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Research Paper

Ethnoecology of *Oxalis adenophylla* Gillies ex Hook. & Arn. ☆

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ABSTRACT

Ethnopharmacological relevance: We studied the ethnoecological knowledge of medicinal *Oxalis adenophylla* in 3 rural villages of north Patagonia, Argentina. To evaluate links between use frequency, ethnoecological knowledge, sociocultural variables and the conservation status of this plant.
Materials and method: Forty informants were interviewed in relation to their knowledge, use, perception and the ecology of *Oxalis adenophylla*. Sociocultural variables were also documented, such as age, gender, size of family group living in the house, economic activities and ethnic self-determination. The abundance and availability of these plants were estimated in two villages, by measuring the number of plants per area, their weight and the relation between time invested and biomass collected. We tested frequency of use and age with Spearman's rank correlation coefficient. The relation between use frequency and gender, family group, economic activities, and ethnic self-determination of the informants was tested with the Mann Whitney non parametric test. An index of ethnoecological knowledge was constructed and correlated with use frequency through Spearman's rank correlation. To estimate conservation status we established a local risk index, taking both intrinsic and extrinsic parameters for this species into account.
Results: Regionally, *Oxalis adenophylla* is a plant known for its medicinal, alimentary and ornamental properties, but it has been poorly studied from a pharmacological point of view. Locally, the leaves of the plant are harvested for the preparation of "tortillas", which are stored and consumed in the cold months of the year for the treatment of flu fevers (95% of informants). Informants know the value of its root as a nutrient source and 35.8% reported its consumption. Use is sporadic and involves the harvesting of a mean of one root per year, which is eaten raw in-situ. Only 12% of informants mentioned the plant's ornamental feature. The ethnoecological knowledge of *Oxalis adenophylla* included references to specific environments where the plant grows, its phenology and morphological and organoleptic characteristics, appropriate times for harvesting, and animals that forage for this species. The informants with the greatest ethnoecological knowledge harvested leaves and roots most frequently. The frequency of use did not differ in relation to age or gender. In contrast, frequency of use was the highest when the informant lived with several generations at home, maintained traditional animal husbandry practices and when they considered themselves as belonging to the Mapuche people. Informants perceived low abundance and availability of the plant in the environment, restricted by the great distances involved in obtaining them, seasonality, and in particular, difficulty in finding the roots. Informants believe that the plant is sensitive and it should be harvested in such a way as to ensure no damage to the whole plant, allowing resprouting. Our ecological measurements agreed with this perception. The local risk index for the plant was medium.
Conclusion: In Patagonian Argentina, *Oxalis adenophylla* is a multipurpose species widely used for its medicinal properties but less for its edible roots and ornamental features. In the rural communities where we worked, frequency of use seems to depend on individual ethnoecological knowledge, the practice of indigenous worldview, living in households interacting with other generations and maintaining the activity of cattle raising. Locally, the main risk for the plant is the particular environment

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where it grows, characterized by slopes vulnerable to erosion. The human practice of local use could promote the conservation of this species through the understanding of its sensitivity to harvesting, and its insipient cultivation. This research shows the importance of obtaining a general overview of useful wild species used by local people.

1. Introduction

Ethnoecology is a scientific field which offers some understanding of the relationship between humans and their plant surroundings. This perspective considers that the use of plants, both historically and in modern times, is based on the conceptions (belief systems) and perceptions (cultural interpretation of sensory and biological information) of those who use them, leading to concrete action with regard to the species (Toledo and Barrera-Bassols, 2008). One of the key concepts in ethnoecology is 'traditional ecological knowledge' or 'ethnoecological knowledge', referring to the integrated body of practices, knowledge, values and beliefs which individuals and groups develop in relation to their environment (Berkes et al., 2000; Folke, 2006). During recent years attention has been paid to the ethnoecological knowledge developed by local communities (Rist and Dahdouh-Guebas, 2006; Richeri et al., 2013a), both for its value in explaining the economic logic of these communities (Henfrey, 2002) and because it helps us understand that institutional resource management plans should be enriched by the experience and knowledge of those who use these resources (Pedroso-Júnior and Sato, 2005).

From this perspective, multiple social and ecological variables influence the structure and dynamics of the knowledge and practices of a group of humans. For example, it has been documented that knowledge of wild plants is positively correlated with age (Teklehaymanot, 2009) and that due to the division of domestic and economic labor, men and women present differences in their plant knowledge and use (Guimbo et al., 2011). Family groups formed by several generations may favor the maintenance of these practices and knowledge, since different possibilities are generated in terms of need and for the transmission of knowledge (Ochoa et al., 2010). In addition, in changeable rural situations traditional economic activities such as livestock raising and horticulture may favor the maintenance of wild plant use, since through these activities the wider environment is explored (Ladio and Lozada, 2004; Eyssartier et al., 2009). Native worldview also play an important role since they are associated with a set of beliefs and values which have, historically, given relevance to wild plants as a source of food and medicine, and have determined social conventions of use. (Montecino and Conejeros, 1985; Bengoa, 2000; Olivos Herreros, 2004). These sociocultural variables interact with the ecological characteristics of the environment and the biological characteristics of the species.

Ecological, nutritional and bio-active features are also important attributes in the selection process (Begossi, 1998). For example, Ladio (2000) found that the Ram Mapuche community expended more energy and made more intensive use of the wild species which had higher nutritional value (*Araucaria araucana*) than other plants. In the Currhuinca Mapuche community, Estomba et al. (2006) found that in the selection of wild medicinal species for use, more energy was invested (greater distances were covered) in search of native species, while the energy invested in obtaining exotic species was less, as they grew in proximity to the dwellings. Nevertheless, as discussed by these authors, decision making with regard to the use of wild plant species is a complex process which does not take only energy investment into account, but also sociocultural factors such as traditional usage, the sacred connotations of some species and the incidence of illnesses in each community.

