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# The use of firewood in a Mapuche community in a semi-arid region of Patagonia, Argentina

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ABSTRACT

This ethnobotanical study was conducted to identify which wild plants were used for fuel by a rural population of the Patagonian steppe. We studied the species used, gathering patterns, socio-economic factors, preference criteria, and alternative fuel sources. Semi-structured and open interviews were conducted with one member of each family unit. It was found that firewood is a vital resource, since it is the main fuel used for heating. The gathering of firewood is performed mainly on foot and is gender-independent. The inhabitants reported a decrease in the availability of firewood because each year they have to travel greater distances to find dead wood and preferred species. This study recorded 27 species used for fuel, of which 22 were wild native bushes and 5 were exotic trees planted by inhabitants. The four preferred species for firewood were: *Schinus jhonstonii*, *Schinus marchandii* (Anacardiaceae), *Prosopis denudans* (Fabaceae) and *Monttea aphylla* (Scrophulariaceae). Resources used as alternative energy were: *Liquefied Petroleum Gas* (LPG), cow dung, and to a lesser degree, horse dung. The findings indicated that 64% of inhabitants depended solely on the gathering of firewood, 32% on gathering and purchasing, and 4% on purchasing alone. Purchased firewood consisted of local bush species from the neighboring Patagonian region, and also species from the northern and central areas of the country. The inhabitants' capacity to adapt to this harsh environment seems to be based on their intensive use of local flora, which is at the same time controlled by their protectionist worldview and care of the plants and environment.



## 1. Introduction

The world's diversity of woody species is suffering serious depletion. Conservation and research into their exploitation by human populations which depend on them is therefore of special interest. Since ancient times, humans have used energy derived from wood as their main source of fuel. This has been mentioned in descriptions of various archeological studies [1–3]. Nowadays, plants represent almost 90% of the worldwide consumption of fuel used for cooking and heating in developing countries [4]. The FAO reported a global decrease in the consumption of firewood per capita due to higher incomes, urbanization, less availability of wood and easier access to alternative sources [4]. However, high consumption of firewood in countries with high population densities and rural settlements still exists [5–10].

In South America, fuel plants continue to be an essential part of subsistence economies, and as previously mentioned, this is especially true in rural populations [4,7,11–14]. In arid or semi-arid environments, firewood generally consists of

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low-shrub plants since arboreal species are less abundant [13,15–17], whereas in forest areas hardwood trees are preferred [10,18–21]. In certain insular territories, however, many softwood species of lesser quality are also used as fuel [22]. Thus, selection processes and the use of fuel respond to various factors such as the availability of the local resource [23], quality and accessibility of wood [7,10,20], the use of alternative fuel resources [24–26] and the socio-cultural aspects inherent in each community [5].

Numerous works have described the negative effects of overexploitation of woody resources and how this leads to a serious decrease in the diversity of native species in various regions [14,21,27–30], and also to accelerated processes of erosion [15,31]. As in other countries, firewood is the main fuel used in rural areas of Argentina, where native forests have undergone serious retrocession due to non-sustainable government policies and other socio-economic reasons [32,33]. For example, from the end of the 19th century to the mid 20th century, wood from native forests was freely available and therefore exploited by European and National companies which used it for their own purposes. At that time, wood was used for railroads, the tanning industry, posts, fences and vineyards; all associated with the roaring boom of agriculture, which became a model for the dominant economic development [32,34].

In rural cultures, the gathering of wild fuel plants is part of the traditional ecological knowledge of accumulated learning, practices, and beliefs developed through cultural transference and adaptive processes and passed down through generations [35]. This cultural transference is a complex cognitive process in which practices, attitudes, and values learned are closely related to ecological and socio-cultural contexts. Therefore, variables such as age, gender, education, and degree of acculturation are all relevant in the intra-population variation [36]. As perception and action are closely linked to the cognitive process [37], perception and cultural interpretation of the environment lead to direct action on plants and surroundings [37,38], which generates patterns of interaction between humans and their environment.

Research studies conducted in Mapuche communities of Northwestern Patagonia show that the knowledge and gathering patterns used for wild plants are related to searching distances [39], resource availability [40], and the gatherer's socio-cultural characteristics, e.g. gender [41–43]. In addition, it was found that certain useful resources were preferred due to their cultural and symbolic values, thus becoming irreplaceable elements [44,45]. These findings demonstrate the strong interrelation between resource, environment, and culture. Furthermore, this relationship varies within the different categories of plant use with regard to how they are perceived, culturally valued, and the peculiarities of their gathering [46].

