Cross-scale analysis of diversification in fuelwood use in three contrasting ecoregions of Argentina (Chaco, Pampa and Patagonia): the role of exotic species in subsistence

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ABSTRACT

Fuelwood is an essential source of energy for rural populations in many ecosystems. However, little research has addressed the role of exotic species in relation to the use of native woody plants for fuel. This study was performed in rural communities of three ecoregions of Argentina (the phytogeographical provinces of Chaco, Pampa and Patagonia). Basing our study on the diversification hypothesis, we evaluated whether the exotic species used alongside native plants vary in each region. We also studied diversification in relation to gathering environments and use strategies. Open and semi-structured interviews were conducted in 72 households, focusing on the total richness of fuelwood used and its use pressure. We used the ratio between exotic and native richness as an indirect measure of diversification. Data were analysed qualitatively and quantitatively. A total of 78 species was recorded, of which 51 were native and 27 exotic. Gathering is the most common supply strategy in all the ecoregions studied, fuelwood being obtained mainly in sites with little human intervention. A generalized linear model showed that the use of native versus exotic species varied according to the ecoregion and the level of human intervention in the supply area, while acquisition strategies were similar for both native and exotic species in all ecoregions. The areas with most human intervention were always used to gather exotic plants. In line with our hypothesis, UWPF diversification with exotic species varied according to ecoregion. Intrinsic characteristics associated with the history of each region possibly explain the findings.

Keywords: Rural communities; Local management; Pressure of use; Human intervention; Acquisition strategies.

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SIGNIFICANCE STATEMENT

Basing our study on the diversification hypothesis, we evaluated the use of woody plants for fuel (UWPF) in rural communities of three different ecoregions of Argentina (the phytogeographical provinces of Chaco, Pampa and Patagonia). Our results show that the UWPF in each ecoregion has diversified with exotic plants in different ways. We conclude that the role of exotic plants is key to minimising the use of native plants from these and other regions.

INTRODUCTION

The use of woody plants for fuel purposes (UWPF) is of great concern to environmental conservationists (Cruz et al. 2020; Medeiros et al. 2011), although it is one of the most important ways that societies–mainly rural–interact with the plants around them. Even today this relationship is essential for everyday existence, satisfying some of the population's basic needs (food preparation, heating of the home, etc.) and forming an important part of their social, economic and cultural lives (Ektvedt 2011; Jiménez-Escobar and Martínez 2019; Kim et al. 2016; Tabuti et al. 2003).

Due to human patterns of exchange and migration, exotic species have been introduced into many regions worldwide as a fuel resource. These species are incorporated into the new social-ecological system in different ways, showing processes of adaptability and diversification (Medeiros et al. 2017). This additive process may result in the diversification of traditions and practices and is linked to maintaining or increasing biodiversity in order to improve human welfare (Pfeiffer and Voeks 2008). However, this situation warrants the attention of conservation biologists, resource managers and policy makers (Meffe et al. 2002), due to the problems generated by invasive woody plants in Argentina (Giorgis et al. 2011; Busso et al. 2013) and on a global level (Richardson 1998; Mack et al. 2000; Pfeiffer and Voeks 2008).

The diversification hypothesis proposed by Albuquerque (2006) as part of the Social-Ecological Theory of Maximization (Albuquerque et al. 2019) predicts that the incorporation of plants into a social-ecological system is a dynamic process based on the need to fill gaps in the system or enrich it with alternatives. This hypothesis has been supported by studies which found that the biological compounds present in exotic medicinal plants differ from those in native medicinal plants (Alencar et al. 2010) and provide medicinal treatment not offered by native plants (Albuquerque 2006; Santos et al. 2014). This theoretical model has only been confirmed in the case of medicinal plant use (Alencar et al. 2010; Hart et al. 2017; Medeiros et al. 2017), but it would be interesting to test it in fuelwood plants. Exotic fuelwood species may fill gaps when native species are scarce and may also have new biophysical properties of interest for combustion purposes.

Diversification in UWPF with exotic species has been little studied, perhaps because these species are considered part of destructive processes of invasion (Richardson 1998; Pfeiffer and Voeks 2008). However, many exotic species are appreciated by locals and incorporated through cultivation, gathering or purchase, thus enriching subsistence practices (Hurrell and Delucchi 2013; Medeiros 2013). The use of exotic species has been highlighted in several parts of the world as a local solution to diverse needs (Santos et al. 2014; Nguanchoo et al. 2019). With regard to medicinal (Bennett and Prance 2000; Medeiros et al. 2017; Palmer 2004) and firewood (Doumecq 2019; Jiménez-Escobar and Martínez 2019) use, it has been pointed out that these plants are readily available, fast growing, and more tolerant to environmental disturbance than native species (Bennett and Prance 2000; Medeiros et al. 2017; Palmer 2004).

Depending on the region studied, patterns of fuelwood acquisition, use, selection and management have shown the wide variety of environmental, biophysical, economic and sociocultural factors involved (Alcorn 2000; Cruz et al. 2020; Martínez 2015). Populations develop strategies to deal with these complex situations, according to their possibilities. The principal method of acquisition in many parts of the world is gathering (Kituyi et al. 2001; Martínez 2015), and the most valued species are generally the most available temporally and those which have certain biocultural characteristics, such as high calorific value, ease of ignition, or long-lasting embers (Cardoso et al. 2015; Gonçalves et al. 2016; Ramos et al. 2008; Tabuti et al. 2003). The purchase of fuelwood is a common acquisition strategy, often in response to scarcity or a lack of access to wood, or in search of species with a high calorific value (Cardoso et al. 2015; Madubansi and Shackleton 2007; Ramos et al. 2008).

In addition, traditional environmental management practices, based on interactions causing medium disturbance, show that the supply of plants can be guaranteed through use (Smith 2009). A recent study in northwest Patagonia demonstrated that fuelwood gathering of intermediate intensity does not affect forest regeneration (Chillo et al. 2020). However, research on this subject is fragmentary as yet.

In general, environments with high levels of anthropic intervention promote the establishment of a

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higher number of exotic species than those with less intervention (Uddin et al. 2013). Peridomestic forest, in particular, constitutes landscapes recreated by humans where exotic species grow not only for use as an energy source, but also for many other purposes, such as shelter and construction (Cardoso and Ladio 2011; Foroughbakhch et al. 2001). However, Morales et al. (2017) found that firewood use intensity is similar despite the different levels of domestication of Patagonian landscapes. That is, the different areas are taken advantage of in a complementary manner, exotic species being added to the repertoire of native species already in use, in order to satisfy the domestic demand for firewood.

