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Fuelwood consumption patterns and resilience in two rural communities of the northwest Patagonian steppe, Argentina

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ABSTRACT

A comparative ethnobotanical study was carried out in two rural communities in northwest Patagonia. The methodology involved semi structured interviews and free listing, through which richness and use patterns of fuel species were registered, as well as socioeconomic factors and alternative fuel sources such as liquefied petroleum gas (LPG) and animal dung. Firewood was found to be a subsistence resource, complemented with the purchase of other firewood resources and the use of alternative fuels. A total of 21 species were registered, of which 18 were native species and 3 exotic; 12 fuel species were used by both communities. The species with highest use consensus were *Berberis microphylla* (michay), *Lycium* sp. (montenegro) and *Senecio subulatus* (romerillo) in the Laguna Blanca community, and *Salix* sp. (sauce) and *S. subulatus* in Comallo. Collection is mainly carried out on foot. Whereas the inhabitants of Laguna Blanca cover large distances in order to collect native woods, in Comallo this is made easier by the use of prunings from urban tree planting, obtained closer to dwellings. This is an interesting result since the recycling of biological products to supplement firewood, together with forestation practices, could contribute to the resilience processes of inhabitants of these arid, hostile environments. We propose that the use of multiple fuel resources could be an indicator of ecological–social resilience processes.

1. Introduction

Woody resources provide renewable energy and constitute the major source of fuel in countries with extensive rural lands (FAO, 2008). The intense use of this resource, however, has put woody species in different regions of the world at risk (Dahdouh-Guebas et al., 2000; Medeiros et al., 2011; Walters, 2005). It has been documented that countries with large rural populations make greater use of wood for heat and cooking fuel (Miah et al., 2003; Moran-Taylor and Taylor, 2010; Ogunkunle and Oladele, 2004). Communities living in forested regions have access to vast woody resources to satisfy their fuel needs (Dahdouh-Guebas et al., 2000; Walters, 2005). However, in arid environments wood as a resource is limited in size and diversity, therefore more difficult to find (Ramos et al., 2008). The populations living in these environments throughout the world, therefore, use various strategies to complement the scarce firewood. Liquefied petroleum gas (LPG) is commonly used, and wood is often bought, hence much of the family income is spent on fuel (Jashimuddin et al., 2006; Madubansi and Shackleton, 2007; Moran-Taylor and Taylor, 2010).

In Argentina there are many widely dispersed rural populations living in the arid environments of the vast region of Patagonia (Golluscio et al., 2010). Studies carried out in communities in northwest Patagonia reveal different cost-benefit strategies related to the gathering and use of plant resources for their subsistence (Estomba et al., 2006; Ladio and Lozada, 2004). These populations know and use their resources, but their quality of life is limited to the diversity available to them (Ladio and Lozada, 2009; Paruelo et al., 2006). The gathering of woody species forms part of rural communities' traditional ecological knowledge (TEK), defined as the accumulated body of practices and beliefs developed by means of cultural transfer from generation to generation (Berkes et al., 2000). It was found that in certain communities new practices are incorporated into this TEK in order to palliate environmental and economic adversity, such as the use of medicinal species of exogenous origin, cultivated plants from other areas and peridomestic forestation (Cardoso and Ladio, 2011; Eyssartier et al., 2008).

It has also been found that the activities which increase resource diversity contribute to alleviating needs and generating processes of ecological and social resilience (Ladio and Lozada, 2008; Walker

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et al., 2006). The term resilience, originally developed for the study of ecosystem dynamics Holling (1993), was applied to socio-economical systems in accordance with Turner et al. (2003); Gunderson et al. (1995); Berkes and Folke (1998); Ladio and Lozada (2008) among others. It has been defined as an ability to cope with change, and refers to processes which are dynamic in time and space, and which are not linear but arise from interactions between gradual changes and those which happen at a faster rate (Folke, 2006). Resilience is a more accurate term to describe bouncing back after disturbances (i.e. to describe dynamic processes that deal with change) than adaptation, a term commonly used to describe long-lasting evolutionary processes. Various authors (Berkes and Davidson-Hunt, 2010; McNeely, 2003) have highlighted the importance of maintaining or facilitating networks which favor community integration, since this has a positive effect on the ecological-social system. In particular, group work which favors the wellbeing of the community is a strengthening factor and helps when facing external adversity (Lozada et al., 2011).

