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Grasslands of South America

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1. Introduction

Grasslands have historically been an area of expansion for human land use (White et al., 2000), and much of the world's highly productive grassland has been converted to crops, mixed farming and artificial pastures (Suttie et al., 2005). In temperate grasslands, this conversion occurred prior to the 1950s (Millennium Ecosystem Assessment, 2005), and the percentage of protection for this biome is lower than for all other biomes (Hoesktra et al., 2005). A current wave of agricultural expansion is occurring in the tropics, with many tropical savannas and grasslands undergoing change (Gibbs et al., 2010). Growth of agricultural sectors in South America (Gavier-Pizarro et al., 2012), southern Africa (Maeda et al., 2010), North America (Landis & Werling, 2010), and Asia (Qiu et al., 2010) heralds new pressures on global grassland ecosystems. Future threats to grasslands also appear high, given a need to feed a rapidly growing human population (Foley et al., 2011).

These threats challenge governments, business and civil society to develop policies that address conversion pressures on global grassland ecosystems and seek to balance development with conservation. However, decision-makers currently lack a framework within which to monitor global grassland biodiversity for both biological uniqueness and total historical distribution. One promising initiative is the International Union for the Conservation of Nature's (IUCN) proposed Red List of Ecosystems, where the likelihood that an ecosystem will persist into the future is assessed (Rodríguez et al., 2010). However, the projected completion date of the global Red List assessment is 2025 (Rodríguez et al., 2012; Keith et al., 2013), and policies are being implemented today. For example, the European Union's Renewable Energy Directive (EU RED) restricts imports of biofuels feedstock harvested from areas containing significant biodiversity and/or carbon stock (European Commission, 2009). A clear intent of this policy is to conserve grassland biodiversity, but the policy cannot be operational on a global basis without a global grassland distribution map as a foundation.

To address this gap, we present a framework for defining world grassland types and a methodology for mapping their geographical distribution. We propose the combination of two systems: the International Vegetation Classification (IVC), to give clarity to the definition of grasslands (Faber-Langendoen et al., 2014), and Terrestrial Ecoregions of the World (TEOW), to provide an initial global geospatial characterization (Olson et al., 2001). By combining these two systems, we generate a systematic, spatially explicit framework that broadly accounts for grassland biodiversity (as vegetation types) and the spatial ecological complexes (as ecoregions) within which grasslands occur. This approach provides a better platform for decision-makers to advance grassland conservation (see APPENDIX **MAP Global Grasslands**).

1.1. Defining grassland: challenges in developing of their conservation

A primary obstacle to developing and implementing effective grassland conservation policies is the wide spectrum of grassland definitions. Unlike forests, for which the United Nation's Food and Agriculture Organization (FAO) provides a clear definition (5 m in height, 10% or more canopy cover, > 0.5 ha, and not under agricultural or other non-forest land use; FAO, 2010), grasslands are variously defined (Gibson, 2009; and see the FAO's compilation of definitions www.fao.org/agriculture/crops/thematicsitemap/theme/spi/gcwg/definitions/en/). This profusion of definitions may be due to the greater difficulty in characterizing the limits of grasslands, a less persistent canopy structure, more frequent disturbance regimes, and their occurrence within a physiognomic continuum between forests and deserts. Grasslands might well be expected to be dominated by grasses, but the term often has a broader meaning when set in the context of defining a comprehensive set of ecological vegetation types (such as grassland versus forest, desert, tundra or wetland). In that context, the concept still emphasizes dominance by grasses or grass-like plants (graminoids) and the lack of trees, but the full suite of growth forms may include grasses, other narrow-leaved grass-like herbs (i.e. non-woody graminoids) and even forbs (broad-leaf herbs). Perhaps the more technically appropriate term is "herbland" [similar to UNESCO's (1973) 'Herbaceous Vegetation'], but "grassland" is the most popular, given that grasses are by far the most typical component and because forbs are often mixed within or patchily distributed among grasses (Davies et al., 2004). In his comprehensive review of major grasslands regions of the world, Coupland (1979) defined "grassland" as referring to "ecosystems in which the dominant vegetative component is comprised of herbaceous species".

Sometimes the term grassland is used even more inclusively to encompass herbs and shrubs (White et al., 2000); grasses and shrubs can form intricate mixes, and dominance may alternate between the two within the span of years or decades. In some cases, grasses may overtop shrubs (Faber-Langendoen et al., 2012). Here, we consider the various concepts of grasslands and provide a synthesized definition based on previous work. First, we clarify the term "grass", which we define broadly as an herbaceous monocot with narrow leaves, sometimes referred to as a graminoid. Raunkiær (1934) defines "grass" as "a caespitose or reptant hemicryptophyte life form". Box (1981) defines it as graminoids that are, "narrowleaved herbs growing from generally well-developed underground rootstocks which may be either perennial (i.e. rhizomes) or annual classified as bunched (cespitose), or spreading (sward-forming), and rooting". The primary taxonomic members are *Poaceae*, but they may also include *Cyperaceae*, *Restionaceae* and other narrow-leaved monocots.

We consider grasslands to be dominated by these members, while often containing, and sometimes dominated or codominated by forbs. A dominant or co-dominant is any species or growth form with at least 10% cover (Faber-Langendoen et al., 2012). Grass dominance is clearly expressed when grasses have greater than 25% grass cover (Kucera, 1981) but may be as low as 10% cover if they exceed that of all other growth forms. Shrub cover in grasslands is typically < 25%. Second, we distinguish largely native or natural grasslands from cultural grasslands. Natural grassland ecosystems are thought to have had a global distribution for at least 15 million years (Jacobs et al., 1999). The widespread expansion of C_4 grasses, which developed with seasonal climatic aridification and/or atmospheric change and which grow exclusively in open terrestrial areas, is seen in the macrofossil and pollen record as far back as the Miocene. Additionally, herbivore dental morphology has been shown to have co-evolved with the newly available C_4 grasses, substantiating the existence of widespread climax grassland ecosystems prior to the Anthropocene (Coupland, 1992; Jacobs et al., 1999; Edwards et al., 2010). Grasslands today range from strongly cultural, human-created systems, such as exotic grass pastures, to those largely shaped by more natural ecological processes of climate, fire and native grazers (FAO, 2005). For example, Mongolian grasslands have been managed as pasturelands since before the days of Genghis Khan (Li et al., 2006). In Australia, native grasslands are recognized by their component species, distinct from recently introduced exotic pasture grasslands (Lonsdale, 1994; Ash et al., 1997). But, the distinction between natural and cultural grasslands is not always black and white: the western North American grasslands are often referred to as rangelands (which include both shrublands and grasslands) and are often managed as such, but currently they form a continuum of natural (native), semi-natural (naturalized exotic), and cultural (intensive pasture) grasslands. For our purposes, we define native or natural (including semi-natural) grasslands, as those where non-human ecological processes primarily determine species and site characteristics. In other words, the vegetation is composed of a largely spontaneously growing composition of plant species shaped by both geophysical (site) and biotic processes (Küchler, 1969; Westhoff and van der Maarel, 1973; Dixon et al., 2014). Natural vegetation forms recognizable groupings that can be related to ecological site features. Human activities influence these interactions to varying degrees (i.e. logging, livestock grazing, fire, introduced pathogens), but do not eliminate or dominate the spontaneous processes (Westhoff & van der Maarel, 1973; Dixon et al., 2014). As with forests in the FAO definition, we exclude cultural grasslands, which are primarily planted and maintained for agricultural reasons (such as pasture, hay, and intensive livestock production). Although these distinctions can sometimes be problematic, they are also consistent with the approach of the Ecosystems of the World project, which provided separate descriptions of natural (Coupland, 1992) and managed grasslands (Breymeyer, 1990).

Third, we clarify the limits of grassland along an ecotone from grassland to woodland. We set a literature-based threshold for grassland with respect to tree cover, beyond which trees become a co-dominant and/or diagnostic part of the plant community concept, exerting disproportionate influence on competition for canopy cover and subsurface resources (House et al., 2003; Lock, 2006; Bucini and Hanan, 2007). In the temperate region, tree savannas are more restricted in area and often closely related to or included within the concept of woodlands (Faber-Langendoen et al., 2012). When tree cover exceeds 10% in temperate regions, we exclude it. In the tropics, tree savannas are extensive and overlap with open savannas or grassland. The canopy cover threshold is notoriously variable for tropical wooded grasslands or tree savannas, and varies from low (25%) (UNESCO, 1973; Mueller-Dombois and Ellenberg, 1974), to high (75%) (Mucina and Rutherford, 2006). We used a 40% canopy cover threshold to distinguish between tropical grassland (including wooded grassland) and tropical woodland, with tropical wooded grasslands having a continuous grass layer, trees < 8 m in height, a simple two-layer structure, between 10 and 40% canopy cover, and open grassland having < 10% tree cover. Similarly in need of differentiation are shrublands, defined as where shrubs > 0.5 m tall have > 25% shrub cover (or if < 25% cover, shrubs have at least 10% cover and exceed herbaceous cover), and tree cover is < 10% (Faber-Langendoen et al., 2012) (see Table 1 for a comparison with definitions provided by Lock, 2006).

Finally, wetlands are excluded where graminoids and other herbaceous vegetation occur in a matrix with wetland species, including aquatic plants, forbs and mosses. We suggest that although these wetlands may technically meet certain aspects of the grasslands definition, they are typically composed of a range of non-grass vegetation and better treated as part of global wetland definitions, such as that of the Ramsar Convention (Matthews, 1993).

In summation, we propose the following definition of grasslands for global application. A natural or semi-natural grassland is defined by the following characteristics: (1) a non-wetland formation; (2) vascular vegetation has at least 10% cover; (3) graminoids have at least 25% cover (but if < 25% cover, graminoids exceed that of other herbaceous and shrub cover); (4) broad-leaved herbs (forbs) may have variable levels of cover and dominance; (5) shrubs have < 25% canopy cover; (6) and trees: (i) in temperate zones, typically have < 10% canopy cover, are < 5 m tall and single- layered, or (ii) in tropical regions, typically have < 40% canopy cover, are < 8 m tall, and are single layered.

Beyond this basic physiognomic definition of grassland, reference can be made to the floristic composition of a division and lower levels of the IVC hierarchy. For example, decisions about how to classify wooded tropical grasslands with > 40% cover could factor in the degree to which specific grassland species are dominant in the ground layer.

Table 1: Comparison of intercontinental variations on the definition of savanna (African and South American) (Lock's, 2006).

Recommended term	**Environment and structure**	**African term(s)**	**Approx. equivalent South American term(s)**
Wooded grassland	Single dry season > 4 months. Trees with crown cover < 40%, > 10%. One tree layer. Grasses narrow-leaved, tussock-forming and xeromorphic. Single dry season > 4 months. Fires regular, often annual. Tree-dominated vegetation; crown cover at least 40%. Usually only one main tree layer. Woody climbers and epiphytes absent or very scarce. Grasses narrow-leaved, tussock-forming, often xeromorphic.	Scattered tree grassland, wooded grassland	Campo cerrado, sabana arbolada*
Bushed grassland	Single dry season > 4 months. Bushes (multi-stemmed, short stature) < 40%, > 10%. One shrub layer. Grasses narrow-leaved, tussock-forming and xeromorphic.	Open bushland, bushed grassland, savanna bushland, bush savanna	Campo sujo, sabana arbustiva
Grassland	Single dry season > 4 months. Woody plants with canopy cover < 10%. Grasses usually tussock-forming and xeromorphic, at least in Africa. Fires regular. Natural grasslands often in sites with seasonal waterlogging, shallow soil or high metallic ion concentrations.	Grass savanna, savanna grassland	Campo limpo (no large woody plants), camp sujo, sabana abierta, sabana lisa

**Our review of the cerrado literature suggests that 'cerrado sensu stricto' also fits with wooded grassland, but may have canopy cover up to 70%. Thus, contra Lock (2006), we would not equate all of the cerrado sensu stricto as 'woodland'. Similar issues may exist in Africa where i.e. Lock places both Miombo woodland and Miombo savanna in the woodland category.*

1.2. Characterizing ecosystems

Natural grasslands occur around the world and have been characterized using a number of methods. For global characterizations, the methods can be grouped into four types: vegetation composition; ecological and economic assessment; ecosystem mapping; and remote sensing classification. The vegetation approach stresses the importance of species and growth forms as a primary expression of a terrestrial ecosystem and uses plant species assemblages to classify stands into plant community types (i.e. "associations", "alliances") and, combined with physiognomy, into broader vegetation types (i.e. classes, divisions, formations) (UNESCO, 1973; Ellenberg, 1988; DiGregario and Janssen, 1998; Faber-Langendoen et al., 2014). The ecological and economic assessment approach characterizes global grassland ecosystem health through an analysis of pressures exerted on the ecosystem, and also reports on the connection to human well-being (Coupland, 1979; White et al., 2000; Suttie et al., 2005). The ecosystem mapping approach emphasizes the geographical or landscape delineation of ecosystem boundaries based on patterns present in biophysical factors, such as climate, landform and, sometimes, floral and faunal evidence (Schultz, 1995; Bailey, 1996; Olson et al., 2001). The remote sensing method uses the vegetation approach in combination with satellite imagery to create global land cover datasets describing generalized spatial patterns in vegetation, abiotic and anthropogenic features on the Earth's surface (Defries et al., 1995; Loveland and Belward, 1997; Bontemps et al., 2011).