Moreover, the importance of wood as the main fuel source for heating and food preparation has been amply shown for rural and peri-urban populations throughout Argentina (Cardoso et al. 2015; Doumecq et al. 2020a; Jiménez-Escobar 2021; Martínez 2015; Morales et al. 2017; Rodríguez López et al. 2015). Therefore, the diversity of species present in domestic areas and involved in rural life are a clear indication of processes of diversification of use, as they not only play different roles, but also satisfy specific and unique needs in the lives of local people. Thus, given the existing background of exotic plant use in rural communities, we believe it important to study the diversification processes relating to fuelwood, and in particular to compare the UWPF between ecoregions. Several studies have shown that the ecological environment is one factor that determines the differential use of plant species (Ladio and Lozada 2004). These environmental differences combine with sociocultural particularities, giving rise to unique biocultural characteristics that affect the use and management of the plant surroundings (Alcorn 2000; Ladio and Lozada 2001).

This study focuses on three very different and geographically distant ecoregions (Chaco, Pampa and Patagonia), which therefore present very different socioenvironmental characteristics (e.g., climate, ecology, flora, culture) In Chaco, the work was carried out specifically in the Dry Chaco Serrano; en Pampa, on the eastern border, where the tala forests grow; and in Patagonia, in the grass-shrub steppe (Figure 1 and Table 1). It should be mentioned that we focused on the diversification of species used as a complement to the number of exotic species that have become part of the socioenvironmental system, but that this depends on the number of native species already in use in the community. This process constitutes a strategy to ensure a continued supply of fuelwood resources. Comparing these case studies also offers an opportunity to analyse and understand UWPF and its diversification, considering acquisition strategies and gathering areas.

The aims of this work were compared in these case studies: 1) Diversification with exotic species, considering total species richness and the ratio between exotic and native species used, 2) Diversification of the pressure of use (UP) on native and exotic species; 3) Diversification of acquisition strategies and gathering areas. Finally, we analysed whether the use of exotic and native species differed according to ecoregion, acquisition strategies, or the level of human intervention in their gathering areas. Our general hypothesis is that diversification processes vary between ecoregions due to biocultural differences. All these aspects will enable us to reflect on the role of exotic plants in the lives of local populations and the tension that exists with the conservationist perspective, which tends to disregard local needs.

This analysis has been enriched by a historical characterisation that explains the principal processes of change that took place in the three areas of study in relation to the use of fuelwood.

MATERIAL AND METHODS

Study Area

This study was carried out in three contrasting ecoregions of Argentina (Figure 1), in the phytogeographic provinces known as Dry Chaco (named in this article as Chaco), Pampa and Patagonia (Brown and Pacheco 2006; Burkart et al. 1999).

The most important climatic and geographic aspects of the ecoregions are given below (Table 1), as well as some general information on the rural populations and flora of these territories.

Chaco: The Sierra de Ancasti is a mountain range that forms part of the Pampean hills in the Ancasti district, in the southeast of Catamarca province. Vegetation in this region consists of species of the Dry Chaco Serrano, but it is also home to species characteristic of other environments such as Montes, Bolsones and Yungas (Palmeri et al. 2008; Perea et al. 2007). Jiménez-Escobar (2019) describes part of the vegetation in the Sierra as a mixture of arboreal elements typical of the semi-arid Chaco, such as "tala" (*Celtis* spp.), "chañar" [*Geoffroea decorticans* (Gillies ex Hook. & Arn) Burkart.], "sombra de toro" [*Jodina rhombifolia* (Hook. & Arn.), Reissek] and *Schinopsis lorentzii* (Griseb.) Engl], with elements typical of the montane Chaco, such as "molle" [*Lithraea molleoides* (Vell.) Engl.], "viscote" [*Parasenegalia visco* (Lorentz ex Griseb.) Seigler & Ebinger], "chuluca" [*Ruprechtia apetala* (Wedd.)] and "coco" (*Zanthoxylum coco* Gillies ex Hook. F. & Arn.), and species from the Yungas ecoregion–transition forest or Cebil forest–such as "cébil" [*Anadenanthera colubrina* (Vell.) Brenan], "ají del
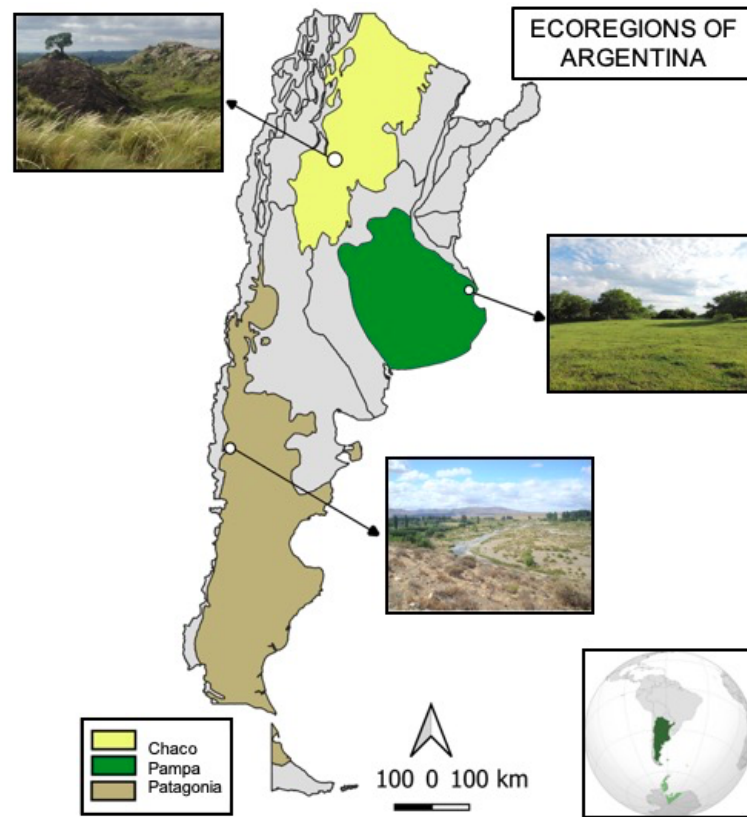
Figure 1. Study areas and their corresponding ecoregions in Argentina: (A) Dry Chaco, named in this article as Chaco (Sierra de Ancasti, Catamarca province); (B) Pampa (Parque Costero del Sur and its surroundings, Buenos Aires province); (C) Patagonia (Cushamen district, Chubut province).

Table 1. Climatic characteristics of the study area in the three studied ecoregions of Argentina.

	CHACO	**PAMPA**	**PATAGONIA**
Average elevation (m a.s.l.)	870	1	625
Annual precipitation (mm)	500 - 1200	1000 - 1200	100 - 200
Average annual temperature (°C)	19	16	12
Province	Catamarca	Buenos Aires	Chubut
Reference coordinates	28°40'S, 65°36'W	35°16'S, 57°14'W	42°10'S, 70°39'W
Climate	Warm humid	Humid temperate	Cold arid

zorro" [*Erythroxylum argentinum* (O.E.Schulz)] and "coronillo" [*Xylosma pubescens* (Griseb.)]. Even so, the richness of woody species for the region is unknown.

