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Declaration of Publication

This is to certify that the article entitled "Legume diversity in the extra Andean Patagonia" by Mónica Stronati, Roberto E. Brevedan and Carlos A. Busso has been found suitable and accepted for publication in our forthcoming book, Frontiers in Biodiversity Research to be published in 2009. Moreover, we have considered Professor Dr. Carlos Alberto Busso, as one of the coeditors to our forthcoming book, Frontiers in Biodiversity Research.

Sincerely yours

(Devarajan Thangadurai)

Addressed To:

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Argentina

Legume diversity in the extra Andean Patagonia

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Location and Regions in Patagonia

Patagonia is one of the few cold temperate semiarid regions of the world. This territory extends from latitude 40 to 55° S and from the Atlantic Ocean to the Andean piedmont in the west, and occupies nearly 786,000 km^2 in the southern portion of Argentina (Figure 1) [1]. This area can be divided into three main regions: (1) the Andean Region, which is coincident with the Southern Andean region. This is characterized by forests, glacier lakes, high valleys, and prairies, where large sheep flocks gather in summer; (2) the Sub-Andean Region, which like the Andean Region, has strong west (>3,000 mm) to east (300 mm) precipitation gradients; and (3) the Extra-Andean Patagonia, where precipitation concentrates in winter, and declines from 300 mm in the west to less than 150 mm in the east, increasing thereafter slightly towards the Atlantic coast. This region has also huge plateaus devoted to sheep rearing (Figure 1).

Climate

The prevailing strong winds from the west, which blow all year round, are among the most noticeable characteristics of the Patagonian climate. These winds, which average 16 km h^{-1} on a yearly mean basis, loose their moisture over the Andes, and subsequently rainfall ranges from 100 to 200 mm yr^{-1}. Patagonia can be divided into two main climatic zones -northern and southern- by a line drawn from the Andes at about latitude 39° S to a point just south of the Valdés Peninsula, at about 43°S [2].

The northern zone is semiarid, with annual mean temperatures between about 12° and 20° C. Recorded maximum temperatures vary from about 41 to 45 °C, and minimum temperatures from -5 to -11°C. Annual rainfall ranges from 90 to 430 millimeters. The prevailing winds, from the southwest, are dry, cold, and strong. Climate of the southern zone is sharply distinct from the humid conditions of the Andean Cordillera to the west. In its northern part, the Atlantic Ocean influences are almost nonexistent. This is likely because of the relatively high elevations at the coastal region, which reach 300 to 600 m around the San Jorge Gulf. In its southern part, which becomes increasingly peninsular at higher latitudes, the Atlantic exerts some influence. Overall, the zone has a cold, dry climate, with temperatures along the coast than inland and strong winds from the west. Mean annual temperatures range from 4 to 13° C. Maximum temperature can reach about 34° C, and minimum temperatures vary between -9° to -33° C.

Soils

Soil was once the sea bed. It emerged in the tertiary age, and gave rise to marine and continental sediments accumulated over crystalline ancient rocks that were eroded by water and winds [3]. Main soil characteristics include the presence of lithological discontinuities, boulders throughout the profile, sandy textured topsoils and clay accumulation in the subsoil. In some cases, volcanic ash has been the parent material [3]. Del Valle (1998) [4] summarized and reviewed the available information on soil heterogeneity at a regional scale. His efforts were integrated in a map at the suborder level, and at an approximate scale of 1:10,000,000; in this map, he pointed out the main inconsistencies between local studies and regional maps. In his review, he also provided of the main soil taxa and their distribution thoughout the study region, and of the variability of the cartographic units. Del Valle (1998) [4] concluded that soil survey development in Patagonia must be geared towards more quantification of map unit composition.

The arid and semi-arid areas of Patagonia begin at the Andean Precordillera foothills in the west, and their altitude decrease gradually towards the Atlantic coast in the east. Besides transverse valleys running from west to east, the tableland is cut by longitudinal steps. These later features interrupt the continuity of the gradual slope towards the Atlantic Ocean. Within the extended tableland which constitutes the dominant physiographic feature, a variety of land forms (i.e., isolated, extended plateaus and terraces with very gentle slopes and smooth surfaces) grade towards up to the west. Other forms, shaped by water and wind erosion, can also be found within these regions [5]. Representative areas of Patagonia are under various degrees of desertification which were wonderfully described by Ayesa *et al.* (1995) [6].

Del Valle (1998) [4] reported an excellent, detailed description of Patagonian soils. Dominant soils in the region are [5]:

- Haplustols and associated soils: they cover most areas with normal relief, and are mainly derived from glacial detritus and volcanic material. Texture is dominantly coarse, with different gravel size and stones (Patagonian pebbles). Associated regosols are located westward of the area covered by brown soils, and are related to a stronger glacial influence.

- Calciorthids and associated soils: these soils predominate in the central and eastern regions of Chubut and Rio Negro provinces, and at the northeastern of Neuquén province. They occupy a vast area of desert and semi-desert environmental conditions, with an annual rainfall below 200 mm. Stones and gravels are commonly found throughout the solum; soil profiles commonly have shallow depths and sandy texture.
- Ustifluvents soils of Patagonian tablelands: they cover a small surface area. The valleys of large rivers crossing the Patagonian tablelands from west to east are of paramount importance for the regional economy. A wide range of soil particle sizes are found in these soils, and are related to the position of a particular site within the valley [5].

Soil moisture is strongly influenced by the recharge through precipitation [7]. Soil water depletion begins in spring with decreases in precipitation, and increases in temperature and evapotranspiration. Soil water is almost depleted by late summer. Most precipitation occurs during autumn, and the highest soil moisture is measured after snowmelt at the end of winter. As in any dry region, the variation in annual precipitation can be quite large from year to year. Dryness of Patagonia results from a combination of low rainfall, high summer temperatures and strong winds which cause high evaporation rates. Mean annual evapotranspiration ranges from 550 to 750 mm yr^{-1}. All these values tend to decrease from the northeast to the southwest. The most negative balance may reach values of over −1000 mm.