In addition, it was found that gathering practices (in the case of edible and medicinal plant use) maintain flexible characteristics, and in most cases represent a resilient strategy when facing situations of change and/or scarcity [44,47]. The inclusion of exotic plant use is an example of how inhabitants have learned to take advantage of new resources and use them in their daily lives [48,49]. However, little is known about the flexibility acquired in a population as regards firewood resources.

In the Patagonian region, few studies have been carried out on the use of woody resources as fuel [47,50] in spite of its importance to past and present rural communities. The lack of firewood in rural steppe areas is one of the most important regional issues, according to local dwellers and technicians who work in extension programs [51]. However, there are no studies up to this time which assess use patterns, gathering strategies, and forestation. Populations living in these harsh environments develop diverse strategies, such as the purchasing of firewood [52], the use of alternative energy [53], and the gathering of non-vegetal supplies [25,26]. In addition, forestation is an acquired practice also carried out to overcome the firewood shortage [15,51].

In arid and semi-arid regions, human populations are subject to environmental limitations which bring about adjustments and restrictions in daily life and also possible structural changes in the plant communities near their settlements [22,51]. Driven to a situation of high-environmental vulnerability [42,53], current populations inhabiting the arid steppe depend substantially on woody species for fuel, while at the same time adding new learning to their traditional knowledge. Rural communities of "Mapuche" origin ("Mapuche" means people who belong to the earth) of northern Patagonia base their economy on livestock, complementing and varying it with home horticulture [38,42,52]. This is the case of the Mapuche community of "Pilquiniyeu del Limay" ("Squirrel Canyon" in Mapuzungun language), the focus of this research. The community consists of two types of settlements, one rural and the other a village, which face different socio-environmental challenges. Given the changes that these populations are currently suffering in relation to the acquisition of fuels due to firewood scarcity, we will explore how dwellers manage to survive in these hostile conditions.

We will identify characteristics of their traditional ecological knowledge related to the use and preference of fuel resources, and ask the following general questions: How do fuel consumption patterns vary within the population and what alternative fuel sources are utilized? How do gender, perception, and the preference criteria used to select woody species influence gathering strategies? We hypothesize that according to their traditional ecological knowledge they would prefer native plants as firewood. Given the scarcity of local flora due to the constant use of native species and the severe environmental conditions in the region, we also hypothesize that dwellers will travel long distances to search for these woody plants, and that they will complement the use of firewood with alternative fuel resources and the purchase of firewood.

## 2. Methodology

### 2.1. *Study area*

Pilquiniyeu of Limay is a Mapuche community located in northwestern Patagonia, Rio Negro province, Argentina. In total there are 55 families distributed throughout an area of 55,000 ha on an indigenous reservation [54]. Nine families are established in the town, where the school is located (40° 31′ 16″ S; 70° 02′ 36″ W) and the remaining families are distributed

throughout different valleys on the reservation (e. g., 40° 26′ 59″ S, 70° 05′ 44″ W; 40° 29′ 58″ S, 70° 01′ 23″ W; 40° 30′ 08″ S, 69° 53′ 28″ W; 40° 316′ 29″ S, 70° 05′ 59″ W; 40° 33′ 09″ S, 69° 57′ 03″ W and 40° 23′ 65″ S, 69° 56′ 23″ W). The educational institution brings the children together from all the families in the community. A distance of approximately 10–20 km separates each family in the disperse area. This landscape contains valleys and wet-meadows as well as rocky outcrops in some areas where the land rises to between approximately 810 and 1093 m.a.s.l. This community is located within the phytogeographical region of the Monte province, adjacent to the northern border of the Patagonian province [55]. The vegetation is predominantly underbrush, where various microenvironments of *Larrea nitida*, *Colliguaja integerrima*, *Schinus* spp. and *Lycium* spp. can be identified. The climate is predominantly arid and cold with annual precipitations of 150–300 mm, mainly during fall and winter in the form of rain or snow, and a median annual temperature of 8–10 °C [56]. In the community of Pilquiniyeu of Limay, 80% of inhabitants are direct descendants of a Mapuche lineage. Spanish is spoken in all homes, however. Only a minority of the population, 20%, are bilingual and speak the native tongue of Mapuzungun, and 10% are structural-bilinguals who know only a few words in their native language. We found women to be the main speakers of the native tongue.