The study of use practices, knowledge and the local value given to wild plants is fundamental to the understanding and evaluation of the state of conservation of these species from a local perspective. The ecological dynamics of wild plants depend on the characteristics of the environment where they grow (climate seasonality) and the biological characteristics of the species (reproduction strategy, life cycle, nutrition and defense characteristics). The two last-mentioned factors influence types of interaction with other organisms; for example, by making them more or less preferred. In the case of wild species used by humans, the method and intensity of collection may have effects, (positive or negative) on the dynamics of local populations of these plants. For example, Casas et al. (2007) reported that in indigenous populations of Mexico, the management practices of wild plants (e.g *Leucaena esculenta*, *Stenocereus stellatus*, and *Escontria chiotilla*) altered the structure of these populations, favoring the persistence of certain phenotypes over others. Other authors have supported these ideas, reinforcing the importance of local traditional management practices (Albuquerque, 1999; Berkes and Turner, 2006; Blancas et al., 2006). Up to the present time, however, these practices have been made invisible to science.

As part of this invisibility, the indices used in the evaluation of the state of conservation of species do not include traditional management practices in their terms, or aspects related to the way humans can increase or maintain local diversity (Reis et al., 2014). We consider, therefore, that greater awareness of these ethnoecological variables in the evaluation of the state of conservation of the species will produce a picture that is closer to reality and have a greater impact on their conservation.

One of the most important indigenous societies living in the Patagonia is the Mapuche people, which have an holistic worldview and where nature ("Mapu" in Mapuduzungum, the Mapuche language) is integrated in their spiritual and material way of life (Bengoa, 2000). Several authors documented the practice of gathering wild plants in this ethnia (Molares and Ladio, 2008) and their relevance in the religion (Foerster, 1993; Vicuña, 1998), and other cultural practices (Ladio, 2000; Cardoso et al., 2010; Ladio, 2011). Within these practices, various native species of the genus *Oxalis* (Oxalidaceae) have stood out due to their medicinal and alimentary uses. *Oxalis valdiviensis* is used as a substitute for lemon (Martinez-Crovetto 1982; Ladio, 2006) and as a painkiller (Conticello et al., 1997). *Oxalis erythroriza* is used for treating heart and liver problems (Saúde-Guimarães and Farias, 2007). *Oxalis rosea* is used for treating fever symptoms, as an emmenagogue or abortifacient (Montecino and Conejeros, 1985), for coughs, scurvy and blurred vision (Houghton and Manby, 1985) and also for its edible stems (Villagrán et al., 1983). *Oxalis lobata* has carminative properties and *Oxalis perdicaria* is used for its edible bulbs (Houghton and Manby, 1985). *Oxalis nahuelhuapensis* and *Oxalis adenophylla* are used as febrifuges and for their edible roots (Ochoa et al., 2010). This paper follows previous investigations (i.e., Ladio, 2000; Molares and Ladio, 2009; Ochoa et al., 2010) that since 2002 were conducted by the Ethnobiology Group of INBIOMA (Instituto de Investigaciones en Biodiversidad y Medioambiente, Biodiversity and Environmental Research Institute) that reveal the importance of this particular species among other medicinal and edible species used in the NW Patagonia by

Mapuche culture, but until now has not been studied from an ethnoecological perspective. *Oxalis adenophylla* is a perennial herb endemic to Chilean and Argentine Patagonia (Bryan, 1989), it is approximately 10 cm in height, acaulescent, with leaves made up of numerous narrow heart shaped folioles. Its flowers have 5 petals, usually pink in color but can be white. The bulb is scaly, and in certain conditions a white napiform tuberous root is developed (Correa, 1998).

The specific objectives of this work are as follows: 1) To analyze, at both regional and local levels, the ethnoecological information currently available on *Oxalis adenophylla*. 2) To compile data on the diversity of uses and current management and conservation practices relating to *Oxalis adenophylla* in three rural populations in Patagonia. 3) To analyze how these populations characterize each species in terms of morphology, organoleptic characteristics, life cycle and ecological interactions, gathering sites and phenology. 4) To evaluate the relation between frequency of use and the ethnoecological knowledge held by the people. 5) To estimate how use varies between inhabitants according to the variables of age, gender, family group structure, economic activities and ethnic self-determination. 6) To estimate the state of conservation of the species according to the vision of the inhabitants and the researchers.

2. Methods and materials

2.1. Bibliographical analysis

The methodology was based on an exhaustive bibliographical analysis of ethnobotanical sources referring to Patagonia. The bibliography was compiled from our own publications archives (ECOTONO – INIBIOMA laboratory) and from the Argentine Electronic Library of Science and Technology (http://www.biblioteca.mincyt.gov.ar/index.php, visited: 10/10/13) using a combination of the key words Oxalis, ethnobotany, ethnoecology and Patagonia. A total of 43 ethnobotanical sources were examined (Martinez-Crovetto, 1982,1983,; San Martín, 1983; Villagrán et al., 1983,1998; Nacuzzi and Pérez de Micou, 1984; Houghton and Manby, 1985; Montecino and Conejeros, 1985; Meza and Villagrán, 1991; Mösbach Wilhem de, 1992; Citarella, 1995; Mellado Campos et al., 1996; Conticello et al., 1997; Diaz-Betancourt et al., 1999; Ladio and Rapoport, 1999; Muñoz et al., 1999; Rapoport and Ladio, 1999; Ladio and Lozada, 2000, 2001, 2003, 2004, 2007, 2008, 2009; Ladio, 2001, 2004, 2005, 2006, 2007; Kutschker et al., 2002; Gonzalez and Molares, 2004; Estomba et al., 2005, 2006; Lozada et al., 2006 ; Ladio et al., 2007; Molares and Ladio, 2007, 2008, 2009, 2012; Ochoa et al., 2010; Richeri et al., 2010, 2013b; Ochoa and Ladio, 2011). During this search, information was gathered on the distribution of the species, the richness of the environments in which it has been recorded, protected areas within which it has been found and its current status of conservation. The sites visited were the Information System of Biodiversity of the Argentine National Parks Administration (http://www.sib.gov.ar/), the Darwinian Institute catalogue of flora of the Southern Cone (http://www2.darwin.edu.ar/Proyectos/FloraArgentina/FA.asp), the International Union for Conservation of Nature (http://www.iucn.org/) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (http://www.cites.org).

