Starting points for the restoration of desertified drylands: puesteros’ cultural values in the use of native flora

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**ABSTRACT**

In rural dryland areas, the socioeconomic diagnosis of the population and their traditional knowledge of the flora are key to restoration. In this study, we asked rural people (locally called ‘puesteros’) about their knowledge of the native flora, in a settlement of 160 inhabitants, located in drylands of Argentine. For this, semi-structured surveys and open interviews were carried out with 30 puesteros. The surveys collected information about the puesteros’ socio-economic characteristics, their knowledge and value about the use of species, and their interest in planting those species in their farms. Once the list of multipurpose species was obtained, we reviewed the scientific literature to know some of their favorable ecological attributes. The interviews were carried out to know the limitations and advantages associated with planting native species in the puesteros’ home gardens. Our results show that 33% of the people surveyed were illiterate, and their primary economic source of income was livestock.

In the surveys, the puesteros mentioned 44 multipurpose species, which were classified by their uses. 97% of respondents expressed interest in planting on their farms and mentioned 21 potentially useful species. Of the 44 multipurpose species mentioned by the puesteros, we found that 22 had ecological attributes for restoration. In the interviews, the puesteros identified the factors that limited and favored plantations. They had already planted 44 species in their home gardens for different purposes. The implications of current local knowledge for future socio-ecological approaches to productive restoration in drylands are discussed.

**Introduction**

In response to critical current socio-ecological problems, the United Nations (UN) in 2015 created the 2030 Agenda for Sustainable Development, which included among its goals the combat of desertification and restoration, particularly in the drylands (arid, semi-arid, and sub-humid ecosystems), that cover 40% of the planet (approximately 15 billion ha) (UNCCD (United Nations Convention to Combat Desertification) 2011). Furthermore, on 1 March 2019, the UN declared the ‘Decade on Ecosystem Restoration’(2021–2030) to promote the recovery of severely degraded ecosystems, particularly drylands affected by desertification (Aronson et al. 2020; UN (United Nations) 2020).

In Argentina, the Monte ecosystem is a dryland area that covers 50 million ha (Busso and Fernández 2017). The southern part of the Monte ecosystem is found in Patagonia, covering around 3 million ha, 2.8 million of which (94%) present low to very severe desertification levels (Mazzonia and Vazquez 2010). The degradation of this ecosystem has a social and cultural origin. At the end of the 19th century (1880), the Argentine government carried out an official project to exterminate all indigenous people (called the ‘Desert Campaign’) whose main objective was to consolidate the political dominance in these extensive territories to expand the livestock production frontier (Blanco 2012). The results of this conquest were the devastation of both natural ecosystems and native inhabitants. Most of the indigenous populations of various ethnic groups (e.g. Mapuches and Tehuelches) were reduced almost to their limit of extinction. The groups that survived were socially marginalized (Falaschi 1996). This social catastrophe produced a strong cultural capital loss (called by some authors ‘cultural erosion’), particularly in relation to biodiversity knowledge (Braitlovsky and Foguelman 2004; Sujarwo et al. 2014).

Within the context of border expansion policies, European immigrants settled in arid and semi-arid Monte areas, where sheep, goats, mules and horses were massively introduced to supply national and international markets, without considering the environmental limitations of these ecosystems (Mazzonia and Vazquez 2010). Livestock produced short-term economic benefits, but with long-term sustainability problems, which resulted in drastic environmental...
degradation (Andrade 2003; Busso and Fernández 2017).

By 1910, with the start of oil and gas extraction, vast extensions of Monte ecosystems were dismantled for the construction of infrastructures, such as roads, pipelines, locations, and additional facilities (Sarandón 2015). The consequences of these activities were numerous, being habitat fragmentation the most severe outcome, especially in ecologically fragile areas, which strongly affected biodiversity attributes (Fiori and Zalba 2003; Ávila et al. 2009; González and Pérez 2017).

The historical context mentioned above could have had a long-term influence on the cultural knowledge of local inhabitants that can be observed nowadays (Nunn 2012). To perform a project, this fact must be inexorably considered in ecological restoration decision-making, taking into account the traditional environmental knowledge (Hull and Robertson 2000; Ceccon 2013, 2016; Pérez and Ceccon 2017; Ceccon et al. 2020a). By introducing the notion of traditional knowledge and biocultural constructs as components of the environment, we are expanding the ecosystem concept from the physical, biological and ecological aspects of natural sciences to the sociological, anthropological, psychological, philosophical, and historical fields (Verschuuren et al. 2014). However, the integration of the socio-cultural aspects with scientific knowledge in restoration projects is still considered a great challenge, mainly due to the lack of participation of local people in the projects and the absence of a dialogue of knowledge among stakeholders (Noy-Meir 1973; James et al. 2013; Ceccon 2013; Pérez et al. 2017; Ceccon et al. 2020a, 2020b).