Overall Vegetation

In this region, vascular plant species can be grouped into three growth-forms: shrubs, grasses and forbs. Shrubs include evergreen and deciduous species. They are taller than 0,5 m and do not have a well-developed main stem. Grasses are tufted, have the C_3 photosynthetic pathway and posses stiff green leaves all year round. Forbs include annual and perennial, either evergreen or deciduous species which are mostly dicots. Factors affecting species composition and diversity in the Patagonian steppe include landscapes of contrasting topography. This is through their direct effects on abiotic environmental heterogeneity. Environmental controls on community composition, however, appear to depend on plant functional type. This is because shrub and grass but not forb species distributions respond to environmental gradients [8].

The Early Eocene Laguna del Hunco flora from Chubut, Patagonia, Argentina is one of the world's most diverse Tertiary assemblages of angiosperms. This paleoflora was deposited in tuffaceous mudstones and sandstones of the Tufolitas Laguna del Hunco, which are described as a lacustrine unit of the middle Chubut River volcanic-pyroclastic complex [9]. The flora is even more interesting because its paleofloristic association is composed of tropical elements (i.e. *Akania* and *Gymnostoma*) restricted today to temperate and tropical Australasia; other elements (i.e. Anacardiaceae and Melastomataceae) are considered to be modern pantropical, and there are elements of austral origin (i.e. Proteaceae and Podocarpaceae). Leguminosae or Fabaceae comprises more than 700 genera and 17000 species belonging to three subfamilies (Papilionoideae, Caesalpinioideae and Mimosoideae). Calvillo Canadell *et al.* (2007) [9] reported morphotypes based on compressions of leaves and a single fruit, and correspond to members of the subfamilies Papilionoideae and Caesalpinioideae. The subfamily Papilionoideae was represented by fossils assignable to the tribes Swarztieae (*Zollernia*), Brongniartieae (*Hovea*), Phaseoleae (*Rhynchosia*), and Desmodieae (*Desmodium*), while the subfamily Caesalpinioideae was confirmed by the presence of the tribes Detarieae (*Hymenaea*), Cercideae (*Cercis*), and Caesalpinieae (*Sclerolobium*). The tribe Caesalpinieae was also represented by a fossil fruit probably belonging to the genus *Caesalpinia*. These fossils allow confirmation of the presence of Leguminosae in Patagonia at least since the early Eocene. The existence of two out of the three subfamilies by the early Eocene also suggests that legumes probably already diversified at the subfamily level in Argentina by the Paleogene [9]. Also, the presence of *Paracacioxylon frenguellii* associated with pulvinate leaves, which has anatomical similarities to *Acacia* Miller, suggests that legumes might have been a component of mesothermal forests developed along the western margin of the Golfo San Jorge Basin during the early Paleocene [10].

If compared with the number of families and genera in Argentina [11], arid and semiarid Patagonia currently include a rather high proportion of the floristic richness of the whole country, having 65 and 40% of all families and genera, respectively [12]. Major plant communities in Patagonia were described by León *et al.* (1998) [13] (Figure 2).

As it is probably true for many regions in the world, the two better represented families in Patagonia are the Poaceae with 440 species and the Asteraceae with 497 species [12].

Results shown by León *et al.* (1998) [13] show that there is considerable variation in the vegetation within the Patagonian territory (Figure 2). Soriano *et al.* (1983) [14] and Fernández and Gil (2006) [15] published a comprehensive review of the Patagonian vegetation, and quoted six floristic districts for this region. Other authors have described the vegetation for Central Patagonia [16-19]. The Patagonia vegetation is characterized by a low shrubby steppe intermingled with tussock grasses. In large areas, shrubs are the physiognomically dominant plant species. The most frequent shrubs are: *Caesalpinia spinosa* (syn: *C. tinctoria*), *Chuquiraga avellanedae*, *Colliguaya integerrima*, *Mulinum spinosum*, *Senecio filaginoides*, *Verbena tridens*, *Berberis cuneata*, *B. heterophylla*, *Baccharis darwinii*, *Anarthrophyllum rigidum*, *Nassauvia glomerulosa*, *Lycium chilense* (Table 1).

The grass family is prevalent in the Patagonian's floristic composition, and the genus *Stipa* is dominant. It includes *S. humilis*, *S. speciosa*, *S. ibari*, *S. neaei*, *S. psylantha* and *S. subplumosa*. Other significant components of the grass flora are *Poa ligularis*, *P. lanuginosa*, *Festuca argentina*, *F. pallescens*, *F. gracillima* and *Bromus setifolius* (Table 1). Large areas are physiognomically characterized by cushion-like shrubs, less than 1 m height. Total cover varies from 15 to 60% depending on the environmental location and particular range management. Low lands frequently present halophytic vegetation characterized by communities of *Frankenia patagonica*, *Atriplex lampa*, and *A. sagittifolia*. *Schinus polygamus* (Table 1) is one of the biggest shrubs of southern Patagonia. This shrub, which can reach a height of three meters, has been almost extinguished from large areas because of its excellent properties as firewood.

Shrubs and grasses differ in their strategies to cope with limited soil water availability, an important constraint to plant growth in Patagonia. Brown (1995) [20] provides a nice overview of the mechanisms which allow them to cope with water stress. For example, shrubs use mainly resources from lower soil layers, and rely primarily on the winter recharge of deep soil water. Tussock grasses, however, use resources mainly from the upper soil layers with their shallower root systems [21]. Grasses and shrubs are less numerous than forbs, but constitute most of the aboveground production. Total plant biomass sharply decreased with decreasing precipitation along an aridity gradient in western Patagonia. However, belowground biomass decreased at a lower rate than aboveground biomass, resulting in increased root:shoot ratios [22]. Depth of the soil horizon (0,50-0,80 m) that contained 90% of the root biomass along this gradient was similar for forests and grasslands, but was shallower in the desert (0,30 m) [22].

