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Environment and anthropogenic impacts as main drivers of plant assemblages in forest mountain landscapes of Southern Patagonia

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ABSTRACT

Management of natural areas generated multiple trade-offs, and changes in the plant assemblages was identified as one of the most critical ones. In this context, understanding the drivers of change of exotic plant diversity is critically important for biodiversity conservation and land planning. The aim of this work was to evaluate the relationships between environmental gradients in mountain landscapes and anthropogenic impacts related to human uses as drivers for plant assemblages (native and exotic species) in Southern Patagonian forests. The study was located in the Andorra Valley basin (12,934 ha) in the southern Tierra del Fuego Island (Argentina), where mountain landscape units (land-cover and land-use) were identified according to their vegetation types (forests and open-lands), elevational effects (< 400 and > 400 m.a.s.l.) and anthropogenic impacts derived from economic activities (harvesting and cattle grazing). Classification was based on Landsat 8 OLI images with fieldwork samplings, relevating a total of 101 landscape units. In each unit, forest structure and floristic surveys (dicots, monocots, pteridophytas and bryophytes) were conducted. Data were evaluated using ANOVAs and multivariate analyses (cluster, detrended and canonical correspondence analysis). A total of 104 plant species were surveyed (88% natives and 12% exotics), where managed deciduous forests (*Nothofagus pumilio*) had the highest values of exotic species occurrence frequency (20%). Multivariate analyses showed that environmental gradients and anthropogenic impacts highly affected the distribution of exotic species. Native species had higher cover values at upper elevations, while exotic plants had a higher cover at lower elevations, where the N-S aspects were strongly correlated with plant preferences for shaded/lighted aspects. The occurrence of exotic species can be specifically related to human activities (e.g., *Agrostis stolonifera* and *Rumex acetosella* with cattle grazing; and *Poa nemoralis*, *Ranunculus repens* and *Stellaria media* with harvesting), however one of them (*P. trivialis*) was related with unharvested forests. We conclude that environmental gradients and anthropogenic impacts define the plant assemblages at landscape level, and they also influence the occurrence of the exotic species, where the main driver was the harvesting. We propose that land-sharing conservation strategy in these mountain landscapes could be the better approach towards sustainability ensuring the preservation of the land-cover and the land-use at the low and upper elevations.

1. Introduction

Impacts on ecosystems by natural and anthropogenic-induced alterations span very different spatial levels, from the management of local ecosystems to understanding globally interconnected processes, and addressing them through international policies (Kueffer et al., 2014). An important example is a framework that distinguishes between the integration (land-sharing) and the separation (land-sparing) of conservation with production systems (Phalan et al., 2011). In a land-sparing scenario, the available land in a landscape is partitioned into some areas focused on producing mainly agricultural products, while others are devoted mainly to maintaining biodiversity and ecosystem services (e.g. maintaining and protecting areas of special interest); while in the land-sharing scenario, the available land is under lower-intensity management (e.g. harvesting or cattle grazing). The increased area of land in production compensates for its lower yield, and the decrease in intensity allows biodiversity to be conserved across the whole landscape (Phalan et al., 2011; Gabriel et al., 2013). However, trade-offs were produced among the different management objectives (e.g. harvesting vs. conservation) and the different ecosystem

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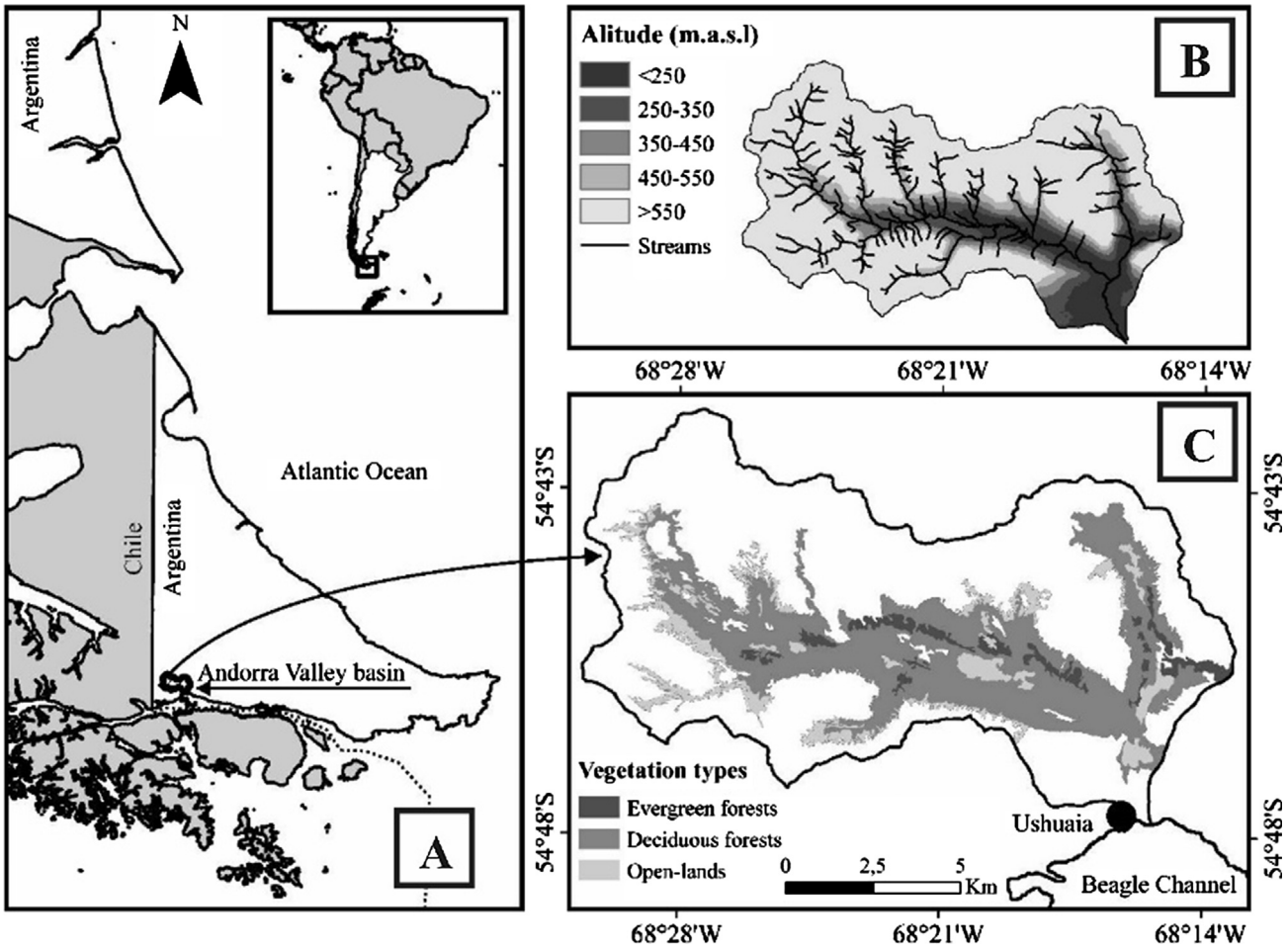