In the Monte ecosystem, restoration ecology is an incipient activity, and the first restoration advances were focused on ecological aspects and in small plots (Dalmasso 2010; Pérez et al. 2010; Dalmasso et al. 2013). However, in the Monte of Patagonia, a new proposal has recently emerged for large-scale restoration, called ‘Dryland Framework Species Approach’ (Pérez et al. 2019a, 2020). This new approach tries to include new ecological and socio-cultural attributes for the selection of plant species for restoration projects, such as high survival and cover, attractiveness for fauna, and multiple uses considered by the local people (Pérez et al. 2019a). To integrate socio-cultural and ecological aspects in restoration projects in the Monte ecosystem, (a model called “Socio-Productive Environmental Unit (USPA, in Spanish) has been proposed, in which measurable short and long-term indicators of advances in sustainability are used (Pérez and Farinaccio 2013).

This model, still under construction, also includes educational programs which contribute to the understanding of the intrinsic values of nature as being a natural and cultural heritage. Local socioeconomic factors are also considered. In this sense, an essential component of the USPA consists of promoting the cultivation of native species that may help to recover the ecosystem and, at the same time, to contribute to people’s economy (Parrotta et al. 1997). This last process is known as ‘productive restoration’ in Latin America and is defined as the relationship of sociocultural and ecological elements, for the recovery of the structure and function of the original pre-disturbance ecosystem, together with sustainable land productivity, using techniques such as agroecology and agroforestry (Ceccon 2013).

One critical aspect to successfully develop productive restoration projects is understanding the socio-ecological context of the local population (cultural, educational, health and socio-economic), and the value that these people assign to plant species (Budiharta et al. 2016; Martinez-Romero and Ceccon 2017). Thus, the objective of this study was to evaluate the socio-ecological and economic opportunities and limitations of Aguada San Roque, a small town located in the Monte ecosystem, to establish future productive restoration projects. In this sense, we evaluate, i) the socioeconomic characteristics of the local puesteros, ii) the knowledge and value that local puesteros place on native flora, iii) the interest of puesteros in growing these species for future restoration projects, iv) the ecological attributes of the species valued by puesteros, as well as the possibility of establishing productive restoration projects using them, and v) the plantation of already existing native species (e.g. uses, yield) in the puesteros home gardens.

**Methods**

**Study site**

Aguada San Roque is located in Neuquén Province in the region of Argentine Patagonia (37°59’59”S, 68°55’22”W) (Figure 1) and is contained in a 900,000-ha endorheic basin, known as the Añelo basin. It is characterized by high altitude variability, from 223 to 2258 masl, over a linear distance of 50 km. Sandy plains, rocky outcrops, and low saline areas predominate (Ferrer et al. 2006). This town is in one of the most arid ecosystems of the country called ‘Monte’, more specifically ‘Monte Austral’ (Busso and Fernández 2017). This ecosystem covers 40% (approximately 3.8 million ha) of the Neuquén Province. Monte Austral ecosystem has an annual average temperature of 12°C, with a high thermal amplitude and an annual range from 40°C to −13°C (Coronato et al. 2017). The relationship between precipitation and potential evapotranspiration ranges from 0.05 to 0.5, indicating a strong water deficit. Annual rainfalls, also highly variable, mainly occur between winter and early spring, from May to October (Labraga and Villalba 2009). The predominant soils are of the aridisol and entisol orders,
with an aridic hydrothermal regime, high pH and CO$_3$ and low content of organic matter (Pereyra and Bouza 2019). These environmental conditions cause severe limitations on cultivation (Muiño 2012a).

