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Biodiversity and Land Systems

PERSPECTIVE

A new focus for ecological restoration: management of degraded forest remnants in fragmented landscapes

Land use and land cover change is the major driver of biodiversity loss in terrestrial ecosystems worldwide, making the management and governance of land systems a key parameter in conserving and sustaining biodiversity. This issue gathers 16 contributions dealing with the relations between biodiversity and land systems from very diverse thematic and regional perspectives.

Photo by: Fabiano M. Scarpa

Andrea **Izquierdo**[1] | Hector Ricardo **Grau**[1]
Julierta **Carilla**[1] | Elvira **Casagranda**[1]

Side effects of green technologies: the potential environmental costs of Lithium mining on high elevation Andean wetlands in the context of climate change

Abstract

Lithium-based batteries are the key component of booming green technologies, including hybrid electric, plug-in hybrid electric and battery electric vehicles. Nearly 80% of the global lithium resources are located in the subtropical "Puna" highlands of Argentina, Bolivia and Chile. In these arid ecosystems, most biodiversity is related to wetlands: this highly valuable biodiversity includes the emblematic native camelids, flamingos, and a rich variety of endemic plants, and other animals. Climatic trends during the past decades, and future climate models suggest persistent drying tendencies. As other mining operations, lithium exploitations of salty flats require relatively large amounts of water. We discuss the research questions and priorities to preserve these valuable ecosystems in the context of growing potential conflicts for the use of water.

Global lithium production has recently boomed in response to growing demand for rechargeable lithium batteries. These applications are associated to technological innovations such us hybrid electric, plug-in hybrid electric and battery electric vehicles; which are mostly branded as "green" alternatives to conventional technologies because they reduce CO2 emsisions, and release comparatively little polutants (Desselhaus and Thomas 2001). Lithium-ion batteries outstand as one of the most promising energy storage technologies (Scrosati and Garche 2010). Harvesting lithium from brines in salt flats only requieres solar energy (Armand and Tarascon 2008). However, given the low concentrations of lithium in brines it is estimated that for each ton of extracted lithium around two million liters of water are evaporated. Brine desiccation to obtain lithium causes a decrease of the base level of groundwater in the basin, thus reducing fresh water outside the edges of the salt flats, affecting the functioning of lakes and associated peatbogs (Gallardo, 2011).

Lithium reserves are concentrated in northern Chile (7.5 million tons), northwest Argentina (6.5), southwest Bolivia (5) and western China (5.4) (USGS 2015). The most economically and energetically viable resources for lithium-ion batteries (LIB), are located in the "lithium triangle" of the Central Andean Dry Puna of Bolivia, Chile and Argentina, (Figure 1). The Dry Puna is a biodiversity hostpot (Myers 1988) with high levels of endemism, unusual ecological or evolutionary phenomena, and global rarity of major habitat type (Olson et al., 2002).While historically the region has been affected by grazing; presently climate change combined with tourism and mining prospects are the main threats of biodiversity and hydrological

Figure 1: *Location of the three salt flats that limits the "lithium triangle" in the northern Chile, northwest Argentina and south-west Bolivia.*

[1] Instituto de Ecología Regional, University of Tucuman
Corresponding author: aeizquierdo@gmail.com

function. Although revious studies of our research team in Northwestern Argentina showed a decrease of human population and livestock during past decades (Izquierdo and Grau 2009), simultaneously with an increase of wildlife populations (e.g. vicuñas); this relatively favorable situation for biodiversity conservation with decreasing conflicts with human activities could be reversing. Future climate change scenarios identify high-elevation ecosystems among the most vulnerable (Bensiton et al 1997), and the combination of global markets and domestic policies suggest that mining will expand rapidly in the region, in particular lithium extraction (Figure 2A).