Fig. 1. Study area: (A) location of Andorra Valley, (B) river networking and elevation (m.a.s.l.), and (C) main vegetation types.

services that the landscape offers to the society (Martínez Pastur et al., 2017).

The occurrence of exotic species in the natural landscapes is one of the main proxies of anthropogenic impact of practical interest to ecosystems management (Butchart et al., 2010). In the case of plants, the occurrence of exotic species is widely recognized to alter ecosystem structure and function, community assemblage, and native species interactions (Sax, 2001; Lencinas et al., 2011), and could endanger the productive systems (e.g. trophic links) (Belnap et al., 2012; Peri et al., 2016). In mountain landscapes, the interest on species diversity has greatly increased during the last years, due to gaining further insight into patterns of invasion and mechanisms driving them along the environments (Alexander et al., 2011; Kueffer et al., 2014). Mountains provide several ecosystem services (Rodríguez-Rodríguez et al., 2011) and usually natural reserves were created in these landscapes (Arpin and Cosson, 2015). However, mountain regions are particularly vulnerable to socioeconomic pressures, where optimal land management to ensure the availability of the natural resources is needed (Grêt-Regamey et al., 2012).

In Southern Patagonia, remaining well-conserved wilderness areas are mainly located across the Andean Mountains, where *Nothofagus* represent the southernmost forested ecosystem on Earth (Peri et al., 2016) and the understory plants typically represented one of the most important components of biodiversity (Lencinas et al., 2011; Mestre et al., 2017). Land-cover includes forests dominated by deciduous (*Nothofagus pumilio* and *N. antarctica*) and evergreen trees (*N. betuloides*). These forests rarely constitute large continuous masses; rather the landscape is usually formed by a mosaic of several forest types and open-lands, where timber and unproductive forests are mixed (Lencinas et al., 2008a). The deciduous forests (henceforth referred only to *N. pumilio*) grow in cool sites with well-drained soils (Frangi and Richter, 1994), while evergreen forests develop in softer environmental conditions at middle elevation on mountain valleys (Allué et al., 2010). The associated environments, such as open-lands, include unique species (Lencinas et al., 2008a, 2008b). The diversity of understory species is particularly associated with the ecology of each site, such as incident light and soil moisture at understory level (Mestre et al., 2017). These forests have very valuable timber species and valleys offered some grassland patches, for this, historical impacts occurred due to anthropogenic-influences such as harvesting and cattle grazing (Martínez Pastur et al., 2017), generating changes in the biodiversity, e.g. both activities reduce understory and insect richness, and significantly changes its original community's assemblage (Lencinas et al., 2011, 2017). Beside this, these mountain environments were also threat due to establishment of many new exotic plant species that established after the interventions (Lencinas et al., 2008a). The relationship between exotic plants, and environment and anthropogenic drivers, is still poorly understood at southernmost mountain landscapes, although they are strongly increasing in remote areas (Seebens et al., 2017, 2018), and was considered as an important pressure over biodiversity (Tittensor et al., 2014).

Many countries of South America base their conservation strategy in natural parks located in remote areas (e.g. Argentina and Chile) (Martínez-Harms and Gajardo, 2008), however, land-use changes increased every year due to worldwide demand for more natural resources (e.g. food, wood, fiber) (FAO, 2014). In this context, land-sharing becomes the most realistic option in Andean mountain landscapes (Martínez Pastur et al., 2013), and the understanding of the