Access to the community is extremely difficult due to unpaved roads and the lack of public transport. The nearest town to this community is Comallo (40° 53′ 54″ S; 70° 13′ 18″ W) (population of 1500) 80 km away, and the nearest city is San Carlos de Bariloche (41° 08′ 35″ S; 71°18′ 12″ W) (population of 108,000) located at a distance of 220 km. Most of the families are therefore isolated from urban centers, although those living in the village have more frequent contact with nearby towns. Some inhabitants live in cement houses and others in mud houses built by themselves. The main economic activity performed by men is cattle raising and the keeping of animals such as goats and sheep from which wool is sold. Women work with the wool, knitting and making products to sell. In most households, women are in charge of harvesting crops and planting home gardens, while men may be involved in this, but to a lesser degree.

This particular Mapuche community has suffered a profound recent uprooting caused by the establishment of a hydroelectric dam supported by government institutions [54]. They were obliged to leave their original settlement and start over. The community does not have electricity but some families use energy from a solar panel purchased with their earnings. The families residing in the village (30%) use diesel generated electricity, provided for only a few night hours.

Regarding the issue of literacy, approximately 30% of respondents completed elementary school, 25% never attended school, and the remaining 45% attended school but only for some time. All the children from the families visited currently attend school, with the goal of finishing the primary level. The traditional Mapuche health system continues to be practiced although specialized cultural leaders called “Machis”, are no longer in existence. Furthermore, the community maintains its traditional authorities called “Lonkos” who coexist with non-traditional political authorities.

### 2.2. Methods

Permission to work in this location was first obtained and then we explained the research project to local authorities and residents. The ethnobotanical information was collected between the months of January and March 2009. A total of 28 families chosen at random (51% of the population) were interviewed in Spanish in their own homes. In order to conduct the interview, within each family we chose the household head as informant. All respondents were adults (mean age: 36, ages ranging from 24 to 76); 16 women and 12 men responded to a semi-structured interview [57], each representing a family unit. Open-question surveys were also used and through these, respondents named the woody species by their vernacular names. Aspects regarding the gathering of firewood such as: species used, preferred species, traveling distances, and socio-cultural information were recorded. In addition, questions were asked in relation to respondents’ perception of their environment and the availability of fuel species in the area.

In order to identify the species named by respondents, walks were taken with them near their dwellings (geo-coordinates for the study area). Two live branches were collected as specimen samples for each species mentioned by the informants. We recorded each species’ vernacular name, site of collection, diameter of cross-section and relative age. Afterwards, branch samples were dried outdoors and kept under dry conditions: We wrapped up the samples inside papers from the field to the laboratory. We then stored them in a herbarium, where each species was identified by its scientific name, and placed in the Ecotono laboratory, National University of Comahue, at room temperature and in the absence of light [58]. Most interviews were conducted in the presence of a government authority who facilitated contact with the residents.

### 2.3. Data analysis

All collected and purchased woody species were categorized as “native” or “exotic” according to their biogeographical origin [59,60]. Shrubs of local origin, belonging to the Patagonian region, were considered natives. We recorded the information obtained as: “grows in the village” or “does not grow in the village” and whether this fact influenced gathering practices and perception of the environment. With respect to the inhabitants, “raises cattle” or “does not raise cattle” was recorded, in addition to other duties such as being public sector employees, casual laborers, artisans, or retired.

In order to analyze searching distances in relation to other variables, the following three categories were established: less than 2 km, between 2 and 4 km, and over 4 km. The type of firewood gathered was assessed according to the following criteria: “deadwood” (found lying on the ground) or “tree borne”. In the latter category we recorded whether the family cut dry firewood, green, or both.

Due to the fact that the population is small, sampling effort and richness of woody species used were analyzed by means of an accumulation curve [61] which indicated that the sampling effort was sufficient (Fig. 1). The tendency of the curve showed that if we increase the quantity of respondents