Soriano started his observations on the Patagonian vegetation in 1945. His first information referred to grasslands overgrazing. He emphasized the importance of considering plant species because of their abundance, and their tendency to either invade or disappear [14]. Patagonian herbivores have preferentially selected grass than shrubs or forbs species in their diet [1]. Selecting herbivores during decades have left impourished lands as a result, where shrubs are the prevailing growth form in the vegetation. Mismanagement of fire has contributed to the current vegetation abundance and distribution [23]. The resulting decreased grass cover and increased shrub cover and bare ground have led to a decreased herbivory biomass. Little of the original natural vegetation remains, and the soil is in a progressive state of erosion, intensified by the permanent, strong winds from the west [1,24-26]. A steady reduction of plant cover induced by grazing, mismanagement has intensified the concentration of nutrients in the remaining plant patches, leaving large areas of bare soil exposed to wind and hydric erosion, with limited nutrient reserves and supplies [27-29].

Legumes

Not much attention has been paid to legume plants species in the semiarid and arid grasslands of Patagonia. Scientists, however, agree that their richness is limited, and their distribution is almost exclusive to grasslands. Ritchie and Tilman (1995) [30] confirm that legume plants are rare in grasslands with nitrogen-poor soils, but the environmental factors can modify their presence. Because of their ability to fix atmospheric nitrogen, legume plants can be especially important on nitrogen-deficient soils like those in Patagonia. Richie and Tilman (1995) [30] reported that legumes may be rare in many natural grasslands because: a) herbivores may selectively consume them in nitrogen-poor soils because they often have a higher tissue nitrogen content than non-legume plant species; b) legume growth might be limited by nutrients other than nitrogen. Legumes can have higher requirements for nutrients other than nitrogen than non-legume plant species [30].

The environmental deterioration with loss of biodiversity, and occurrence of irreversible changes in some ecological systems, attracts the attention on the presence of legumes in grasslands. Eighteen percent of the species in the Patagonia flora belong to the Fabaceae with 160 species distributed in 21 genus [31]. All three subfamilies are represented in the region. The 27 legume genus present in Patagonia are: *Acacia*, *Adesmia*, *Anartrhophyllum*, *Astragalus*, *Caesalpinia*, *Cercidium*, *Cyamopsis*, *Cytisus*, *Galega*, *Geoffrea*, *Geoffroea*, *Glycyrrhiza*, *Hoffmanseggia*, *Labumum*, *Lathyrus*, *Lotus*, *Lupinus*, *Medicago*, *Melilotus*, *Trifolium*, *Prosopidastrum*, *Prosopis*, *Rytidosperma*, *Senna*, *Trifolium* ,*Ulex*, *Vicia* (Table 1) [31-36]. The present biological forms, characteristic of legumes, are perennial herbs and shrubs, either thorny or not.

The flora of Patagonia is largely unexplored for sources of industrial products [32]. These authors reported that there are two ways for searching new materials: (1) collection and extraction of each type of compound from the available plant material, and (2) a systematic search for prospective species which are selected by phylogenetic relationships. The first way tends to be used with medicinal plants. The second way is considered by Ravetta and Soriano (1998) [32] as a better approach for industrial raw materials. Within a list of prospectives families, the Fabaceae appear promising.

Gums, complex carbohydrates produced by several plants, are used as adhesives in the textile and pharmaceutical industries, to manufacture mucilages, pastes, paints and varnishes, and in the food industry. None of the gum producing species is commercially grown in Argentina. Argentina imports from Sudan around 2,500 tons of Arabic gum and 700 tons of guar gum from India annually [38].

Together with soybean and lupin (two of the world's most important sources of commercial seed-oils), there are many species in the family that produce C_{18} fatty acids, and would face competition from established sources of these seed-oils [32]. On the other side, desert adapted legumes are important commercial sources of exudates (*Acacia senegal* and others = gum Arabic; *Astragalus* sp. = gum tragacanth; *Prosopis* and *Cercidium* species = mesquite gum) and seed-gums (*Cyamopsis tetragonoloba* = guar gum). Ravetta and Soriano (1998) [32] reported that the genus *Prosopis* is widely distributed in the northern areas of Patagonia; several species of this genus contain between 3 and 14% oil in the seeds with major components of palmitic, oleic and linoleic acids. In *Prosopidastrum globosum*, 70% of the seed oil fatty-acids is linoleic acid with a total oil content of about 5% [32]. Several genera from Patagonia should be considered for seed-oil, seed-gum and sugar and protein production [i.e., the fruits of *Astragalus* (26 species in Patagonia) and *Adesmia* (53 species in Patagonia)]. In addition, the production of gum-exudates from *Prosopis* and *Cercidium* needs quantification [32]. The *Prosopis* gum is similar to the one produced by the *Acacia senegal* in terms of the composition of its polysaccharides and aminoacids and its physical properties. The endosperm of the *Prosopis* seeds contains galactomannans that can be separated through a water process, producing 85-95% pure gums. The value and use of the *Prosopis* gum can be comparable to that of the guar, due to the fact that the amount of purified galactomannans in some species (*P. velutina* and *P. chilensis*) is similar to that of the guar gum. *Prosopis* gum exudes, commercialized in North America as "mezquite gum" have been used to replace Arabic gum [38].

Acacia senegal is a savanna shrub or tree, up to 20 m tall, over 1.3 m in girth, spiny [39]. It thrives on dry rocky hills, in low-lying dry savannas, and areas where annual rainfall is 25–36 cm [40]. It yields commercial gum arabic, used extensively in pharmaceutical preparations, inks, pottery pigments, water-colors, wax polishes, and liquid gum; for dressing fabrics, giving lustre to silk and crepe; for thickening colors and mordants in calico-printing; in confections and sweetmeats. Gum acacia contains neutral sugars (rhamnose, arabinose, and galactose), acids (glucuronic acid and 4-methoxyglucuronic acid), calcium, magnesium, potassium, and sodium. Its complex structure is still not completely known [41]. Gum arabic is reported to exhibit tolerance to alkali, drought, fire, high pH, poor soil, sand, slope, and wind [39]. *Acacia senegal* is also used as firewood, yielding 0.5-5 m^3 ha^{-1} wood annually, with an energy value of ca 3,500 kcal kg^{-1}. A nitrogen,fixing species, it can be used to reestablish vegetation cover in degraded areas, as well as for sand-dune fixation and wind erosion control [42]. Fungi reported on this plant species are *Cladosporium herbarum*, *Fusarum* sp., *Ravenelia acaciae-senegalae* and *R. acaciocola*. Spiders (*Cyclops* sp.) may completely cover the young growing apex. Seedlings are often grazed by gazelles, goats, and pigs [43]. Plants are useful for afforestation of arid tracts, soil reclamation, and windbreaks [39].