2.2. Study Sites

The ethnobotanical fieldwork was carried out in three populations living in the northwest of Argentine Patagonia (Fig. 1, Table 1). All the populations were rural, with a historical dominance of livestock raising and current diversification into other economic activities. From an ethnic point of view, the populations are characterized by being made up of families which consider themselves Mapuche or Creoles, which offers the possibility of comparing knowledge and practices relating to *Oxalis adenophylla* in different worldviews.

2.3. Ethnoecological methodology

2.3.1. Field methods

The work was carried out between the months of August and April in three consecutive years (2010–2012). In each community information was given to the local representatives on the context and characteristics of the research project, and informed consent was obtained from each interviewee (Albuquerque et al., 2010). Open and semi-structured interviews and participant observation were carried out (Alexiades, 1996) with reference to ethnoecological knowledge and use practices. In addition, *Oxalis adenophylla* gathering sites were visited. Homes were selected by means of a randomized design, and from those which agreed to participate in the study, one family member was chosen for the interview. Each participating family was asked to consider who should be interviewed, based on each family member's knowledge of plants. In Cuyín Manzano 16 participants were interviewed, 10 men and 6 women (age X:54 ± 15), who identified themselves as Mapuche (5) and Creoles (11); Villa Llanquín: 18 people, 11 men and 7 women (age X:61 ± 10), identifying themselves as Mapuches (10) and Creoles (8); Nahuelpan: 7 people, 4 men and 3 women (age X:63 ± 15), identifying themselves as Mapuches (5) and Creoles (2). In the interviews information was gathered on the socioeconomic characteristics of the inhabitants, as well as variables related to knowledge of the properties and morphological, organoleptic and ecological characteristics of the plant species. The interview also included questions on use practices and environmental perception of the abundance and availability of the species. The audio records and field notebooks can be found in the laboratory of the Institute of Research on Cultural Diversity and Processes of Change (*Instituto de Investigaciones en Diversidad Cultural y Procesos de Cambio)* (CONICET-UNRN).

2.3.2. Botanical–ecological methods

Based on the *Oxalis adenophylla* gathering sites indicated by inhabitants of Villa Llanquín ($N=10$) and Cuyín Manzano ($N=10$), sampling of an area of 200 m^2 around each site was carried out and the richness and plant community present were characterized. At each site the number of *Oxalis adenophylla* individuals was determined by means of an exhaustive census in a circular area of approximately 628 m^2. In order to map out this area, a circumference with a 10 m radius was drawn from a central point chosen at random. This area was then inspected and the numbers of individuals lying within were counted. At 5 of these sites 5 specimens were chosen at random and collected, from which the depth, size, biomass and moisture content of the edible underground organs were determined. These measurements were carried out at two different times of the year in order to detect seasonal differences. Moisture content was measured in a laboratory using a stove (60 °C during 24 h). To estimate the productivity of edible biomass from a gatherer's perspective, at 5 sites the number of underground organs which could be collected in 1 min was recorded, a small spade being used to dig them up (Llano, 2010).

Finally, to record the phenology of the species, one gathering site was chosen in Cuyín Manzano and one in Villa Llanquín, and these were visited once a month from September to April in the years 2011 and 2012. The samples of *Oxalis adenophylla* were taxonomically identified following Correa (1998) and were placed in the herbarium (Vouchers: *Oxalis adenophylla* JJO 001, *Oxalis*

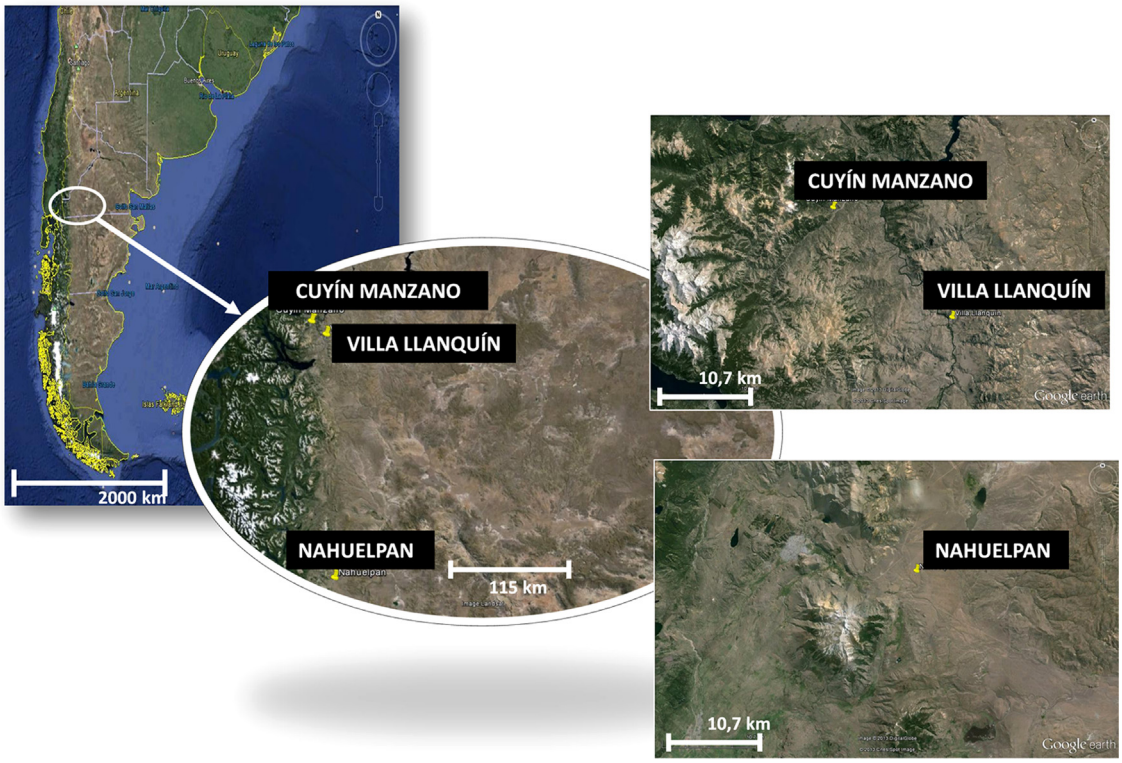

Fig. 1. Study Sites: Cuyín Manzano (Prov. Neuquén); Villa Llanquín (Prov. Río Negro); Nahuelpan (Prov. Chubut). Image created using Google Earth © Google Inc. (visited 12/2013).