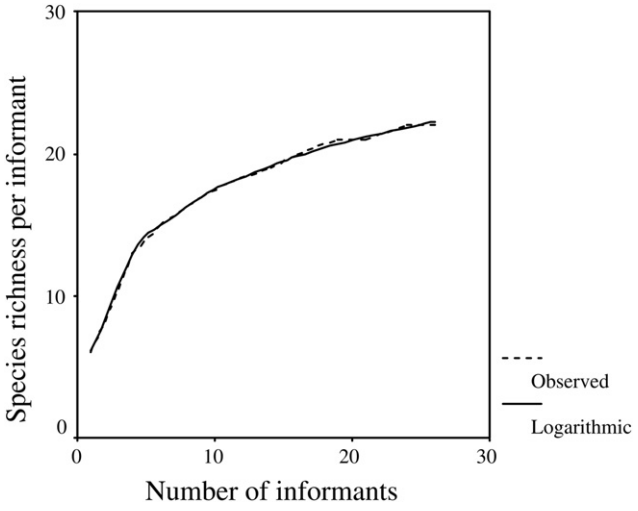


**Fig. 1 – Richness of cited firewood species. Accumulation curve based on the number of fuelwood plants cited per informant in Pilquiniyeu of Limay community ($N = 28$).**

an asymptotic distribution will be observed, confirming that the species richness identified in this research is representative of the fuel species used by this community (logarithmic model, $F = 7472$, $p = 0.001$, $R^2 = 0.99$). A consensus of use (CU) value was calculated for each of the species cited, taking the number of people who mention a certain species as being used or preferred over the total number of interviewees as the value representing frequency of use or frequency of preference of any given species [48,57]. In this way, the effective use of species was recorded separately from their preference, which represented the set of plants residents considered valuable for fuel. Furthermore, the forestation frequency was calculated for each of the forested species, taking the number of respondents who planted certain species over the total number of interviewees. In accordance with the method used to gather the data, the analyses were carried out using non-parametric statistics. We used the binomial test to analyze within sample data, the Mann–Whitney test for independent data, as well as the Spearman correlation test [62,63].

## 3. Results and discussion

### 3.1. *Traditional ecological knowledge of woody plants*

This research identified firewood as a vital resource for the Pilquiniyeu of Limay community, which invests great physical effort in gathering and using it as their main source of biofuel. Due to the scarcity of this resource in the area, 64% of residents depend on the gathering of firewood, 32% gather and purchase, and 4% only purchase. The evolution of different strategies to obtain fuel plants as essential elements indicates dependency on the environment, since alternatives that preserve forest diversity have not been developed.

#### 3.1.1. *Species used*

The community's traditional ecological knowledge related to woody plants described the use of 27 species. Specimen branches ranged from 0.5 to 2 cm in cross-section diameter. The height of bushes ranged from 0.5 (e.g., *Senecio filaginoides* or *Grindelia chiloensis*) to 2 m (*Ochetophila trinervis*), all samples being adult specimens. Of the 27 species used as fuel, 22 are regional native bushes, and 5 are exotic trees (binomial test, $p = 0.002$). The latter had been planted by residents or their relatives several years before (Table 1). As hypothesized, due to their ancient ecological knowledge of fuelwood resources, the dwellers used more native species than exotic ones. Most dwellers expressed their awareness of the scarcity of native firewood resources, and expressed their preference for local resources, a tendency also found in other studies [64,65]. All woody plants available to them are used as a source of heat, due to the scarcity of both preferred and arboreal species. This pattern was observed in several communities of different regions [7,18,20]. In addition, the total richness of the woody species used in this community is similar to that found in arid and semi-arid areas of other parts of the world [1,15,17,19,66,67]. In most of these environments, the proportion of woody species is low in comparison with forest ecosystems where species diversity is higher, favoring better living conditions for human populations. In arid environments, dwellers suffer greater firewood scarcity, which compels them to find resilient strategies for survival in these harsh landscapes. Thus, populations living in unfavorable environments are forced to develop ways of gathering and using alternative resources, in order to obtain fuel. The species with the highest (CU) in this community were: *Schinus jhonstonii* 82%, followed by 64% for *Schinus marchandii* (Anacardiaceae) and *Monttea aphylla* (Scrophulariaceae) (Table 1). The residents cited an average of 6 species (±2) of plants from their environment that they are able to identify and use as fuel.

The frequently used species were those frequently preferred by inhabitants (correlation coefficient = 0.59; $p = 0.001$) (Table 1). The preferred species were those which residents selected following experimentation, also influenced by the traditional ecological knowledge of species suitable for firewood. This suggests that the preferred species are those which stand out due to the quality of their wood and are also of cultural importance to inhabitants.

#### 3.1.2. *Preferred species*

In the Pilquiniyeu of Limay community it was found that within the preferred species, the following 4 were natives of the region: *S. jhonstonii*, *S. marchandii*, *Prosopis denudans* and *M. aphylla*. The principal criteria employed by residents to determine their preferred species was wood hardness and durability of embers. These criteria coincide with research studies which identify the inherent combustion properties of woods, i.e. hardness, heat potential, durability of embers, or Fuel Value Index (FVI) as recorded for other species in other regions [12,30,68,69]. It would be interesting to conduct combustion analysis on the preferred species, comparing results with the characteristics perceived by residents, thus evaluating traditional ecological knowledge.