Water is the main limiting ecological factor in this region, and wetlands are key functional units (Figure 3). Peatbogs contribute a significant proportion of primary productivity, maintain vertebrate populations, and regulate hydrological resources, sometimes affecting urban and agricultural areas downstream. Vegetation communities of the region are dominated by species of the family Juncaceae (Oxychloe andina and Distichia muscoides), Cyperaceae (Eleocharis, Phylloscirpus), and several species of Poaceae. These plants occur in large sponge-type ecosystems called "bofedales", "vegas" or peatbogs, with waterlogged and marshy soils, where biodiversity productivity is concentrated. Lakes and lagoons present different salinity range, related to evapotranspiration rates and mineral substrate, where particular aquatic plants grow, e.g. Isoetes, Myriophyllum, Lilaeopsis, Halophytic plants such as Distichlis humilis, Sarcocornia sp. are commonly found in salty shores. Vegas´ plant communities, showed approximately 25% of endemisms recorded for Laguna Blanca Reserve, Catamarca (Argentina) (e.g. Arenaria catamarcensis, Festuca argentinensis; Borgnia *et al.* 2006), where was recorded c. 34 especies of vascular plants, similar to Chile (Peñaloza *et al.* 2013) and Bolivia's "bofedales", also with comparative shannon diversity index (2.1 in average. Domic, 2014). In addition, these wetlands present high diversity of macro invertebrates and zooplancton, which are a vital component of freshwater ecosystems as they contribute to the process of organic matter while serving as food for other organisms such as fish and amphibians (Nieto et al 2015).

South American camelids, Vicuñas (Vicugna vicugna) and guanacos (Lama guanicoe) are most prominent amongst mammals; while flamingos are the most emblematic birds that migrate long