Table 1
Climatic, phytogeographical and social features of the study populations (Barros et al., 1983; Molares, 2010).

	Rural villages		
	Cuyín Manzano	**Villa Llanquín**	**Nahuel Pan**
Annual average temperature (°C)	7,4	8	8
Annual average rainfall (mm/year)	600	500	400
Phytogeographical environmental	Ecotone between Andean Patagonian Forest and Subantarctic Steppe	Steppe – Andean Patagonian Forest fragments	Patagonian Steppe, Andean Patagonian Forest (W side)
Dominant plant communities	Forest (*Nothofagus pumilio*, *Austrocedrus chilensis*, *Maytenus boaria*, *Lomatia hirsuta*) herbaceous and shrub steppe (*Pappostipa* spp; *Mulinum spinosum* and *Senecio* spp.)	Herbaceous and shrub steppe (*Pappostipa* spp; *Mulinum spinosum* and *Senecio* spp., Nassauvia spp.). Forest fragments of *Austrocedrus chilensis*, *Maytenus boaria*, *Lomatia hirsuta*.	Herbaceous and shrub steppe (*Poa, Pappostipa, Festuca*; *Mulinum spinosum, Nassauvia spp., Berberis heterophylla, Adesmia campestris, Nardophyllum obtusifolium, Azorella monantha, Senecio filaginoides, Corynabutilum bicolor* and *Schinus roigii*), Forest of *Nothofagus pumilio* y *N. antartica*.
Population	50 inhabitants	113 inhabitants	60 inhabitants
Institutions	Primary school, Health care service, Police, Communal Association, Ranger	Primary school, Health care service, Police, Communal Association	Primary school, Train Station
Economic activities	Tourism, Big game, public and private employment, extensive livestock.	Extensive livestock horticultural production, tourism, public employment.	Extensive livestock, tourism.

adenophylla JJO 002, *Oxalis adenophylla* JJO 003 and *Oxalis adenophylla* JJO 004) of the ECOTONO laboratory of INBIOMA.

2.4. Data analysis

The data obtained in this study were analyzed in two ways, i) qualitatively, through analysis of the interview data and participant observation, then reinterpretation as categorical qualitative data; ii) quantitatively, by means of frequency estimates and the use of indices, detailed below, analyzed statistically (Albuquerque et al., 2010). In Table 2 all the categories are shown for the variables which have been quantified and used in the construction of the indices employed in the statistical correlations. The knowledge of the species possessed by each interviewee was estimated by means of a quali-quantitative index known as the Ethnoecological Knowledge Index (EKI).

EKI = *Gathering sites* + *Phenology* + *Best harvesting time* + *Morphology* + *Organoleptic characteristics* + *Interaction with other organisms* (See Table 2). Each term of the equation was chosen by the authors, but symbolized the main characteristics that people refer when they have to describe what is important to know about useful species for them. Frequencies of use were correlated with the age of each interviewee and with the EKI, using the Spearman test ($p < 0.005$). Gender differences, family

Table 2
Categorization of used variables for the construction of indices and statistical correlations.

Sociocultural variables	Category
Gender	Women (0), men (1)
Family group living in the house	One generation – alone, with partner or brother/sister - (1), more than one generation, children, grandchildren, grandparents - (2)
Economic activities	Livestock activities (1); public or private employment (non-livestock) (2)
Ethnic recognition	Non-indigenous (0); Indigenous (1)
Variables related to the practice of use	
Current use	Never used (0), used in the past (1), used in the present (2)
Gathering frequency (medicinal)	Number of plants harvested per person per year
Gathering frequency (edible)	Number of roots harvested per person per year
Variables related to the ethnoecological knowledge index (EKI)	
Useful property	Edible (1), medicinal (2), ornamental (3)
Harvest environment	One environment (1), to-*n* environments (n)
Phenology	Has no mention (0), with mentions (1)
Best harvesting time (leaves)	Has no mention (0), with mentions (1)
Best harvesting time (roots) harvest	Has no mention (0), with mentions (1)
Morphological features	Has no mention (0), with mentions, one feature (1)- to *n* feature (n)
Organoleptic features	Has no mention (0), with mentions, one feature (1)- to *n* feature (n)
Interaction with other organisms	Has no mention (0), with mentions, one feature (1)- to *n* feature (n)
Variables related to the local risk index (LRI)	
Endemicity	Not endemic (1), regional endemism (2), local endemism (3)
Distribution area	Continuous (1), discontinuous (2)
Ecological amplitude	Great ecological amplitude (0), mean amplitude (1), low amplitude (2)
Cover	+ 30% (0), 5 y 30% (1), less than 5% (2)
Grazing pressure	not preferred (0), some preferred (1), preferred (2)
Human use	firewood (2), medicinal/edible (1), without use (0)
Intensity of use	daily use (3), seasonal use (2), marginal use (1)
Sensitivity (Slope)	> 30° (4), between 15 and 30° (3), between 5 and 15° (2), between 5 and 0 ° (1)
Sensitivity (proximity to dwellings)	Less than 500 m (3), between 500 m and 1 km (2), more than 1 km (1)

group structure, job, cultural affiliation and their relation to frequency of use were analyzed using the Mann–Whitney test ($p < 0.005$). Ecological–botanical data were also recorded from the inspection of gathering sites together with inhabitants, from which the number of individuals presents in the gathering sites and the abundance of underground organs was calculated. This also enabled description of the morphological characteristics of the species at each site. With the averages of number of individuals and underground organs the production per hectare (average individuals per site × 10,000 m^2/surface area sampled per site) was estimated. These data were compared qualitatively with the perception of abundance expressed by the interviewees.