2. South America Grasslands

Grasslands exist all over the world under a wide range of climates, soil types, topography conditions and seasonality (Figure 1). The South America grasslands cover a wide range of ecosystems and vegetation types, going from desert areas to steppes, subhumid temperate, subtropical and tropical savannas embodying also portions of the tropical rain forest environment, and represent one of the Earth's largest expanses of natural rangelands (Oesterheld et al., 1992). They represent developed ecosystems requiring acquaintance to accept sound agronomic and ecological activities. The diversity of vegetation determined by the latitudes 6° N, down to the southernmost tip of the continent at 55°58' S originated a spectrum of users and uses without knowledge of its potential, imposing pressures upon the natural resources, seeking more profit, and jeopardizing its sustainability, since it encompasses a wide range of contrasting situations and conflicts in resource use (Deregibus, 2000).

The grassland resources were defined as ecosystems where the dominant vegetation components comprise herbaceous species, which includes planted pastures as well as native pastures (Hadley, 1993). They are culturally and economically important to the mankind because it can be harvested by the herbivores and transformed into saleable products for farmers, into use full fibers and healthy food for human being, to be preserved for recreation and environmental protection, to develop tourism, to feed the industries and has no substitute for conservational purposes and a reliable substrate for ecological studies. Lands that are too poor or too erodible for cultivation become productive once they are considered with wisdom.

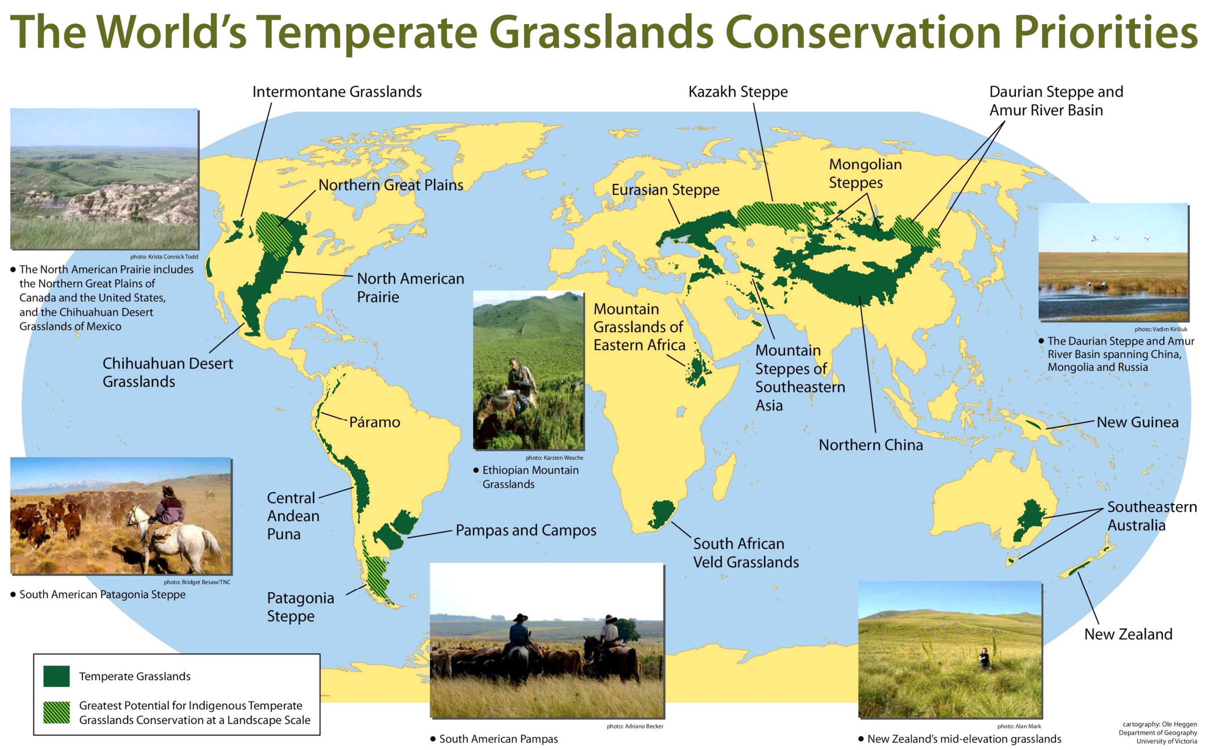

Figure 1: *Map of different type Temperature Grassland of the world.*

Natural grazing is a form of land use of those unsuited areas to more intensive exploitation because poor soil, unsuitable topography or short growing season.

The sustainable development of grasslands involves activities to meet the needs of the present, without compromising the ability of future generations. And the concept of “needs” goes to the essential needs of the world’s poor. But today’s “needs” are much more than survival, and some products have to be obtained to cope with population conservation and health. Despite the concern about the deterioration of pastoral vegetation over wide areas, most grazed plant communities have great resilience and power to recover, if rested and properly managed. Native pastures rehabilitation can be sought under grazing management methods, making provision for water catchment, rather than the costly reseeding and tree-planting techniques which are advocated in aid programs without thoughts in economics or sustainability. Mismanagement of grazing causes damage which is not limited to the pasture, since the increased erosion and run-off causes serious harm to arable land and infrastructure lower in the catchment, as well as siltation of irrigation systems and reservoirs. The preservation of wildlife habitat, its recreational purposes, as source of useful and medicinal products, and as *in situ* reserves of genetic material, all contribute to the importance of this natural grassland resource. The examples referred by Riveros (1993) from Xinjiang Altai, in

China, and from the Sahel, in Africa, are worth to consider for critical ecosystems of South America.

The South America grasslands will continue to be a major source of feed for all grazing animals in arid, flooded, montane or remote areas as far as one can foresee it. The intrusions of cropping will continue locally, but for what remains as ***natural pasture*** (**NP**), exploitation by grazing will continue to be the major flow for economic returns. The grassland managers are in an increasing fast race to maintain sustainable systems over the grasslands of South America due to the changes that are occurring because of human activities. The challenges are numerous and include saving some of the intact pieces of natural systems in order to finish working out the puzzle of the role of biotic interactions and diversity in maintaining ecosystem functioning and stability. They have to develop the capacity to predict how the natural systems will respond to the many challenges that are occurring. Also have to use today's knowledge to predict the response of systems to combinations of stress that have not occurred in the past, i.e., tourism in rural areas. There is the need to develop and evolve adaptive management schemes to maintain production systems. The management alternatives being evaluated in the "Cerrados" area of Brazil with partial removal of the vegetation, followed by burning, disking and direct seeding pasture species for animal production changed the physiognomy of vast areas (Macedo, 1997). This practice allowed moving from 0.3 beast ha^{-1} to 1.0 beast ha^{-1} by replacing the native vegetation with introduced grasses. Today there are more than 40 million ha of savannas sown into *Brachiara sp* and turned into degraded pastures, with the advanced stages causing damage to the environment.

In the subhumid temperate grasslands the technological levels of animal husbandry are more developed than the remaining pastoralism of some remote tropical areas. The animals are maintained under pasture conditions most of the year, rarely fed supplements, and efforts are devoted to improvement of animal status; herds are organized into categories, ranches are fenced and paddocking is largely practiced, the provision for drinking water is abundant, health care is a rewarding investment, predators and parasites are controlled, and breed purity is highly appreciated (Oesterheld et al., 1992). The biomass of livestock supported per unit of primary production is accompanied by an increase in average herbivore body size. The proportion of small herbivore biomass decreased, whereas the proportion of cattle increased along the productivity gradient. The heavier herbivore load supported by South America grasslands over the last two centuries may be a factor contributing to the vulnerability of those subhumid NP (Hadley, 1993), as well as for the tropical savannas of central Brazil (Barcellos, 1996; Macedo, 1997).

2.1.The Natural Grasslands of South America

Most of the natural South America grasslands evolved under low soil fertility conditions. The vegetation types encountered by the colonizers might have not being too much attractive, but was what the region had for the explorers (Maraschin, 2001). Except for the Pampas of Argentina, southern Chile and the southern portion of Uruguay, the greater part of South America lies on very poor soils. And the characteristic environments of various regions are very vulnerable to excessive use. Although the temperature and light factor are favorable, and the water regime is abundant, the soil factor sets the limits for development. Toledo (1993) observed that the extent of the degradation process of these savannas could be larger than what occurred in other savannas of the world. Their fragility would reflect also less resilience due to the weackness of the natural resources and the abusive utilization. The grasslands of Colombia and "Cerrados" evolved with the adoption of management practices, with the introduction of legumes as protein bank and the establishment of new cultivated species, which brought substantial increments in productivity, as observed with the *Brachiaria sp* that influenced most the decisions of producers toward the species to be sown for animal grazing. To restore and preserve what was left, research has to be conducted on a holistic approach including the ecosystem processes, social, economical, political, educational and general human awareness and consideration (Maraschin, 2001).

2.2.Physiognomic Aspects of the South America Grassland

Most of South America displays a grassland physiognomy, where grasses grow and cattle graze year round, allowing for plenty grass-fed beef production. The temperate grasslands of the cool semi-desert of Patagonia in southern Argentina and Chile are covered by C_3 species with most of the native flora being temperate grasses used by the grazing animals. The fertile soils, short and mild summers, are all essentials for C_3 grasses and temperate legume species to grow during the cooler season and alternate with species of the other photosynthetic pathway (Deregibus, 2000). The cool season forage species thriving are grasses of the *Agrosteae*, *Aveneae*, *Festuceae*, *Phalarideae* and *Stipeae* tribes. The warm season components are the C_4 grasses of the *Panicoideae*, *Chlorideae*, *Andropogoneae* and *Oryzeae* tribes that are water efficient, nutrient thrifty and low quality forage species. The seasonal combination of species maintains the grasslands greenness yearlong and is ideal for resource utilization in a variable climate environment, with mild water deficits during summer. These temperate grasslands of South America can embrace production systems in which financial inputs are minimal, being represented by those that produce year round grazing, with minimal or no inputs such as supplementary feeding, herbicides, fungicides, fertilizers, antibiotics and growth promoters (Gomez and Jahn, 1993). These systems in general are located in nonindustrialized zones and away from pollutants, but not immune to them. Up to parallel 33° S, in the humid subtropical, warm and cool season species exhibit their growth in alternation along the appropriate seasons, according to variations in humidity and soil fertility.

Around 33° S up to 26° S, embodying north of Uruguay, north and northeast Argentina, southern Brazil, south of Paraguay and the Mediterranean portion of Chile, the low soil fertility, low soil pH and bellow critical P levels and shallow soils, the legumes account for the presence of few individuals of *Adesmia sp*., *Vicia sp. Lathyrus, Trifolium sp, Medicago sp*.*Desmodium sp*., and *Rinchosia sp*. *Aeschynomene sp, Arachis sp, Vigna sp,* The whole of the region enjoys the same thermal effects of the climate, encompassing a wide range soil types and elevations, and where the moisture is abundant the dominant tall grasses, such as *Andropogon sp, Schizachyrium sp, Setaria sp, Bothriochloa sp, Paspalum sp, Stipa sp, Aristida sp, Axonopus sp,* restrain the growth of the legumes. As a consequence, the massive dry matter (**DM**) production during the long warm season is of low quality (< 60% digestibility), the species diversification and selective grazing along the seasons of the year makes that growth to accumulate, senesce and loose quality further more during the winter and often requires to be burned before the onset of the following spring season (Deregibus, 1988). This accumulation overtops cool season grasses and prevents its growth, determining scarce forage production and quality feed supply during the winter. There is marked seasonality in DM production where the spring-summer season is responsible for 60-85% of the forage yield, and the short days and low temperatures of the winter preclude growth of the C_4 plants. Throughout the region there is the recognition that ***stocking rates*** (**SR**) is the dominant pasture management practice determining production and stability of the **NP**. But very few research centres accept to evolve from fixed **SR** to the flexible and reliable procedure of stocking the pastures according to the growth pattern of the pastures. And this still happens in those areas where estimates of daily dry matter accumulation rate already exist. It seems to be just a matter of pasture research philosophy and of applying knowledge into it.