#### 3.1.3. *The history of fuel species*

Several of the species used for fuel by the Pilquiniyeu del Limay community were also mentioned with the same use in

**Table 1 – Origin, habit, frequency of use, frequency of preference and species richness of firewood plants used by the community of Pilquiniyeu of Limay in NW Patagonia, Argentina.**

| Botanical family | Scientific name, local name | Origin | Frequency of use | Frequency of preference | Habitat |
|---|---|---|---|---|---|
| Anacardiaceae | *Schinus johnstonii*, Molle colorado | N | 82 | 75 | Shrub |
| | *Schinus marchandii*, Molle blanco | N | 64 | 46 | Shrub |
| Scrophulariaceae | *Monttea aphylla*, Yaque | N | 64 | 7 | Shrub |
| Zygophyllaceae | *Larrea nitida*, Jarilla | N | 50 | – | Shrub |
| Solanaceae | *Lycium ameghinoi*, Monte negro | N | 50 | – | Shrub |
| | *Lycium chilense*, Monte negro | N | 29 | – | Shrub |
| | *Lycium gilliesanum*, Monte negro | N | 4 | – | Shrub |
| Asteraceae | *Chuquiraga erinaceae*, Montetachuela | N | 7 | – | Shrub |
| | *Nassauvia axillaris*, Uña de gato | N | 7 | – | Shrub |
| | *Senecio subulatus*, Romerillo | N | 50 | – | Shrub |
| | *Senecio filaginoides*, Charcao | N | 4 | – | Shrub |
| Fabaceae | *Adesmia volckmanni*, Mamuel choique | N | 4 | – | Shrub |
| | *Prosopis denudans*, Alpataco | N | 36 | 21 | Shrub |
| Euphorbiaceae | *Colliguaja integerrina*, Coliguay | N | 32 | – | Shrub |
| | *Stillingia patagonica*, Mata de perro | N | 14 | – | Shrub |
| Rhamnaceae | *Ochetophila trinervis*, Chacay | N | 29 | – | Tree or Shrub |
| Salicaceae | *Populus alba*, Álamo plateado | E | 4 | – | Tree |
| | *Populus x canadensis*, Álamo chileno | E | 4 | – | Tree |
| | *Populus nigra*, Álamo verde | E | 7 | – | Tree |
| | *Salix viminalis*, Sauce mimbre | E | 25 | 4 | Tree |
| Malvaceae | *Corynabutilon bicolor*, Monte moro | N | 18 | – | Shrub |
| Berberidaceae | *Berberis microphylla*, Michay | N | 11 | – | Shrub |
| Apiaceae | *Mulinum spinosum*, Neneo | N | 4 | – | Shrub |
| Chenopodiaceae | *Atriplex lampa*, Zampa | N | 4 | – | Shrub |
| Lamiaceae | *Satureja darwinii*, Tomillo | N | 4 | – | Shrub |
| Ulmaceae | *Ulmus minor*, Olmo | E | 4 | – | Tree |
| Verbenaceae | *Neosparton aphyllum*, Matasebo | N | 4 | – | Shrub |

an earlier work conducted in Patagonia [47]. Such is the case of the following: *Ochetophila trinervis* and *Maytenus boaria* (maitén) [70], as well as: *Chuquiraga erinaceae*, *Condalia microphylla* (piquillin), *Larrea* spp., *M. aphylla*, *Prosopis* spp., *S. jhonstonii* and *Salix* spp. [47]. This research supports the historic importance of these species, showing the accumulated experience and long-lasting use of these plants as biofuels.

### 3.2. *The purchase of firewood and its implications*

The purchase of firewood is a way to supplement the resource. This comes from shrubby species from the area, trees and shrubs of the same Patagonian region, and from central and northern parts of the country. The average economic value is 230 \$ $t^{-1}$. Families living in the village purchase significantly more firewood than those living in the surrounding area (Mann–Whitney, $Z_{adjusted} = 3.43$; $p = 0.02$), demonstrating greater dependence on exogenous plant resources. This probably occurs because the families living in the village are situated at shorter distances from each other, where vegetation is scarce.