Gum from *A. senegal* exudes from cracks in the bark of wild shrubs or trees, mostly in the dry season. In some areas, a long strip of bark is torn off and the gum allowed to exudate. Either shrub or trees begin to bear between 4–18 years of age and are said to yield only when they are in unhealthy state due to poor soil, lack of moisture or damage. Attempts to improve conditions tend to reduce yield. Gum arabic annual yields may range from 188 to 2856 g (avg. 900 g) for young trees, to 379 to 6754 g (avg. 2,000 g) in older trees [39]. Gum from wild shrubs or trees, is variable and somewhat darker colored than that from cultivated plants. Collected gum is carefully cleaned from extraneous matter, sorted and sometimes ripened in sun before export. Gum arabic is odorless with a bland taste, yellowish and some tears are vermiform in shape. Ripened or bleached gum occurs in rounded or ovoid tears over 2.5 cm in diameter, and in broken fragments. Tears are nearly white or pale yellow and break readily with a glassy fracture. Gum is almost completely soluble in an equal volume of water and gives a translucent, viscous, slightly acid solution, but is insoluble in 90% alcohol [39].The demulcent, emollient gum is used internally in inflammation of intestinal mucosa, and externally to cover inflamed surfaces, as burns, sore nipples and nodular leprosy [44]. Causing partial destruction of many alkaloids including atropine, hyoscyamine, scopolamine, homatropine, morphine, apomorphine, cocaine, and physostigmine, gum arabic might be viewed as a possible antidote. Pharmaceutically used mainly in the manufacture of emulsions and in making pills and troches (as an excipient); as demulcent for inflammations of the throat or stomach and as masking agent for acrid tasting substances such as capsicum; also as a film-forming agent in peel-off masks. Its major use is in foods, for example, as suspending or emulsifying agent, stabilizer, adhesive, flavor fixative, and to prevent crystallization of sugar, etc. Used in practically all categories of processed foods (candy, snack foods, alcoholic and nonalcoholic beverages, baked goods, frozen dairy desserts, gelatins, and puddings, imitation dairy products, breakfast cereals, and fats and oils). Use levels range from less than 0.004% (40 ppm) in soups and milk products, 0.7 to 2.9% in nonalcoholic beverages, imitation dairy, and snack foods, to as high as 45% in candy products [41]. Strong rope made from bark fibers. White wood is used for tool handles, black heartwood for weaver's shuttles. The long flexible strands of surface roots provide one of the strongest fibers, used for cordage, well-ropes, fishing nets, horsegirdles, footropes, etc. Seeds are dried and preserved for human consumption [42]. In modern pharmacy, it is commonly employed as a demulcent in preparations designed to treat antitussive, astringent, catarrh, colds, coughs, expectorant, gonorrhea, hemorrhage, sore throat, typhoid, throat irritation, and fevers [44]. It serves as an emulsifying agent and gives viscosity to powdered drug materials; it is used as a binding agent in making pills and tablets and particularly cough drops and lozenges. Because of its enzyme, the gum is not suitable for use in products having readily oxidizable ingredients. For example, it reduces the vitamin A content of cod liver oil by 54% within three weeks. It is incompatible with (1) aminopyrine, morphine, vanillin, phenol, thymol, a- and b-naphthol, guiacol, cresols, creosol, eugenol, apomorphine, eserine, epinephrine, isobarbaloin, gallic acid, and tannin, and (2) strongly alcoholic liquids, solutions of ferric chloride and lead subacetate, and strong solutions of sodium borate. It was formerly given intravenously to counteract low blood pressure after hemorrhages and surgery and to treat edema associated with nephrosis, but such practices caused kidney and liver damage and allergic reactions and have been abandoned [43].

Ingested orally, acacia is nontoxic. However, some people are allergic to its dust and develop skin lesions and severe asthmatic attacks when in contact with it. Acacia can be digested by rats to an extent of 71%; guinea pigs and rabbits also seem to utilize it for energy, as man does to a certain extent. Gum arabic may actually elevate serum or tissue cholesterol levels in rats [41]. Young foliage makes good forage.

Adesmia is a genus that belongs to the Papilionoideae subfamily. It occupies a rather isolated systematic position, since it was set up a new tribe: Adesmieae. It has exclusively a southamerican distribution, and there is no doubt that it is the largest genus within the austroextratropical legumes in South America; Burkart (1952, 1967) [37,45] reported that it includes 230 species. *Adesmia* represents the genus with more species richness in Patagonia (51 species). It is an important part of the genetic diversity of the family because of its number of species, and extension and importance of the patagonian environments where it grows.

The genus *Astragalus* includes only a few useful species to mankind. The Patagonian species of this genus were extensively studied by Gomez-Sosa (1979, 1983, 1984) [46-48]. The native species of southern Chile and Argentina were cited in the literature as toxic plants with the name of "hierbas locas" [49-51]. With 16 species, the genus *Astragalus* follows *Adesmia* on species number regarding the patagonian legumes. Toxic substances in *Astragalus* include some alkaloid or selenium compounds [52,53]. Selenium poisoining is often associated with consumption of selenium accumulator plants as *Astragalus* spp., which may contain up to several thousand ppm Se. At present, practical measures for controlling selenium poisoining of grazing livestock rely on pasture rotation and use of feeds from non-seleniferous areas. Locating seleniferous soils and mapping them in sufficient detail are essential. The selenium content is highest in young plants and declines rapidly at later stages of maturity. Therefore, use of pastures of low selenium content during the growing season, and selenium accumulator forages toward the end of the growing season is a very effective control measure. Both genus, *Adesmia* and *Astragalus*, are often found in disturbed areas [54].