Natural vegetation is generally distributed in oval-shaped patches of approximately 3 × 2 m, formed by bushes and grasses with high horizontal and vertical heterogeneity (Busso and Bonvissuto 2009). The most abundant shrub species are: *Larrea divaricata* Cav., *L. cuneifolia* Cav., *Monteia aphylla* (Miers.) Benth. & Hook. var. *aphylla*, and *Atriplex lampa* (Moq.) D. Dietr. The most common herbaceous plants that generally develop under the shrub’s canopy are the perennial grasses *Pappostipa speciosa* (Trin. & Rupr.) Romasch, and *Poa ligularis* Ness Ap. Steudel. In the lower parts, with clayey soils (sometimes compacted and semi-permeable), the most abundant species are Chenopodiaceae and Halophytaceae of the genera *Atriplex*, *Suaeda*, *Allenrolfea*, and *Halopyrum* (Gandullo et al. 2010). The typical fauna include granivorous birds, large herbivores, and rodents (López de Casenave 2001; Sassi et al. 2007).

Aguada San Roque is a small rural settlement of 160 inhabitants (according to the census by INDEC (Instituto Nacional de Estadísticas y Censos) 2010), extends over an area of 142,000 ha (according to the Province of Neuquén Statistics and Census, Dirección Provincial de Estadística y Censo Provincia de Neuquén (DPECPN) 2019). The population is distributed in a small urban area and 63 rural households are located in a dispersed arrangement (around 12 km apart from each other) (INDEC (Instituto Nacional de Estadísticas y Censos) 2010). This settlement does not have indigenous communities or any descendants (Dirección Provincial de Estadística y Censo Provincia de Neuquén (DPECPN) 2019). The population studied called themselves *puesteros*, pastoral families with different situations regarding land tenure (Muiño 2012a). The poverty rate is 24%, around 20% of the population lives in very precarious houses and only 15% has electricity. There is no access to drinking water and gas (Dirección Provincial de Estadística y Censo Provincia de Neuquén (DPECPN) 2019). The water supply comes mainly from boreholes and people depend on liquefied gas or firewood for heating and cooking. The main economic activity in the region is extensive livestock farming, mostly goats and, to a lesser extent, sheep, cattle, and horses. Furthermore, since 2012, along the Añelo basin, there is an intensive activity of hydrocarbons exploitation, due to the presence of the largest unconventional hydrocarbon deposit called ‘Vaca Muerta’ (Subsecretaría de Planificación Territorial de la Inversión Pública (SPTIP) 2016). This activity, together with livestock, are the main reasons why Aguada San Roque belongs to one of the most desertified areas of Argentina (Pérez and Farinaccio 2013).

Figure 1. (A) Neuquén Province in the Argentine Republic. (B) location of the Monte and Monte Austral ecosystems and the study site. Geographical coordinates system WGS-84.
Data collection

To obtain information on the socioeconomic characteristics of the puesteros, their knowledge about the use and their preference related to native species, and their interest in planting those species in their farms for future restoration projects, we carried out semi-structured surveys using the ‘Survey Monkey®’ platform. This tool has an application for smartphones and tablets, which may be easily used in the field. The interviewer completed the survey as the puesteros were answering the questionnaire. Once the data was collected, they were downloaded and processed on this same platform. Socioeconomic information included education level, source of income, heads of livestock, health care, and birthplace. Interviewees also answered questions about their knowledge of the uses of species. In this sense, respondents were asked to make a free list of known wild and/or cultivated species. This information was provided spontaneously and classified according to different categories such as medicinal, forage, firewood, edible, construction, ornamental, brooms manufacture, and dye. Also, the list of species that the puesteros preferred to use for future restoration projects was grouped according to preferences and uses, such as forage, firewood, protection against climate factors, and ornamental.

Once the first list of species was obtained (use of species), we reviewed the scientific literature about some favorable ecological attributes and potential use of these species to productive restoration projects, and also the most important ecological characteristics of local species for productive restoration. We used as reference the above-mentioned methodology of species selection called the ‘Dryland Framework Species Approach’ (DFSA) (Pérez et al. 2019a, 2020). In this study, we considered criteria such as optimal germination in nurseries, survival percentages in plantations and direct seeding, and attractiveness for fauna.

Also, open interviews were carried out to ask about the background knowledge puesteros have of native species plantations in their home gardens (area surrounding the house in which plants are cultivated for different purposes (Albuquerque et al. 2005). Surveys and interviews were carried out with the same 30 puesteros (about 19% of the total population) chosen at random in Aguada San Roque, between 2017 and 2018.

Open individual interviews, were audio recorded, with a previous oral consent by interviewees, with a digital recorder Philips Voice Tracer model DVT-2710 and transcribed with the program ‘Dragon Naturally Speaker Recorder Edition 13’. Questions addressed the limitations and advantages associated with planting native species in the puesteros’ home gardens, such as (i) the availability/scarcity of water resources, (ii) abiotic factors (e.g. climate, soil), (iii) economic resources, (iv) infrastructure and inputs, (v) biotic factors (e.g. herbivory), and (vi) the knowledge about the plantations in their home gardens (e.g. species used, techniques).