North of parallel 26° S and up to 22-23° S there is a transition zone crossing along the Paraná River and Paraguay River basins, which receives adequate rainfall in the eastern portion, and less precipitation moving westwards. As one gets closer to the Andean Mountains, differences in soil drainage (Blanco, 1994) determine distinct grassland potential, with the livestock raising activity being very extensive, since the bushy savannah vegetation represents the most important natural resource for animal production. Relatively large portions of north Argentina, South of Bolivia and NW of Paraguay are covered by short trees like *Prosopis sp, Acacia sp, Caesalpinia sp, Lithraea sp*, and bushes, intermingled with herbaceous species of C_4 type, where *Paspalum sp, Elyonurus sp, Trachypogon sp, Aristida sp, Sorghastrum sp, Schizachyrium sp, Bothriochloa sp*, helped in shaping the “Chaco” vegetation. The aboveground DM of this vegetation lignifies along the season imposing limitations to animal performance, and burning has been a reliable tool to renovate those substrates for grazing.

The "Chaco" is a savannah within the zone of summer forage production due to the concentration of rain in that season (Toledo, 1993). Fire was the main ecological factor in forming the structure of the “Chaco” landscape. In the past, the surpluses of biomass in late season were periodically or occasionally burned as a result of electrical storms in the spring, or later by indigenous burning. In this way the tall grassland intermingled with patches of forest developed the typical “fire climax savannah”, analogous to many other ecosystems worldwide. With the settlement of the region, watering points were created and made for most of the herbage produced to be consumed, leaving little or none to be burned. So, the “fire climax savannah” turned into an area of increased scarcity of forage through increased livestock grazing pressures and growth of unpalatable woody species. The range of grazing extension set by the watering points, whose number is reduced for the yearly round-up, worsening the effects of grazing pressure and heavy grazing. This maintained scattered trees with almost no grass, creating a condition known as “Peladeros”. The suppression of fire and reduced ***grazing pressure*** (**GP**) tend to lead the “Chaco” to a very undesirable and destructive situation.

North of the Tropic of Capricorn one approaches the scenario the developed world has about the tropics in Latin America. Within the savannah grassland, this huge environment known as the “Cerrados” area of Brazil deserves special attention since it occupies an area from 6° N to 25° S where *Trachypogon sp, Leptochoryphium sp, Paspalum sp, Axonopus, Andropogon, Leersia sp, Elyonurus sp, Aristida sp*, together with *Poa sp, Stipa sp, Agrostis sp, Festuca sp, Bromus sp*, contribute to the herbaceous plant cover. Between the parallel 10° and 24° S (38° and 58° W) lays ca. 70% of the “Cerrados” and 40% of the beef cattle herd of Brazil. The main grasses for this region are *Echinolena sp*, and other *Paniceae*, and the *Aristida sp, Arthropogon sp, Axonopus sp, Paspalum sp, Schizachyrium sp, Andropogon sp*.. The legumes are represented by *Arachis, sp, Centrosema sp, Desmodium sp, Stylosanthes sp, Macroptilium sp, Rinchosia sp*. which in combination with grasses and other species made up for the natural pastures of the region. The existing DM during the dry season is the main limiting factor, lengthening the productive cycle in the cattle raising activity (Macedo, 1995; Barcellos, 1996; Zimmer, 1997). For most of the area there was no technological support for ranchers who stand away from farm administration, and livestock was practically raised by nature. The cowcalf operation was the main activity for the use of those natural resources. In the last 25 years the green revolution was initiated and most of the “Cerrados” vegetation was replaced by agriculture and after one or two years of growing crops, the areas were turned into sown tropical pastures (Macedo, 1995). Most of the applied knowledge came from Australia and CIAT, and the **SR**s were increased several fold. After a few years they were no longer feeding the initial 1.2 *animal units* (**AU**) ha^{-1} on the improved pastures. They were degenerating very rapidly soon after the establishment year. This raised the suspicious that land use for farming followed by pasture establishment and the intensive management imposed to those environments were not suited to their sustainability (Macedo, 1995; Zimmer, 1997).

In the eastern portion of Brazil, most of the animal production is based on pastures developed on cleared pastureland, where *Melinis minutiflora* predominated on poorer soils of the steep slopes, whose forage mass was of accepted nutritive value but supported low carrying capacity (Maraschin, 2001). The pastures based on *Hiparrhenia rufa* were persistent, but the productivity was also low. On some of the remaining fertile soils, *P. maximum* (guineagrass) strived and still is the main beef pasture for the region. In the last 20 years the *Brachiaria sp.* took over the region and the cultivar Marandu is being strongly recommended due to its resistance to the spittle bug disease (*Deois flavopicta* and *Manarva sp.*). Either the “Cerrados” and the eastern Brazil make low usage of fertilizers for the introduced pastures that are grazed under high ***stocking rates*** (**SRs**), and the high ***grazing pressure*** (**GPs**) determine a weakening condition, and soon those pastures degenerate. Tropical legumes are scarcely used, and the highly seasonal DM production do not compromise forage quality with animal demands (Pereira et al., 1995).

According to Leite et al. (1994) the semi-arid region of NE Brasil with a dry season of 8-9 month and an average rainfall of 400-600 mm per year uses a mixed livestock and compromise the use of the natural resources. The main genus for the region are *Mimosa sp, Caesalpinia sp, Dalbergia sp, Paspalum sp, Setaria sp, Cenchrus sp, Aristida Sp, Elyonurus sp, Zornia sp, Stylosanthes, Centrosema sp,.* In the short rainy season the herbaceous vegetation and green leaves of trees compose the forage mass. With the onset of the long dry season the leaves of the trees become dried and fall into the ground and serve as source of feed to the animals. By the middle of the dry season 62% of their diet is made of dead leaves of the woody vegetation and up to 28% is from the standing herbaceous vegetation. Early in the rainy season, green leaves of trees comprise 65% of the diet and the herbaceous vegetation the other 35%. Due to the importance of the fodder trees for the diets of the grazing animals, manipulation of that vegetation is very important, and is a common practice to cut the old branches of the trees and the top of the trunk to develop new sprouts and branches from where the goats get most of their feed.

Thinning off the stand is also practiced, and gradually they get trunks height with less 0.50 m from the ground, when all leaves are at reach of the animals, increasing the foraging substrate. Under natural conditions of the “caatinga” vegetation, mixed grazing of cattle, sheep and goats are more productive. By thinning that vegetation, cattle and goats are favoured. But when that canopy is manipulated, the trunks are cut close to the ground for new branching, and cattle alone or cattle and sheep make better use of those natural resources.

The vast amazonian region occupies an area almost half of the Brazilian territory (Falesi and Veiga, 1986). The climate is wet and hot in the northern 2/3 and wet-dry in southern 1/3 of the region, with temperatures ranging from 8°- 40° C. It lies on very acid soils, with extremely low P levels and exhibits low ***cation exchange capacity*** (**CEC**), besides other mineral deficiencies. The high P fixing capacity of those soils contributes to reduced opportunities for pasture development. Guineagrass and *H. rufa* are more responsive to P than

B. humidicola, and tropical legumes may be more tolerant than the grasses to lower levels of P. The lowland grasslands are subjected to periodic inundations, where species of *Echinochloa sp, Hymenachne sp, Oryza sp, Leersia sp, Luziola sp and Paspalum sp*, cover poorer soils over huge areas in the region. The upland grasslands which represent around 60 % of the region, display a similarity in its botanical composition, where the *Andropogon sp, Axonopus sp, Trachypogon* and *Paspalum sp*, sets the productivity and forage quality, extending in the wet/dry savannas of Guyana and Venezuela (Serrão and Simão Neto, 1975). Also important are the legumes *Pueraria sp, Centrosema sp* and *Dolichos sp*. This ample substrate produces forage with a lower quality than the lowland grasslands. Within those grasslands nutrient cycling is the driving force for their sustainability.

After clearing sections of the tropical rain forest, pasture development brought significant ecological changes to that environment. Initially there was an increase in soil fertility due to the ashes. The rapid establishment of guineagrass, *Brachiaria humidicola* and *Andropogon gayanus* pastures encoraged intensive grazing and within three years, signs of degradation were evident.

But the more leniently grazed pastures could be maintained for more than ten years. The P levels of those soils imposed limitations to pasture productivity, although Serrão and Simão Neto (1975) showed five to six fold (up to 25-36 t DM ha^{-1}) increase in pasture responses of the upland areas when fertilised and sown to cultivated species. The evaluation of those pastures was in terms of animals carried and ***live weight gain*** (**LWG**) ha^{-1}, with no indication of DM production and animal performance. This left no single message about what would be the animal product being produced by the new pastures. Although the guineagrass pastures produced better on the heavier soils but degraded earlier under high **SR**, irrespective of the grazing methods, this fact detracted against the suitability of the specie for the region.

This tropical rain forest when converted to pastureland maintained the stable forest C pool, showed a rapid decline of labile forest C but a much faster accumulation of labile crop C, which contributed to the return of the organic C levels to previous levels of the forest, before the deforestation seven years ago (Noordwijk et al., 1997).

2.3.Ecophysiological Characteristic of Some South America Grasslands

According to Deregibus (1988) in the humid and subhumid regions, mismanagement, burning and other aggressive abuses on the **NP** would not eliminate herbaceous vegetation, but partially would affect the water infiltration rate. The dead plant material that dropped at the soil surface is decomposed by soil microrganisms, whose activity is determined by reliable moisture conditions. In the semi-arid or arid ecosystems the **NP** is much more unstable and the water availability is the regulating factor. The dead plant materials laid in the soil surface undergoes oxidation. So, leaves and stems remain static until physically removed or burned. When associated with alkaline soils, and adequate water, there are excellent productions.

When the water is limiting, the smaller number of plants grow sparsely, with plant litter covering the bare ground.

The grazing regime may cause reduction in the plant biomass by affecting its vigour, especially during the long dry period. In this way the more palatable perennial species are being eliminated and the canopy is thinned, leaving space and opportunity for the bushes or herbaceous annuals. The uncovered bare spots develop a smooth and hard surface between the sparse plants as a result of the continuous processes of moistening and desiccation of those thin plant parts laid on the ground. These spots become crusty, almost impermeable to water rainfall, which limits further the biomass at that site. This causes rainfall runoff and is appointed as responsible for the loss of productivity and degradation of the **NP** in those unstable ecosystems. The effectiveness of rainfall in this environment allows understanding the low productivity of regions in the range of 500-800 mm precipitation, where some flooding does occur. This situation seems to be not too far apart from the Brazilian “Cerrados” ecosystem. The edaphic component allows for a small number of species to grow in the area, and the erosion process was already established long before the agriculture enlarged it (Macedo, 1997).

Among various studies on the soil as a source or deposit of Carbon CO_2, Corazza et al. (1999) observed C reserves in natural systems and in the agroecological systems practiced in the "Cerrados". One third of the C was located within the 20 cm of the top soil layer, and the disturbances brought in by disking or plowing reduced it markedly. On the other hand, tree plantings, cultivated pastures and direct seeding promoted increasing C reserves in the soil.

Practices that do not mobilize the top soil layers would contribute to increase the C in the soil, and perennial pastures seem to be effective on that, at very low costs. The contribution would be rewarding if one considers the inclusion of an adapted tropical forage legume, with a potential of 2.5 to 5 fold increase in carbon sequestration. Since nitrogen was the limiting factor to the carbon fixation by plants, and to incorporate it into the soil (Fisher and Trujillo, 1999). Poorly drained soils are a common feature in many areas, and can deposit more carbon in the organic matter as related to what occurs in the better drained soils of the tropics. Similar conditions were observed by Bertol et al. (1998) where increased forage on offer on **NP** added different quantities of organic matter to the top soil, without any fertilization. There was 10 % increase in soil *organic matter* (**OM**) of the top layer, while by resting during summer increased 8 % the soil. Within integrated systems where farming and livestock production are practiced more intensively, Jones (1996) suggested the reconstruction of the top soil layer as an important component from pasture production. The interrelationship between soil, plants and animal mean that the livestock production will be sustainable after the systems of soil utilization overcome the "acceptable" losses of the top soil.

In the humid subtropical region, there is a combination of thermal amplitude that allows temperature conditions for C_4 and C_3 types of plant to grow on the same area, where the C_4 type predominates in summer and the C_3 type in the winter season. Where the growth rate is high, the plants are not grazed accordingly, become coarse and ranked. The uneaten and remaining older leaves preclude the development of new leaves and tillers, since they avoid the incident light to trigger bud initiation. The ranked biomass accumulation dilutes N and reduces the forage potential of those **NP**, although it is suited to feed brood cows, but not adequate for finishing slaughter animals. As the winter temperatures do not impose limitations to the growth/or stay alive of the subtropical species, this competes and limits the incident light that would promote the growth of temperate species. As a consequence, there is no seed production and no contribution of C_3 plants. This reduces the **NP** productivity since during winter and early spring they are standing but not growing.