In this work we analyzed the richness and use patterns of species used for fuel in two rural communities in northwest Patagonia. In addition, we evaluated the incorporation of new practices in fuel collection and use as possible indicators of resilient processes, given that they reflect a capacity to adjust to new socio-ecological circumstances. Due to the scarcity of wood in these arid environments, greater diversity of fuel resource use could be an effective indicator of resilient processes. We hypothesize that a more resilient community will exert less pressure on native species, conserving the local richness and landscape, thus conserving species diversity. Moreover, we expect to find that such a community will use a greater diversity of fuel resources, i.e. alternative fuel supplies, external fuelwood purchase, travel shorter gathering distances and practice forestation.

2. Methods and materials

2.1. Study area

The rural Laguna Blanca and semi-rural Comallo communities are situated in the northwest of Patagonia, Rio Negro province, Argentina, separated by a distance of 70 km (41° 02′ S and 70° 51′ W).

Comallo lies in the Comallo stream valley, at 782 masl, in the last foothills of the Andean pre-cordillera, while Laguna Blanca lies at a higher altitude, 1251 masl. Laguna Blanca is situated within a designated Indian Reservation, whereas Comallo inhabitants own their own properties. The cities closest to both communities are Jacobacci, at a distance of 90 km and San Carlos de Bariloche at 120 km. Access to the study area is difficult; there is a regular public transport service to Comallo but not to Laguna Blanca.

Phytogeographically, both communities belong to the Patagonian region (Cabrera, 1976). The climate is predominantly dry and cold, with strong winds throughout the year and annual precipitations of 150–300 mm, mainly during fall and winter in the form of rain or snow. The median annual temperature is 8–10 °C (Bran et al., 2000). Vegetation consists mainly of native bunchgrass species like *Stipa* spp. and *Festuca pallescens*, and low shrubs such as *Mulinum spinosum* (neneo), *Senecio filaginoides* (charcao), *Senecio subulatus* and *Grindelia chiloensis* (botón de oro) (Asteraceae) (Ezcurra and Brion, 2005).

In both Comallo and Laguna Blanca a large proportion of the population interviewed have parents and grandparents of Mapuche ancestry (the ethnic group native to the region) (94 and 97% respectively). Nevertheless, only 60 and 56% of the parents, and 80 and 86% of the grandparents spoke the native language in their homes. Of the informants, 70 and 83% respectively do not speak the native language at all, 30 and 10% have learned odd words and only 3 and 7% can actually speak the Mapuzungun language.

2.2. The Laguna Blanca rural community

This village is situated in an area comprising an educational institution and 30 homes, plus a dispersed area of houses. Livestock (sheep and goat) breeding is the primary source of income. Dwellers' economy is complemented with the sale of woolen handicrafts knitted by the women and, to a lesser extent, by employment at the school. Most adults are literate and all the children from the families we visited currently attend school, with the goal of finishing the primary level. Most of the families are isolated from urban centers; a professional health care assistant visits the community, but infrequently. All families live in houses of baked bricks. The community is not connected to the electrical grid; they have diesel-generated electricity, provided for only a few night hours. In addition, most people use LPG cylinders sparingly for cooking. This community has a serious problem; the lack of permanent water availability.

2.3. The Comallo semi-rural community

The community of Comallo has approximately 1500 inhabitants (INDEC, 2010). Much of this community has street lighting and is connected to the gas mains, but this study dealt only with the sector of the population that depends on wood as their main fuel resource. Due to its semi-rural character, Comallo fulfills the role of service center to the surrounding rural area. Many dwellers are government employees (e.g. council workers, employees of educational and health establishments) or have small stores, and some of them depend on livestock activities. Most adults are literate (80%); and most children attend the local school.

2.4. Field sampling

In order to carry out a survey of the population, permission to work in these two locations was first obtained and the research project was explained to local authorities and residents. In the Laguna Blanca community 28 people of different ages (min = 27, max = 83) were interviewed, 13 women and 15 men. In Comallo we interviewed 23 women and 12 men (min = 19, max = 92); in both locations, whether male or female, all informants were the heads of families. Informants were selected by census. In Comallo, we interviewed all families that used wood for heating purposes (14% of the total population), and in the Laguna Blanca community all families living in the town (75% of the total population) The ethno-botanical information was collected between January of 2009 and July of 2010 using semi-structured interviews and free listing. The questions were related mainly to the use of domestic firewood, use patterns and search distances. Relevant socio-cultural and economic relevant information was also recorded for each community. In addition, open interviews were carried out on general topics related to gathering practices. A herbarium was set up where each species was identified by its scientific name, and this can be found in the Ecotono laboratory, Universidad Nacional del Comahue.