Data analysis

To determine the importance that local people give to each species, we calculated the index of consensus of use (CU) and species versatility (SV) (Ladio and Lozada 2008). The CU corresponds to the percentage of respondents who mentioned each species, while VS represents the total sum of different uses for each species. We used Spearman’s correlation tests to check for correlations between CU and VS for each species (Conover 1980). We identified the species in situ with the help of the puesteros, and registered their common names along with other information related to the taxon. We finally consulted the database of the Catalog of Vascular Plants of CONO SUR (Zuloaga et al. 2009) for potential updating in the scientific nomenclature. To analyze the qualitative data, we used ATLAS.ti software version 7.5.18 (Hwang 2008).

Results

Socioeconomics characteristics

As regards the birthplace of the first settlers, 53% came from different regions of the Neuquén Province, 17% were born in Aguada San Roque, 13% came from neighboring provinces, and the remaining 7% did not know their origin. No indigenous populations were identified. People who mentioned Neuquén Province as their birthplace came from small or medium-sized towns (between 300 and 19,000 inhabitants), situated between 65 and 250 km away, all located in dryland regions (mainly from Monte and Patagonian steppe ecosystems). Of the 30 puesteros interviewed, 18 were women and 12 were men, with an average age of 50 years (± 11.6 SE). One-third of them (33%) were illiterate, 60% finished primary school, and only 6% attended secondary school, but did not finish. They are provided with basic health care attention from a health worker who visits rural homes at least once a month. The closest hospital is 65 km away from the town. The primary source of income recorded was the raising and sale of goats and, to a lesser extent, sheep and cattle. At the time of the surveys, the average number of livestock for each puestero was 315 (± 127.5) goats, 81 (± 35.3) sheep, and 13 (± 5.9) cows.
Local knowledge and use value given to native species

In the surveys, puesteros mentioned a total of 44 species with different uses, 38 of which were native and six were exotic, belonging to 14 families (Table 1). 25 species were identified as forage, 23 as medicinal, 18 as firewood, and 11 species for other uses such as human consumption (edible) or as an ingredient for food preparation, construction, ornamental, dye, and brooms manufacture (Table 1).

We found a significant correlation ($r = 0.76$, $n = 44$, $p < 0.01$) between the plants with the highest consensus of use (CU) and species versatility (SV) (Figure 2). Prosopis flexuosa var. depressa, Atriplex lampa, Larrea spp., and Parkinsonia praecox were the species with the highest CU and VS values (Figure 2).

Preferred species for future restoration projects

In the surveys, puesteros mentioned a total of 21 species that they would like to plant in their fields, 11 native, and ten exotic. Of the total of species, six were trees, ten shrubs, and four herbaceous (Figure 3a). The most frequently mentioned were three native species (Atriplex lampa, 70%; Prosopis flexuosa var. depressa, 53%, and Pappostipa speciosa, 40%), and one exotic (Medicago sativa, 53%). The main reasons why they would be willing to plant these species in their fields were related to the following purposes: forage (69%), firewood (16%), protection against climatic factors (14%), and ornamental (1%) (Figure 3b).

Ecological attributes and potential use of the local species mentioned for productive restoration projects

Among the species mentioned by the puesteros, twelve were identified for their easy propagation in nurseries, five of them even not requiring any pre-germination treatment (Hyalis argentea var. latisquama, Senecio subulatus var. subulatus, S. filaginoides, Gutierreria solbrigii, Grindelia chiloensis). The six remaining species, even though require some type of pre-germination treatment, showed high germination rate (> 60%): Atriplex lampa, A. undulata, Ephedra ochreata, Larrea divaricata, Parkinsonia praecox, and Schinus johnstonii (Table 1).

Thirteen native species were successfully evaluated in previous restoration experiments by their survival rates after direct seeding or planting as seedlings. Of these, seedlings of eleven species showed 70% survival: Atriplex lampa, Bougainvillea spinosa, Grindelia chiloensis, Hyalis argentea var. latisquama, Larrea divaricata, Lycium chilense, Pappostipa speciosa, Parkinsonia praecox, Prosopis flexuosa var. depressa, Schinus johnstonii, Suaeda divaricata. Four species were successfully planted by direct seeding: P. speciosa, A. lampa and H. argentea var. latisquama, Pappophorum sp., and Senecio subulatus var. subulatus (Table 1).