The proportion of species in each group of plants depends on the length of the warm season, on soil conditions, on the presence of trees, on botanical composition, pasture management and associated animal production. They allow for yearlong grazing since there is no interruption in forage production and supply along the year. Once seasonal humidity does not limit plant growth these pastures can be maintained evergreen, and the yellowish in winter or summer is due to weak pasture management that did not promote the species that would make their best growth in that particular season. Forage quality *per se* is high due to the presence of *Aveneae*, *Agrosteae*, *Phalarideae*, *Festuceae* and *Stipeae*, and since there is a continuous regrowth on those pastures, the available forage for grazing is also rich and with high digestibility. These characteristics render those grasslands to abuse, and heavy grazing is a constant and closer to irrationality than approaching to what would be called grazing efficiency (Lemaire and Agnusdei, 2000).

3. TEMPERATE GRASSLANDS OF SOUTH AMERICA

Temperate grasslands are one of the most extensive biomes on the planet, occupying about 9 million km^2, the equivalent of 8% of the earth's surface. These biomes are present in all continents, except Antarctica (White et al., 2000).

Temperate grasslands are indigenous ecosystems found mainly in the middle latitudes where seasonal climates and soils favour the dominance of perennial grasses and other graminoids; and also in areas of tropical and temperate high mountains above the regional tree line where generally similar environments and temperate biogeographic affinities occur (Peart, 2008).

Temperate grasslands were occupied and used by man since early stages of civilization. They are one of the most favourable environments for human settlement, among other motives given their high productivity. In many cases, they are the most important source for food on a global scale (Henwood, 2006).

The degree of modification of the biome by human activities was so great that currently very little remains in a natural state. After years of exploitation and non-sustainable use, the temperate grasslands are presently considered the most threatened ecosystem in the world.

Examples of this are the North American prairies, the pampas of South America, the grasslands in Southeast Australia and the steppes of Eastern Europe (Henwood, 2006).

The elevated animal and plant diversity and the numerous endemism that they harbour, as well as the goods and services they provide to man, give these ecosystems a high conservation value. However, they are one of the most scarcely represented biomes in protected areas. Only 5.5% of the temperate grassland biome is protected worldwide (Peart, 2008).

In South America, there are four temperate grassland eco-regions (Peart, 2008): *Páramos, Central Andes, Pampas and Campos*, and the *Patagonian steppe*. Together, these eco-regions occupy approximately 2.3 million km^2, which represents 13% of South American continent (Table 2) (Michelson, 2008).

In addition to their elevated biological diversity, the ecosystem services that they provide carry out a fundamental role in sustaining the life and livelihoods of millions of people on the continent. In that sense, these are environments of high social and economic importance.

In terms of the formal protection of this biome, 6% of the South American temperate grasslands are included in conservation units. The Páramos are the most represented eco-region in protected areas, followed by the high altitude grasslands of the Central Andes. On the other hand, the eco-regions of Pampas and Campos and the Patagonia steppe are scarcely protected (Table 2) (Michelson, 2008).

Table 2: South American Temperate Grassland Eco-regions. Countries in which they are represented, total and protected surface (Michelson, 2008).

Eco-region	Countries	Total area (km^2)	Total area formally protected (km^2)	% Protection
Páramos	Ecuador, Colombia, Venezuela	35,770	15,515	43.4%
Central Andes	Perú, Bolivia, Argentina, Chile	740,000	68,820	9.3%
Pampas & Campos	Argentina, Uruguay, Brasil	750,000	6,685	0.9%
Patagonian Steppe	Argentina, Chile	800,000	25,000	3.1%
		2,325,770	**149,600**	**6.4%**

3.1. Páramo or Northern Andes (Venezuela, Colombia, Ecuador, northern Perú)

3.1.1. Major indigenous temperate grassland types

The tropical Andes region tops the list of worldwide hotspots for endemism and species/area ratio (Myers et al., 2007). A major contributor to the rich biodiversity and endemism of the tropical Andes is the Páramo, a neotropical alpine ecosystem covering the upper parts of the tropical Andes from Venezuela south to northern Peru (6°30" S) (Figure 2). Two isolated systems are located in the Sierra Nevada de Santa Marta in Colombia and in Costa Rica.

The Páramo extends between the upper tree line and the perennial snow border (about 3200-5000 m altitude) reflecting a sort of island archipelago. Its total area is estimated at 35770 km^2 (Josse et al., 2008). The isolated and fragmented occurrence of tropical mountain wetlands promotes high speciation and an exceptionally high endemism at the species and genera level (Sklenář and Ramsay 2001). At the regional and landscape scales, factors such as climate, geological history, habitat diversity and also human influence determine Páramos biota diversity (Luteyn, 1992). Local climatic gradients further complicate within-mountain diversity patterns, with spatial community changes often occurring over short distances (Ramsay 1992; Sklenář and Balslev, 2005). The Páramo ecosystem hosts 3595 species of vascular plants distributed in 127 families, and 540 genera (Sklenář et al., 2008). About , 14 of these genera and 60% of these species are endemic to the Northern Andes (Luteyn, 1999), and adapted to the specific physio-chemical and climatic conditions, such as the low atmospheric pressure, intense ultra-violet radiation, and the drying effects of wind (Luteyn, 1992). The physiognomies of tropical alpine vegetation vary within and between regions but certain features are shared such as similar growth forms of the dominant plants (Smith, 1994; Smith, 1977). Previous works that describe the Páramo vegetation (i.e. Cuatrecasas 1958; Harling 1979; Cleef 1981; Acosta-Solis 1985; Jørgensen and Ulloa, 1994; Ramsay 1992) define three main páramo units above the treeline, according to the physiognomy and structure of the vegetation: (1) the sub-páramo or shrub páramo, (2) grass páramo or pajonal – frequently dominated by stem rosettes of the genus *Espeletia* or *Puya* - and (3) super-páramo. *Polylepis* woodlands, probable remnants of more extensive upper Andean forest in the past (Fjeldså, 1992; Lægaard, 1992), also contribute to the mosaic of páramo habitats

The sub-páramo covers the ecotone between the transition of the upper montane forest and the treeline, and in many cases is dominated by upright shrub (i.e. *Valeriana microphylla*) and prostrate shrubs (i.e. *Pernettya prostrata*) of the genera *Valeriana, Gynoxys, Diplostephium, Pentacalia, Monticalia, Chuquiraga, Berberis, Hypericum, Gnaphalium, Lupinus, Loricaria, Calceolaria* and *Hesperomeles*. The grass páramo appears gradually as the effects of elevation and climate lessen the shrubby growth-forms and the dominance of the tussock grasses (i.e. *Festuca*, *Calamagrostis* and *Stipa*) is evident together with stem rosettes (i.e. *Espeletia*, *Puya*), small patches of upright shrubs of the genera *Diplostephium*, *Hypericum* and

Pentacalia (Ramsay and Oxley, 1997), and patches of monotypic or mixed forest of *Polylepis*, *Gynoxis* or *Buddleja*.

The **super-páramo** vegetation is primarily found in Ecuador and Colombia, on the slopes of the highest mountains at 4100-4800 m altitude. This category can be divided in two altitudinal belts (Sklenář, 2000). The lower super-páramo has a closed vegetation of postrate shrubs (i.e. *Loricaria*, *Pentacalia*), cushions (*Plantago rigida*, *Xenophyllum* spp., *Azorella* spp.), acaulescent rosettes (*Hypochaeris*, *Oritrophium*), and tussock grasses (*Calamagrostis*, *Festuca*). The upper super-páramo at 4400-4800 m lacks postrate shrubs and tussock grasses and plant cover is patchy. Recent observations indicate that floristic composition of the super-páramo depends on site-specific water availability, which in turn is highly correlated with precipitation pattern of each mountain area (Sklenář and Lægaard 2003; Sklenář et al., 2008). Topographic variations at site scale result in azonal habitats (cushion bogs, mires and aquatic vegetation) at perhumid areas, and even finer scale differences within these habitats (Cleef, 1981; Bosman et al., 1993).

This ecosystem plays a fundamental role in sustaining the livelihoods of millions of people, providing essential ecosystem services such as water production for urban use, irrigation and hydropower generation (Buytaert et al., 2006; Bradley et al., 2006). The generation and preservation of these services strongly depend on the integrity of the ecosystem, which is expressed as a delicate inter-dependency amongst three key elements: 1) hydro-physical properties of the soil, 2) vegetation structure, and 3) water cycle. The maintenance of these properties allows the existence of different elements of this rich biodiversity aggregated at different spatial scales.

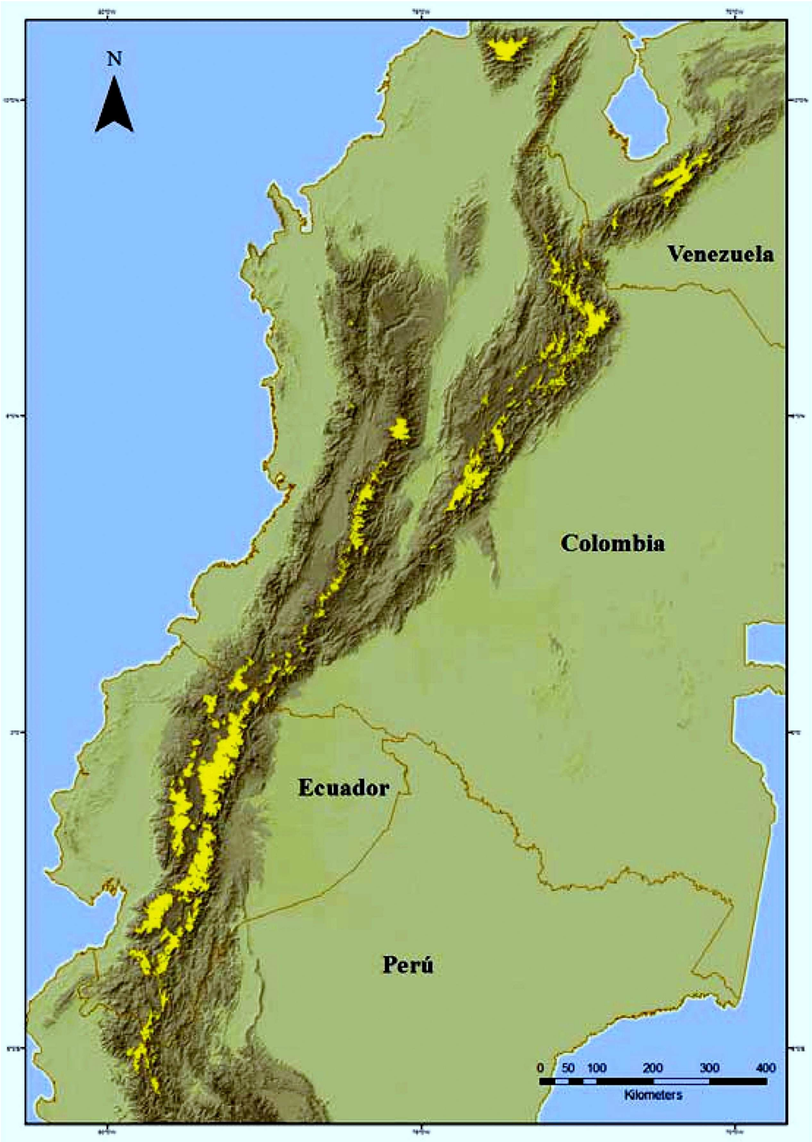

Figure 2: *Map of important existing and proposed páramo areas are highlighted in yellow (Michelson, 2008).*

3.1.2. Impact of human settlement in páramo

Human activities in the páramo have increased drastically over the last two decades (de Koning et al. 1998). The páramo is progressively more used for intensive cattle grazing, afforestation with exotic species, cultivation and human inhabitance (Buytaert et al. 2006). There are strong scientific evidences that these activities have a drastic impact on the integrity of the ecosystem. Land use practices have a significant, negative effect on composition and structure of the vegetation (Hofstede 1995; Ramsay and Oxley, 1997; Suárez and Medina

2001), on their abovebelow ground biomass ratio (Hofstede et al. 1995; Ramsay and Oxley, 1997), on hydrological behaviour of the system - in particular water production and regulation capacity (Farley et al. 2004; Buytaert et al., 2006, 2007), and on chemical/physical properties of the soils (Podwojewski et al., 2002; Poulenard et al,. 2001, 2004).