In order to determine the state of conservation of the species, a local risk index was drawn up (LRI), based on the extinction index proposed by Roig and Martinez Carretero (1998). This index is quali-quantitative in nature and takes into account both intrinsic and extrinsic parameters of the species. Amongst the first are the chorological features (the level of endemicity and type of dispersion area); ecological amplitude; density and demands of use. Amongst the extrinsic components are: habitat type, sensitivity – degradation of the community.

LRI = *Endemicity* + *Distribution area* + *Ecological amplitude* + *Cover* + *Grazing pressure* + *Human use* + *Intensity of use* + *Sensitivity* (*Slope* + *proximity to dwellings*) (See Table 2).

The LRI can vary between 5 and 24, considering the range of risk for the species to be: very high (> 20), high (20–16), medium (16–12), low (12–8), very low (< 8).

3. Results

3.1. The sociocultural, economic and ecological importance of *Oxalis adenophylla*

Oxalis adenophylla Gillies ex Hook. & Arn. (Fig. 2a–d) is a species with multiple uses at regional scale. Amongst the reports published in the bibliography studied, the medicinal, edible and ornamental uses stand out. It was found that its febrifuge properties associated with flu symptoms, for which locals consume the leaves of the plant, are commonly known. Knowledge of its use for the treatment of dermatological problems (Duzevich, 2011) is also widespread. The plant leaves are also eaten raw because of their acid flavor, without being associated with any therapeutic effects. Another use is the sporadic consumption of its tuberous root (Ladio and Lozada, 2001; Ochoa et al., 2010). Finally, its use as an ornamental plant was recorded, due to the beauty of its flowers, its easy reproduction and non-invasive character; it is used in landscape design (Seydouglu et al., 2009) and as a pot plant (Van Leeuwen, 1991; Armitage et al., 1996). To this end, the plant is beginning to be marketed in Argentina (*pers. obs.*), its sale is growing in Chile and it is commonly found on sale in horticultural societies in Europe and the United States, often through the Internet (for example, http://amazon.co.uk/Garden-by-Post-Oxalis-adenophylla; http://davesgarden.com/products/ps/go/2171/). It must also be mentioned that this species has not been studied from a phytochemical perspective, and the only study carried out on its bioactivity was a test of its inhibitory effect on the acetylcholinesterase enzyme (Rhee et al., 2003), in contrast to the more intense study of other Patagonian species such as *Oxalis rosea* (Schmeda-Hirschmann et al., 1992; Rodriguez et al., 1994; Insunza and Aballay, 1995) and *Oxalis erythrorryza* (Feresin et al., 2003).

This species, like others in the genus, is popularly known by the name *culle*, *cuye*, *cuyi*, and *cuye colorado*, amongst others (Ladio, 2006; Molares and Ladio, 2008; Ochoa et al., 2010). From an ethnotaxonomic and phytonymic point of view, the name '*culle*' is derived from the indigenous word *kulle or kulli* (Febres, 1846), and represents a generic ethnocategory that group diverse sets of species of the region (Villagrán, 1998). Nevertheless, although often named by the simple name of *cuye*, in some populations it is distinguished from other species in the genus, using compound names. For example, in the rural population of Arroyo Las Minas it is known as *"cuye colorado"* (red cuye) or *"cuye verdadero"* (true cuye), while the simple name of '*cuye*' tends to be associated with

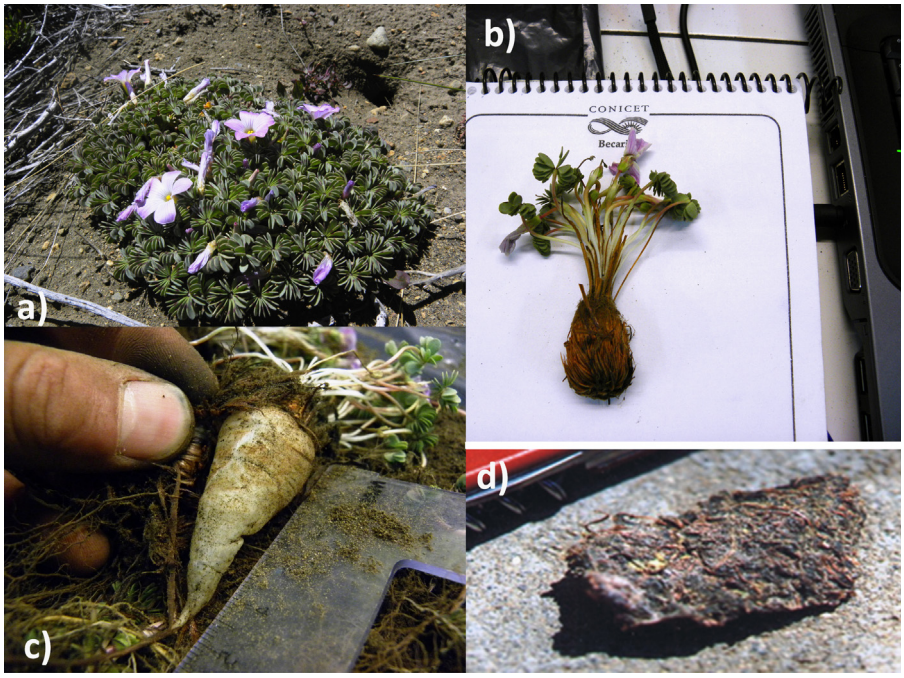

Fig. 2. a) General view of *Oxalis adenophylla*, b) bulb; c) edible napiform root; d) "*tortilla*" of leaves for medicinal use.

Oxalis nahuelhuapensis, a less preferred species used for similar purposes as *Oxalis adenophylla* (Ochoa et al., 2010).