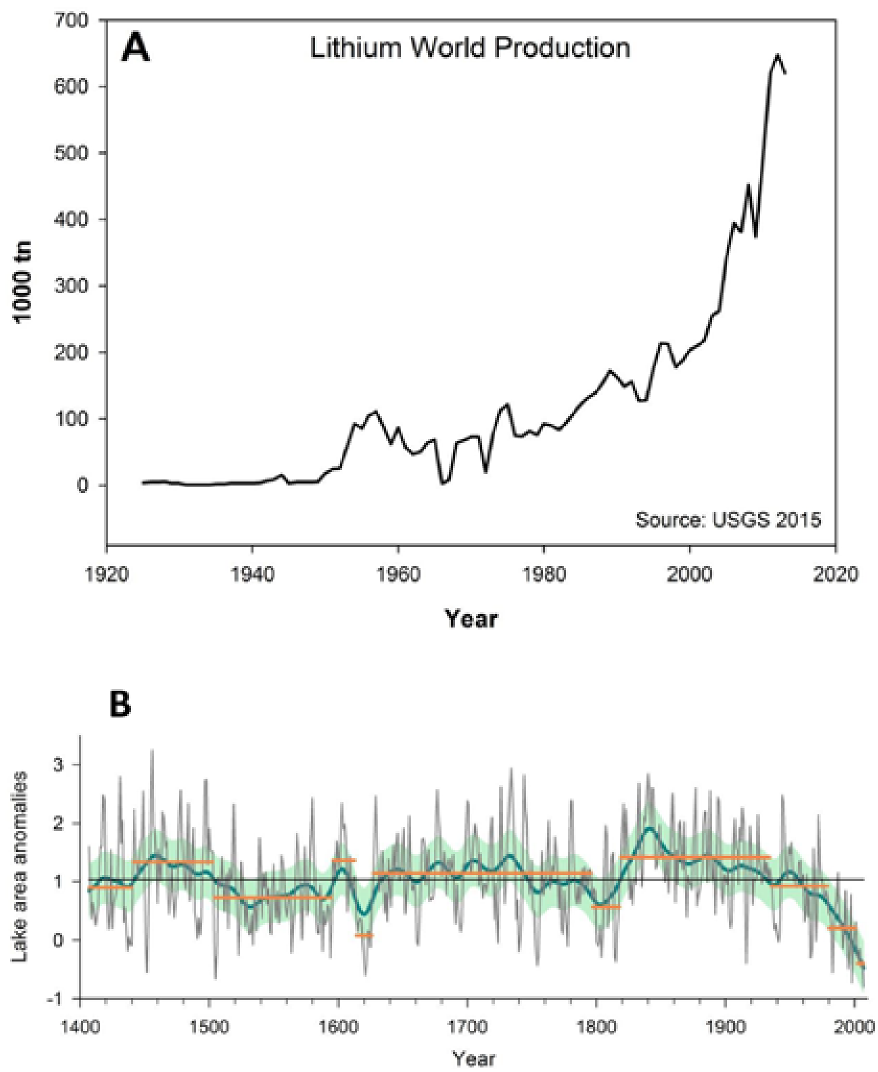

Figure 2: *Increasing trends of Lithium world production (A) and decreasing trends of precipitation showed by annual (January–December) Vilama-Coruto lake area reconstruction for the period AD 1407–2007 (Morales et al. 2015) (B)*

distances for reproduction and feeding in these wetlands. Three of the worlds´s five flamingo species are in the region: the rarest and least known are Puna or Jame´s flamingo (Phoenicoparrus jamesi), the vulnerable by IUCN Andean flamingo (P. andinus), and the more comun Chilean flamingo (Phoenicopterus chilensis). Among carnivores species are mountain vizcachas (Lagidium viscacia), Pampas cat (Leopardus colocolo), culpeo fox (Lycalopex culpaeus), puma (Puma concolor) and the endemic and endangered Andean cat (Leopardus jacobita). Seasonal and temporal patterns of wetlands are the key determinants of carnivore distribution in these environments (Cuyckens et al 2015). Wetlands were the most important factor detemining distribution of the culpeo fox, most likely because it uses aquatic birds as prey (Cuyckens et al 2015). In addition to plant and fauna, recent discoveries of microbial biodiversity and stromatolite communities in the extreme habitats of salty lakes are having important implications on theories about the origins of life (Farias *et al.* 2013).

Water is not only the most vital and limited resource for biodiversity but also for human populations. For example Messerli *et al.* (1997) concluded that water resources in the Salar de Uyuni watershed in Bolivia must be considered a non-renewable resource (or renewed extremely slowly). In this context, expanding mining industry may lead to ruin this sensitive ecosystem and also represent a threat to the region's water supply. Based on an opportunity cost estimation of the lithium extraction in the same salt flat, Aguilar (2009) concluded that using the same water source as a production input, lithium extraction and crop irrigation cannot simultaneously take place.

Most climate scenarios for high elevation ecosystems predict a 2-4 °C increase in temperature (Urrutia and Vuille 2009), as well as decreasing water availability and longer dry seasons (Buytaert et al 2010). While models have more uncertainties for precipitation trends, the most accepted scenario suggest a decrease in precipitation and cloudiness for subtropical Andes (Viulle et al 2008). Consistently, our analysis of historical range of variability based on dendroecological reconstructions of water balance and ecosystem productivity shows a clear drying trend for the last 30 years. (Figure 2B; Carilla *et al.* 2013, Morales *et al.* 2015). If persistent, this trend could affect vegetation range distribution, increase wetlands salinity, decrease oxygen amount, promote eutrophication and, increase carbon emissions (Anderson et al 2011) as well as Andean human population vulnerability.

In summary, there is no doubt that low-carbon technologies represent a major progress in reducing global negative effects of economic growth. However, when the resources demanded by these technologies come from very specific geographic locations, they can resultd in major environmental degradation. This is potentially the case in the Dry Andean high elevation wetlands, which with a few hundred thousand hectares

Figure 3: *Lakes, peatbogs and salt flats; linked eco-hydrological systems of the Puna (Polulos basin, Northwest Argentina) (A), and Salt flats and vicuñas (Hombre Muerto salt flat, Argentina) (B). While covering less than 1% of the area, peatbogs harbor much of regional productivity and biodiversity; and regulate the hydrological cycles (C) and salt flats are a source of minerals including lithium (D). Picture credits: H.R. Grau and A.E. Izquierdo*

appear bounded to supply the largest part of the global lithium demand. Significant research effort is needed to understand the vulnerability of these ecosystems and their biodiversity to the combined effect of mining expansion and climate change; and these effort should be coupled with clear transnational planning guidelines to ensure the sustainable development of the region.

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