Caesalpinia spinosa, commonly known as tara, is a small leguminous tree or thorny shrub. It is grown as an ornamental plant because of its large colorful flowers and pods. *Caesalpinia spinosa* pods are an excellent source of environmentally friendly tannins most commonly used in the manufacture of furniture leather. Tara gum is a nearly odorless powder that is produced by separating and grinding the endosperm of *C. spinosa* seeds. This gum has been deemed safe for human consumption as a food additive. Tara gum is used as a thickening agent and stabilizer in a number of food applications. *Cercidum praecox* has also been mentioned to produce gum [55]. *Caesalpinia spinosa* is generally resistant to most pathogens and pests, and it will grow between 0 and 3,000 meters above sea level, tolerates dry climates and poor soils including those high in sand and rocks. To propagate, seeds must be scarified (pre-treated to break physical dormancy) and young plants should be transplanted to the field at 40cm in height; trees begin to produce after 4-5 years. Mature pods are usually harvested by hand and typically sun dried before processing. If well irrigated, trees can continue to produce for another 80 years, though their highest production is between 15 and 65 years of age. Medicinal uses include gargling infusions of the pods for inflamed tonsils or washing wounds; it is also used for fevers, colds and stomach aches. *Caesalpinia spinosa* can also be a source of lumber and firewood, and as a live fence. Water from boiled dried pods is also used to kill fleas and other insects. The seeds can be used to produce black dye while dark blue dye can be obtained from the roots [56]. *Caesalpinia gilliesii* is a fast growing shrub, which flowers in summer and is very drought resistant; it is also an ornamental shub [57]. It was cited as a poisonous plant to vertebrate mammals by Lampe and McCann in 1985 [58]. *Caesalpinia pulcherrima* has also been cited as an ornamental and toxic plant [59].

Cyamopsis tetragonolobus, an annual leguminous adapted to semi-arid environments, is one of the most important sources of seed gum (guar gum) in the world. The cultivation of guar, together with the extraction of native gum species of high commercial value possibilities is a productive alternative for arid and semi arid zones in Argentina. However, to exploit and cultivate these species, strong evidence on the production and quality of the gums cumulated and their behavior under diverse environment conditions is needed. This information, on the species in general and for each genotype in particular, is poor and must be generated in order to grow guar in Argentina. On the other hand, there are some native leguminous species with potential as gum producers. Gums are produced in fruits, seeds and trunks exudation [38].

Galega officinalis was found as a new host plant for the Erysiphaceous taxa (Ascomycetes) by Havrylenko and Takamatsu (2005) [60]. This legume is a bushy plant that may grow to a height of 0.90 m, with branching stems and oval, opposite leaves. The long flower stalk produces many light purple-to-pink-to-white flowers similar to those in the pea family. It has been used to lower blood sugar levels and is thus used in alternative treatment of and for the prevention of diabetes mellitus. *Galega officinalis* has also been used to reduce fevers through its diuretic and diaphoretic (sweat inducing) properties. It has also been said the most effective herb in the stimulation of milk production. It was formerly used in England to increase milk production in goats and cattle, and the belief soon developed that *G. officinalis* would also stimulate breast development in human females as well. In the past, this legume was also used to treat snakebite, plague and intestinal parasites. Active constituents of *G. officinalis* include flavonoids, saponins, glycosides, tannins and galegin, the compound said to be responsible for its blood sugar reducing capability.

Geoffroea decorticans pertains to the Papilionaceae's family. It flowers in spring, most of the times before leaf production. When it grows associated, it has a shrubby growth form and can reach 2-4 m height. It grows in the Province of Río Negro (Figure 1) and has spinescent branches. The trunc measure from 40-60 cm when it grows solitary to 10-15 cm when it grows forming intraspecific woodlands; this is because of shoot growth from vegetative buds in the roots. Its foliage is caducifolius, and it grows in clay, salty, and coarse soils. It can be found in areas with soils from dry to wet. It is a heliophyte, mesexerophyte to xerophyte species. Its fruit is edible, and with it an alcoholic breverage is prepared (the aloja of chañar). Fruits are also a food source for horses and cattle. Goats browse *G. decorticans* branches. This species' wood is medium-hard and moderately heavy (specific weight between 0.585-0,600 kg dm^{-3}); it is used for making rustic furniture, tool ends, stirrups, firewood, etc. Its cortex, leaves and flowers have expectorant properties. It is ideal for providing shade to livestock, and obtaining waterproof inks [32].

Glycyrrhiza astragalina is a native legume herb from Patagonia [61]. These authors reported that this legume is conspicuous in the grass prairies of the Patagonian Phytogeographical Province in the Chubut Province, Argentina. Pollen content of honeys produced in the River Senguerr prairies reflects prairie species composition, where *G. astragalina* is abundant [61]. Forcone and Tellería (2000) [61] conducted a palynological analysis on honey samples to know the plants used by honeybees in the Senguerr river plains; they found the legumes *Melilotus* sp., *Trifolium* sp., *Medicago* sativa, *Trifolium pretense*, *Glycyrrhiza astragalina*, *Adesmia volckmanii*, and *Prosopis denudans* in that palynological analysis. In most honey samples, pollen content was lower than 2,000 grains/honey gram [61].

The legume *Hoffmanseggia trifoliata* is associated with the sub-shrub stratum, which has a plant cover of approximately 5% and a plant height of 10 cm in Punta Delgada, located at the southeast of the Península de Valdés, Province of Chubut, Patagonia, Argentina [62]. It is a preferred legume by cattle, but its scarce biomass production makes that this species is not taken into account in rangeland management practices.