From a historical perspective, reliable documentation on the use of this species began in the 20th Century (Ochoa and Ladio, 2011). However, due to the fragmented nature of sources and the generic character of the name '*culle*' it is likely that the species mentioned by this name in the 16th Century (for example, Molina, 1795) and identified as *Oxalis rosea*, may also include *Oxalis adenophylla*, a species with similar morphological characteristics. Finally, the geographic distribution of its use shows us that in Argentina this has been documented in the provinces of Chubut (Molares and Ladio, 2008, Ochoa and Ladio, 2011), Rio Negro (Ochoa and Ladio, 2011) and Neuquén (Ladio, 2000; Ladio and Lozada, 2003, 2004, 2008; Estomba et al., 2006; Duzevich, 2011), mainly in populations located in ecotonal zones, or in the Cordillera. The absence of ethnobotanical data in the provinces of Santa Cruz and Mendoza is more probably due to a lack of ethnobotanical investigations in these regions rather than the absence of local use of the plant. In the case of Chile, no ethnobotanical records of this species were found.

With respect to ecological characteristics, this species, endemic to Argentina and Chile, is found from the south of Mendoza (36° S; 70° W) to Santa Cruz (51° S, 71° W) in Argentina and from the Metropolitan region (33° S, 70° W) to the Aisen region of Chile (48° S, 72° W) (Zuloaga and Morrone, 1999). *Oxalis adenophylla* grows in at least three different environments: high Andean with an abundance of steep slopes, high plains, and stony steppe (Ferreyra et al., 1998). As to its conservation status, the species has not been evaluated by the IUCN (the International Union for Conservation of Nature) and is not included in CITES list of endangered plants. Finally, it is worthy of note that this species grows in several protected areas in Argentina (Lanín, Nahuel Huapi, Lago Puelo, Los Alerces, Los Glaciares and Perito Moreno National Parks).

3.2. Knowledge, uses and conservation practices

Oxalis adenophylla was recognized by 95% of interviewees, showing a high frequency of cites and uses. All informants who recognized the species attributed febrifuge properties to its leaves and 92.3% recognized the edible nature of its roots and leaves. Only 12% of interviewees mentioned its ornamental character due to the beauty of its flowers. In no event among informants ritual or religious use within this plant were documented.

Of the interviewees who knew of the plant's medicinal properties, 85% reported using the plant every year, gathering an average of two plants per year (SD: 1, Max: 6, Min: 1). In practice, a specimen of good size is selected and the aerial part (the leaves) are cut during the summer; 50% of interviewees mentioned that during harvesting it is important to cut only the leaves, so that the underground part of the plant is not damaged, thus ensuring that the plant will sprout again the following year. The collected parts are prepared by pressing and flattening on a wooden table or a wood-fired stove, forming a "*tortilla*" (Spanish denomination related to a general mode of cooking vegetables) which is stored in a dark, dry place for the winter (Fig. 2d). In the case of fever, mainly a result of flu, part of this 'pancake' *tortilla* is eaten. The informants mentioned that this recipe is a long standing tradition by the Mapuche, previous to white people arrival. Finally, one practice to highlight is the commercialization of these medicinal tortillas, even though this was only mentioned by one interviewee. This practice consists in the preparation of several pancakes and their subsequent sale at a regional craft fair in the month of February.

Of the interviewees who reported knowledge of the root as being edible, 69.2% mentioned having eaten it at some time; however, only 35.8% reported eating it every year. In practice, the tuberous root developed by the plant is collected and eaten in situ. For this use, 'large plants' are dug up, which are the ones that develop this white root (Fig. 2c). This root gathering is sporadic in intensity, with an average of one root collected per year (SD: 1, Max: 3, Min: 1). From the locals' perspective, this root is not widely used since it is difficult to find, and it was mentioned several times that the '*culle*' is a 'jealous' plant; if many are dug up it will not grow any more. In addition, the practice of collecting this root was always associated with the search for medicinal plants or the work of herding animals. Finally, in Villa Llanquín community the cultivation of this plant close to dwellings was reported, from the transplanting of wild bulbs. There are several

reasons for this practice, related to the perception of the beauty of the flowers, the need to have easy access to the plant, which in its wild state tends to grow at a distance, and also to experiment with its cultivation. This practice is insipient and restricted, only two interviewees have been carrying it out for the last four years.

3.3. Ecological, morphological and organoleptic characterization

Informants had a wide knowledge of the species, mentioning morphological, organoleptic and ecological attributes. There is a relative consensus – intra and inter population – with respect to the growing sites indicated for this species. Stony areas were mentioned by 90% of informants as being the principal growing sites of the plant, although other environments were mentioned as alternatives (close to wooded areas and ravines). We characterized two types of environment indicated by interviewees. One is high stony ground between 860 and 1350 masl. This environment is distinguished by its slopes of up to 60°, with soil formed from broken up rocks and 30% maximum plant cover. The plants associated with this environment were principally species from the genera *Pappostipa*, *Poa*, *Siyrinchium*, *Phacelia, Pozoa, Cerastium, Mulinum, Oreopulus, Leucheria, Rhodophiala and Rumex.* The other type of environment these plants are collected in has similar characteristics in terms of slope and stony soil surface, but is situated on the edges of *Austrocedrus chilensis* forests and thickets of *Schinus patagonicus, Lomatia hirsuta,* and *Maytenus boaria,* associated with species belonging to the genera *Mulinum*, *Geranium*, *Lathyrus*, *Euphorbia*, *Balbisia* and *Pappostipa*, with a higher maximum ground cover (60%). These sites are found between 770 and 900 masl.