The Sierra is currently inhabited by rural populations who define their ancestry as Creole-Serrano, and who maintain a clear vocation for their rural lifestyle (Jiménez-Escobar 2019, 2021). Their subsistence economy is principally associated with traditional systems–the open field system–of livestock production. Although a lot of cattle production takes

place in this region, Ancasti is known mainly for its goat and sheep production. Agriculture carried out on a family scale is generally limited to small crofts where the principal crops are maize (*Zea mays* L.) and squash (*Cucurbita maxima* Duch.). The latest National Census revealed that the population in this district was 2900, representing 786 households or family units (INDEC 2010). It is noteworthy that in this region almost 45% of the population depend on fuelwood and coal for cooking.

Pampa: On the eastern edge of the Pampa re-

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gion we find tala forest (made up of *Celtis tala* Gillies ex Planch), which belongs to the Espinal phytogeographic province (Burkart et al. 1999; Cabrera 1971; among others). The southernmost sector of these forests is protected by the Parque Costero del sur Biosphere Reserve, which includes a small part of the coast of the district known as Magdalena, and approximately 70% of the Punta Indio district. Also growing in the tala forests of this area are "coronillo" (*Scutia buxifolia* Reissek), "sombra de toro" [*Jodina rhombifolia* (Hook. and Arn.) Reissek], "molle" [*Schinus longifolius* (Lindl.) Speg.], and to a lesser extent, "sauco" (*Sambucus australis* Cham. and Schltdl.), "curupí" (*Sapium haematospermum* Müll. Arg.), "ombú" (*Phytolacca dioica* L.) and "brusquilla" (*Colletia spinosissima* J.F. Gmelin); all these species grow in association with grasses, climbing plants and creepers. The tala forest alternates with grasslands in high zones, and with hydrophilic plants in low zones. Many introduced exotic woody species are also present, many of which have become naturalised, such as "mora" (*Morus alba* L.), "acacia negra" (*Gleditsia triacanthos* L.) and "ligustro" (*Ligustrum lucidum* Ait. F.) (Delucchi and Torres Robles 2009). The richness of woody species is estimated at 7 native and 16 exotic trees, plus 25 native and 5 exotic shrubs (Torres Robles and Arturi 2009). The reserve covers an area of 35000 hectares, consisting mainly of privately owned land. An extension of the area was recently requested, to include the Parque Costero del sur, and nucleus and buffering zones were created. The pruning and felling of native species in the tala forest are banned by municipal decrees and ordinances (Ordinance N°294/98, Punta Indio). In addition, conservation is promoted through tax benefits for those who preserve native species on their property (Decree N°761/2014, Magdalena) (Ghiani Echenique et al. 2018).

The principle economic activities in this region are extensive livestock production, exploitation of calcium carbonate from the soil substrate (for road construction), and tourism (Arturi et al. 2006). It should be noted that the presence of the tala forest does not hinder livestock farming; on the contrary, the forests provide food and shelter for the animals and this activity is thought to favour the permanence of these forests (Arturi et al. 2006). The local people have electricity but no running water or natural gas. According to the last INDEC census (2010), the largest urban centre within the Parque Costero del sur is Punta del Indio (569 inhabitants). In addition, around the park there are several small towns, such as Atalaya (720) in the district of Magdalena, and sectors which are mainly rural and have a widely dispersed population, like the Los Naranjos (115) neighbourhood. It is important to note that this census

revealed that 0.6% of homes in the Magdalena district and 1% in Punta Indio use wood or coal as their main cooking fuel.

Patagonia: the study area included the rural communities of Costa del Lepá and Gualjaina, in the District of Cushamen in the northeast of Chubut province. The predominant vegetation is grass-shrub steppe, made up principally of species such as "coirón" (*Festuca* sp.), "pasto hilo" (*Poa lanuginosa* Poir), "neneo" [*Azorella prolifera* (Cav.) G.M. Plunkett & A.N. Nicolas], "senecio" (*Senecio filaginoides* DC.), "mata perro" [(*Spegazziniophytum patagonicum* (Speg.)], "uña de gato" (*Nassauvia axillaris* D. Don), "calafate" (*Berberis microphylla* G. Forst), "molle" (*Schinus johnstonii* F.A. Barkley) and "barba de chivo" [*Retanilla patagonica* (Speg.) Tortosa], corresponding to the Central district of the Patagonian phytogeographical province (Cabrera 1971; Quintana 2014).

The main economic activities in the region are centred on sheep and goat farming, complemented by small-scale agriculture which is mostly for domestic consumption (Morales et al. 2017). In addition, a small proportion of the population is involved in commerce or construction or are employed by the state or private ranches. Some families with school-age children, and the elderly, receive state benefits. In general, the inhabitants lead a subsistence lifestyle and lack certain critical elements to satisfy their basic needs. They have no access to the gas or sewer networks, limited access to electricity, and use wood as their principal fuel for domestic heating and cooking. The statistics for Chubut province show that 14% of the homes in Cushamen use wood or coal for cooking (INDEC 2010).

Fieldwork phase

Following the ISE (2006) recommendations, previously informed consent was obtained from 72 family units living in rural contexts in the three areas: 22 in Chaco, 17 in Pampa and 33 in Patagonia; a total of 39 women and 33 men took part in the study. Interviewees were chosen using the "snowball" technique, complemented by random sampling (Albuquerque et al. 2014). Information on UWPF was obtained through open and semi-structured interviews, free listing, and participative workshops. We investigated the richness of plant species used by informants for fuel, in relation to their uses (i.e., heating, food preparation and cooking, ignition and production of fire), as well as their fuelwood acquisition strategies and gathering sites. These methods were complemented with other ethnobotanical techniques such as participant observation and guided walks with locals for plant identification (Albuquerque et

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al. 2014). In order to determine the species, botanical material was collected for reference. This material was used to make up herbaria which were deposited, depending on the study area, in the *Herbario del Museo Botánico* (CORD), of the *Instituto Multidisciplinario de Biología Vegetal* (IMBIV), *Universidad Nacional de Córdoba*; in the *Laboratorio de Etnobotánica y Botánica Aplicada* (LEBA), *Facultad de Ciencias Naturales y Museo de la Universidad Nacional de La Plata*; and in the *Centro de Investigación Esquel de Montaña y Estepa Patagónica* (CONICET-UNPSJB), following the recommendations for collections made by Martin (1995).

Data Analysis

Taxonomic, biogeographical and nomenclatural classification of the species was carried out following the proposal published in Plantas Vasculares del Cono Sur (Zuloaga et al. 2008) and corroborated by The International Plant Names Index (IPNI 2020). The categories "native" and "exotic" were used to refer to the biogeographic origin of the species, following Das and Duarah (2013), who defined exotic species as human-introduced plants that become established, proliferate and spread from one geographical area to another; the introduction may or may not be intentional. To determine the invasive character of the exotic species surveyed, we consulted the database of the National System on Invasive Exotic Species (SNEEI 2020). This database also includes species being cultivated or in captive breeding situations, but which have a history of invasion on an international level.