3.2. Central Andean Grasslands (Páramo, Puna) and High-Andean (central and southern Perú, western Bolivia, northern Chile and northwestern Argentina)

3.2.1. Major indigenous grassland types

Here we describe the Central Andean Grasslands, understood in a broad way as open vegetation, mostly dominated by grasses, herbs and sometimes shrubs, without, or with sparse, tree cover, in the high Andes, mostly above 3000 m. The geographic delimitation is to some degree arbitrary and practical. The northern Andean grasslands of the Páramos are treated in a separate chapter (Venezuela, Colombia, Ecuador and northern Peru). For the Central Andes we include here a variety of physiognomic and floristic types south of the northern Páramos and extending along the Andes through central and southern Peru, western Bolivia, northern Chile and northwestern Argentina.

Origin and nature of grasslands discussed. As the purpose of this work is to identify conservation priorities, it must include a discussion about the origin and nature of these "grasslands", an issue still hotly debated and far from definitely resolved. In summary, the debate relates to whether these grasslands are "natural" (i.e. original, pre-human), or anthropically determined. What does emerge from this debate is that there is no single answer, either for the whole region, or for one of its vegetation types. Rather there will be particular answers for particular areas. Some areas now in grasslands were previously woodlands. Through fire and grazing, they have become grasslands. Conservation of these areas must therefore consider the human history of use, and define priorities based on landscape values, flora and fauna, endemism and unique representativeness.

There are many ways to classify the "grasslands" within the geographic region defined above. In such a short treatment we can only superficially deal with the huge real heterogeneity, without doing justice to the abundant literature and expert opinions on the subject. In addition, whatever classification is used, mapping these categories has not been done for the whole region at a reasonable scale. Here we have therefore had to make some rough educated guesses about the equivalence of ground based classifications (such as those based on floristic and physiognomic elements described below) with satellite based large scale mapping exercises such as those of (Eva et al., 2002). One of us (Juan Carlos Ledezma) superimposed the Eva et al. (2002) classification with the IUCN protected areas shapefiles for South America to arrive at the percentages of each category under some form of protection.

The Central Andean grasslands are classified into types by physiognomy, floristics and bioclimates. Within the area defined, moister, denser grasslands on the eastern fringes of the Andes are called Páramos, Páramo yungueño or Andean pastures (pastizal andino). These are a southern extension of the northern Andean Páramos, floristically and physiognomically related, extending from the northern Páramos, through Peru, Bolivia and northwestern Argentina south to the mountains of Córdoba province.

To the west and in rainshadow areas, Páramos are replaced by progressively drier vegetation types broadly encompassed in the term Puna. The term Puna encompasses diverse ecosystems of the high Central Andes above 3400 m from northern Peru to northern Argentine. Troll, 1959; Troll, 1968; Beck, 1985 and Ruthsatz, 1983, distinguished between moist Puna, dry Puna, thorn Puna and desert Puna. The term covers high dense grassland with some shrubs in the moist puna and transition to the Páramo yungueño, open grassland, cushion vegetation (*Azorella*, *Pycnophyllum*) and tolares (evergreen resinous shrublands of *Baccharis* and *Parastrephia*) in the dry Puna and thorn Puna. The desert puna is dominated by the huge salt lakes with scattered halophytes around and in the depressions. The thorn Puna may be included as a type of desert Puna in the SW. New terms and delimitations for the Puna of Bolivia were recently proposed by (Navarro, 2002; Ibisch et al., 2003).

The highest reaches above Puna and Páramo (mostly above 4200 m depending on areas) belong to a phytogeographically distinct unit called the High-Andean (altoandino) region (i.e. (Cabrera, 1976). Here grasses become sparser but cushions and cryptofruticetum become dominant, with a larger number of endemic species (Halloy, 1985).

Each one of these broad types can be subdivided into distinct categories, some of which are briefly discussed below.

3.2.1.1. Páramo

The páramo yungueño is found on the Eastern fringe of the Andes, above present day treeline, and conditioned by extremely moist and cloudy conditions (perhumid). It extends from northern Perú to central Argentina (Beck, 1998; Rangel, 2004).

The vegetation is tall tussock grassland with *Cortaderia, Deyeuxia (*sometimes included in *Calamagrostis), Festuca* and *Poa*, “chusqueales” with bamboos of the genus *Chusquea*, undescribed species of *Neurolepis* rare herbaceous gramineae such as *Aphanelytrum procumbens* and *Hierochloe redolens*. Between the grasses are prostrate shrubs such as *Miconia chionophylla*, herbs such as *Arcytophyllum*, *Oritrophium*, *Laedstadia*, *Jamesonia* ferns and occasionally the short arborescent fern *Blechnum loxense* (or related species). There are also shrubs and subshrubs of the compositae *Baccharis, Gynoxys*, *Loricaria, Senecio,* and also *Buddleja montana*, *Escallonia myrtilloides* and *Hypericum laricifolium*. Overgrazed areas become short pastures.

Ever-wet climatic conditions are unfavorable to stock, and the human population is low. There are however ancient Inca and pre-Inca roads, terraces and houses. Mining in colonial times also increased penetration. Occasional burns in exceptionally dry years (Laegaard, 1992) seem to maintain this ecosystem. Stock raising is still dispersed nonetheless, and mining as well as extraction of firewood and canes is still performed.

The distribution of these Páramos is naturally fragmented by topography and climate. Their total area is reduced. Being located in a transition between low and high areas, dry and wet, they are probably highly vulnerable to climate change and desiccation. They are also increasingly fragmented by roads, deforestation, mining and other activities.

3.2.1.2. Puna

The puna is dominated by grasses (*Deyeuxia*, *Festuca*, *Poa*) with prevalence in the dryer areas of *Festuca orthophylla* and several species of *Stipa*. Low herbaceous grasses of *Muhlenbergia* and *Distichlis humilis* together with halophytic shrubs cover the extended salt plains. Local fresh water cushion peat bogs or fens (bofedales or ciénagas) are dominated by vascular plants in the *Juncaceae*, *Cyperaceae*, and *Asteraceae* (García and Beck, 2006).

The aquatic flora of the numerous lakes is diverse with a few endemic species; playing an important role for human use (boats, handicrafts) and cattle fodder. Few trees besides *Polylepis* and *Buddleja* grow nowadays in the Puna.

Human habitation is widespread in the Puna, tending to increase toward the moister eastern areas.

Large areas of the central Puna are cultivated with native tubers and grains. Practically all of the Puna is grazed in some form or other by sheep, alpaca and llamas, with cattle, horses, donkeys and pigs in localized moister areas. Grazing is typically migratory, with extensive grasslands/shrublands used during moister parts of the year and stock concentrated in the ciénagas/bofedales in the drier part of the year. Grazing is accompanied by fire as a management tool.

In spite of altitude and extreme climatic conditions the Puna is home to about 1500 plant species with about 40 endemic genera. Most of the genera known from the Parámo and Jalca are also found in the Puna.

As described above, the Puna covers an area of more than 10 degrees latitude and up to 300 km wide with a large diversity of subtypes. The following physiognomic types can be distinguished, in addition to the climatic types distinguished by Troll:

- Praires or pastures, dominated by grasses and other herbs.
- Tolares or resinous shrublands, dominated by evergreen resinous shrubs (*Baccharis* and *Parastrephia*, also *Chersodoma* and other genera).
- Bosquecillos de Polylepis or open Polylepis woodlands (these woodlands raise the issue mentioned above of what the original vegetation was, i.e. (Kessler and Driesch, 1993).

- Salt soils and salt flats in the central and southern endorheic basins with halophytes.
- Ciénagas, bofedales, fresh water peat bogs or fens (Ruthsatz, 2000).
- Aquatic vegetation.

The latter two, although of small extension, are a conservation priority. They concentrate high levels of biodiversity, endemism, provide pasture for stock, and are critical for water regulation and availability. They have also shown clear signs of vulnerability to climate change and to poor management practices (Alzérreca et al., 2003; Yager et al., 2007).

Many Puna areas are modified, to different degrees, depending on proximity of human settlement. Extensive grazing (with the adjunct of fire) is most widespread and threatens pastures, shrublands and woodlands, as well as being concentrated in ciénagas and at the edges of wetlands in the dry season. More locally, Puna areas are affected by mining and mine tailings, by agriculture, and by urban development and waste disposal. However, the millennial development of agriculture in the northern moist Puna has become part of the hybrid or comensal human-nature landscape, with large areas developed over centuries into terraced hills. This landscape itself, with its attendant sustainable agricultural methods, is worthy of preservation (Halloy et al., 2005).

3.2.1.3. High Andean

Above the puna region, between around 4200 or 4500 m and the highest limit of vegetation, grows a sparse vegetation dominated by a few grasses (*Deyeuxia*, *Poa*, and endemics such as *Anthochloa lepidula, Dielsiochloa floribunda, Dissanthelium calycinum, D. trollii* and *D. macusaniense* (Beck, 1998; Renvoize, 1998) and a large number of cushion, plaque, rosette and dwarf shrubs (*Azorella*, *Pycnophyllum*, *Nototriche*, *Werneria*, *Xenophyllum*).

At lower altitudes (4400- 4800 m), denser grass swards develop with *Deyeuxia (Deyeuxia minima), Agrostis, Poa and Stipa*. Within the graminoid mosaic there are also *Luzula racemosa* and *Gentianella* (Beck, 1988) and cyperaceae of the genus *Trichophorum* and the endemic *Oreobolopsis tepalifera*, together with mostly perennial herbs. Most common families include *Asteraceae, Caryophyllaceae, Geraniaceae*, and *Malvaceae* (Gonzales Rocabado, 1997).

Peat bogs and lakes also form large wetlands in the high Andean. These are critical areas, although small, for their inordinately large diversity, concentration of bird fauna, and water regulation for lower regions.

Being more remote, and mostly above the limits of human habitation, the high-andean has only sparse grazing impacts. However it has suffered from targeted harvesting of particular species of animals and plants (particularly medicinal plants and firewood). And given slow regeneration rates due to cold temperatures and low atmospheric pressure, combined with the insular nature of the high altitude sites, small populations of restricted endemics are threatened. Climate change has already meant a rise in the limits of cultivated plants into this region and a rise in the range of grazing camelids (Seimon et al., 2007a; Seimon et al., 2007b).

3.2.2. Impact of human settlement

The landscape has been modified in the past and is changing under man's action as shown by the pre-Hispanic settlements, terraces and the present intensive farming activities (Ellenberg, 1979). A lot of the humid Puna has been converted in farming ground, the steeper areas and the fallow land are used for grazing by cattle, sheep, lama and alpaca, in the southern more arid areas only lama survive under hard environment conditions. Recently more areas of the dry Puna in the south of Oruro are converted in mechanized quinua cultivation.
Numerous edible tubercles of *Solanum*, *Oxalis*, *Ullucus* and *Tropaeolum* are originated in the Puna, beside the pseudo cereals *Chenopodium quinoa* (quinua) and *Ch. pallidicaule* (cañahua) and many medicinal plants known by the Aymara and Quechua.
Stock grazing and attendant fire management is one of the main threats in the three broad grassland types described. This is clearly more obvious in the drier areas, where desertification has progressed over wide areas (dry puna, shrubland, and in bofedales) (Alzérreca et al., 2003).

3.3. Río de la Plata Grasslands or Pampas & Campos (Argentina, Uruguay and Brazil)

3.3.1. Major indigenous temperate grassland types

The Rio de la Plata grasslands are the largest complexes of temperate grasslands ecosystems in South America, comprising an area of approximately 750,000 km^2 (Soriano et al. 1992) (Figure 3). These grasslands include the Pampas ecoregion of Argentina (540,000 km2) and the Campos ecoregion of Uruguay, northeastern Argentina and southern Brazil (Miñarro and Bilenca, 2008).