Animals which forage for the plant were mentioned by 80% of interviewees, who referred exclusively to sheep and goats, which occasionally eat the leaves. However, they considered that these plants were not sought out much by these animals. Only four interviewees from Cuyín Manzano mentioned that the root is eaten by wild boar (*Sus scrofa*). All inhabitants know about the aerial seasonality of the plant, and to a lesser extent mentioned suitable times for the harvesting of its leaves (90%) and root (70%). Finally, the aerial part of the plant received a larger number of morphological and organoleptic descriptions (70%) than the underground organs (30%). Amongst the morphological descriptions was recognition of the flower (77%), the similarity of its leaves to those of clover (5), or to the pages of a book (6%); the presence of small bulbs (12%) and the similarity of its root to a carrot (26%). The organoleptic characteristics mentioned were the acid flavor of the leaves (46%), the pink color of its flowers (14%), and the sweet flavor and white color of its root (26%).

3.4. Ethnoecological knowledge and its relation to frequency of use

Inhabitants with a higher index of ethnoecological knowledge (EKI) use the plant for medicinal purposes ($r=0.42$, p:0.05) and/or edible purposes ($r=0.51$, p:0.016) more frequently than the others. No association was found between age and current frequency of gathering of *Oxalis adenophylla* for medicinal purposes (aerial organs) ($r=0.255$, p:0.345) or edible purposes (underground organ) ($r=0.354$, p:0.42). Men and women showed no differences in frequency of use of this species, whether for medicinal or edible purposes (Mann Whitney test, p:0.592; p: 0.524). In addition, it was found that interviewees who lived with several generations in one home tended to have a higher frequency of use, both for medicinal (Mann Whitney test, p:0.053) and edible (p:0.016) purposes than those who lived alone or with their partners. Concerning economic activities, interviewees who currently worked as state employees, carrying out farming activities to a lesser extent, either did not use the plant or gathered it with less frequency, whether for medicinal purposes (Mann–Whitney test, p:0.001) or edible purposes (p:0.005) than interviewees whose main work was livestock raising and other farming activities. Finally, informants who identified themselves as Mapuche or Tehuelche gathered with a higher frequency than the others (for medicinal and edible purposes, Mann Whitney test, p:0.000; p:0.000, respectively).

3.5. Phenology and spatial-temporal abundance

Of all interviewees, 80% considered that the species was not abundant, whether by comparison with other wild species in the landscape or referring to its growth in specific sites, which are also relatively scarce. In addition, 50% of interviewees stressed the fact that the species is found at great distances and that this is one of the reasons that it is used infrequently or not at all. Another important aspect that contributes to the perception of its relatively low abundance is its seasonality. In all interviews the fact that the plant is not present for most of the year (only a few months at the beginning of summer) was highlighted. It appears in the months of November/December and disappears in February, March or April. With regard to its edible root, it was mentioned that finding these was a difficult matter since not all plants produce them. In addition, 100% of interviewees mentioned that the best time for harvesting is at the beginning of the season, before the plant flowers, since this is when the root is the largest. The observations and measurements made during this study coincide with these perceptions (Table 3) and also confirm the great distances (between 1 and 10 km) that must be travelled to the collection sites, and the low abundance and low production of the edible root. With respect to the range within which the aerial part of the plant occurs, it was observed during the two years we studied the phenology that the plant appeared between the months of October and November, flowered between November and December, and the vegetative part died between February and March. It is worthy of note that in both communities the weight of the root was, on average, larger in the month of November (0.438, SD: 0.005; 0.4, SD: 0.013) than in January (0.311, SD: 0.006; 0.365, SD: 0.009). This is in accordance with the information given by interviewees as to the ideal month for harvesting.

3.6. The conservation status of Oxalis adenophylla

The evaluation of status conservation of this species gives us a medium value for its local risk index (Table 4). Apart from this orientational value, it is interesting to note the contribution of the different variables to the index; we wish to highlight the fact that the pronounced slopes where the plant grows is the variable that most contributes to the local risk of extinction of the species. An increase in gradient is associated with higher probability of soil erosion, both due to infiltration and less accumulation of organic material, and so is a key factor in the vulnerability of this species at a local level. On the other hand, the characteristics of animal and human use, which are generally considered because of their potential impact on the populations of forage plants, actually play a relatively less important role. To complement this quantitative approach, we would like to show how a series of local considerations are reflected in practices of use, which could contribute to the plant's conservation. On the one hand, these plants are not only gathered at low intensity, for domestic use, but also only the leaves are cut and the bulb is left undisturbed. This allows the plant to sprout again during the following year. There is also a shared consideration related to the sensitivity of the plant to the harvesting of its underground organ, since digging up many plants has a negative effect and the plant will no longer appear. This is reflected in the attribute of 'jealousy' often associated with the

Table 3
Ecological and morphological features about *Oxalis adenophylla* and their harvest sites mentioned by inhabitants of Villa Llanquín and Cuyín Manzano (ds: Standard deviation).

	Cuyín Manzano	Villa Llanquín
Average distance to harvest sites (km) ($N=10$)	3.21 (ds: 1.6)	5,9 (ds: 3.1)
Average plants per site (area 628 m^{22}) ($N=10$)	20.9 (ds: 8.97)	11.9 (ds: 4.79)
Estimation of plants/hectare	320	190
Number of underground organs/plant ($N=10$)	0.05	0.01
Edible underground organs/hectareha	18	18
Number of underground organs collected/min ($N=5$)	0	0
Average depth ($N=5$)	0.25 (ds: 0.023)	0.2 (ds: 0.018)
Root diameter ($N=5$)	0.02 (ds: 0.02)	0.08 (ds: 0.003)
Root length ($N=5$)	0.0185 (ds: 0.066)	0.0165 (ds: 0.018)
Root weight (initial) (gGR) ($N=5$)	0.4 (ds: 0.013)	0.438 (ds: 0.005)
Root weight (final) (GRg) ($N=5$)	0.365 (ds: 0.009)	0.311 (ds: 0.006)
Moisture (%) ($N=5$)	87 (ds: 4.7)	73.2 (ds: 6.87)
Average edible biomass/hectare (GRg)	6885	6666

Table 4
Local risk index (LRI) of *Oxalis adenophylla* populations in Cuyín Manzano and Villa Llanquín and their main components.