In contrast, families who live in the surrounding area have denser and woodier vegetation within their reach. Another factor involved in this difference may be purchasing possibility, related to higher income and frequency of merchants' visits. The current quality of life in the village allows residents to have access to paid jobs and this favors differential consumption, as also found in other communities [25,26,52]. The preferred native species are bought and sold between neighbors (Table 1). The firewood transported and sold by merchants is harvested from areas affected by forest fires in adjacent Andean-Patagonian zones and belongs to the following species: *Nothofagus pumilio* (lenga), *Schinus patagonica* (laura), *Austrocedrus chilensis* (ciprés), *Lomatia hirsuta* (radal) and *Cytisus scoparius* (retama).

In addition to this, inhabitants purchased firewood from exotic species such as *Pinus* spp. (pine), which comes from neighboring areas, and also wood from central and northern regions of the country [32,55]. In the latter case, the most common species were: *Prosopis alba* (algarrobo blanco); *Prosopis caldenia* (caldén) and *C. microphylla*. The wood purchased, which comes from the central and northern regions of the country, in this case representing 23% of fuel species purchased, is very dense and produces long-lasting embers, qualities believed by residents to be beneficial attributes for fuel use.

According to interviewees, decades before, residents sold local firewood of their preferred species in order to earn an income. Nowadays, however, the purchase of firewood is very common in the community. This shift from selling to purchasing may indicate a decrease in the availability of wild wood in the area, or in the searching radius. Such evidence of wild resource decrease, associated with an increase in purchasing, has been recorded in other rural areas of the world where in addition to firewood, coal is also bought and sold [25,26,52,69].

This change in habits causes a decrease in traditional knowledge and practices that maintain and promote the close relationship between environment and culture. The gradual loss of contact with the environment and their cultural beliefs, along with greater dependence on the market society, produces serious retrocession and vulnerability [29,41,71,72]. They could be losing the habit of looking for their own responses and solutions for survival.

### 3.3. *The practice of gathering woody species*

The ax was the main tool employed in the gathering of firewood, and the work was mainly done on foot (39% of respondents), whilst the other respondents stated that they used horses, or to a lesser degree, a vehicle provided by the local government authority. According to 100% of interviewees, each year they have to travel greater distances to find firewood, which is further evidence of the resource's increasing scarcity.

Residents gathered a greater richness of wild native fuel species (82%) than of planted exotic species (18%) (Table 1). Due to the current scarcity of woody resources, most inhabitants traveled great distances and spent large amounts of time searching for firewood, mainly to find the preferred type. During each searching session, one third of the population traveled more than 4 km, another third approximately 2–4 km, and the remaining third did not exceed 2 km radius. These walks were conducted mostly by adults, although in some cases by all family members. Families living in the village gathered an average species richness of 5 (±3), similar to those in the dispersed area, 6 (±2) (Fig. 2). Of the total population, two-thirds gathered dead firewood and had no need to use live wood.

The residents combined live and dead wood to make a beneficial mix, which according to most respondents causes fire to last longer than if using dry wood alone. In this community, all the gathered firewood is used for domestic needs. However, in places where wood is used for other purposes, dead wood goes to households, and live wood to small factories and coal production. The different qualities of wood are used to suit the requirements of each situation [5].

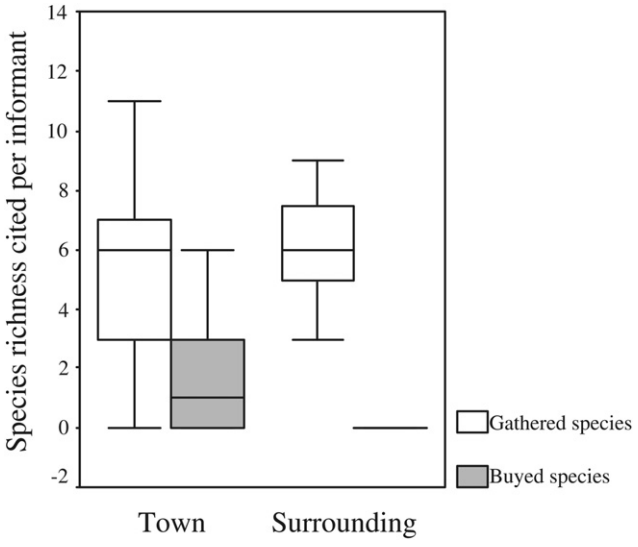


**Fig. 2 – Firewood consumption patterns. Richness of species collected and purchased in the town and its surroundings by the Pilquiniyeu of Limay community.**

Although the dry season is best for the gathering of woody resources, in this community gathering was performed daily and few families stored gathered firewood. Some studies in other countries, however, have described communities that gathered firewood in the dry season and stored it in piles as a reserve [25,26,53]. The observation that in this community most families replenished their small storage of firewood daily may be due to the fact that the sampling was conducted during the summer, when the need for fuel was less. Thus, although at this site the people did not tend to collect large stores of the resource, it is possible that they do so in winter when the need is greater and the climate harsher.