2.5. Data analysis

The woody species named were categorized as "native" or "exotic" according to their bio-geographical origin (Ezcurra and Brion, 2005). Shrubs of local origin, belonging to the Patagonian region, were considered natives. In this way we can see the richness used by each community, the species used frequently and the similarity of collection between communities. In addition, using the

Jaccard similarity index (IJ: $c/(a + b + c) \times 100$), the percentage of species shared by both communities was estimated, where c is the number of species common to both communities, a is the number of unique species in one community and b is the number of unique species found in the other community (Höft et al., 1999).

A consensus of use (CU) value was calculated for each of the species cited, taking the number of people who mention a certain species over the total number of interviewees as the value representing intensity or frequency of use of the species. The curves for range-frequency of use were drawn with CU data using the analysis criteria of the range–abundance curves, in which the richness of species, relative frequencies and sequence of species can be compared (Feinsinger, 2001) (Fig. 1). Consequently, the graphed values correspond to $pi = ni/N$, where, ni = number of people who cited a certain species in a community and N = the total number of informants in each community.

In both communities we analyzed the purchase of wood, the use of alternative fuels and the searching distances for collection. With regard to searching distances the following 3 categories were established: under 2 km, between 2 and 4 km, and over 4 km. We also recorded whether dwellers cut dry firewood, green, or both, and the type of forestation practiced, considering these to be possible indicators of resilience. In accordance with the method used to gather the data, the analyses were carried out using non parametric statistics, the binomial test and Mann–Whitney test (Siegel and Castellan, 1995). The SPSS 10.0® program for Windows was used for data analysis.

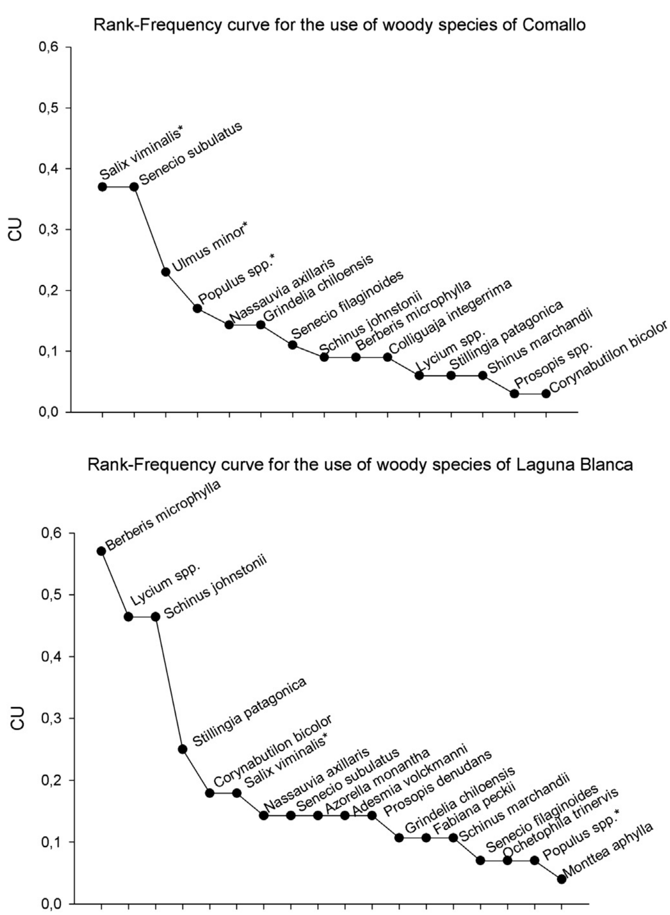

Fig. 1. Consensus of use (CU) for woody species used as fuelwood in the Comallo and Laguna Blanca communities. CU = pi = ni/N, where, ni = number of people who cited a certain species in a community and N = the total number of informants in each community.

