. http://dx.doi.org/10.1111/j.1931-0846.2004.tb00177.x

Bellon, M. R. 2004. Conceptualizing interventions to support on-farm genetic resource conservation. *World Development* 32(1):159–172. http://dx.doi.org/10.1016/j.worlddev.2003.04.007

Berkes F., J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10:1251–1262. http://dx.doi.org/10.1890/1051-0761(2000)010[1251:ROTEKA]2.0.CO;2

Bodin Ö., and J. Norberg. 2005. Information network topologies for enhanced local adaptive management. *Environmental Management* 35(2):175–193. http://dx.doi.org/10.1007/s00267-004-0036-7

Bodin Ö., B. I. Crona, and H. Ernstson. 2006. Social networks in natural resource management: What is there to learn from a structural perspective? *Ecology and society* 11(2). [online] URL: http://www.ecologyandsociety.org/vol11/iss2/resp2/

Bodin Ö., and B. I. Crona. 2009. The role of social networks in natural resource governance: what relational patterns make a difference? *Global Environmental Change* 19:366–374. http://dx.doi.org/http://dx.doi.org/10.1016/j.gloenvcha.2009.05.002

Borgatti, S. P., M. G. Everett, and L. C. Freeman. 2010 [2002]. *Ucinet for Windows: software for social network analysis.* Harvard: Analytic Technologies, Lexington, Kentucky, USA.

Borgatti, S. P., and P. C. Foster. 2003. The network paradigm in organizational research: a review and typology. *Journal of Management* 29(6):991–1013. http://dx.doi.org/10.1016/S0149-2063(03)00087-4

Brewer, D. D. 2000. Forgetting in the recall-based elicitation of personal and social networks. *Social Networks* 22:29–44. http://dx.doi.org/10.1016/S0378-8733(99)00017-9

Brown, A. H. D. 1978. Isozymes, plant population genetic structure and genetic conservation. *Theoretical and Applied Genetics* 52:145–157. http://dx.doi.org/10.1007/BF00282571

Brush, S. B. 1991. A farmer-based approach to conserving crop germplasm. *Economic Botany* 45:153–165. http://dx.doi.org/10.1007/BF02862044

Calvet-Mir, L., M. Calvet-Mir, and V. Reyes-García. 2010. Traditional ecological knowledge and landraces in situ conservation in high mountain home gardens of Vall Fosca, Catalan Pyrenees, Iberian Peninsula. Pages 457–464 *in* M. L.

Pochettino, A. H. Ladio, and P. M. Arenas, editors. *Tradiciones y tranformaciones en etnobotánica*. CYTED, Argentina.

Calvet-Mir, L., M. Calvet-Mir, L. Vaqué-Nuñez, and V. Reyes-García. 2011. Landraces in situ conservation: a case study in high-mountain home gardens in Vall Fosca, Catalan Pyrenees, Iberian Peninsula. *Economic Botany* 65(2):146–157. http://dx.doi.org/10.1007/s12231-011-9156-1

Cleveland, D. A., D. Soleri, and S. E. Smith. 1994: Folk crop varieties: do they have a role in sustainable agriculture? *Bioscience* 44:740–751. http://dx.doi.org/http://dx.doi.org/10.2307/1312583

Cox, P. A. 2000. Will tribal knowledge survive the millennium? *Science* 287:44–45. http://dx.doi.org/10.1126/science.287.5450.44

Feld, S., and W. Carter. 2002. Detecting measurement bias in respondent reports of personal networks. *Social Networks* 24:365–383. http://dx.doi.org/10.1016/S0378-8733(02)00013-8

Guzmán-Casado, G. I., J. J. Soriano-Niebla, S. F. García-Jiménez, and M. A. Díaz del Cañizo. 2000. La recuperación de variedades locales hortícolas en Andalucía (España) como base de la producción agroecológica. Pages 339–362 *in* G. I. Guzmán-Casado, M. González de Molina, and E. Sevilla-Guzmán, editors. *Introducción a la agroecología como desarrollo rural sostenible.* Mundiprensa, Madrid, Spain.