It should be clarified that the analysis of richness used in each ecoregion may have been underestimated; however, we consider that the species registered in our work are representative of the main species used as fuelwood in each region, according to the literature (Cardoso et al. 2013; Doumecq 2019; Doumecq 2020 a,b; Jiménez-Escobar and Martínez 2017; Jiménez-Escobar 2021; Martínez 2017; Rodríguez López et al. 2015; Morales et al. 2017).

Based on interviewees' comments about the woody species in current use (native and exotic) in each ecoregion, we calculated the ratio of exotic richness and native richness as an indirect measure of diversification. That is, diversification refers to an increase in the number of exotic species used, but is related to the number of native species currently used.

In addition, three categories related to acquisition strategies were established for the study of diversification of this aspect: 1) Species that are searched for, cut, collected and transported by locals (gathered); 2) Species bought in grocer's or other shops in urban areas (purchase); 3) Fuelwood received by family units through programmes of action, assistance, help from the state or other public bodies (social welfare programmes).

Furthermore, the data given by interviewees on gathered fuelwood were assigned to two etic categories, according to the level of intervention of the gathering sites: A) Fuelwood from forested zones, protected areas or natural reserves (low intervention level); B) Fuelwood gathered in or close to peridomestic areas, vegetable gardens, roadsides, hedges, smallholdings and plantations (high intervention level). These categories, based on human intervention, are related to two factors: one is associated with the proximity of gathering sites to the domestic unit; the second is defined at different levels by the norms and regulations–at a regional level–of the protected natural areas. For this reason we limited the high intervention level–in local terms–to the areas that the public can access, where fuelwood gathering is permitted, and to areas inhabited by locals. With regard to the categories of intervention level, it is important to note that exotic species are present in all the environments mentioned (Busso et al. 2013), including the conservation areas (Delucchi and Torres Robles 2009; Kutschker et al. 2015). We therefore consider it possible to analyse this category independently of biogeographic origin of the species cited. In addition, purchased fuelwood was separated into two categories: local origin (high or low intervention), or non-local, originating from other regions of the country. For an indirect evaluation of the UP of the fuel species, we estimated the consensus of use (CU): we calculated the number of informants (n) that used species (i) in relation to the total number of family units surveyed per ecoregion (N): CU= ni/N (Molares and Ladio 2012). We also established species similarity between the three ecoregions according to biogeographical origin using the Jaccard similarity index, by means of the formula: SJ = C/(A+B+C´) x 100, where SJ = the Jaccard similarity coefficient; A = number of species present in ecoregion a but absent in ecoregion b; B = number of species present in ecoregion b but absent in ecoregion a, and C = the number of species present in both ecoregions a and b (Real and Vargas 1996). In addition, to visualise the similarity of species present in the different ecoregions, we performed a multidimensional scaling analysis (PROXSCAL-MDS). This analysis spatially represents the relative positions of all the species according to their similarity level, using the Euclidean distance. The normalised raw stress value was considered a criterion for adjustment of the model, showing values close to 0.1 (Hair et al. 1998).

Experimental design

The total richness of species used as fuelwood was analysed according to biogeographic origin, us-

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ing the binomial test to test the null hypothesis that exotic and natives are used in the same proportion ($p < 0.05$). To evaluate diversification of species, we analysed how the proportion (or ratio) of native and exotic species used varied between ecoregions, using the Chi-square test ($p < 0.05$). We also assessed the influence of biogeographical origin (i.e., binary dependent variable) on the UP for each species, and between the different ecoregions (principal effect) using a generalised linear model (GLM) ($p < 0.05$). Species richness was compared according level human intervention using using the binomial test ($p < 0.05$).

Finally, a GLM was also used for an integral study of how biogeographical origin (binary dependent variable) varied with the following independent variables: the three ecoregions, the acquisition strategies, and the level of intervention of the gathering sites as principal effects. For application of the statistical model, these categories of acquisition strategies were grouped into two variables: gathered fuelwood (1) and non-gathered fuelwood (2 and 3). The variables of the model and the distribution of all the cases are detailed in Table 2.

In both models we used a binomial distribution and a logit link function, which was significant (Omnibus test, chi-square test, $p < 0.05$). The deviation/gl was considered an adjustment criterion, whose values were close to 1, indicating the suitability of the models. We also calculated the tolerance and the variation inflation factor (VIF) to evaluate multicollinearity within the models. Tolerance and VIF values were close to 1 for all the covariables, indicating that multicollinearity did not significantly affect the estimates made (Chatterjee et al. 2000). Heteroscedasticity was corrected using a heteroscedasticity-consistent covariance estimator (robust estimator).

The statistical analyses were performed using the SPSS 22.0 program.

RESULTS

Diversification of species between ecoregions

The total number of plant species used for fuel in the three ecoregions was 78, belonging to 56 genera and 27 botanical families (Table 4). Of this total 51 fuelwood species (65.3%) were native plants, which were complemented by 27 exotic species (34.6%) (Binomial Test, $p = 0.009$).

Differences between the proportions of native and exotic plants used depended on ecoregion (Chi-square test, p=0.03). The ecoregion that used the highest number of exotic fuelwood species was Pampa (15 species, 62.5%), followed by Chaco (9 species, 30%) and Patagonia (7 species, 23.4%).

The similarity of fuelwood species used in relation to biogeographic origin was low: total species similarity between Chaco and Pampa was 6%, between Chaco and Patagonia, 5% and Patagonia and Pampa, 0% (Figure 2A). Figure 2B shows the 2 species shared by Pampa and Chaco (*M. alba* and *V. caven*), to the right of Dimension 1, whereas *P. alba*, *U. minor* and *S. humbolditiana*, the species shared by Chaco and Patagonia, are on the left. Regarding biogeographical origin, the similarity value for exotic species between Chaco and Pampa was 9% (*Morus alba* and *Populus* spp.) and for native species 3% (*Vachellia caven*); Chaco and Patagonia shared 14% of their exotic plants (*Populus alba* and *Ulmus minor*) and 2% of native plants (*Salix humboldtiana*).

Diversification in use pressure between ecoregions

There was no ecoregion effect on the UP of native species (Chi-square test, $p = 0.98$); that is, the pressure was distributed in a very similar way between native and exotic species.

The species with the highest UP in Chaco were *Vachellia caven* (UP: 77.3%) and *Condalia* spp. (UP: 68.2%), both native species, whereas in Patagonia the plants that stood out were *Salix* sp. (UP: 87.9%), a much cultivated and very invasive species in this area, and *Schinus johnstonii* (UP: 78.8%), a native plant endemic to Argentina. Finally, in Pampa the highest UP was shared by various exotic species of the *Eucalyptus* genus (UP: 76.5%) and *Celtis tala* (UP: 58.8%), a native species characteristic of the tala forests.