3. Results

3.1. Richness, use frequency and biogeographic origin of woody species

In Comallo, the total richness of woody species used (collected and bought) was 26. The species collected were 15, of which 11 were shrubs native to the region and 4 were exotic trees planted by the inhabitants themselves (binomial test $p < 0.05$). The most frequently collected species, i.e. with the highest CU, were *Salix viminalis* and *S. subulatus* (Table 1; Fig. 1a). The total richness used in Laguna Blanca was 30 species; 18 were collected, of which 16 were native shrubs and 2 were exotic tree species (binomial test $p < 0.05$), with another 12 species of firewood bought to supplement the small amount of wood available for collection. The woody plants with the highest CU in this community were *Berberis microphylla*, species from the genus *Lycium* spp. and *Schinus johnstonii* (molle colorado) (Table 1; Fig. 1b). Both communities, on average, presented a similar CU of fuel species, i.e. the intensity of

Table 1
Origin, life form, consensus of use, and species richness of firewood plants used by the communities of Laguna Blanca and Comallo in NW Patagonia, Argentina.

Botanical family	Scientific name, local name	Origin	Consensus of use[a] of Laguna Blanca	Consensus of use[a] of Comallo	Life form
Anacardiaceae	*Schinus johnstonii*, Molle colorado	N	46	9	Shrub
	Schinus marchandii, Molle blanco	N	11	6	Shrub
Apiaceae	*Azorella monantha*, Leña de piedra	N	14	–	Shrub
Asteraceae	*Grindelia chiloensis*, Botón de oro	N	11	14	Shrub
	Nassauvia axillaris, Uña de gato	N	14	14	Shrub
	Senecio subulatus, Romerillo	N	14	37	Shrub
	Senecio filaginoides, Charcao	N	7	11	Shrub
Berberidaceae	*Berberis microphylla*, Michay	N	57	9	Shrub
Euphorbiaceae	*Colliguaja integerrina*, Coliguay	N	–	9	Shrub
	Stillingia patagonica, Mata de perro	N	25	6	Shrub
Fabaceae	*Adesmia volckmanni*, Mamuel choique	N	14	–	Shrub
	Prosopis denudans, Alpataco	N	14	–	Shrub
	Prosopis spp., Algarrobillo	N	–	3	Shrub
Malvaceae	*Corynabutilon bicolor*, Monte moro	N	18	3	Shrub
Rhamnaceae	*Ochetophyla trinervis*, Chacay	N	7	–	Tree or Shrub
Salicaceae	*Populus* spp., Álamo	E	7	17	Tree
	Salix viminalis, Sauce mimbre	E	18	37	Tree
Scrophulariaceae	*Monttea aphylla*, Yaque	N	4	–	Shrub
Solanaceae	*Lycium* spp., Montenegro	N	46	6	Shrub
	Fabiana peckii, Siete camisas	N	11	–	Shrub
Ulmaceae	*Ulmus minor*, Olmo	E	–	23	Tree

[a] The consensus of use was calculated considering those respondents who used a certain species in relation to the total number of respondents.

use is similar (pi Comallo = 0.136 Vs. pi Laguna Blanca = 0.188; Mann–Whitney $p = 0.078$; Fig. 2). Of the species used, 57% are shared. Comparing the CU value only of native shrubs used in both communities, we see that the highest use pressure is exerted in the locality of Laguna Blanca (Mann–Whitney, $p = 0.007$). With regard to the use of exotic species, we found no significant difference between communities (Mann–Whitney, $p = 0.248$).

3.2. *The purchase of firewood*

Locals buy firewood to supplement the fuel available for collection, and this accounts for 42% of the total number of plant species used in Comallo and 40% in Laguna Blanca. This firewood comes from both the Patagonian region and other regions of the country. In both communities the purchase of firewood is based, on the one hand, on species native to the region, such as *Schinus marchandii* (molle blanco), *S. johnstonii*, *Prosopis denudans* (alpataco), *Ochetophila trinervis* (chacay), *Condalia microphylla* (piquillín) and *Geoffroea decorticans* (chañar). However, exotic species from neighboring domestic plantations can also be bought, such as *Ulmus minor* (olmo), *Populus* spp. (álamos), *S. viminalis*, *Eucalyptus* spp. (eucalipto) and cuttings of *Malus domestica* (manzano) and *Pyrus communis* (peral), from the pruning of commercial plantations in the valleys of the northern Patagonian region. In addition, *Prosopis* spp. (algarrobos) and tree species native to the center and north of the country are bought (Demaio et al., 2002). In Comallo more than half the informants (63%) buy firewood (binomial test, $p = 0.045$) compared to 83% in Laguna Blanca (binomial test, $p = 0.001$).

