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Natural grasslands in the Chaco. A neglected ecosystem under threat by agriculture expansion and forest-oriented conservation policies

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ABSTRACT

In most tropical and subtropical biomes, conservation strategies are mainly focused on the preservation of forests. However, neotropical dry forest and savanna ecoregions include open habitats that may deserve conservation attention. We analyzed the historical patterns and potential distribution of natural grasslands, as well as their biodiversity in the northern Argentina dry Chaco, which is one of the largest and yet most rapidly transforming neotropical ecoregions. Paleoecological literature, historical records, and bioclimatic modeling support the hypothesis that Chaco grasslands distribution was more extended in the past, and has been historically reduced by woody encroachment resulting from environmental changes occurred in the past century. Recent research shows that natural grasslands host distinctive components of the Chaco biodiversity, and a significant proportion of the vertebrate species have a negative association with woody biomass. Ongoing land use trends continue to threaten native grasslands both in unprotected sectors (where they are converted into agriculture and planted pastures) and inside protected areas (were fire suppression is favoring woody encroachment). Current conservation policies (Protected Areas, Argentine forest law, REDD+) neglect the importance of native grasslands for biodiversity conservation. Such forest-centered initiatives should be revised to specifically include native grasslands and their biodiversity into land use strategies that adequately balance agriculture and livestock production with biodiversity conservation.

1. Introduction

Given the costs and complexity of accurate and detailed spatial models, much biodiversity conservation planning is based on proxies. Forest distribution is paramount example. Deforestation rates and forest cover are used as key indices of national or regional ecosystem conservation (e.g. Moran et al., 1996; Gibson et al., 2011). Global conservation initiatives such as REDD + are largely based on the assumption that to some extent, biodiversity co-varies with biomass, both being maximized in well-developed forests (Phelps et al., 2012; Strassburg et al., 2012).

Forest cover and structure can be good indices of conservation in ecoregions clearly dominated by forests, but in non-forested ecoregions (e.g. grasslands, deserts), conservation should be based on other variables. By limiting the supply of potentially arable lands, forest-centered conservation initiatives could even redirect land conversion towards open ecosystems (Miles and Kapos, 2008). The dichotomy between forest or non-forest conservation schemes becomes particularly problematic in ecoregions where the natural landscape is a mosaic of forests and open areas, such as tropical and subtropical open and semi-open woodlands and savannas. Because they frequently have fertile soils in flat topographies, they are highly suitable for agriculture (Lambin et al., 2013), include some of the most active deforestation fronts (Aide et al., 2013; Hansen et al., 2013) and are among the most threatened ecoregions globally (Hoekstra et al., 2005).

Extending over north–central Argentina, western Paraguay, and Southeastern Bolivia, the dry Chaco is one of the largest remaining patches of forest/savanna ecosystems in Latin America (Portillo-Quintero and Sánchez-Azofeifa, 2010). The region currently undergoes one of the highest rates of deforestation in South America (Gasparri and Grau 2009, Clark et al., 2010; Aide et al., 2013; Gasparri et al. 2013) and such deforestation constitutes a

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significant source of carbon emissions (Gasparri et al., 2008). In response to this, and considering its valuable biodiversity heritage (Bucher and Huszar, 1999), the Chaco is subject of much conservation concern. In Argentina, protected areas represent only a very small proportion of the dry Chaco (c. 1%, Izquierdo and Grau, 2009), but a more ambitious conservation initiative has been implemented since 2007: the "*Ley de Presupuestos Mínimos de protección Ambiental a los Bosques Nativos*" (law 26331). This "forest law" obligates the provinces to define maps with three categories of allowed land use (Quispe Merovich and Lottici, 2011): "protected forest" (red zones), "managed forest" (yellow zones), and areas where deforestation is allowed (green zones). Such forest-defined land-use scheme essentially ignores grasslands as a specific conservation target.

The neglect of grasslands as a valuable ecosystem in the dry Chaco may be influenced by the common perception of the ecoregion as a "forest", since present-day non-agriculture landscapes in the region are dominated by woodlands. However, the dry Chaco also includes non-forest habitats such as grasslands, scrublands and wetlands. Indeed, it has been hypothesized that the pre-European landscape had a much higher representation of fire-prone grasslands (Morello and Saravia Toledo, 1959a, 1959b; Adámoli et al., 1990). The introduction of domestic livestock in the last centuries might have removed fine fuels and favored woody encroachment over grasslands, a process globally reported across drylands and savannas (Dougill and Trodd, 1999; Eldridge et al., 2011).

In this essay, we evaluate the assertion that natural grasslands (i.e. dominated by *Elionorus adustus*, *Trichloris crinita*, *Gouinia latifolia* or *Setaria macrostachya*) are a valuable ecosystem in the dry Chaco, due to its contribution to biodiversity derived from a historically larger extension. Specific questions to be addressed here are: (1) what is the "historical" importance of the grasslands in the dry Chaco landscapes?; (2) how much Chaco grasslands contribute to the biodiversity of the ecoregion?; (3) what are the current trends on land use of grassland areas in the dry Chaco? Based on this, we discuss to which degree the current forest-oriented conservation paradigm fails to preserve the Chaco biodiversity. Most of the examples and concepts here presented are based on northern Argentina case studies, but many of the derived ideas can be also applied to the rest of the dry Chaco ecoregion, and potentially to other savanna ecoregions.