Results show a total of nine native species whose properties attract the fauna of the Monte ecosystem. The zoocchorous species were Prosopis flexuosa var. depressa, Lycium chilense, Schinus johnstonii and Geoffroea decorticans. Those which were recognized as shelter for different fauna species were Atriplex lampa, Hyalis argentea var. latisquama, G. decorticans, Larrea divaricata, L. cuneifolia and L. nitida (Table 1). The zoophilous species were Prosopis flexuosa var. depressa, G. decorticans, Senna aphylla, Erythrostemon gilliesii, Larrea divaricata and Monttea aphylla (Table 1).

Limitations and advantages associated with planting native species in the puesteros’ home gardens

The information provided was classified into three categories: a) factors that limited plantations, b) factors that favored plantations, and c) characteristics of plantations and their uses (Figure 4).

Among the factors limiting plantations, some interviewees mentioned water scarcity or no availability, adverse climate factors, and low-quality soils (Figure 4a; Figure 5). One third of the puesteros (30%) mentioned having some knowledge about plantation (Figure 5) obtained by previous work experiences and training on plant production and nursery, provided by a government program called ‘Programa de Desarrollo Alimentario’ (Programa de Desarrollo Agropecuario (PRODA) 2020), and, to a lesser extent, by other programs. Likewise, the puesteros mentioned the lack of greenhouses or other systems to protect their crops from the extreme winter cold weather. On the other hand, 7% said they had problems related to herbivory caused mainly by native and exotic mammalian species and domestic livestock (Figure 5).

On other hand, the availability of water, economic resources, infrastructure, tools (e.g. shovels, hoes, rakes), and inputs (e.g. fertilizers, seeds) were the factors that favored the plantations for the puesteros (Figure 4b; Figure 5). Water is usually obtained through drilling wells, while tanks were the most common way to store it (Figure 6). In 47% of cases, the puesteros mentioned having economic resources to perform tree/shrub plantations (Figure 5). These potential resources may come from credits, contributions from the local municipality, payment of oil royalties’ charges, and own resources.

All the puesteros interviewed (100%) already had plantations in their farms. They planted 44 species (85% exotic) and used them to obtain forest products (from tree afforestation), 47% for ornamentation, and only 40% to obtain forage, food, and medicine (from kitchen gardens) (Figure 4c; Figure 7a). A kitchen garden
Table 1. List of species mentioned by the puesteros, their uses, and ecological attributes (from literature review). Life form: AG: annual grass, PG: perennial grass, PS: perennial shrub, PT: perennial tree, SSP: perennial sub-shrub, Status: E: exotic, N: native, Uses: BR-Broom, BU-Building, ED-Edible, DY-Dye, FI-Firewood, FO-Forage, ME-Medicinal, OR-Ornamental. Ecological attributes for productive restoration: EG-Easy to germinate in a nursery, DS-Direct seeding survival, PL-Plantation survival, SH Shelter, ZO-Zoocorous, ZP-Zoophyli.CU: consensus of use, SV: species versatility.