3.3. *Patterns of collection*

In the Comallo region, the locals who collect fuel close to their dwellings dedicate few hours to this activity each day, whilst those who bring native shrubs from neighboring areas dedicate over half a day. However, most families in the Laguna Blanca community cover considerable distances in their search for firewood, dedicating more than half of each day to this task. In both communities, collection is carried out mainly by men, but the women and children also take part, as seen in other communities in this region (Cardoso et al., 2010). In this work, the time dedicated to searching was not quantitatively analyzed, but was qualitatively evaluated based on the informants' comments (personal communication).

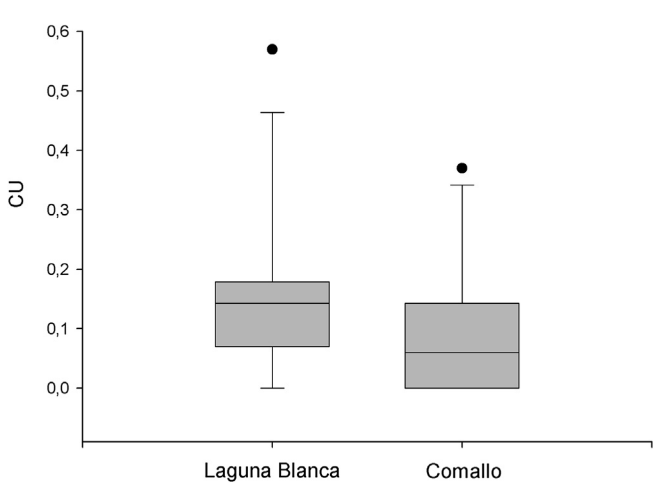

Fig. 2. Comparison of CU = pi = ni/*N* for species collected from Laguna Blanca and Comallo communities.

3.3.1. *The use of dry and green wood*

The firewood collected is mainly dry wood, and is supplemented with green wood. A mixture of these is calculated so as to maintain heat for the longest possible time. In Comallo, green wood comes mainly from urban prunings of the trees planted in the locality. Most inhabitants prefer this mixture to the use of dry wood alone (binomial test $p = 0.003$; Fig. 3). In Laguna Blanca, due to the lack of prunings and the greater search distances, both native dry and green wood is collected, and the two types are used indistinctly (binomial test $p = 0.229$; Fig. 3).

3.3.2. *Alternative fuels*

The inhabitants of both communities use cow and horse dung to supplement woody resources. In Comallo 43% of the population use this resource, compared with 59% in Laguna Blanca (binomial test, $p = 0.860$). Another alternative source of fuel is LPG, bought in tubes and used sparingly for cooking. In Comallo more inhabitants use this resource (91%) than in Laguna Blanca (74%) (binomial test, $p = 0.170$).

3.3.3. *Search distance for collection*

The communities differ in terms of search distances. Comallo presents a higher frequency of collection sites in the close surroundings, from 0 to 2 km (Mann–Whitney, $p = 0.001$; Fig. 4), where the most-collected species are *S. viminalis*, *Populus* spp. and *S. subulatus*; and from 2 to 4 km (Mann–Whitney, $p = 0.001$; Fig. 4) with the collection of species such as *S. subulatus*, *S. filaginoides*, *S. viminalis* and *Nassauvia axillaris* (uña de gato). The most-collected species at a distance of over 4 km in Comallo are *S. subulatus*, *S. viminalis* and *U. minor*. However, the inhabitants of Laguna Blanca collected more species at distances of over 4 km (Mann–Whitney, $p = 0.004$; Fig. 4) in the search for native shrubs like *B. microphylla*, *Lycium* spp. and *S. johnstonii*.

3.4. *Forestation*

The forested species in both communities are the tree species elm (olmo), willow (sauce) and poplar (álamo) (Table 1). The majority of Comallo informants (66%) practice forestation (binomial test $p = 0.045$). This practice is carried out by individuals in the peridomestic area, and also in a collective way supported by the local council, with urban tree planting on community plots. Due to

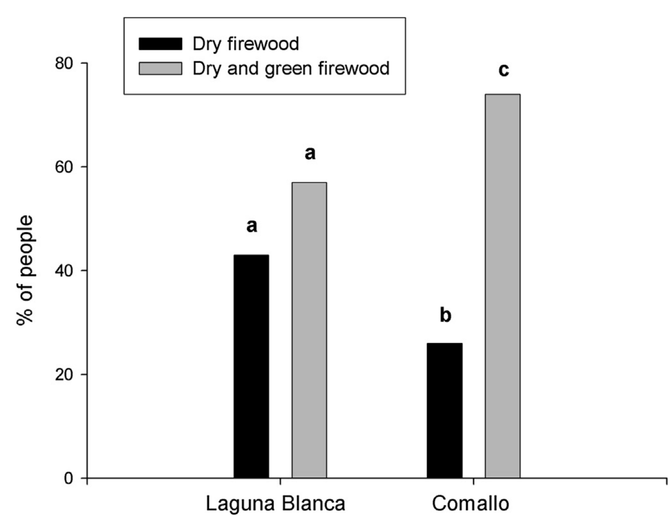

Fig. 3. Comparison of the collection of dry wood versus green and dry between the Laguna Blanca and Comallo communities. Different letters illustrate significant differences between columns.