Diversfication strategies in the acquisition of fuelwood species

The most common acquisition strategy in all the studied ecoregions was gathering, complemented with purchase and welfare programmes (Table 5). Of the total number of species used in Chaco, 96.7% were gathered; in Pampa this number was 87.5%, and in Patagonia 93.3%. Diversification was evidenced by the purchase of fuelwood, which accounted for 28.6% of the total species in Pampa and 13.3% in Chaco. In contrast, in Patagonia gathering was diversified with wood obtained from welfare programmes, the state, or other institutions (16,6%).
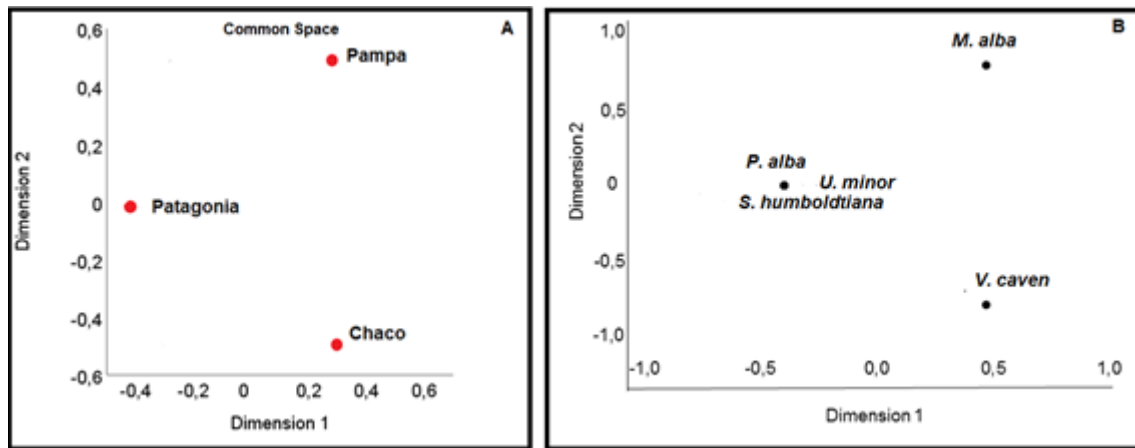
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Figure 2. Multidimensional scaling (PROXSCAL) of Dimensions 1 and 2. (A) Common space shared by the three ecoregions. (B) Species shared between the ecoregiones.

Table 2. Summary of variables analysed using the generalised linear model in relation to management of fuelwood species in three ecoregions of Argentina.

Variables	Categories	N	Percentage of cites (%)
Dependent variable			
Biogeographical origin	Native	347	72.6
	Exotic	131	27.4
Independent variables			
Ecoregion	Chaco	200	41.8
	Pampa	60	12.6
	Patagonia	218	45.6
Acquisition strategies	Gathered	410	85.8
	Non-gathered	68	14.2
Gathering areas	Low intervention	145	30.3
	High intervention	333	69.7

Table 3. Diversification of fuelwood species according to biogeographic origin and their acquisition, management and gathering areas in three ecoregions of Argentina.

	Chaco			Pampa			Patagonia			All ecoregions		
	N	E	Total	N	E	Total	N	E	Total	N	E	Total
Acquisition strategies*												
Gathering	20	9	**29**	6	15	**21**	22	6	**28**	46	26	**72 (92.3%)**
Purchase	3	0	**3**	4	2	**6**	2	2	**4**	9	4	**13 (16.6%)**
Welfare programmes	4	0	**4**	0	0	**0**	2	3	**5**	6	3	**9 (11.5%)**
Gathering areas												
Major intervention	15	9	**24**	1	13	**14**	1	7	**8**	16	26	**42 (53.8%)**
Minor intervention	21	0	**21**	6	8	**14**	23	2	**25**	48	10	**58 (74.4%)**
Not local	1	0	**1**	4	0	**4**	0	0	**0**	5	0	**5 (6.5%)**

N= native species; E= exotic species
* These categories are not exclusive; a single species may be obtained by different strategies and from different areas.

Table 4. Fuelwood species currently in use in three contrasting ecoregions of Argentina. Organised by ecoregion, scientific name and botanical family. Biogeographical origin: exotic (E), native (N), native species endemic to Argentina (N*). Acquisition strategies: purchased (P), gathered (G), social welfare programmes (W). Gathering areas: major intervention (Ma), minor intervention (Mi), Pressure of use (UP) for the 72 family units (Chaco: 22, Pampa: 17, Patagonia: 33). **Combustible species with high UP (> 50). ***Invasive or potentially invasive exotic species.

ECOREGION, Scientific name (FAMILY)	Biogeographic origin	Acquisition strategies	Gathering sites	UP
CHACO				
Allophylus edulis (A.St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl. (SAPINDACEAE)	N	G	Mi	9.1
Anadenanthera colubrina (Vell.) Brenan var. *cebil* (Griseb.) Altschul (FABACEAE)	N	P, W, G	Mi	13.1
Aspidosperma quebracho-blanco Schltdl. (APOCYNACEAE)	N	G	Mi	4.5
Broussonetia papyrifera (L.) Vent. (MORACEAE)	Ex***	G	Mi	13.6
Celtis iguanaea (Jacq.) Sarg. (CANNABACEAE)**	N	G	Ma, Mi	59.1
Celtis sp. 1 (CANNABACEAE)**	N	G	Ma, Mi	59.1
Condalia buxifolia Reissek (RHAMNACEAE)**	N	G	Ma, Mi	68.2
Condalia microphylla Cav. (RHAMNACEAE)**	N*	G	Ma, Mi	68.2
Ficus carica L. (MORACEAE)	Ex	G	Mi	9.1
Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart (FABACEAE)	N	G	Ma, Mi	9.1
Lithraea molleoides (Vell.) Engl.(ANACARDIACEAE)	N	G	Ma, Mi	54.5
Melia azedarach L. (MELIACEAE)	Ex***	G	Ma	18.2
Mimosa farinosa Griseb. (FABACEAE)	N	G	Ma, Mi	13.6
Morus alba L. (MORACEAE)	Ex***	G	Ma	13.6
Myrcianthes cisplatensis (Cambess.) O. Berg (MYRTACEAE)	N	G	Mi	13.6
Parapiptadenia excelsa (Griseb.) Burkart (FABACEAE)	N	W, G	Ma, Mi	4.5
Parasenegalia visco (Lorentz ex Griseb.) Seigler & Ebinger (FABACEAE)	N	W, G	Ma, Mi	18.2
Populus alba L. (SALICACEAE)**	Ex***	G	Ma	18.2
Populus spp. (SALICACEAE)	Ex***	G	Ma	18.2
Prosopis alba Griseb. (FABACEAE)	N	G	Mi	27.3
Prunus persica (L.) Batsch (ROSACEAE)	Ex***	G	Ma	9.1
Ruprechtia apetala Wedd.(POLYGONACEAE)	N	G	Ma, Mi	4.5
Salix alba L. (SALICACEAE)	Ex***	G	Ma	9.1
Salix humboldtiana Willd. (SALICACEAE)**	N	G	Ma	59.1
Sarcomphalus mistol (Griseb.) Hauenschild (RHAMNACEAE)	N	G	Ma, Mi	4.5
Schinopsis lorentzii (Griseb.) Engl. (ANACARDIACEAE)	N	P, W	Mi, Not local	45.4
Ulmus minor Mill. (ULMACEAE)	Ex	G	Ma	4.5
Vachellia aroma (Gillies ex Hook. & Arn.) Seigler & Ebinger (FABACEAE)	N	G	Ma, Mi	9.1