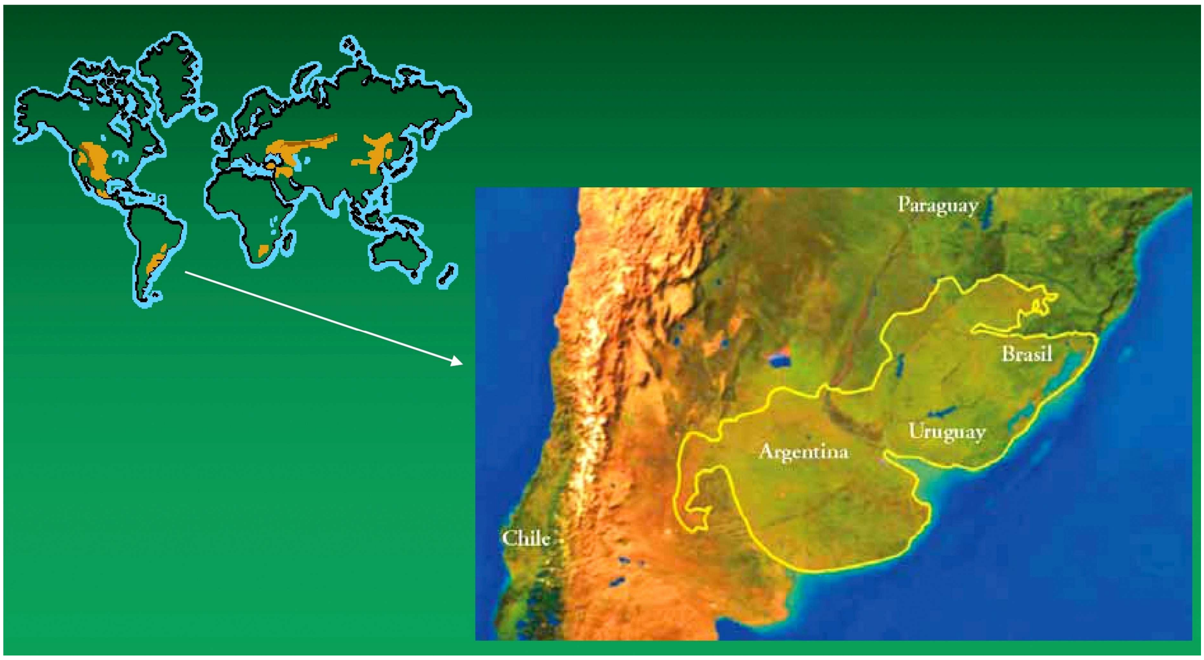

Figure 3: *The Rio de la Plata Grasslands represent one of the largest temperate grassland regions of the world 750,000 km^2 (Soriano et al., 1992).*

Most of the Río de la Plata grasslands occur over a vast plain, the Pampas, formed by thick Quaternary loess deposits that have experienced varying degrees of local reworking. Exceptions to this general pattern are most of the Uruguayan and Brazilian portions of the region, where a diverse array of rocks such as Precambrian granite, Carboniferous sandstone, and Jurassic basalt is exposed to surface and soil-forming processes (Paruelo et al., 2007).

Pampas and Campos (Figure 4, 5, 6), have a conspicuous and unique biodiversity, with thousands species of vascular plants, including more than 550 different grass species. Mesothermic grasses prevail in this region of mild climate (mean annual temperature of 10° to 20° C) and a mean annual rainfall between 400 and 1600 mm (Soriano et al., 1992). Pampas grasslands were formerly dominated by tussock grasses that covered most of the ground. Dominants comprise several warm-season (C_4) and cool-season (C_3) grasses in approximately similar proportion. The most common genera among the grasses are *Stipa*, *Piptochaetium*, *Paspalum* and *Bothriochloa*. Shrubs are little represented, but in some places, probably as a result of disturbance, one of several species of *Baccharis* and *Eupatorium* may become locally dominant (Paruelo et al.. 2007).

Campos grasslands are dominated by grasses of the genera *Andropogon, Aristida, Briza, Erianthus, Piptochaetium, Poa, Stipa, Paspalum, Axonpus and Panicum* (León, 1991). Species composition in Northern Campos is even more enriched in subtropical species

(*Andropogon*) (Paruelo et al. 2007). There are about 450-500 bird species -60 of them are strict grassland dwellers- and nearly 100 species of mammals (Bilenca and Miñarro, 2004).

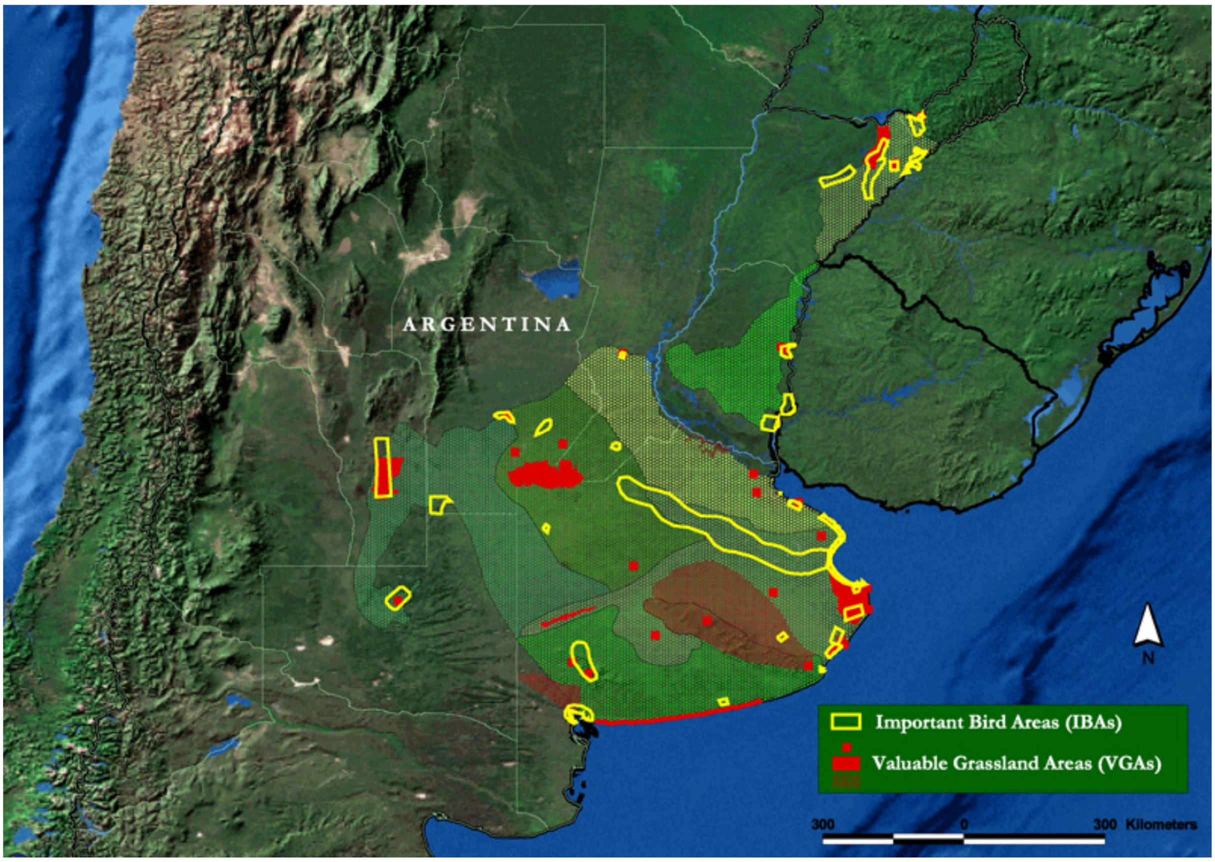

Figure 4: *Valuable Grassland Areas (VGAs) and Important Bird Areas (IBAs) identified in the Pampas and Campos of Central and NorthEastern Argentina, classified by eco-region and by sub-regional units (Bilenca and Miñarro 2004).*

The community of grassland birds that make use of the southern cone grassland biome is really diverse and abundant. There are several threatened species, and the main reason of this decline is habitat loss. Perhaps the most emblematic species is the Eskimo Curlew (*Numenius borealis*), which is probably extinct, owed to habitat loss and sport hunting during late 1800s. Other species are endemic to southern cone grassland, and deserve special attention. It is important to note that among bird grassland dwellers, several grassland shorebirds that migrate from the arctic to the southern cone have suffered important global declinations owed (at least partially) to habitat loss in this region. In this sense, BirdLife partners in the region, in the framework of the Alliance for Grassland Biodiversity Conservation, is about to publish a report on the 20 most important sites for nearcticneotropical grassland shorebirds (Aldabe et al., 2009).

Both Pampas and Campos have good aptitude for agriculture and cattle breeding (Miñarro and Bilenca, 2008).

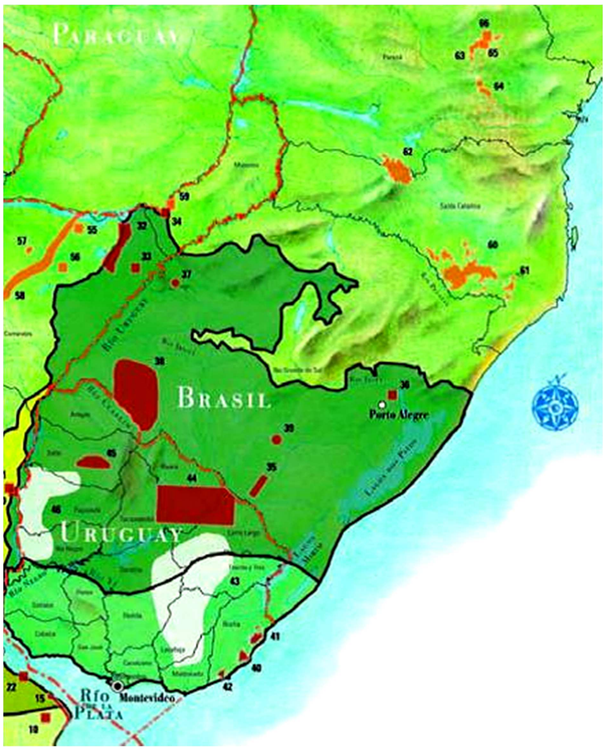

Figure 5: *Valuable Grassland Areas (VGAs) identified in Campos of Uruguay and South Brazil. (Red, orange and white areas and dots)* (Bilenca and Miñarro, 2004).

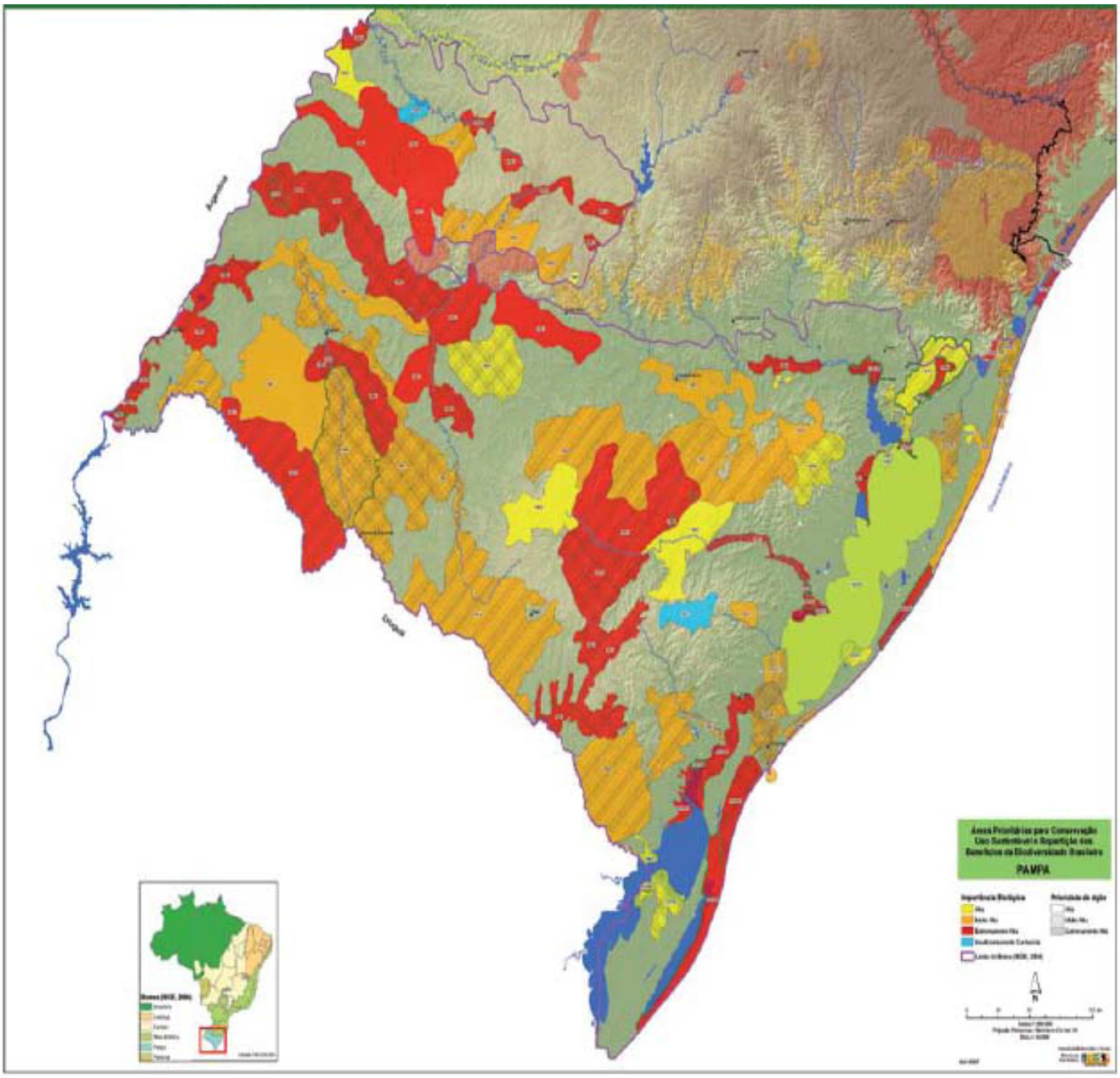

Figure 6: *Priority Areas identified for Campos Sulinos, Brazil (MMA-SBF 2007).*

3.3.2. Impact of human settlement

After European colonization, Río de la Plata Grasslands have progressively become one of the most important areas of beef and grain production in the world (Miñarro and Bilenca, 2008). The introduction of cattle, sheep and horses during the XVI century, and the introduction of agriculture by the end of the XIX century have deeply modified the original landscape, which led to a great loss of grassland habitat, at least in its pristine form (Soriano et al., 1992). Habitat loss, hunting pressures, zoonotic diseases and introduced alien species have threatened many native species. For example, the emblematic Pampas deer (*Ozotoceros* *bezoarticus*) is the most threatened mammal species of the region (Bilenca and Miñarro, 2004).