Lupinus polyphyllus is an ornamental, perennial genotype which has become a wild plant in Patagonia. Plants can live for more than two years, and have a stem which is either 1 or more meters tall. It is sturdy and branched at the plant base, and develops terminal flower bunches during summer. Flowers can be of various colours (violet, white, yellow and fuchsia). Fruits have pod form and contain various small seeds. Plant multiplication is through sexual reproduction (i.e., seed production). When it is cultivated, not only is utilized as ornamental but also as green fertilizer or forage for animals to be hunted [63].

Prosopidastrum globosum is a 1-2 m tall shrub, endemic to Argentina. It has green, spiny stems with almost no leaves [64].

Senna candolleana is an evergreen shrub, semi-hardy (-5ºC), 1 to 2 m tall, with dark green leaves. It produces an abundance of buttercup-like yellow-goldish flowers from late winter to early summer [65].

In the Sub-Andean district of SW Chubut province, *Festuca pallescens*, *Rytidosperma picta* and *Lathyrus magellanicus* are major species of the herbaceous steppe that characterizes the region. *Vicia bijuga* is a companion species in that community. The deciduous shrubs appear in more arid areas. Stronati *et al.* (1995) [54] suggested that in the more degardated areas of the Chubut province, there was an increase in legume species richness. This increase was associated with the appareance of new, more xerophytic legume species, adapted to the new environmental conditions. *Lathyrus magellanicus* and *Vicia bijuga* spread the most, meanwhile *Trifolium repens* was associated to more conserved areas.

When the effect of long-term exclusion from grazing was evaluated on *Lathyrus magellanicus* and *Vicia bijuga* there was no significant difference in the frequency of each species in the grazed area, but their relative frequency increased in the non-grazed area. This increase was greater in *Lathyrus magellanicus* than in *Vicia bijuga*. It is likely that in the disturbed areas, perennial herbaceous species are avoiding grazing by maintaining their growing points at a barely below the soil surface during part of the growing season. This would make these species less vulnerable to grazing such as they can recover once the disturbance pressure is reduced. Their bud bank at the stem bases or in the rhizomes would be critical for their restoration. However, Soriano *et al.* (1994) [12] recently reported that some legume species are in a regression stage of succession: *Adesmia lotoides; Astragalus patagonicus; Lathyrus magellanicus* and *Vicia bijuga*. Domestic livestock overgrazing would be a major cause of this regression. Even more, Stronati (2000) [66] mentioned that some of these species were not found. They determined the presence of *Astragalus cruckshanksu, Vicia pampicola, Adesmia muricata* var. *muricata* and *A. smithiae* as part of the herbaceous strata of the shrub steppe in the coastal low-lands of the San Jorge Gulf floristic district. These species were associated with disturbed areas by man. Likewise, the herbaceous legumes *Adesmia lotoides* and *A. villosa* were found on impermeable soils of Patagonian pebbles, in the highest San Jorge Gulf plateaus (700 m above sea level). Working with grassland ecosystems of the Mediterranean region, Cooks (1995) [67] pointed out that legumes that develop under disturbed ecosystems represent a resource of great value for them. Cooks (1995) [67] also expressed the need to prepare a collection program leading to conservation of the legume species, and their potential use in improvement programs. Besides, he indicated to prevent genetic erosion in the legume species, as a result of their habitat destruction. In arid ecosystems, all biological processes are controlled by temporal changes in water availability which is limited and unpredictable [68-71]. Also, in natural grasslands of east central Minnesota with soils poor in nitrogen, legume aerial biomass and abundance responded to factors like herbivory, drought and nutrients other than nitrogen, (i.e., phosphours and potassium) [30].

Many of the Patagonian legumes would feed native and domestic herbivorous. Pelliza Sbriller and Sarasqueta (2004) [72] found that *Adesmia lotoides*, *Astragalus* spp. and other herbs were important components of *Rhea* diet in Patagonia. These authors showed that the morphological diversity within species like *Adesmia volckmanni*, *A. salamancensis*, *Prosopis denudans* and *Anarthrophyllum rigidum* was similar among several locations in the Patagonian plateau of Chubut, south of 44º latitude. However, individuals at the same locality or neighbouring areas did not present defined associations [73]. This can be explained because relief at the study area did not constitute an effective barrier. Landscape of dominant plateaus without geographic barriers allows the dispersion of species without interruption, unless other environmental factors become limiting.

Adesmia volckanii, *Cytisus scoparius*, *Labumum anagyroides*, *Lathyrus latifolius*, *Lotus uliginosus*, *Lupinus polyphyllus*, *Medicago sativa*, *Melilous albus*, *Trifolium pratense*, *Trifolium repens*, *Ulex europaeus* and *Vicia nigricans*, all legumes pertaining to the Fabaceae family, were reported as species of interests for bee-keepers in Patagonia by Forcone and Kutchker (2006) [33].

Within the vascular plants, legumes that fix nitrogen are candidates to be designated as a functional group [74]. Davis (1982) [75] found that species of *Astragalus* can transfer nitrogen to the system when they grow with grasses. In mesic systems, it is a common practice to do companion crops of legume plants with species for grain or forage harvest to incorporate nitrogen to the system [76]. It is important to think of the symbiotic system as a whole if we are interested in biodiversity conservation and sustainability of ecosystems.

Approximately 20% of the study species did fix nitrogen. However, the majority of them, which pertained to the herbaceous Papilonaceae, did not. Farías *et al.* (1989) [77] only studied 21% of the species of that family about their symbiosis with diazotrophic bacteria. Further research in the Patagonian steppe should focus on studying nitrogen fixation of its legume species.

If we want to deal with the persistence and use of legumes, we need to know about their capacity to symbiotically associate with soil diazotrophic bacterias. Studies done in the Universidad Nacional de la Patagonia, Argentina, during the last years allowed to know that the native herbaceous legumes of the genus *Adesmia*, *Astragalus*, *Glycyrrhiza*, *Lathyrus* and *Vicia* were found nodulated. Besides, shrubs species of the genus *Adesmia*, *Anarthrophyllum* and *Prosopis* were also found nodulated [66,78-80]. Diazotrophic nodules extracted from these herbaceous and shrub species were shown to fix nitrogen.