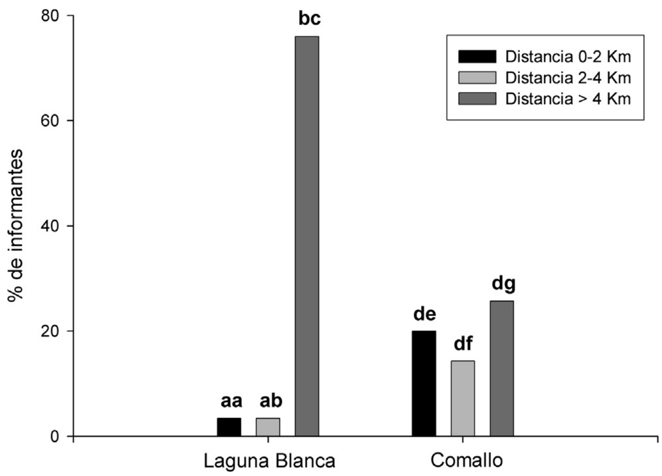

Fig. 4. Distance to search for woody species; collected at 0–2 km, 2–4 km and >4 km in Laguna Blanca and Comallo communities. Different letters illustrate significant differences between columns, i.e. In Laguna Blanca, aa and ab are not significantly different, whereas bc is different from aa and ab; in Comallo, de, df and dg denote non significant differences. The comparison of each distance between communities shows significant differences between aa and de, ab and df, bc and dg.

environmental conditions in the Comallo region, as well as the higher population in comparison with Laguna Blanca, and the local council's forestation policies, prunings from the trees in the town constitute an important woody resource. The reasons for forestation are: wind protection, shade, firewood, posts for fence construction, animal fodder and decorative purposes. Almost all Laguna Blanca informants (86%) practice forestation in the peridomestic zone (binomial test $p = 0.001$), but due to the greater exposure to wind, cold and drought, only certain trees grow and these are left for shelter and not used for firewood. In this community there are no urban plantations and therefore no prunings.

4. Discussion

In the present work we found that firewood is an essential resource in both communities studied in this arid region of northwest Patagonia. Due to the scarcity of woody species in both these hostile environments, locals travel significant distances each day in search of firewood, and use a greater richness of native than exotic species. Nevertheless, differences were observed between use patterns in these communities. The population in Comallo uses a higher proportion of wood from exotic trees, resorting mostly to the use of a mixture of dry and green wood. In addition, the members of this community generally gather their fuel resources closer to their homes than the people of Laguna Blanca. In accordance with our hypothesis, the use of multiple fuel resources in Comallo could suggest higher levels of resilience in this community, where greater advantage is taken of planted species, given that the practice of forestation favors the recuperation of the local ecosystem while at the same time aiding inhabitants.

The richness of species shared by both communities reveals the phytogeographical similarity of these settlements, where the low number of unique species used for fuel reflects the very small difference between these landscapes. In addition, these values for fuel species richness are similar to those found for other arid region settlements (Kaschula et al., 2005; Sá e Silva et al., 2008). The CU with regard to exotic species is similar in both communities, probably due to the low number of species used. In Comallo, however, use tends toward exotic tree species. This is directly related to the presence of plantations for decorative or windbreak purposes, and the resulting use of prunings as a bioenergetic resource. In contrast, the higher CU of native species in Laguna Blanca could reflect the scarcity of forest products to satisfy the need for fuel in this community. If we consider the constant use of these native shrubs, the use pressure on the local ecosystem can be clearly envisaged, possibly provoking a future decrease in biodiversity.