Endemicity	Regional endemism (2)
Distribution area	Discontinuous (2)
Ecological amplitude	Mean amplitud (2)
Cover	5–30% (1)
Grazing pressure	Some preferred (1)
Human use	Medicinal/edible (1),
Intensity of use	Marginal use (1)
Sensitivity (slope)	$>$ 30° (4)
Sensitivity (proximity to dwellings)	more than 1 km (1)
LRI	**15 (mean risk)**

plant. Finally, the experience recorded of its cultivation (transfer of bulbs from distant sites to others in proximity to dwellings), although this is not a generalized practice, implies an incipient domestication management practice. It is worthy of note that both interviewees who carried out this cultivation mentioned that their parents and grandparents had also carried out the relocation of *Oxalis adenophylla* specimens.

4. Discussion and conclusions

This contribution to the regional ethnobotany and local ethnoecology of *Oxalis adenophylla* shows multiplicity of uses (medicinal, alimentary and ornamental) of this species, and therefore its great potential for future ethnopharmacological studies. The inexistence of stories, myths, old illustrations, legends, etc in the published scientific literature (and chroniclers of travelers and explorers) shows that, on one hand, the record about this species is entirely fragmentary making difficult any inference (more data about this topic could be found in Ochoa and Ladio (2011); and on the other hand, that this particular species was considered as a whole by Mapuche, as part of a local category called “culle” that includes different taxa of the genus *Oxalis*.

At a regional level, the plant is widely known to rural dwellers of northwest Patagonia, knowledge of the medicinal properties of its leaves being the most prevalent. Knowledge of its edible use is less common, and gathering practices are currently infrequent. Its ornamental character is little appreciated regionally, in contrast to the position it holds in horticultural circles in Europe. Its incipient cultivation at a local level and its commercialization as a medicine are marginal practices which indicate current processes at work regarding this species, and which are an example of how this type of multifunctional species, valued culturally, can be the object of flexible and innovatory practices (Brush, 1993; Bennett and Prance, 2000; Lozada et al., 2006). This ethnoecological approach helps us to understand the importance of a general panorama that includes socio-cultural, economic and ecological–botanical aspects, which are continually changing and becoming redefined as time goes on. The use of this species does not seem to vary with the age of the interviewees, showing, as in other studies (Ladio and Lozada, 2004; Lozada et al., 2006), that when a resource is greatly valued in a society and useful for subsistence, its use is maintained and is open to exploration, care and innovation. According to our results, men and women know and use this species equally, showing that it holds a cultural value that cannot be compartmentalized by gender; its use is shared and strengthened by the daily practices of both sexes. These results coincide with Figueiredo et al., 1997; Monteiro et al., 2006, and indicate the singularity of the relationships that develop with certain species, which take on a general, wide-ranging dimension. The findings revealed that when interviewees share a home with other generations they show more frequent use than those who live alone or with a partner. This reinforces the importance of the social environment in favoring the maintenance of practices, forming a context where health care, alimentation, games and other types of social interaction promote the exploration of useful resources in the environment (Tezoquipa et al., 2001; Keller, 2010; Pochettino and Capparelli, 2011; Martínez-Pérez et al., 2012). Livestock practices seem to play a similar role, the routine of looking after animals being associated with constant interaction with the environment, thus offering the possibility of access to wild plants (Ladio, 2011). This is even more important in relation to a species of this type, which is not abundant and is found far from dwellings. Finally, ethnic self-identification as part of the indigenous peoples of Patagonia (Mapuche) is also associated with greater use of this species. In the native worldview wild plants have constituted an important material and symbolic resource for the historical subsistence of these peoples. In addition to this, they are currently being reconfigured as elements which provide a connection with the practices of ancestors, strengthening association with the land and becoming marks of identification of the native way of life; key factors in the current political processes dealing with identity .

The results found reveal that inhabitants know the best moments for the harvesting of *Oxalis adenophylla*, the spatial and temporal availability of its biomass, and how this species varies in production throughout the year. This local ethnoecological information coincides with that obtained from our fieldwork (Table 3). The considerable distances to the gathering sites and the low availability of the tuberous root are the principal reasons put forward by interviewees for the difficulty encountered in gathering. As well as this, gathering is also seen to lie within a

framework of 'norms' of extraction and very precise local forms of appreciation which promote respect and care, thus preventing excessive extraction. This plant, according to inhabitants, is 'jealous' and so its use should be occasional and of low impact. This possibly refers to people´s thinking of plant as human being treating them as if they have feelings and emotions. This is consistent with the Mapuche worldview that believes that every natural component has an inner life and spirit. This significance and the social regulations form the foundation which sustains a reciprocal relationship of mutual support, where the plants provide a means of healing and care and should therefore be protected by locals (Wiersum, 1997; Rai et al., 2000; Santos Fita et al., 2009).

The estimate of the local risk index for *Oxalis adenophylla*, with a medium value found, indicates that the main risks affecting this species are due to environmental variables (Table 4). Local human practices, in some cases disruptive to the environment, such as livestock raising, do not seem to have a negative impact on this species; on the contrary, as long as the practices and norms of care and cultivation are followed, the *culle colorado* will continue to form a substantial part of this knowledge system.

The richness of local ethnoecological knowledge of this plant and its effective use, placed in a context of economic and cultural practices, are key factors in the understanding of the dynamics between this plant and the people. It would be of great interest to explore in the future how this relationship will respond throughout time, trying to see if these valuable ethnoecological knowledge and practices are suitable for re-adaptation to a new ecological and sociocultural contexts. We suggest that phytochemical and pharmacological analyses be carried out to study its medicinal bioactivity, that research into its cultivation be done which will provide useful tools in the case of an increase in its commercialization, and that the incorporation of local ethnoecological knowledge be considered in all management policies that affect the environments where these plants grow. As well as this, we consider that the use of this integrated ethnoecological approach with the use of quantitative indices should be replicated for the study of medicinal and edible species of interest, in order to obtain a complete panorama of species that play a significant role for ours and future generations.

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