Blondel and Aronson (1995) [74] suggested that some herbaceous nitrogen-fixing legumes made mutualist associations with grasses in natural grasslands. O'Connor (1983) [81] reported that biological nitrogen fixation is most important during early successional stages in natural ecosystems. Legume nitrogen fixation appears to be a link between biodiversity and ecosystem functioning, which would be the result of species co-occurrence [74].

In arid environments, nutrient concentrations and microorganism populations have been reported to be significantly greater under than between shrub canopies [82-86] and that their abundance is positively correlated with soil humidity levels. The capacity to nodulate and fix atmospheric nitrogen of the herbaceous legumes which grow in the shrub surrounding areas, contribute nitrogen, a critical element required by arid ecosystems.

The population of native *Rhizobium* spp. in the soil could be assumed one of the causes of the strategy of the legumes to colonize in early successional stages after a disturbance.

There is a tendency in Patagonia to incorporate native species as new crops. Among these species considered are legumes. They can provide species of ornamental and landscape value; and a source of fuel, forage, and stress-resistance species to alleviate processes of degradation with the reintroduction of some valuable genotypes. Different methods for the restoration of key herbs in the ecosystem performance of temperate, semiarid continental zones of southeast Oregon, were reported by Wirth and Pyke (2003) [87].

Moisture availability is obviously one of the most important factors that control germination [20]. *Anarthrophyllum rigidum*, *A. desideratum*, *Prosopis denudans*, *Adesmia salamansencis*, *A. volkmanni*, *A. lotoides*, *Glycyrrhiza astragalina* and *Astragalus cruckshanksii* showed a strong germination inhibition because of their tegument which was removed by chemical and/or mechanical scarification (Stronati *et al.*, unpublished). When the same species were in contact with solutions of decreasing water potentials, all of them decreased germination rate and percentages as solution water potentials were reduced. However, these decreases in germination occurred in different proportion for each species. *Prosopis denudans* was the most tolerant to germinate under low water potential conditions.

As seedlings develop, they become more sensitive to environment desiccation, and changes with drying are irreversible [88]. Studies related to early plant development indicated that seedlings of *Anarthrophyllum rigidum* and *Astragalus cruckshanksii* did not show significant differences in emergency when they grew at different levels of soil moisture availability. However, other species like *Adesmia lotoides* and *Glycyrrhiza astragalina* showed seedling appearance under low levels of soil moisture [89].

Increases and/or maintenance of plant diversity and desirable community cover are good indicators of a sustainable use of arid and semiarid rangelands [90].

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Table 1. Some major species of the Patagonian steppe.

Trees	***Shrubs***	***Perennial Grasses***	***Annual Grasses***	***Perennial Forbs***	***Annual Forbs***
Araucaria araucana (Molina) Koch	*Acacia senegal* (L.) Willd. Syn.: *Acacia verek* Guill. et Perr.	*Bromus setifolius* J. Presl.	*Agrostis pyrogea* Speg.	*Astragalus patagonicus* (Phil.) Speg.	*Daucus pusillus* Michaux
Labumum anagyroides Medik.	*Adesmia salamancensis* Burkart	*Festuca argentina* (Speg.) Parodi	*Bromus tectorum* L.	*A. cruckshanksii* (Hook. & Arn.) Griseb.	*Doniophyton patagonicum* (Phil.) Hieron.
	A. volckmanni Phil.	*F. gracillima* Hook.	*Deschampsia antarctica* Desv. in Gay	*Adesmia lotoides* Hook.f.	*Erodium cicutarium* (L.)L'Hér.
	Anarthrophyllum rigidum (Gillies ex Hook. & Arn.) Hieron.	*F. pallescens* (St. Yres) Parodi	*Hordeum comosum* Presl.	*A. muricata var. muricata* (Jacq.) DC.	*Gnapyalium pratense* Phil.
	Anarthrophyllum desideratum (DC.) Reiche	*Poa lanuginosa* Poir.	*Koeleria mendocinensis* (Hauman) Calderón nov. stat.	*A. smithiae* DC.	*Melilotus albus* Desr.
	Atriplex lampa Gill ex Moquín	*P. ligularis* Nees ex Steud.	*Poa annua* L.	*A. villosa* Hook.f.	*Microsteris gracilis* (Hook.) Greene
	A. sagittifolia Speg.	*Panicum urvilleanum* Kuntz	*Polypogon australis* Brongn. in Duperrey	*Arjona patagonica* Hombr. & Jacquinot	*Oenothera contorta var. divaricata* (Gay) Munz
	Baccharis darwinii H. & A.	*Piptochaetium napostaense* (Speg.) Hackel		*Azorella trifurcata* (Gaertn.) Pers.	*Plantago patagonica* Jacq.
	Berberis cuneata DC.	*Sporobolus rigens* (Tr.) Desv.		*Carex andina* Phil.	*Silene antirrhina* L.
	B. heterophylla Jussieu in Lam.	*Stipa humilis* Cav.		*C. argentina* Barros	*S. armeria* L.

	Poir.				
	Bouganvillea spinosa (Cavanilles) Heimerl.	S. *ibari* Phil.		*Cerastium arvense* L.	*Vicia magellanica* Hook.f.
	Caesalpinia gilliesii (Hook) Wallich ex. D. Dietr.	*S. neaei* Nees ex Steud.		*Colobanthus crassifolius* (D'Urv.) Hook.f.	*V. pampicola* Burkart
	Caesalpinia pulcherrima (L.) Sw.	*S. psylantha* Speg.		*C. subulatus* (D'Urv.) Hook.f.	
	Caesalpinia spinosa (Molina) Kuntze	*S. sorianoi* Parodi		*Glycyrrhiza astragalina* Gillies ex Hook. & Arn.	
	Cercidium praecox (Ruiz et Pavón) Harms subsp. *glaucum* (Cav.) Burkart et Carter	*S. speciosa* Trin. & Rupr.		*Hoffmanseggia* spp.	
	Chuquiraga avellanedae Lorentz	*S. subplumosa* Hicken ex Roig		*Hyalis argentea* Don	
	Chuquiraga histrix on Flicky			*Hypochoeris radicata* L.	
	Colliguaya integerrima Gillies & Hook. ex Hook.			*H. acaulis* (Remy) Britton	
	Condalia microphylla Cav.			*H. montana* (Phil.) Reiche	
	Cyamopsis tetragonoloba (L.) Taub.			*H. patagonica* Cabrera	
	Cytisus scoparius L. Link (P)			*Lathyrus latifolius* L.	