In Laguna Blanca some native species of the genera *Berberis*, *Lycium* y *Schinus* stand out in particular as fuel species, due to their high level of consumption. Even though they seem to be the most abundant shrubs, it is important to clarify that they are the species most in demand, mainly due to the hardness of the wood and the long-lasting embers, according to locals. This is the case of the "molles" (*Schinus* spp.), which are the best fuel resource and the most sought after by dwellers in the region. The use in the region of some of these species as fuel has been documented (Ladio and Lozada, 2009). This highlights the importance of making an effort to recover these species, whose slow growth also favors their decline. In these environments, the need to generate heat has to be satisfied by the available resources, regardless of the quality of the wood (Dahdouh-Guebas et al., 2000; Thomas et al., 2009).

Residents are practically obliged to purchase wood to make up for the lack of available woody resources. In these communities locals buy some species native to the area, but mainly external woody resources. Although the purchase of wood from other regions of the country allows the regeneration of local species, these species belong to other ecological environments which also suffer the deforestation process (Demaio et al., 2002). The fact that Laguna Blanca inhabitants buy more firewood than those from Comallo suggests the scarcity of firewood and the lack of prunings. Furthermore, in Laguna Blanca fewer families use LPG, hence more wood is required for cooking.

As a result, taking into account the low temperatures typical of the region, and the money necessary for the purchase of firewood, the cost is not sustainable. A kg of firewood costs U$S 0.25, and a typical family uses approximately 4000 kg during a winter season. Due to the need for this resource, as has also been documented for other countries, many families have to spend a large proportion of their income on firewood (Madubansi and Shackleton, 2007; Misra et al., 1995; Moran-Taylor and Taylor, 2010). Means of heating should therefore be made available which can achieve a balance between conservation of our natural heritage and the economic possibilities of the population.

The mixing of dry and green wood for combustion is beneficial to dwellers of this region. This method of taking advantage of fuel can be considered an indicator of resilience. The fact that in Comallo more families use this mixture is due to the use of urban prunings, which are cut when green. In contrast, in Laguna Blanca, the scarcity of forestry products to complement native species is notable. In addition, the gathering of wild green wood causes social problems due to the physical effort involved in cutting and transportation, as well as the ecological danger implied by the cutting of green wood from native shrubs. Because of this, the possibility of recycling biological products in these communities, and in rural populations in general, could be an important step in the development of resilient processes.

Alternative fuels play a major role in supplementing scarce firewood. In Laguna Blanca more families use animal dung than in Comallo. This reinforces the evidence of lack of firewood in Laguna Blanca, plus the fact that a greater abundance of livestock was not observed. Although inhabitants make use of the dung often, they are reluctant to use it since it produces more ash and smoke than wood. The use of this alternative fuel in Argentina and in other countries is intimately related to a lack of firewood (Jashimuddin et al., 2006; Miah et al., 2003). The problem of smoke produced by this combustion and its effect on the health of the population could be a subject worthy of future study. It has been documented in Africa that the impact of carbonic smoke as a product of biofuels causes the death of millions of people every year (Bates, 2007).

In both communities LPG tubes are also used, although they are more common in Comallo, perhaps due to the semi-rural character of this population, which has easier access to urban centers. This community also has more buying power than Laguna Blanca, which influences fuel choices (Misra et al., 1995; Moran-Taylor and Taylor, 2010; Sáez Villalobos, 2004). Proximity to urban centers increases market opportunities, favoring greater diversity in alternative fuels (Pattanayak et al., 2004) and this may also contribute to less extensive use of local flora. It is interesting to bear in mind that access to the mains gas supply is of great benefit to dwellers in isolated rural areas (Moran-Taylor and Taylor, 2010). However, it is essential to find a future replacement of clean, renewable energy, e.g. plantations of woody species, so as to decrease the pressure of use on native plants, and at the same time improve the quality of life of these rural populations (Köhlin and Parks, 2001).

Locals cover differing distances in search of firewood. Close to their homes, they gather in a similar way, and in both communities native species such as *G. chiloensis*, *S. filaginoides* and *N. axillaris*, all small shrubs, are used to start the fires. The inhabitants of Comallo in general travel shorter distances in search of trees and shrubs than those in Laguna Blanca. However, the forested tree species, although collected in a peridomestic, urban area, are also found at greater distances in adjacent plantations. It is interesting to note the presence of the species *S. subulatus* throughout the entire search trajectory in Comallo, suggesting its easy availability, made even more notable due to the scarcity of other native shrubs. The high quality of its wood and the use pressure exerted on this species calls for attention to be paid to its care and recovery.