During the last 40 years, human intervention in Río de la Plata Grasslands has become more intense, which has been reflected in an increase in the cultivated area, especially in the Pampas (Viglizzo et al., 2006). Between 1988-2002, over 900,000 hectares of natural or semi-natural grasslands of Pampas ecoregion have been lost (Paruelo et al., 2005). More recently, agricultural expansion has been led by soybean crop (Miñarro and Bilenca, 2008). In the early 1970s, soybean was a marginal crop that represented less than 3% of the sown area. Now it has become the main crop in Argentina, covering nearly 40% of the sown area (i.e., more than 14 million ha in 2003/2004; Paruelo et al., 2005). In 1996, a transgenic soybean cultivar resistant to the herbicide glyphosate was introduced on the market and rapidly adopted by farmers, so that the growth of the sown area of soybean has increased even further (Martínez-Ghersa and Ghersa, 2005).

Due to these changes, strict grassland dwellers like the Greater Rhea (*Rhea americana*) or the Elegant Crested-Tinamou (*Eudromia elegans*) have shown important retractions in their distributions. Other consequences of recent agricultural intensification and expansion in the Pampas were the re-allocation of livestock to areas with less agricultural aptitude, and an increased grazing pressure in typical cattle breeding areas (Rearte, 2007).

Influence of agriculture has been lower in the Southern Campos, although floristically very similar to some portions of Pampa ecoregion. This is probably due to relatively shallow soils (Paruelo et al., 2007; Miñarro and Bilenca, 2008).

Only 1/3 of Uruguayan Campos and 20% of Argentinian Campos have been modified for agricultural purposes and timber plantation (Miñarro and Bilenca, 2008; MGAP 2008).

Although Campos ecoregion has been used less intensively than Pampas, it has suffered an important biodiversity and habitat loss. This was due to the accelerated process of agricultural expansion started in 1970´s (and which continues at the present days). More recently, this was aggravated with 1970 to 1996, Brazil Campos area has reduced from 14 to 10.5 million ha, which represents a 25% conversion (MMA-SBF 2007; Bilenca and Miñarro, 2004).

Livestock breeding is one of main economic activities in Brazilian Campos, due to the great diversity of plants with high foraging value. As a consequence, intensive grazing has become an important cause of degradation in this ecoregion (MMA-SBF 2007).

In Uruguay, livestock grazing has demonstrated to produce the greatest impact on natural grasslands productivity, which can reach almost 20% of the original output (Olmos and Godron, 1990). An equivalent drop of productivity can be obtained after an agricultural period followed by 10 years of rest.

3.4. Patagonian steppes (Argentina and Chile)

3.4.1. Major indigenous temperate grassland types

The Patagonian steppes occupy a vast area in the southern tip of the continent, between latitudes 39° and 55° S. These steppes cover more than 800,000 km^2 of Chile and Argentina, and are framed by the Andes to the west and the Atlantic coast to the east and south (Paruelo et al., 2007). Patagonia has relatively low mean annual precipitation (150-500 mm MAP), 46% of total precipitation falling in winter (Jobbágy et al., 1995). Mean annual temperature is also low (0 to 12°C) (Adler et al., 2006). The grasslands and steppes of Patagonia are very heterogeneous, both physiognomically and floristically. This high heterogeneity contradicts the common perception of Patagonia as a vast desert at the southern end of the world. Vegetation types range from semi-deserts to humid prairies with a large variety of shrub and grass steppes in between. Vegetation heterogeneity at a regional level reflects the constraints imposed by the climatic, topographic, and edaphic features (Paruelo et al., 2007). Grass steppes characterize the most humid portions of the region, which are dominated by grasses of the genus *Festuca*, accompanied by several other grasses, highly preferred by native and exotic herbivores, and sometimes by shrubs. In some portions of the steppe shrubs seem to be indicative of degradation by grazing (i.e. *Mulinum spinosum*, *Senecio filaginoides* and *Acaena splendens*) (Bertiller et al., 1995), whereas in other districts shrubs are common constituents of the grass steppe (i.e. *Nardophyllum bryoides*, *Chilliotrichum diffusum* and *Empetrum rubrum*) (Collantes et al., 1999).

At a finer grain, heterogeneity is due to altitude, slope, and exposure (Jobbágy et al., 1996, Paruelo et al., 2004).

There are 1,378 recorded vascular plant species in arid and semi-arid Patagonia (Correa, 1971), almost all of which are angiosperms and close to 30 percent of which are endemic species. Vegetation is characterized by the dominance of xerophytes, which have evolved remarkable adaptations to cope with severe water deficit (León et al., 1998).

3.4.2. Impact of human settlement

The main economic activities in Patagonia are sheep husbandry and oil exploration and extraction. Oil industry activities are the most intensive disturbance in Patagonia, though restricted in extent (Paruelo and Aguiar, 2003). They cause extremely severe and irreversible damage in focal areas because they remove all vegetation cover, and often entire soil layers (Paruelo et al., 2007).

Sheep farming is almost a monoculture in the arid and semi -arid steppes. Intensive agricultural activities such as fruit and horticultural crops are important in a few irrigated valleys, but are almost absent on sheep farms (Borrelli et al., 1997). Cattle production has become important on mountain ranges near the Andes, where sheep farming is more difficult due to the presence of forests, steep landscapes and losses to predators (Cibils and Borrelli, 2005).

Grazing affects almost all the region, but nowhere has it completely eliminated plant cover (Paruelo et al., 2007). It has been perceived to be the main agent of desertification in Patagonia (Ares et al., 1990). Patagonian vegetation is generally described as having few adaptations to cope with grazing by domestic ungulates, since the entire region is thought to have evolved under conditions of light grazing by native ungulates (Milchunas et al., 1988). Although this notion has recently been challenged by Lauenroth (1998), there is general consensus that vegetation throughout most of Patagonia has been modified significantly by sheep over the last century, particularly in the last 40–50 years (Golluscio et al., 1998). Deterioration of grazed vegetation has usually been demonstrated by replacement of palatable grasses by unpalatable woody plants (Cibils and Borrelli, 2005; Paruelo et al., 2007).

The impact of grazing varies widely among vegetation units. The grass-shrub steppes of the Occidental District (45°S, 70°W) show in general no major changes in vegetation physiognomy due to grazing (Perelman et al., 1997). In contrast, the grass steppes of Subandean District (45°S, 71°W) have experienced dramatic physiognomic changes due to grazing. Shrub encroachment is sometimes the final stage of grazing degradation of the grass steppes. Such changes reduce primary production (Paruelo et al., 2004) and modify water dynamics and herbivore biomass (Aguiar et al., 1996). In both vegetation units plant diversity is higher in ungrazed areas. European settlement in Patagonia's steppe and introduction of cattle only began at the end of the nineteenth century (Barbería, 1995). Sheep numbers had two phases, one growing till middle of XX century (over 21 million in 1952) and the latter gradually decreasing (about 8.5 million in 1999) (Golluscio et al., 1998; Méndez Casariego, 2000).This reduction have been interpreted as the result of productivity decay and desertification of Patagonia's steppes due to overgrazing (Ares et al., 1990).

Impacts of sheep on this landscape have become more extensive during the past decade due to a reduction in wool prices, the lack of productive alternative land uses, and the absence of an environmental policy from federal and state agencies and governments (Cibils and Borrelli, 2005).

4. Conservation of Temperate Grasslands

The grasslands after cradling the needs of humankind for countless centuries, the temperate grassland ecosystem is now considered the most altered on the planet (White et al., 2000; Gauthier et al., 2003). In fact, it is currently the most endangered ecosystem on most continents, especially in the prairie or plains of North America, the pampas of South America, the lowland grasslands of southeast Australia and New Zealand, the steppes of Eastern Europe, and the grasslands of southern Africa (Henwood, 2004, 2006). While not necessarily endangered, significant signs of stress are also appearing in the more healthy and intact temperate grasslands in parts of South America and the vast steppes spanning the breadth of Asia (Henwood, 2006; Peart, 2008). Historically, grasslands at all latitudes have presented one of the most amenable environments for human settlement and have provided for human needs since early evolutionary times (Food and Agriculture Organization, 2005). Indeed, grassland landscapes and many species of grasses, including corn, wheat, rice, oats, and sugarcane, continue to be a foundation of the world's food supply. From a conservation perspective, however, this productivity has come at a significant cost. Grasslands in temperate latitudes have now been modified by human activity to such a degree that little remains today in a natural state, and substantially less than other biomes in some form of long-term protection (White et al., 2000; Henwood, 2006; UNEP-WCMC, 2008). Once home to some of the world's greatest assemblages of wildlife, most temperate grasslands now support only remnant populations of this former abundance (Benedict et al., 1996; Miñarro and Bilenca, 2007).

Globally, about 41% of temperate grasslands have been converted to agricultural use, another 6% to urbanization, and an additional 7.5% to commercial forestry and other disturbances (White et al., 2000). With this level of conversion, an analysis in 2005 confirmed that temperate grasslands represent the biome most at risk in the world (Hoekstra et al., 2005). Using the "Conservation Risk Index," a measure of the ratio of total area converted to the area protected within a biome, the index for temperate grasslands is the highest of all biomes at 10 to 1 (Hoekstra et al., 2005). In such a scenario, whether formally protected or not, remaining natural areas of indigenous temperate grasslands take on a heightened importance for the ongoing ability to provide a range of essential ecological services, including the yield of water, the maintenance of biodiversity through the protection of habitat, the conservation of genetic diversity, recreation and tourism, areas of religious or spiritual significance, and as sources of natural foods and medicines (Food and Agriculture Organization, 2005).

In this age of rising concern over climate change, one of the more significant benefits of natural grasslands is their ability to store large amounts of carbon (Food and Agriculture Organization, 2005). As grasslands grow, they absorb carbon from the atmosphere. At a global level, natural grasslands represent a very large carbon sink, playing almost as important a role as forests in recycling greenhouse gases (Minahi et al., 1993). Of further significance, natural grasslands store considerably more carbon in the soil than in the vegetation itself (White et al. 2000). So when natural grasslands are converted to other uses, particularly intensive agriculture, carbon is released, becoming a major source of greenhouse gas emissions (White et al., 2000; Worldwatch Institute, 2009). In fact, land use and land-use change, especially from agriculture, deforestation, burning, and irrigation, are responsible for more than 30% of greenhouse gas emissions (Worldwatch Institute, 2009).

Modern technologies for carbon capture and sequestration are at least a decade away, and can therefore only promise to assist with capturing greenhouse gases that have yet to be released

(Worldwatch Institute, 2009). The only method immediately available for sequestering greenhouse gases already in the atmosphere is managing land-use change, primarily agricultural (Worldwatch Institute, 2009). Recently, five major strategies have been suggested to increase carbon capture and storage through managing agricultural land use and land-use change; among them are protecting natural habitats, restoring grasslands, and minimizing tillage to enhance the ability of soils to sequester more carbon through producing and storing organic matter (Scherr and Sthapit, 2009).

Despite the essential role grasslands have played and will continue to play for both humans and nature, temperate grasslands have not until quite recently been visible on the global conservation agenda (Henwood, 2004, 2006). Opportunities to protect significant representative and ecologically viable examples of this biome have been largely overlooked. This is particularly evident in those temperate grasslands offering relatively high productivity, such as North America’s tallgrass prairie, Argentina’s pampas, and southeast Australia’s tussock grasslands. Here, and in other grassland regions, levels of protection often range from 1% to 3% (Table 3). The level of communication and international cooperation within the conservation community that is so often evident in other biomes such as tropical rainforests, mountains, or coral reefs has been missing for temperate grasslands. Quite to the contrary, there has been a pervasive reluctance to recognize this ecosystem as being worthy of protection, which has essentially precluded conservation and protection from being considered legitimate land uses.