| Family/Species | Common name | Life form | Status | Uses | Ecological attributes |
|----------------|-------------|-----------|--------|------|-----------------------|
| Anacardiaceae | Schinus johnstonii F.A. Barkley | MOLLE | PS | N | DY, FI, FO, ME | EG², PE³, ZO⁴ |
| Asteaceae     | Gutierrezia tomentosa Cabrera | PS | N | FO | EG¹ |
| Grindelia chiloensis (Cornel.) Cabrera | Botón de oro | SSP | N | OR | EG³, PL⁵,⁶ |
| Cyclolysa genistoides Gillies ex D. Don | Palo azul | PS | N | FI, ME | EG², DS⁷ |
| Senecio subulatus D. Don ex Hook. & Arn. var. subulatus | Romerillo | PS | N | FI, FO, ME | EG², DS⁷ |
| Baccharis salicifolia (Ruiz & Pav.) Pers. | Chilca | PS | N | ME | |
| Hylis argentea D. Don ex Hook. & Arn. var. latisquama Cabrera | Olivillo | PG | N | FO, ME | EG², DS⁷, PL⁸, SH⁹ |
| Baccharis mutabilis (Hook. & Arn. ex DC.) J. Remy | Pichanilla | PS | N | BR, FE, FO | EG² |
| Senecio filagoïdes DC. var. filagoïdes | Contrapuna | PS | N | FO | EG² |
| Baccharis sp. | Carqueja | PS | E | ME | |
| Matricaria chamomilla L. | Manzanilla | AG | E | | |
| Taraxacum oficinale F.H. Wigg. | | | | | |
| Chenopodiaceae | Atriplex lampa (Moq.) D. Dietr. | Zampa | PS | N | ED, FI, FO, ME | DS⁴,⁵, EG²,⁸, PL⁵,⁶, SH⁹ |
| Atriplex undulata (Moq.) D. Dietr. | Zampa crespa | PS | N | FO | EG² |
| Suaeda divaricata Moq. | Vidriera | PS | N | FI, FO | PL⁶ |
| Allionvilloea vaginata (Grisseb.) Kunz | Jume | PS | N | FI | |
| Dysphania multifida (L.) Mosyakin & Clements | Paico | PS | E | ME | |
| Euphorbiaceae | Euphorbia chameleonica Miers | Solupé | PS | N | ED, FO, ME | EG³⁴ |
| Euphorbia collina Phil. var. collina | Píchoa | PG | N | ME | |
| Fabaceae | Erythrostemon gillesii (Wall. ex Hook.) Klotzsch var. gillesii | Barba de chivo | PS | N | OR | ZP²⁴ |
| Geoffroea decorticans (Gillies ex Hook. & Arn.) Burkart | Chañar fruto | PS | N | FI, FO, ME | RE⁴, ZO⁵,⁶, ZP²⁷ |
| Parkinsonia praecox (Ruiz & Pav. ex Hook.) Hawkins | Chañar brea | PT | N | ED, FI, OR | EG⁴, PL⁵ |
| Prosopis glandulosa (Gillies ex Hook. & Arn.) Burkart | Manca caballo | PS | N | FO | |
| Prosopis flexuosa DC. var. depressa F.A. Roig | Alpataco | PS | N | BU, FI, FO, ME, OR | Pl⁵,⁶, ZO⁵,⁶, ZP²⁷ |
| Senna aphylla (Cav.) H.S. Irwin & Barneby var. aphylla | Pichana | PS | N | BR, FI, FO | |
| Senna kurtzii (Harms) H.S. Irwin & Barneby | Pichanilla | PS | N | FO | |
| Prosopis strombulifera (Lam.) Benth. var. strombulifera | Pata de loro | PS | N | ME | |
| Hoffmanseggia gialua (Ortega) | Porotillo | PS | N | FO, ME | |
| Nyctaginaceae | Bougainvillea spinosa (Cav.) Heimerl | Monteco negro | PS | N | FI, FO | PL³¹ |
| Plantaginaceae | Plantago aphylla (Miers) Benth. & Hook. | Mateseo | PS | N | FI | ZP²¹ |
| Pooaceae | Panicum uroviolaceum Kunth | Tupe | PG | N | FO | |
| Pappostipa speciosa (Trin. & Rupr.) Romasch. | Coiron/Cogron | PG | N | FO | EG², DS², PL² |
| Sparabolus rigens (Trin.) E. Desv. var. rigens | PG | PG | N | FO | |
| Pappophorum sp. | Corno de zorro | PG | N | FO | DS² |
| Schoenoplectaceae | Arjona tuberosa Cav. var. tuberosa | Papa de monte | PG | N | ED | |
| Solanaceae | Lycium chilense Miers ex Bertero var. chilense | Yayoín | PS | N | ED, FI, FO | PL³, ZP¹ |
| Fabiana imbricata Ruiz & Pav. | Palo de piche | PS | N | ME | |
| Tamaricaceae | Tamarix ramossissimo Ledeb. | Tamarisco | PT | E | FI | |
| Verbenaceae | Acantholippia seriphoiides (A. Gray) Moldenke | Tomillo | PS | N | ED, FI, ME | |
| Neopostur ephedroides Griseb. | Retamo | PS | N | BU, ME | |
| Aloysia polyestachya (Griseb.) Moldenke | Burrito | PS | E | ME | |
| Zygodraeaceae | Larrea divaricata Cav. | Jarilla hembra | PS | N | BU, FI, FO, ME | EG², PL⁵, SH²⁶, ZP²⁵ |
| Larrea cuneifolia Cav. | Jarilla macho | PS | N | BU, FI, FO, ME | SH¹⁶ |
| Larrea nitida Cav. | Jarilla de río | PS | N | BU, FI, FO | SH¹⁶ |