In Laguna Blanca inhabitants collect mainly native shrubs, and the search generally involves long distances. The native shrubs are the ones that provide good wood, particularly those with thicker branches, more height and harder wood, as in the case of *P. denudans*, *S. johnstonii*, *S. marchandii*, *Stillingia patagonica* (mataperro), *Colliguaja integerrima* (coliguay) and *B. microphylla*, some of which are collected in both communities.

The energetic cost of this is high but necessary. The differences in these distances may be due to the topography, since Laguna Blanca lies at a higher altitude than Comallo, which generally signifies a change in plant physiognomy, therefore leading to longer search distances.

Search distance is a measure of the availability of woody species. At the present time, when other activities have become increasingly important, reducing these search and transport distances with the use of new fuel sources could also be related to resilient processes. If wood were not a limited resource, it would be expected that dwellers would collect it close to their homes in both communities, thus minimizing the energy and time spent on this practice. Since this resource must be used daily, principally in winter but also for cooking purposes in summer, the communities have to cover distances of km for its collection (Miah et al., 2003; Tabuti et al., 2003). In addition, the distances traveled require certain strategies in terms of cost-benefit for the family group.

Nevertheless, going beyond this, we should realize that the daily search carried out in these communities, combined with the scarcity of fuel species in these arid regions, requires an urgent solution. One way to palliate this hardship could be through forestation. The most notable characteristic of the forested species in both communities is fast growth, and it is common in this region for rural inhabitants to develop peridomestic plantations (Cardoso and Ladio, 2011). Because Comallo is situated in a valley with easy water availability, plantation would be possible in this environment and trees could be grown for several uses, including as a fuel resource. In this locality the existing peridomestic plantations offer ample benefits to the society, one being firewood. Laguna Blanca, in contrast, lies at a higher altitude in a drier region, where the growth of forested species is more difficult. Since this population has problems with water availability, forestation practices are notably limited. Although in comparison with Comallo a higher percentage of Laguna Blanca inhabitants carry out peridomestic plantation, few trees grow well. In contrast, in Comallo, where the percentage of informants who plant trees is lower, there is a significant level of urban plantation at a local level, from which the annual prunings are a useful resource for those families that depend on wood for fuel.

In arid regions where the production of woody species is limited it is important to encourage and support the development of woody copses with the plantation of suitable species (Sáez Villalobos, 2004), thus promoting wellbeing and benefitting both the community and local biodiversity. Forestation of rapidly growing species like the exotic species requires strict control. In this region the commonly planted species belong to the *Populus* and *Salix* genera, which are currently being studied for forestry and energy purposes (Sixto et al., 2007). Although peridomestic forestation or the development of woody copses develops on a smaller scale than a forestry plantation, it is necessary to understand the characteristics of the forested species in order to avoid possible problems of invasion (Speziale and Ezcurra, 2011). Forestation as a practice incorporated into traditional ecological knowledge would be linked to bio-cultural experience. This undertaking would indicate a resilient action within the framework of the ecological–social system where the integration of ancestral knowledge with new practices is seen (Ladio and Lozada, 2009; Prober et al., 2011; Walker et al., 2006), and where the new landscape offers collective social benefits (Lozada et al., 2011). In addition, the practice of forestation for the acquisition of firewood would increase redundancy in the category of fuel use, thus diminishing use pressure on wild native species (Soares Ferreira Júnior et al., 2011), contributing to their conservation and suggesting a kind of local management in these communities.

5. Conclusion

This case study shows how TEK knowledge and skills may have a direct impact on the adaptive capacity of the communities living in arid lands. The resilience indicators evaluated in this study indicate that the use of greater diversity of resources favors greater conservation of native species, which contributes to a better quality of life of the inhabitants of these arid regions. Moreover, the degradation and desertification processes of these lands could be mitigated by the provision of alternative energetic resources, for example, by promoting and facilitating the cultivation of woody species. Hence, the revitalization and legitimating of this local knowledge and practices might be an important means of increasing awareness and participation in environmental issues that might contribute to the recovery of vulnerable arid landscapes.

In addition, the present work suggests the need to encourage the appropriate inclusion of local organizations to support public policy and training projects that promote greater self-sufficiency and social networking. In this way, local dwellers could not only satisfy their basic needs but could also utilize these tools to develop resilient practices which help them take care of themselves and their natural surroundings. We propose plant nurseries containing both native and selected exotic species be set up. These nurseries would contribute to alleviating the problems of degraded areas and also favor the maintenance of forestation practices.

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