Table 3: Status of the conservation and protection of the world's temperate grasslands (Henwood, 2010)

Grassland region	**Area of original extent (km^2)**	**10% conservation target (km^2)**	**Percentage remaining in native cover (%)**	**Current percentage protected (%)**	**Remaining area (km^2) and percentage required to meet target**
EURASIA					
Eastern Europe	440,000	44,000	3-5	0.2	43,120 (9.8%)
Black Sea–Kazakh steppe	760,000	76,000	76	0.5-2.1	64,600 (8.5%)
Russian steppe	500,000	50,000	15	0.1	49,500 (9.9%)
EAST ASIA					
Mongolia	822,760	82,270	90	10.3	Undetermined
China	3,386,000	338,600	53	35	Undetermined
Russia's Amur Basin	100,000	10,000	5-20	5	5,000 (5%)
AUSTRALIA, NEW ZEALAND, AND SOUTH AFRICA					
Southeast Australia	60,000	6,000	0.5-2.0	2.0	4,800 (8%)
New Zealand	82,430	8,240	44	15.4	Undetermined
South Africa	360,590	36,100	65	2	28,900 (8%)
NORTH AMERICA (NA)					
Tallgrass	600,000	60,000	1-3	0.5	57,000 (9.5%)
Mixed grass	835,700	83,600	36-40	1.5-2.6	62,000 (7.4%)
Shortgrass	1,190,900	120,000	40-48	8.0	24,000 (2.0%)
Intermontane shrub steppe	53,300	5,300	46-70	5.9	2,200 (4.1%)
Chihuahuan	573,600	57,400	15	2.5	43,000 (7.5%)
SOUTH AMERICA (SA)					
Northern Páramo	35,700	3,600	60	43.4	Undetermined
Central Páramo and Puna	740,000	74,000	Unknown	9.3	Undetermined
Pampas	540,000	54,000	30	1.05	49,100 (9.1%)
Campos	210,000	21,000	65-80	0.2	20,500 (98.8%)
SA Patagonian steppe	800,000	80,000	95	5.0	40,000 (5.0%)

To build a strong case for conserving and protecting temperate grasslands, it is essential to understand and document their total economic value and true contribution to human social and cultural well-being. Recent research assessed the current state of knowledge about the total value of goods and services provided by indigenous temperate grasslands (Heidenreich, 2009). While the total economic value of other biomes appears relatively well understood, this study found no empirical valuation research that addressed intact temperate grasslands. As a result, temperate grasslands likely represent the least understood biome in the world in terms of their true value to sustainable economic uses and provision of sociocultural and ecosystem goods and services that contribute to human health and well-being (Heidenreich, 2009).

This lack of understanding about the true value of temperate grasslands puts them at a serious disadvantage and, if not corrected, could continue to threaten the long-term ecological viability of remaining indigenous grasslands. If our economy is not fully able to recognize through the market pricing system the net benefits of temperate grasslands, then inappropriate land use and investment decisions will result and the total value of these grasslands will be lost to society.

4.1.The Conservation Status of Temperate Grasslands

The *Rio de la Plata Grasslands* (RPG, 750,000 km^2, Soriano et al., 1992, Figure 7) are the main complex of temperate grasslands ecosystems in South America. About 60% of the RPG (460,000 km^2) are included in Argentina, comprising the entire eco-region of the Pampas and a small part of the Uruguayan savannas or Northern Campos in the North-east of the country (Dinerstein et al., 1995).

Pampas and Campos have a conspicuous and unique biodiversity, with thousands species of vascular plants, including more than 550 different grass species. Mesothermic grasses prevail in this region of mild climate (mean annual temperature of 10 to 20°C) and a mean annual rainfall between 400 and 1600 mm (Soriano et al.,1992). In some subtropical grassland areas, species richness of grasses and legumes is as high as the vegetation of some tropical forests (Nabinger et al., 2000; Overbeck et al., 2007). There are also about 450-500 bird species -60 of them are strict grassland dwellers- and nearly a hundred species of mammals (Bilenca and Miñarro, 2004).

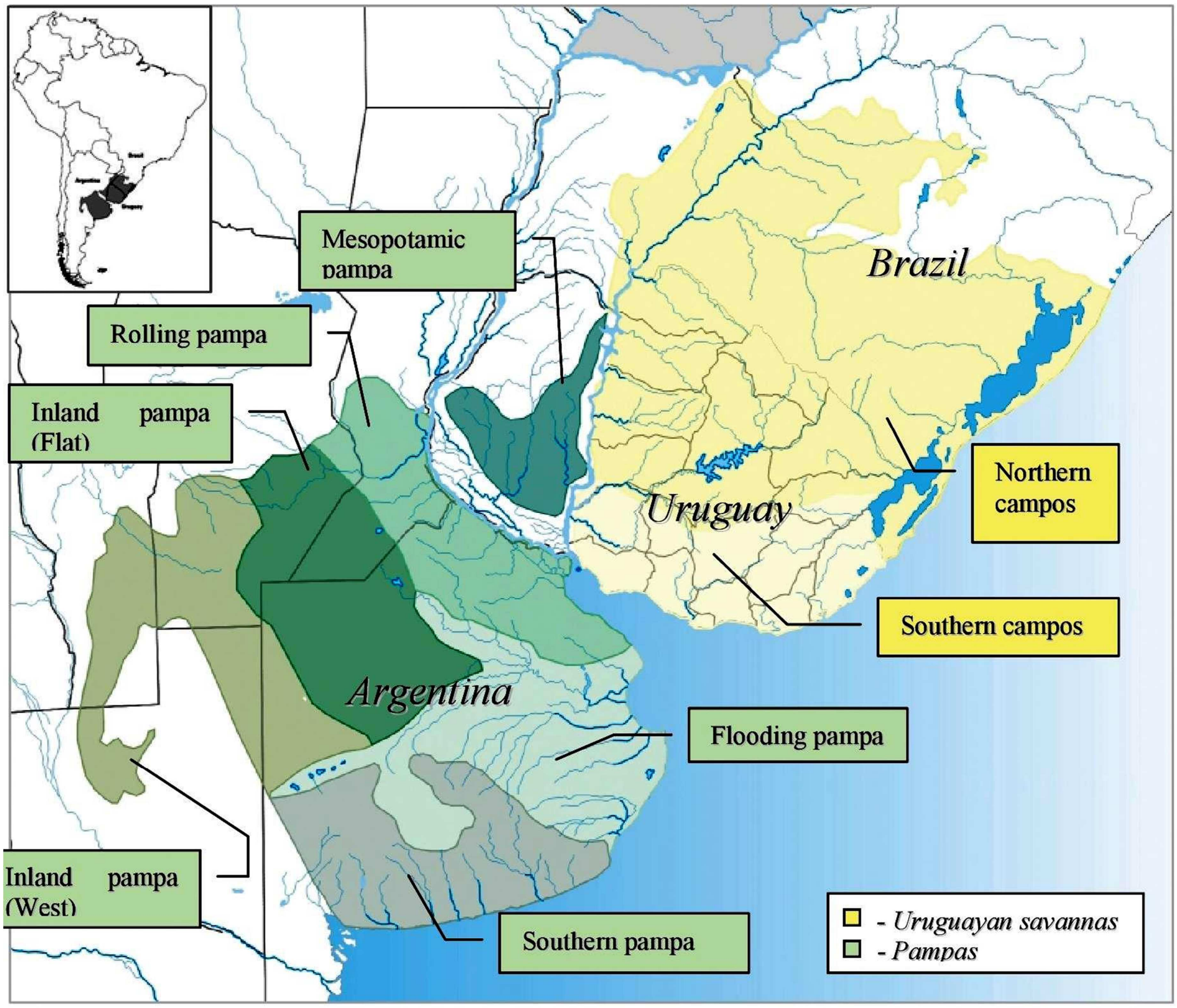

Figure 7: *The Rio de la Plata Grasslands, classified by eco-regions and regional units.*

4.1.1. Brief description of the regional units of the Rio de la Plata Grasslands

Several units can be recognized at the *Rio de la Plata Grasslands* in Argentina, on the basis of geology, geomorphology, drainage, soils and vegetation (Soriano et al., 1992, Figure 7).

4.1.1.1.Rolling Pampa

The relief of this unit is gently rolling. Good drainage is provided by a distinct network of fluvial valleys, tributaries of the Río de la Plata and the Paraná River. This network is plainly exoreic, and natural ponds are lacking.

On fertile soils main original plant communities include the “*flechillares*” of genera like *Stipa*, *Paspalum*, *Piptochaetium* and *Aristida*. However, even at the begining of the XX century it has been almost impossible to find in this unit flechillares or other grasslands communities in its pristine form (Soriano et al., 1992; Miñarro and Bilenca, 2008).

4.1.1.2. Inland Pampa

This unit lacks a fluvial network, the flat landscape being broken by ridges of fixed sand dunes. In some cases, dunes have been reactivated by farming activities. Good drainage conditions characterize the Eastern part of this unit, due in part to the sandy nature of the soil. Notwithstanding, extensive marshes and natural ponds occur because of the slight slope and the impervious layers underneath. To the West of this unit strong aeolian forces have moulded the structurally flat landscape into an undulating relief; drainage is not impeded and many palaeodepressions originated by deflation have turned into natural ponds.
Dominant species are the grasses *Sorghastrum pellitum* and *Elionurus muticus*, with and increasing cover of *Poa ligularis* and *Stipa* spp. to the Southwest. There are also shrubs and small trees like *Prosopis alpataco* and *Geoffroea decorticans*, which increase in density in overgrazed areas (Soriano et al., 1992; Miñarro and Bilenca, 2008).

4.1.1.3.Southern Pampa

The southernmost unit includes the mountains of the Tandilia and Ventania Systems, as well as their pediments and the coastal plain with a moderate slope to the Atlantic Ocean. The fluvial network is well defined and exoreic. There are rock outcrops and deep soils in the alluvial fans; over large parts of this area silt deposits overlie a continuous limestone sheet.
Pristine vegetation of this unit includes several species of *Stipa* (*S. neesiana*, *S. trichotoma*, *S. tenuis*) and *Piptochaetium* (*P. napostaense*, *P. lejopodum*). The unit is also rich in endemisms, with more than 400 species of native vascular plants (Soriano et al., 1992; Frangi and Barrera, 1996; Miñarro and Bilenca, 2008).

4.1.1.4.Flooding Pampa

This unit includes the lowlands known as the Laprida basin and Río Salado basin. Low morphogenetic potential results from the very slight slope of the plain in this area. Drainage is endoreic or areic, resulting in extensive and lengthy flooding during periods of abundant rainfall.

Distinctive features of relief are some dorsal ranges and crescent-shaped ridges on the Eastern side of natural ponds. There are also ridges of fixed dunes and of deposits of shell debris parallel to the Atlantic coast.
This unit includes most of the plant species of the Rolling pampas, plus a series of species adapted to frequent floodings. Typical grassland communities include *Bothriochloa laguroides*, *Paspalum dilatatum* and *Briza subaristata*, whereas at the South and Southwest of the unit plant communities are dominated by *Paspalum quadrifarium*. However, in many areas grazing has changed the original structure and composition of the grassland and includes several forbs and exotic species (Sala et al., 1986; Miñarro and Bilenca, 2008). Several communities are also developed in flooded areas, depending of the timing and length of the flooded period and soil salinity (Soriano et al., 1992, ; Miñarro and Bilenca, 2008).

4.1.1.5.Mesopotamic Pampa

This unit is located between the Uruguay and Paraná rivers. The relief of this unit is mostly rolling and even hilly in a portion of the area. Well-dissected rivers and streams surrounded by gallery forests form a remarkable network. Sediments are loessic to the West and richer in clay to the East.
Plant communities are represented by species of several genera such as *Axonopus*, *Paspalum*, *Digitaria*, *Schizachyrium* and *Bothriochloa*. Halophytic steppes are typical of the bottoms of the valleys.

4.1.1.6.Northern Campos

The relief of this unit is generally flat, but interrupted in some areas by low mesas or rock outcrops and sand deposits. Drainage is free resulting in a rich fluvial network; rivers and streams are sorrounded by gallery forests.
Main grass species are *Paspalum notatum*, *Axonopus compressus* and *Andropogon lateralis*, and several species of *Luziola* y *Leersia* in humid soils (Soriano et al., 1992; Nabinger et al., 2000; Miñarro and Bilenca, 2008).


Llanos
Guianan Savanna
Amazonian Savanna
Llanos de Moxos
Cerrado
Pantanal
Chaco
Puna
Monte
Espinal
Pampas
Patagonia
Grasslands of South America

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