Jarvis, D. I., and T. Hodgkin. 2008. The maintenance of crop genetic diversity on farm: supporting the Convention on Biological Diversity's Programme of Work on agricultural biodiversity. *Biodiversity* 9:23–28. http://dx.doi.org/10.1080/14888386.2008.9712876

Louette D., A. Charrier, and J. Berthaud. 1997. In situ conservation of maize in Mexico: genetic diversity and maize seed management in a traditional community. *Economic Botany* 51(1):20–38. http://dx.doi.org/10.1007/BF02910401

Louette D., and M. Smale. 2000. Farmers' seed selection practices and traditional maize varieties in Cuzalapa, Mexico. *Euphytica* 113:25–41. http://dx.doi.org/10.1023/A:1003941615886

Maffi, L. 2002. Endangered languages, endangered knowledge. *International Social Science Journal* 54:385–393. http://dx.doi.org/10.1111/1468-2451.00390

Oldfield M. L., and I. B. Alcorn. 1987. Conservation in traditional agroecosystems. *Bioscience* 37:199–208. http://dx.doi.org/10.2307/1310519

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action.* Cambridge University Press, Cambridge, UK.

Perrault-Archambault, M., and O. T. Coomes. 2008. Distribution of agrobiodiversity in home gardens along the Corrientes River, Peruvian Amazon. *Economic Botany* 62:109–126. http://dx.doi.org/10.1007/s12231-008-9010-2

Prell, C., K. Hubacek, and M. Reed. 2007. *Stakeholder analysis and social network analysis in natural resource management.* SRI Papers, Number 6. http://dx.doi.org/10.1080/08941920802199202

Prescott-Allen, R., and C. Prescott-Allen. 1982. The case for in situ conservation of crop genetic resources. *Nature and Resources* 231:5–20.

Reyes-García, V., S. Vila, L. Aceituno-Mata, L. Calvet-Mir, T. Garnatje, A. Jesch, J. J. Lastra, M. Parada, M. Rigat, J. Vallès, and M. Pardo-de-Santayana. 2010. Gendered home gardens. A study in three mountain areas of the Iberian Peninsula. *Economic Botany* 64(3):235–247. http://dx.doi.org/http://dx.doi.org/10.1007/s12231-010-9124-1

Stromberg P., U. Pascual, and M. R. Bellon. 2010. Seed systems and farmers' seed choices: the case of maize in the Peruvian Amazon. *Human Ecology* 38:539–553. http://dx.doi.org/10.1007/s10745-010-9333-3

Sunwar, S., C. G. Thornström, A. Subedi, and M. Bystrom. 2006. Home gardens in Western Nepal: opportunities and challenges for on-farm management of agrobiodiversity. *Biodiversity and Conservation* 15:4211–4238. http://dx.doi.org/10.1007/s10531-005-3576-0

Thiele, G. 1999. Informal potato seed systems in the Andes: why are they important and what should we do with them? *World Development* 27(1):83–99. http://dx.doi.org/http://dx.doi.org/10.1016/S0305-750X(98)00128-4

Vogl, C. R., and B. Vogl-Lukasser. 2003. Tradition, dynamics and sustainability of plant species composition and management in homegardens on organic and non-organic small scale farms in alpine Eastern Tyrol, Austria. *Biological Agriculture and Horticulture* 21:349–366.

Zeven, A. C. 1999. The traditional inexplicable replacement of seed and seed ware of landraces and cultivars: a review. *Euphytica* 110:181–191. http://dx.doi.org/10.1023/A:1003701529155

Zimmerer, K. S. 1996. *Changing fortunes: biodiversity and peasant livelihood in the Peruvian Andes.* University of California Press, Berkeley, California, USA.

Zimmerer K. S. 2003. Geographies of seed networks for food plants (Potato, Ulluco) and approaches to agrobiodiversity conservation in the Andean countries. *Society and Natural Resources* 16:583–601. http://dx.doi.org/10.1080/08941920309185