2. Past and potential extent of the Chaco grasslands

Based on the names of localities which refer to the presence of grasslands ("*pampas*" or "*simbolares*"), Morello and Saravia Toledo (1959a, 1959b) suggested that grasslands were more extensive in the past, and that their current paucity was a consequence of relatively recent environmental change mostly derived from the introduction of livestock. For the year 2006, Clark et al. (2010) estimated 12% of "grasslands" for the whole dry Chaco ecoregion, but this figure includes a substantial (and unknown) proportion of planted pastures. In the northern sector of the Argentine dry Chaco, a 2007 assessment of non-cultivated area using remote sensing indicates that the area covered by natural grasslands was approximately 7% (Gasparri and Baldi, 2013).

Paleoecological evidence shows that during the Quaternary (last million years), the Chaco region experienced periods of much drier conditions with substantial reduction in forest cover (Iriondo and García, 1993; May et al., 2008; de Vivo and Carmignotto, 2004). The records of megafauna (e.g. *Glyptodon*, *Sclerocalyptus*, *Scelidotherium*, *Megatherium*, *Macrauchenia*, *Smilodon*, *Protocyon*) from Late Pleistocene with dryer conditions than present (Hoffstetter, 1968; Marshall and Sempere, 1991; Zurita et al., 2009; Huáscar Azurduy, 2006; Prevosti and Schubert, 2013) suggest an expansion of grasslands at expenses of forests during that period (de Vivo and Carmignotto, 2004), given that most South American megamammals were associated to open grasslands (Carlini et al., 2004; Zurita et al., 2004). For instance, *Equus neogeus*, *Toxodon platensis* and *Stegomastodon platensis* fed on C_4 grasses in sites where today Chacoan dry forests (dominated by C_3 plants) thrive (McFadden et al., 1994; McFadden, 2005; Alberdi et al., 2008; Prado et al., 2011).

Humans likely arrived at the region during the early Holocene, and for thousands of years indigenous populations probably lived out of gathering and hunting based to some degree in the use of fire to drive game and generate open habitats (Coltorti et al., 2010) as occurred in other regions around the world (Kirch, 2005). Accounts from the 18th century describe extensive areas of grassland and palms, both in frequently flooded sectors near the main rivers and in extensive sectors far away from rivers, where indigenous set frequent fires (Jolis, 1972). Documents of the late 19th century also mentioned extensive grasslands and palm savannas, especially in the margins of the Bermejo and Pilcomayo rivers, the foothills of the sierra de Tartagal (northwest in Fig. 1), and in *Campo del Cielo* (southeast sector in Fig. 1) (Boedo, 1873; Fontana, 1881; Baldrich, 1889; Burmeister, 1899). For sectors of the current Formosa and Chaco provinces, Baldrich (1889) and Burmeister (1899) estimated that approximately half of the territory was covered by forest and described forest patches as east-west oriented longitudinal "islands" within a matrix of open habitats. At the beginning of the 20th century, descriptions emphasized the progressive woody encroachment and depletion of natural grasslands. Barbrooke Grubb (1919) commented: "some thirty years ago great plains of luxuriant grass extended along the banks of the upper Bermejo and in others parts. Owing, however, to overstocking and other causes, these grass plains have become to a great extent covered with low scrubs, and during the dry season, many large stretches become perfectly bare". The progressive loss of grassland due to woody encroachment (particularly by *Prosopis ruscifolia*) was postulated as a driver of human outmigration from the margins of the Bermejo river in the area near the actual limit of Salta and Formosa provinces towards central Formosa (Muello, 1926). These anecdotal observations coincide with later interpretation of the Chaco landscape by Morello and Saravia Toledo (1959a, 1959b) and Adámoli et al. (1990), who concluded that the process of natural grassland depletion continued until the 1940s and 1950s, when following a dry period of severe overgrazing, woody encroachment was accentuated and defined in part the current landscape configuration of non-cultivated areas.

To further assess the hypothesis that grasslands could be more widely distributed in the dry Chaco, we developed a consensus model (*sensu* Araújo and New, 2007) of the habitat suitability for grasslands based on climatic, soil and water-related variables. We used sites currently covered by grasslands as training points (Appendix 1) in the northern Argentina dry Chaco. Over 13% of the area showed a suitability of 50% or higher for grasslands, approximately doubling the current proportion (Fig. 1). Soil related variables, temperature seasonality and distance to water bodies were the variables more associated with grassland distribution (Appendix 2). Interestingly, 10 of 14 localities in the study area with words in their names referring to open sites covered by grasses ("*pampa*", "*aibal*", "*simbolar*" and "*tacuruzal*)" were mapped into the areas with medium to high suitability values for grasslands, despite that more than 70% of them are currently located in landscapes dominated by forests (Fig. 1).

In summary, both at the scale of millennia and of centuries, evidence suggest that dry Chaco grasslands where much more extensive in the past. Furthermore, even under present-day climatic conditions, grasslands could be much more extensive under a different land use regime.