The practice of gathering is related to other tasks performed by residents. We found that those who traveled to care for their cattle gathered significantly more fuel plants than those involved in other tasks (Mann–Whitney, $Z_{adjusted} = 2.22$; $p = 0.027$). This type of multi-purpose trip has also been described in other studies related to the gathering of wild resources [42,73] and is associated with reducing the frequency of trips and performing other important tasks. This demonstrates that families who are most dependent on a rural subsistence economy rely more on gathering than those with other opportunities.

In spite of the strong cultural, social, and environmental impact that Mapuche communities in northeast Patagonia have suffered, firewood gathering is one of the traditional practices which has been least modified by the successive processes of acculturation from European colonization times. This may be due to the fact that it is a difficult practice to replace, except by alternative energies which require a technological advance, as with natural gas or electricity networks.

The conquest of the Patagonian territory modified, by imposition, other wild species gathering practices related to feeding and healing, which obliged local communities to develop new strategies [29,74]. This new forced way of relating to the environment brought with it a negative process of acculturation, reflected in the retrocession of use of the native tongue, dependence on modern medicine, and the absence of religious rituals and customs belonging to the Mapuche cultural legacy [34,41,44,75]. In certain indigenous groups the imposition of new practices from colonial times has caused a lack of interest which can currently be seen in the absence of customs and the limited use of traditional resources, which works against the strengthening of the culture [41,72].

### 3.4. *Alternative sources*

Residents possess vast knowledge of non-vegetal resources which can also be used as fuel to complement firewood. Regarding the use of alternative fuels in this community, we found that inhabitants used cow dung (*Bos taurus*) or horse dung (*Equus ferus caballus*), also gathered in the fields. Of the families visited, 60% did not use this type of fuel, satisfying their fuel needs with gathered firewood alone. However, according to respondents, of the families that did use this fuel, 40% preferred cow dung due to its long-lasting embers. In this

community, the use of alternative supplies is related to the scarcity of firewood. Although several communities have been using animal dung for a long time [25,26], to our knowledge nothing is known about the potential harm that this may cause to humans. The use of dung by various communities in the world could suggest the development of this practice through observation and experimentation, eventually becoming part of traditional ecological knowledge. This interest in using dung reflects the scarcity of the woody resource and the need to find complementary alternative energies.

Of the population interviewed, 86% had LPG, which was used to a limited extent for cooking, as were all the alternative fuels. Families who did not use this resource gathered a significantly higher quantity of woody species (9 ± 2) than those who did use it (6 ± 2) (Fig. 3). This may indicate that the presence of alternative energy influences gathering practices and fuel consumption habits of families.

Although populations are located in different environments, the scarcity and indeed lack of firewood leads the communities to develop strategies oriented towards the use of alternative energies to supplement woody resources [10,25,26,52]. In South Africa, for example, policies have been developed to support the change from bio-energetic resources to clean energies, as in the case of electricity [52]. In the Patagonian region, it might be relevant to promote forestation practices or attempt to replace bio-mass and non-renewable energies for clean and renewable ones. These structural changes would give birth to policies aimed at the conservation of the vegetation and would protect residents' quality of life.

### 3.5. *Gender differences*

Men and women used firewood in a similar way, thus its gathering in terms of richness does not seem to be influenced by the division of genders and their ways of perception (Mann–Whitney, $Z_{adjusted} = 1.41$; $p = 0.160$). The men, who usually went out to care for the cattle, gathered fallen firewood or cut it green. On the other hand, the women were in charge of keeping the stove lit and selecting the firewood to be used daily. Therefore, use and knowledge regarding woody species is similar, although complementary, and separate tasks were performed by men and women.