Vachellia caven (Molina) Seigler & Ebinger (FABACEAE)**	N	G	Ma, Mi	77.3
Zanthoxylum coco Gillies ex Hook. f. & Arn. (RUTACEAE)	N	G	Ma, Mi	45.4
PAMPA				
Celtis australis L. (CANNABACEAE)	Ex	G	Ma	5.9
Celtis tala Gillies ex Planch (CANNABACEAE)**	N	G	Mi	58.8
Colletia spinosissima J.F. Gmel. (RHAMNACEAE)	N	G	Mi	5.9
Eucalyptus camaldulensis Deginani(MYRTACEAE)	Ex***	G	Ma	5.9
Eucalyptus globulus Labill.(MYRTACEAE)	Ex***	G	Ma	5.9
Eucalyptus saligna Sm. (MYRTACEAE)	Ex	G	Mi	5.9
Eucalyptus spp. (MYRTACEAE)**	Ex***	G, P	Ma, Mi	58.8
Fraxinus pennsylvanica Marshall (OLEACEAE)	Ex***	G	Ma	17.6
Gleditsia triacanthos L. (FABACEAE)	Ex***	G	Ma, Mi	17.6
Handroanthus heptaphyllus (Vell.) Mattos (BIGNONIACEAE)	N	P	Not local	5.9
Laurus nobilis L. (LAURACEAE)	Ex***	G	Ma, Mi	23.5
Ligustrum lucidum W.T. Aiton (OLEACEAE)	Ex***	G	Ma, Mi	23.5
Morus alba L. (MORACEAE)	Ex***	G	Mi	5.9
Parkinsonia aculeata L. (FABACEAE)	N	G	Ma, Mi	11.8
Populus spp. (SALICACEAE)	Ex***	G, P	Ma, Mi	17.6
Prosopis kuntzei Harms (FABACEAE)	N	P	Not local	5.9
Prunus domestica L. (ROSACEAE)	Ex***	G	Ma	5.9
Racosperma melanoxylon (R. Br.) Pedley (FABACEAE)	Ex***	G	Ma, Mi	11.8
Robinia pseudoacacia L. (FABACEAE)	Ex***	G	Ma	11.8
Salix spp. (SALICACEAE)	Ex***	G	Ma	11.8
Schinopsis balansae Engl. (ANACARDIACEAE)	N	P	Not local	5.9
Schinus longifolius (Lindl.) Speg. (ANACARDIACEAE)	N	G	Mi	5.9
Scutia buxifolia Reisseck (RHAMNACEAE)	N	G	Mi	6.1
Vachellia caven (Molina) Seigler & Ebinger (FABACEAE)**	N	G, P	Ma, Mi, Not local	5.9
PATAGONIA				
Adesmia volckmannii Phil. (FABACEAE)	N	G	Mi	6.1
Atriplex lampa (Moq.) D. Dietr. (CHENOPODIACEAE)	N*	G	Mi	3
Azorella monantha Clos (APIACEAE)	N	G	Mi	6.1
Azorella prolifera (Cav.) G.M. Plunkett & A.N. Nicolas (APIACEAE)	N	G	Mi	3
Baccharis salicifolia (Ruiz & Pav.) Pers. (ASTERACEAE)	N	G	Mi	18.2
Berberis microphylla G. Forst. (BERBERIDACEAE)	N	G	Mi	27.2
Chuquiraga avellanedae Lorentz (ASTERACEAE)	N*	G	Mi	18,2
Corynabutilon bicolor (Phil. ex K. Schum.) Kearney (MALVACEAE)	N	G	Mi	33.3
Ephedra ochreata Miers (EPHEDRACEA)	N	G	Mi	3
Fabiana imbricata Ruiz & Pav.(SOLANACEAE)	N	G	Mi	3

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Lycium sp. 1 (SOLANACEAE)	N	G	Mi	27.3
Maihuenia patagonica (Phil.) Britton & Rose (CACTACEAE)	N	G	Mi	3
Malus domestica Borkh. (ROSACEAE)	Ex***	G	Mi	6.1
Nassauvia axillaris (Lag. ex Lindl.) D. Don (ASTERACEAE)**	N	G	Mi	54.5
Nothofagus antarctica (G. Forst.) Oerst. (NOTHOFAGACEAE)	N	P, W	Mi	45.4
Ochetophila trinervis (Gillies ex Hook. & Arn.) Poepp. ex Miers (RHAMNACEAE)	N*	G	Mi	21,2
Pinus sp. 1 (PINACEAE)	Ex***	W	Mi	3
Populus alba L. (SALICACEAE)**	Ex***	G, P, W	Ma, Mi	54.5
Prosopis denudans Benth. var. *patagonica* (Speg.) Burkart (FABACEAE)	N*	G	Mi	15.2
Prunus cerasus L. (ROSACEAE)	Ex***	G	Ma	9.1
Retanilla patagonica (Speg.) Tortosa (RHAMNACEAE)	N*	G	Mi	15,1
Salix humboldtiana Willd. (SALICACEAE)**	N	G; W; P	Ma, Mi	9.1
Salix sp. 1 (SALICACEAE)**	Ex***	G, P, W	Ma, Mi	87.9
Salix viminalis L. (SALICACEAE)	Ex***	G	Ma	3
Schinus johnstonii F.A. Barkley (ANACARDIACEAE)**	N*	G	Mi	78.8
Schinus patagonicus (Phil.) I.M. Johnst. (ANACARDIACEAE)	N	G	Mi	3
Senecio filaginoides DC. var. filaginoides (ASTERACEAE)	N	G	Mi	24.2
Senecio sp. (ASTERACEAE)	N	G	Mi	3
Spegazziniophytum patagonicum (Speg.) Esser (EUPHOR-BIACEAE)	N	G	Mi	24.2
Ulmus minor Mill. (ULMACEAE)	Ex	G	Ma	4.5

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Exotic species play a significant role in the diversification of acquisition strategies in all three ecoregions studied. In Chaco, 32% of the gathered species were exotic, while all the fuelwood obtained through purchase or welfare programmes was native; in Pampa 66.6% of the gathered species and 33.3% of the purchased species were exotic. Finally, in Patagonia 21.4% of gathered species, 50% of purchased species and 60% of those obtained through welfare programmes were exotic in origin.

Level of human intervention in the fuelwood gathering sites

Local inhabitants generally gathered more fuelwood from sites which had a minor level of intervention (Mi) than from those that suffered major intervention (Ma) (Table 2). Nevertheless, the results show no significant differences (Binomial test, $p = 0.159$). With regard to ecoregion, in Chaco 80% of the species currently used as fuelwood came from areas with major intervention (Binomial test, $p = 0.0001$). In contrast, in Patagonia 83% of the species were obtained from areas with minor intervention (Binomial test, $p = 0.0001$). The total richness in Pampa did not vary according to gathering area: minor-intervention areas provided 58% of the species, and major-intervention areas 62% (Binomial test, $p = 0.69$).