*Martin et al. (2001);¹Beider (2012);²Becker et al. (2013);³Masini et al. (2016);⁴Dalmasso (2010);⁵Ciano (2013);⁶Pérez et al. (2019a);⁷Pérez et al. (2019b);⁸Ojeda and Tabeni (2009);⁹Villagrasa and Álvarez (2019);¹⁰Pérez et al. (2020);¹¹Piován et al. (2014);¹²Rodríguez Araujo et al. (2019);¹³Cocucci et al. (2019);¹⁴Renison et al. (2010);¹⁵Mezquida et al. (2004);¹⁶Eynard and Galetto (2002);¹⁷Funes et al. (2009);¹⁸Álvarez and Villagrán (2009);¹⁹Laporta (2004);²⁰Tadey (2011);²¹Farinaccio et al. (2013);²²Aparicio et al. (2002);²³Quiroga et al. (2009);²⁴Hernández et al. (2020);²⁵Chaffee et al. (2012).

comprises a small area devoted mainly to growing fruit trees and vegetables for household members (Toppo et al. 2016). Afforestation consisted of a monoculture of exotic species around the houses or in the corralas (Supplementary Material-Table S1). Regarding the main purposes of afforestation, people mentioned shade/protection, fodder, firewood, and ornamentation (Figure 7b). In kitchen gardens, the most common crops were seasonal species (Table S1). In 67% of cases, these food crops were alternated with medicinal species such as Aloysia polyestachya, Matricaria
Figure 2. The relation between the consensus of use (CU) and species versatility (SV) of 44 species mentioned by the surveyed puesteros of Aguada San Roque (Neuquén, Argentine Patagonia), according to their most common uses: medicinal, forage, firewood, ornamental, and others (edible or as an ingredient in food preparation, construction, ornamental, dye, and brooms manufacture).

Figure 3. The interest expressed by the puesteros in cultivating species to restore their fields (obtained by surveys) in terms of the percentage (%) of the puesteros’ preference of species (a), and the percentage (%) of their preference of uses (b).
chamomilla, Menta sp., Mentha pulegium, Chenopodium ambrosioides, Taraxacum officinale, and Artemisia absinthium. In places with higher water availability, there were also exotic fruit species such as Ficus carica, Cydonia oblonga, and Vitis sp. In addition to producing food for consumption and growing plants for medicinal use, in 33% of cases, the puesteros also had forage species in their kitchen gardens (Table S1). In this sense, 13% of the interviewees have delimited sectors in their home gardens (approximately 0.5 ha), for forage production. In this case, exotic perennial herbaceous species of the genera Agropyron, Elymus, and Festuca, adapted to aridity conditions (Table S1), are usually sown.

**Discussion**

The socio-economic, ecological, and cultural contexts of the Aguada San Roque community showed an unfavorable well-being panorama of its inhabitants, reflecting low local education level and quality of health services. Likewise, the extensive livestock production system, which all puesteros depend on as means of subsistence, has as a consequence a correlation with a high pressure on natural resources of this ecologically fragile ecosystem, triggering an irreversible desertification process (Mazzonia and Vazquez 2010).

In the present study, we documented a list of 44 species with possible uses identified by the puesteros. Considering that more than 300 plant species have
been described in the Monte ecosystem (Morello 1958), it is possible to conclude that the local people’s knowledge about potential uses was low (less than 15% of species). In previous experiences with rural communities in the Monte ecosystem, more locally known species were described (between 50 and 145) (Ladio and Lozada 2009; Muñoz 2010; Muñoz and Fernández 2015). Of the total of species described in these studies, 22 of them coincide with those mentioned in our study, for example, *Atriplex lampa*, *Prosopis* spp, and *Larrea* spp., among others. On the other hand, the percentage of exotic species in the puesteros’ home gardens was very high (85%). These high values of exotic species were also recorded in other studies in drylands (Albuquerque et al. 2005; Trillo et al. 2010; Eyssartier et al. 2011). The low results regarding the use of native species by the local inhabitants, and the preference in the use of exotic species, show a loss of traditional ecological knowledge, which could be a consequence of the above-mentioned historical occupation of the Monte ecosystem (Brailovsky and Foguelman 2004). Arias Toledo et al. (2010), also mentioned that the low level of traditional ecological knowledge is one of the main consequences of the historical processes of exploitation of natural resources and indigenous genocide.