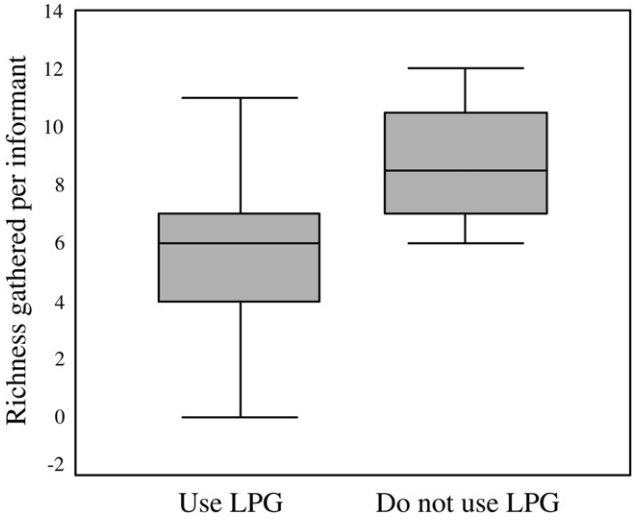


**Fig. 3 – Collected richness of fuelwood plants and use of LPG. Relationship between collected richness and the use of LPG by the residents of Pilquiniyeu of Limay.**

In this particular community, all family members went out to search for wood, so both genders had contact with the resource. Although the gathering of this resource, as observed by a few research studies within the country, is a task generally performed by men [10], in this community it was performed by both genders. In research studies conducted in other regions, the practice of gathering has shown differences regarding gender [5,69]. This demonstrates that rural communities that maintain close contact with the environment adopt customs according to current conditions and the requirements of certain practices.

### 3.6. *Perception and forestation*

According to interviewees, in previous decades the bio-mass of dead firewood was considerably greater than at present. In this community, all the families planted trees around their households for various reasons, but not necessarily for firewood. The trees planted were all exotic and had different forestation percentages among dwellers: *Populus nigra* 89%, *Salix viminalis* 79%, *Ulmus minor* 71%, *Populus alba* 61%, *Populus x canadiensis* 29%, *Pinus contorta* 18%, *Salix erithroflexuosa* (sauce eléctrico) 3.6%, *Salix babylonica* (sauce llorón) 3.6% and *Robinia pseudo-acacia* (acacia) 3.6%. These species were provided by neighbors or national institutions working in the area (INTA, National Institute for Agricultural Technology). Such species were used as windbreaks, to provide shade, cattle forage, posts, fences, and for the making of furniture; in only a few cases, and as second choice, was the wood used as fuel.

In spite of this being an arid environment, the planted trees that receive sustained care develop well within a few years. This may be related to the physiological characteristics of exotic plants, achieving fast growth compared to native species [76–78]. The introduction of exotic wood species in the peri-domestic area increases the variety of plants with diverse purposes and also the mechanisms of cultural adaptation [71].

It would be interesting, therefore, to blend scientific with traditional ecological knowledge and carry out work to promote a strategy of sustainable use for each of the households. This could increase the availability of fuel to residents, with a management plan established by locals and authorities, while upholding their ethnobotanical knowledge [35,79]. Intra-population differences, such as in the purchasing of firewood, its various uses, utilization of LPG, and species richness gathered by the community, show that the population demonstrates flexibility, as they incorporated new practices to satisfy their heating needs. These changes modify the population's relationship with the environment and at the same time highlight their ability to adapt [44,47,71].

## 4. Conclusions

In spite of the difficult situation experienced by Mapuche communities, even at present, the Pilquiniyeu de Limay

population maintains its traditional ecological knowledge, and this, added to knowledge from outside, reveals community cultural adaptation processes and resilience. Due to the scarcity of woody resources in arid Patagonian environments, the practice of gathering firewood is supplemented by the purchase and use of alternative fuel. Nevertheless, firewood is a limiting resource for those who cannot purchase it, and purchasing is also regulated by socio-economic factors.

Gathering patterns demonstrate a strong connection with ecological-environmental factors related to the search mainly for dead firewood, but also for live wood, and involve vast searching distances. Gender is not a discriminating factor in the use of firewood, although it does have an influence on gathering. The scarcity of firewood perceived by residents, and low Patagonian temperatures are important indicators that suggest the need to promote initiatives to mitigate the harshness of these arid environments where the development of human communities is extremely difficult.

In the future, it will be necessary to calculate the coverage of the different species in this area and estimate pressure of use exercised on preferred species. This type of research provides valuable information to be taken into account in the formulation of environmental and social policies of conservation, while at the same time it reveals the isolation and vulnerability of marginalized social sectors. In addition, it demonstrates the need to develop alternative ways of providing this vital resource for the inhabitants, promoting and facilitating the cultivation of woody species.

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