Differential use of native and exotic species, by ecoregion

According to the model, the biogeographical origin of the species used varied between ecoregions and gathering areas, but not acquisition strategies (GLIM, $\chi^2 = 269$; $GL = 4$; $p = 0.0001$, Table 6). In relation to ecoregion, the proportion of native and exotic species used varied according to biogeographic origin ($\chi^2 = 45$; $GL = 2$; $p = 0.0001$). In Chaco, native species were used 67 times more frequently than in Patagonia, whereas Pampa used more exotic than native species (21% more exotic than native species when compared to Patagonia). Similarly, biogeographic origin varied with the gathering areas of fuelwood species ($\chi^2 = 48.1$; $GL = 1$; $p = 0.0001$).

As regards diversification, Pampa was the ecoregion that diversified most with exotic species and Chaco diversified less than Patagonia (Table 6).

DISCUSSION

The role of exotic fuelwood in diversification

The incorporation of exotic species can be considered a means of diversification rather than competition with native species (Albuquerque 2006; Alencar et al. 2010), given that exotic species are added to the repertoire of native plants already used as fuelwood. Our results show that diversification with exotic species differs between ecoregions due to socioenvironmental differences between the regions. As regards the richness of plants used, the three regions contained a total of 78 fuelwood species, of which 35% were exotic species. This may be associated with scarcity, lack of access or a decrease in native resources, which may lead inhabitants to diversify and use new kinds of fuelwood in place of the traditional species, as suggested by the diversification hypothesis (Albuquerque 2006). Considering each ecoregion separately, however, we see that Pampa has the highest level of diversification with exotic species (63%), followed by Chaco (30%) and Patagonia (24%). In Chaco and Patagonia the use of native species predominates, a pattern that concurs with other studies (e.g., Cardoso et al. 2013; Ramos et al. 2008; Rodríguez López et al. 2015).

Diversification of the UWPF in the three ecoregions varies in the richness of exotic fuelwood, and the species are mostly unique to each region, with very low similarity. Despite the expected differences in native plants between the different ecoregions, we could have found a higher number of shared exotic species because of the cultivation of exotic fuelwood species promoted by government institutions, and also because of the propagation capacity of these species. The native species used indicate local particularities due to phytogeographical and sociocultural differences. Furthermore, the exotic species are influenced not only by environmental requirements, but also multiple cultural factors–associated with selection, use and management–which determine their importance in the culture and domestic life of rural areas and define their establishment in any particular region (Martínez and Manzano-García 2019).

The few fuelwood species shared between regions are native species with a wide geographical distribution, such as *Vachellia caven*, which is found in both the Chaco and Pampa regions. On the other hand, the exotic species registered are plants that have long been cultivated in Argentina, and have even become naturalised, like some species from the genera *Morus*, *Populus* and *Salix* (MAGyP 2014). This diversification with exotic species, therefore, is associated with historical processes of intentional species introduc-

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Table 5. Diversification of fuelwood species according to biogeographic origin and their acquisition, management and gathering areas in three ecoregions of Argentina.

	Chaco			Pampa			Patagonia			All ecoregions		
	N	E	Total	N	E	Total	N	E	Total	N	E	Total
Acquisition strategies*												
Gathering	20	9	**29**	6	15	**21**	22	6	**28**	46	26	**72 (92.3%)**
Purchase	3	0	**3**	4	2	**6**	2	2	**4**	9	4	**13 (16.6%)**
Welfare programmes	4	0	**4**	0	0	**0**	2	3	**5**	6	3	**9 (11.5%)**
Gathering areas												
Major intervention	15	9	**24**	1	13	**14**	1	7	**8**	16	26	**42 (53.8%)**
Minor intervention	21	0	**21**	6	8	**14**	23	2	**25**	48	10	**58 (74.4%)**
Not local	1	0	**1**	4	0	**4**	0	0	**0**	5	0	**5 (6.5%)**

N= native species; E= exotic species

* These categories are not exclusive; a single species may be obtained by different strategies and from different areas.

Table 6. Parameters estimated from the generalised linear model.

Parameter	B	Standard error	Chi-square Wald	d.f.	Sig.	Exp(B)
(Intercept)	1.805	0.2293	61.969	1	0.000	6.078
Ecoregion						
Chaco	4.204	0.7633	30.337	1	0.000*	66.966
Pampa	-1.328	0.4231	9.846	1	0.002*	0.265
Patagonia	0	.	.	.	.	1
Acquisition strategy						
Non-gathered	-0.380	0.5381	0.499	1	0.480	0.684
Gathered	0	.	.	.	.	1
Gathering areas						
Major intervention	-5.113	0.7367	48.154	1	0.000*	0.006
Minor intervention	0	.	.	.	.	1

*Dependent variable: Biogeographical origin; B (Beta): Standardised regression coefficient; Wald: the chi-square that tests the null hypothesis, df: degrees of freedom; Sig: level of significance; Exp (B): Odds ratios calculated by exponentiation of the coefficients (the probability that an event will happen in relation to the probability it will not). *Indicates significant differences.*

tions carried out by the communities and technical institutions working in the regions.

Whether introduced intentionally or accidentally, most of these exotic plants have behaved in the country in ways deemed negative for environmental conservation. Several authors have warned of the potential of some of these exotic species to invade ecosystems and impact negatively on native populations, due to their rapid propagation and growth rates (Busso et al. 2013; Das and Duarah 2013; Mack et al. 2000). Nevertheless, this characteristic may be attenuated through diversified fuelwood use, as proposed

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by Richeri et al. (2013).

With regard to the UP component affecting native and exotic plants, the patterns observed are different to those found for the richness of plants used. The UP value is similar in all three ecoregions for native and exotic species, which could be interpreted as a possible process of attenuation, due to the impact generated by their use. Nevertheless, at equal use pressure the native species are more affected than the introduced species, which generally have a more rapid growth rate (Rejmánek and Richardson 1996).

Although the UP on native species has been highlighted (Marofu et al. 1997; Ogunkunle and Oladele 2004), little is known about this feature for exotic UWPF. Our results corroborate the fact that exotic species are also currently under strong use and consumption pressure in the ecoregions studied here. These results, like those found for richness, support the diversification hypothesis put forward by Albuquerque (2006). Considering the scenarios proposed by the Social-Ecological Theory of Maximization (Albuquerque et al. 2019), exotic species are highlighted in local systems only when they present competitive advantages over native plants. The caloric properties of exotic woods and their phylogenetic profile, rapid growth and abundance throughout the year, among other sociocultural components, could be important variables of the n-dimensional space that explains human firewood selection. Future research should be carried out to elucidate these aspects.