	Frankenia patagonica Speg.			*Lotus uliginosus* Schkuhr	
	Galega officinalis L.			*Lupinus polyphyllus* Lindl.	
	Geoffroea decorticans (Gill. ex Hook. et Arn.) Burkart			*Medicago sativa* L.	
	Grindelia chiloensis (Corn.) Cabrera			*Perezia recurvata* (Vahl) Less.	
	Hoffmanseggia trifoliate Cav.			*Polygala darwiniana* Benn.	
	Junellia tridens (Lagasca) Mold			*Potentilla anserina* L.	
	Larrea nitida Cav.			*Silene antarctica* (Kuntze) Pedersen, nov. comb.	
	Lycium chilense Miers			*S. chilensis* (Naud.) Bocquet	
	Mulinum spinosum (Cav.) Pers.			*S. chubutensis* (Speg.) Bocquet	
	Nardophylum obtusifolium Hook. & Arn.			*S. patagonica* (Speg.) Bocquet	
	Nassauvia glomerulosa (Lag.) Don			*Trifolium pretense* L.	
	Prosopidastrum globosum (Hook. & Arn.) Burkart			*T. repens* L.	
	Prosopis denudans Bentham (Hooker)			*Vicia nigricans* Hook & Arn.	

		Schinus polygamus (Cav.) Cabrera *Senecio filaginoides* DC. *Senna candolleana* (Vogel) Irwin & Barneby *Tetraglochin ameghinoi* (Speg.) Speg. *Trevoa patagonica* Speg. *Ulex europaeus* L. *Verbena tridens* Lag.				

Figure 1. Location of Patagonia in Argentina, and Regions in Patagonia.

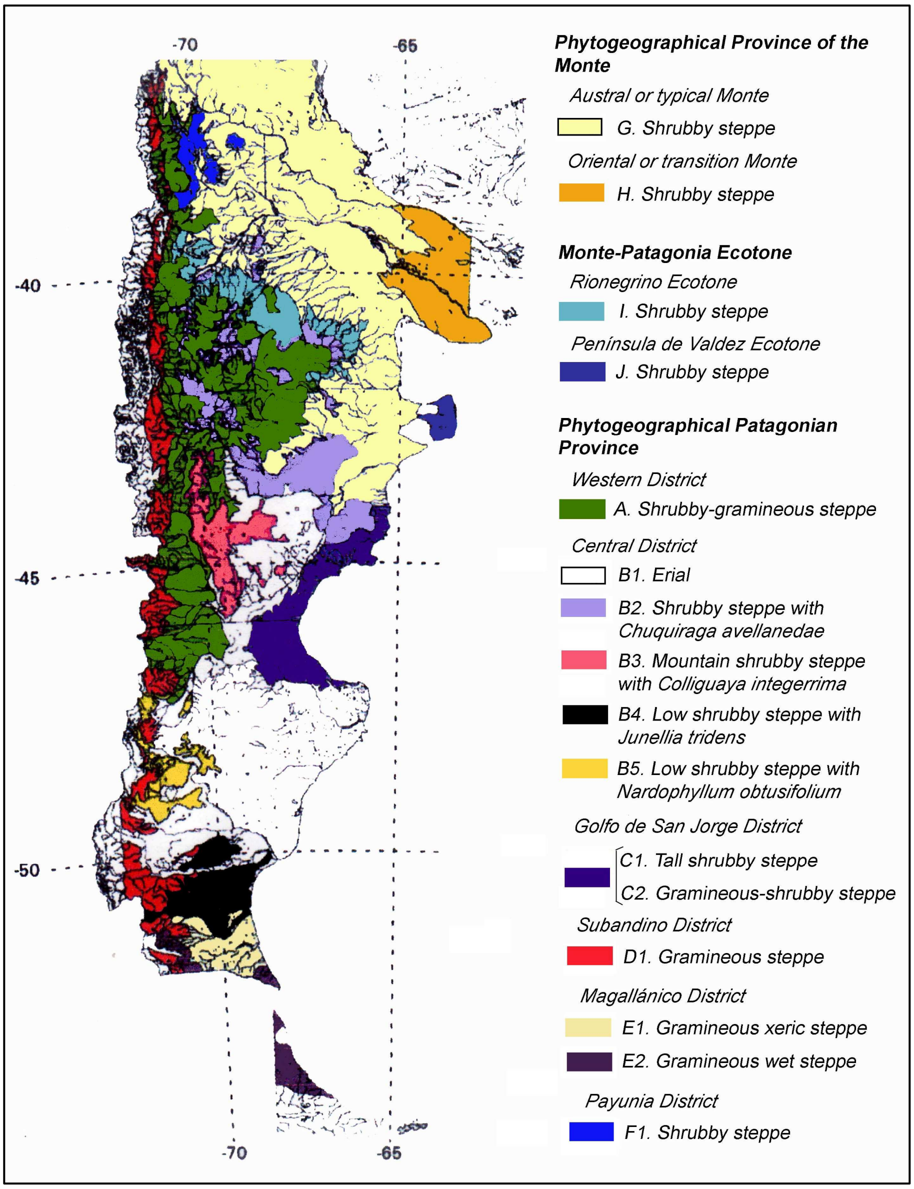

Figure 2. Map of the vegetation units defined for Patagonia (adapted from León *et al.*, 1998) [13].