Traditional ecological knowledge is deeply interconnected with biological diversity and the erosion of one can profoundly affect the other (Turvey and Pettorelli 2014). In this sense, a recent study warns that, in the face of deep and ongoing environmental changes, it is likely that both biological and cultural diversity will be seriously affected, as well as local resilience capacities from this loss (Aswani et al. 2018). Efforts, therefore, should be made not only to restore biodiversity but also the knowledge systems of indigenous and rural people.

Our results also confirm that previous knowledge about environmental history and a diagnosis about local knowledge of native species management are very necessary for establishing productive restoration programs. Also, it became evident from surveys and interviews that there is a need to establish environmental education programs to supply the eroded knowledge about native plant biodiversity, their reproduction, and use adapted to the socio-ecological reality.

It is important to emphasize that the puesteros prefer to increase the productivity of their fields through the cultivation of forage, as well as producing species to improve the availability of firewood and protection against climate factors. For this reason, we consider inappropriate trying to promote among the puesteros agricultural systems that are not perceived as viable, in the short term. In this sense, knowing and integrating local people’s species-use preferences in restoration projects could ensure their success, since not only would the quality of the degraded ecosystem be improved, but also the puesteros’ well-
being through the tangible benefits that they can visualize beforehand (Cecon 2013; Cecon and Pérez 2016).

Previous studies highlight that the implementation of restoration strategies that incorporate trees and shrubs in agricultural landscapes would not only favor productivity and the protection of biodiversity, but also would have positive financial impacts on rural people (Zucca et al. 2011; Brancalion et al. 2017). Therefore, the use of agroforestry and agroecological approaches is recommended. For example, people living in the arid regions practice the mixed farming, combining perennial crops or grasslands with multipurpose native species (Verma et al. 2017). These systems may generate wood, firewood, and forage; improve soil conditions (through nitrogen fixation and accumulation of organic matter), and increase interactions with local fauna (Cecon 2013). While multipurpose native species and their importance for restoration have been studied of the Monte ecosystem (Pérez et al. 2019a, 2020), there is still the challenge of advancing in the socio-ecological viability of these projects.

Of the total species selected by the puesteros, 13 native species were successfully established in previous restoration experiences (Dalmasso 2010; Pérez et al. 2019b, 2020). Atriplex lampa and Hyalis argentea var. latisquama had even been previously considered as framework species of Monte Austral (Pérez et al. 2019a), and together with Senecio subulatus var. subulatus and Ephedra ochreata were used in restoration projects through direct seeding (Rodriguez Araujo et al. 2019; Pérez et al. 2019b). However, other species, highly valued by local people (e.g. Pappostipa speciosa, Senecio filaginoides, Geoffroea decorticans) or with a great variety of locally recognized uses, have not yet been incorporated as part of the ‘framework species’. The latter is the unique tree species of particular interest because it is practically extinct in the study area and could be successfully reproduced by local people (Pérez and Farinaccio 2013; Pérez et al. 2019c).

It should be noted that 40% of the puesteros cultivated some type of plantation. Similar studies, carried out in the drylands of Argentina, highlight that crops were scarcely developed (Muiño 2012a, 2012b). According to these studies, the inhabitants justify the low percentage of

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**Figure 6.** Results of the interviews based on water management in the puesteros’ home gardens. (a): Percentage (%) of the types of sources used for water supply. (b): Percentage (%) of the water storage systems most used by the puesteros. (c): Percentage (%) of the most used water distribution systems for plantation irrigation.
crops on the grounds of scarcity of water, climate limitations, low soil quality, and herbivory, which is consistent with the opinion of some farmers in this study about the factors that limited plantations. This emphasizes the need for a transdisciplinary approach in the productive restoration projects in Aguada San Roque, in search of a common objective for restoring the relationship between local society and its ecosystem, guaranteeing the health of the landscape and the well-being of the local people, in a framework of sustainability.

**Conclusions**

Immersed in unfavorable socio-ecological and cultural context, the *puesteros* of Aguada San Roque recognize a low percentage of native useful species. However they use a large proportion of exotic species in their home gardens, a result of the historical context of extermination of indigenous people and cultural erosion. However, local people expressed motivations and an interest to carry out productive restoration actions in their fields, using native plantations. A cultural and productive restoration program, with an axis in education based on restoration, may help to successfully implement these projects. The program may promote the strengthening of local capacities and the rescue of traditional knowledge; increase collective learning, to ultimately restore the historical links between local people and the natural ecosystem.

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