If we consider acquisition strategies, we also see that gathering has diversified through purchase and welfare programmes. However, gathering remains the most frequently used strategy, as described for other rural societies (Bhatt and Tomar 2002; Jashimuddin et al. 2006; Silva et al. 2018). This phenomenon shows that diversification depends on the possibilities presented in each context. While inhabitants have other acquisition options, multi-level or nested relationships, such as economic conditions and social organisation (e.g., pooling), are crucial in defining the deployment of such strategies (Berkes and Ross 2016).

Regarding the level of intervention of gathering areas, the patterns found are complex and vary between ecoregions. Patagonia is characterised by the use of areas with minor intervention, whereas the opposite is true for Chaco. In Pampa, areas with minor and major intervention are used equally. These results reveal the processes of transformation of the landscape in these regions. A temporal analysis of the changes in the three regions could provide numerous tools to help us understand how human action has affected the landscape, for different reasons, and how in turn this action is, recursively, a consequence of these changes (Berkes and Ross 2016).

Our integral analysis showed that the use of exotic in relation to native species varied according to ecoregion and the level of human intervention in gathering areas, unlike the acquisition strategies. Patterns differed between regions, but areas with major intervention were always used to extract exotic species, in agreement with Uddin et al. (2013), whereas native plants were gathered principally from areas with minor intervention, even though many exotic species grew in these areas. In effect, exotic species are strongly associated with anthropogenic environments (Santos et al. 2014). Within this framework, the areas with major intervention in this work are principally linked with domestic activities (patios, paths, vegetable gardens, smallholdings, roads and plantations). Therefore, as mentioned by Cardoso et al. (2015) and Silva et al. (2018), the proximity of these spaces to dwellings probably facilitates the acquisition of fuelwood, ease of access playing an important role in its acquisition.

The importance of historical background in diversification

Leonti et al. (2020) have recently proposed that the diversification hypothesis should be enriched by the historical background of the plants used. In line with this, we understand the importance of the different historical trajectories related to fuelwood acquisition in the ecoregions studied. These regions have different histories of occupation and landscape construction. We will include a brief summary of this below, which will help explain the different diversification patterns currently observed, although they cannot be tested against the available data from a hypothetical deductive approach (Ferreira et al. 2021).

In Pampa in particular, where more exotic species are used than in the other ecoregions, trees were introduced early (in the 16th century), and this became common practice during the consolidation of ranches as the productive unit of the region. These trees were introduced for various reasons, one being the scarcity of fuelwood, since the tala forests were being devastated due to the arrival of immigrants (Colonial period). These exotic species, now part of the landscape, are much used and highly valued by locals (Doumecq 2019).

Migratory processes and occupation of the study area in Chaco differ from Pampa. The Chaco region became very prosperous in terms of livestock breeding from the mid 17th century till the end of the 19th century, when certain economic and social processes led to a considerable decline in its population, with constant migratory waves (Bazán 2006). Furthermore, it could be said that for many years the peasant community of Sierra de Ancasti was rather isolated ge-

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ographically due to its orographic conditions; it was also isolated in terms of communication (mainly due to poor access roads, the lack of a railroad system and little contact with the provincial capital.

This may explain why the inhabitants of this region developed such a strong bond with their surroundings, adapting to it and taking advantage of it, experimenting predominantly with native resources.

In Patagonia a similar process occurred, particularly in the rural communities of the steppe, whose subsistence lifestyle depends largely on native woody plant resources for fuelwood. Although locals traditionally obtained wood from wild natural environments close by, and still do, over time they have developed other strategies to guarantee a continuous supply of this resource to satisfy their energy needs. Mainly in recent years, peridomestic afforestation of exotic species has been promoted in the south of the country by external organisms. This has played an important role in mitigating the fuelwood shortage and also provides other services and uses associated with construction materials (Cardoso and Ladio 2011; Morales et al. 2017).

Why do we highlight exotic species as agents of diversification?

The prominence being gained by exotic species due to certain advantages they have over native species has been emphasised by several authors. These advantages are related to growth patterns, availability and accessibility, and offer numerous benefits to locals (Cardoso et al. 2015; Doumecq 2019; Jiménez-Escobar 2021; Martínez and Manzano-García 2019; Medeiros 2013; Morales et al. 2017; Santos et al. 2014; Silva et al. 2018).

All this invites us to reflect on the role played by exotic species in terms of the conservation of native species. What would happen if these exotic species were not available? Conservation policies in protected areas tend to promote eradication or elimination of exotic species (regardless of their biology, reproductive ecology or invasive character) as they are considered harmful (Doumecq et al. 2020b; Silliman et al. 2014). Similarly, many environmental agents evaluate the presence of these resources as negative, interested only in the conservation of native species, exotic species–in environmental terms–being considered disruptive (Doumecq 2019; Gantchoff et al. 2018). Even so, it should be clarified that from the perspective of rural communities, these academic categories (native/exotic) tend not to be considered or to coincide with locals' appropriation of the fauna; the idea of "invasive" even tends to include certain native species that hinder them carrying out their subsistence activities (Martínez and Manzano-García 2019). Exotic

species form part of the local cultural heritage; they are known, used, and included in everyday practices independently of their origin, enriching the repertory of plants used by the local people (Chamorro and Ladio 2021; Doumecq et al. 2020b; Ghiani Echenique et al. 2018; Martínez and Manzano-Garcia 2019). The exotic species used for fuel are thus just as important as the native species in the subsistence lifestyle of the rural communities studied.

CONCLUSION

In contrast to the concerns associated with cases of biological invasion generated by exotic plants, this study reveals the importance of exotic fuelwood plants for rural dwellers. Currently, these exotic species not only expand the repertoire of plants that are known and used by locals, but also form part of intricate cultural processes (e.g., selection, local management, pressure of use, human intervention, and acquisition strategies) directly related to diversification. Although this study does not evaluate the effect on the environment of fuelwood gathering, its relation to deforestation rates, or the extraction of native plants, these exotic plants may play an important role in the conservation of native species. Furthermore, the plant richness and high percentage of native species used can be taken advantage of for future conservation projects, since using a high number of species may imply efficient use of the available resources, reducing risk for some specific plant groups and mitigating to some extent the pressure on natural plant coverage. Considering the importance of historical background in understanding current diversification processes, we propose the implementation of social welfare programs, national policies and conservation strategies associated with the provisioning, use and management of fuelwood, focusing on satisfying the needs of each of the regions and localities from the starting point of their own local trajectories. We underline the importance of identifying and valuing the knowledge and wisdom of rural communities in relation to the exploitation of plant resources.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare there are no competing interests.

CONTRIBUTION STATEMENT

Conceived the idea presented: AL, DM, MBD, NDJ
Carried out the study: DM, MBD, NDJ
Carried out the data analysis: AL, DM, MBD, NDJ
Wrote the first draft of the manuscript: DM, MBD, NDJ
Review and final writing of the manuscript: AL, DM, MBD, NDJ
Supervision: AL

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