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Positive Changes in Regional Vegetation Cover in Patagonia Shown by MARAS Monitoring System

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Key words: [three to five key words; separated by semicolons]

Abstract

MARAS (Environmental monitoring of arid and semiarid lands) is a vegetation and soil monitoring system in Patagonia, a 700.000 km2 area in southern South America. Installed between 2008-2015 within INTA-Argentina and INIA-Chile national agricultural research institutes, it includes photographs, 500-point intercepts, 50-m canfield lines to detect patches, 10 land function observations and 0-10 cm soil samples in 458 ground sites. Data is centralized and freely accessible https://maras.inta.gob.ar. We analysed changes based in the first 255 reassessments made at 5-year intervals. At a regional scale significant changes (P<0.05 paired T test) were detected for: perennial vegetation cover, that was originally 42% and increased +3.1%. Plant species richness of 13.7 species/monitor increased +0.7, bare soil of 35% decreased -7.9%. Length of bare soil interpatches was 157 cm and decreased -42 cm. Land function indexes of Stability 46.2%, Infiltration 45.1% and Recycling 31.0% showed small non-significant changes (-1.3, +0.7 and +1.42 respectively). Significant changes in soils under vegetated patches were: conductivity 0.59 dS/m increased +0.49, and pH 7.3 +0.33. Organic matter was 2.0% and increased 0.35%, and sand was 73% and increased 3%. Finer soil particles decreased non-significantly. Bare soil interpatches had 1.4% organic matter and also increased 0.33%, and clay, that initially was 9.3% reduced -2.3%. The long-term ground sites provide a means to monitor slow changes in these rangelands in relation to global climatic change and regional grazing patterns. Patagonia has currently the lowest domestic stocking rates of the last century and vegetation seems to be slowly growing in perennial cover, with significant reductions in exposed bare soil, increase in biodiversity and soil organic carbon.

Introduction

Drylands are distributed over 100 of the world's nations, comprise about 45% of the earth's land total area, and are highly prone to land degradation and desertification. Patagonia, with 624.500 km^2 in southern Argentina and Chile, is mostly drylands (Gaitán et al. 2020) and has been heavily degraded in the last century due to the introduction of domestic animals at high stocking rates (Del Valle et al. 1998). The region has been de-stocked in the last two decades, and this could drive a slow regional recovery of vegetation, but climate change and the increases in aridity associated with it are expected to interact also, driving losses in vegetation cover, biodiversity and key soil properties such as soil carbon content, features that influence the functioning and capacity of these drylands to provide essential ecosystem services. In order to describe changes in these vast areas, a network of field-based observations over regional scales that encompass different ecosystem types and measures variables such as plant cover, species richness and indicators of soil fertility and indicators of Landscape Function is necessary. The task requires cooperation of scientific teams specialized in different ecosystems and working in diverse institutions. The MARAS (Spanish acronym for "Monitoreo Ambiental de Zonas Áridas y Semiaridas" or "Environmental Monitoring of Arid and Semiarid Regions" in English) network is a field-based ecosystem monitoring protocol developed by the National Institute of Agricultural Technology of Argentina (INTA, https://www.argentina.gob.ar/inta), which has also been adopted by the National Institute of Agricultural Research of Chile (INIA, http://www.inia.cl/). Development of this methodology started in 2002 with funding of Global Environmental Funds, Project GEF Patagonia PNUD ARG 07/G35 and have subsequently been funded by different Argentine institutions and projects. In Chile data has been contributed by the INIA Kampenaike node and funded by Ministerio de Agricultura through Project 502093-70 Sistemas de Praderas Estepáricas de Zonas Frías de Chile. Formal setup of the MARAS network of monitoring plots started in 2007, and 426 monitoring plots have been surveyed until December 2019 (Fig. 1), distributed along an area with vegetation that ranges from shrublands to grasslands and semi-deserts. Re-evaluation in a 5-year cycle of the 436 monitoring plots is currently in progress, and 255 monitoring plots have been assessed twice. In this paper we analyse changes that the main variables show across the region.

Methods and Study Site

Monitoring plots (426) were chosen to represent ten biozones (Oliva et al. 2019). They were progressively placed in the period 2007-2014 in uniform areas representative of dominant vegetation types, under the usual management: grazed by sheep, cattle or goats, or native *Lama guanicoe* (guanacos). A manual describing in depth the protocol is available (Oliva et al. 2011). Each monitoring plot consisted in three 50-m transects (Fig. 2) positioned between permanent poles in which vegetation and soil variables were recorded and reassessed ideally every five years. Vegetation was sampled using two 50-m line transects with 250 interception points each, and patch structure was sampled with 50-m gap intercept lines for interpatches (areas that lose resources, minimum length 5 cm) and patches (resource sink areas, minimum length 10 cm). Soil stability, infiltration and nutrient cycling were assessed using 11 soil superficial condition indicators recorded in ten bare soil patches following the Landscape Function Analysis (LFA) methodology (Tongway y Hindley 2004). Two 0-10 cm depth composite soil samples were obtained, one from patch and one from interpatch areas, which were analysed in laboratory for pH 1:2.5, conductivity (dS/m), Organic matter / Walkley - Black (%), Total N Kjeldahl (%) and texture was obtained using a using Bouyoucos hydrometer. All data was entered in a database that was developed by the National University of Austral Patagonia (UNPA) and is freely accessible via https://maras.inta.gob.ar/portal/app/index.php. Data has also been deposited in an international database in the Figshare public repository (Oliva et al. 2020). In the period 2015-2019, 255 of these monitoring plots were reassessed after a period of 6.3±1.7 years and we compared key indicators of vegetation and soil using paired T test.

Results
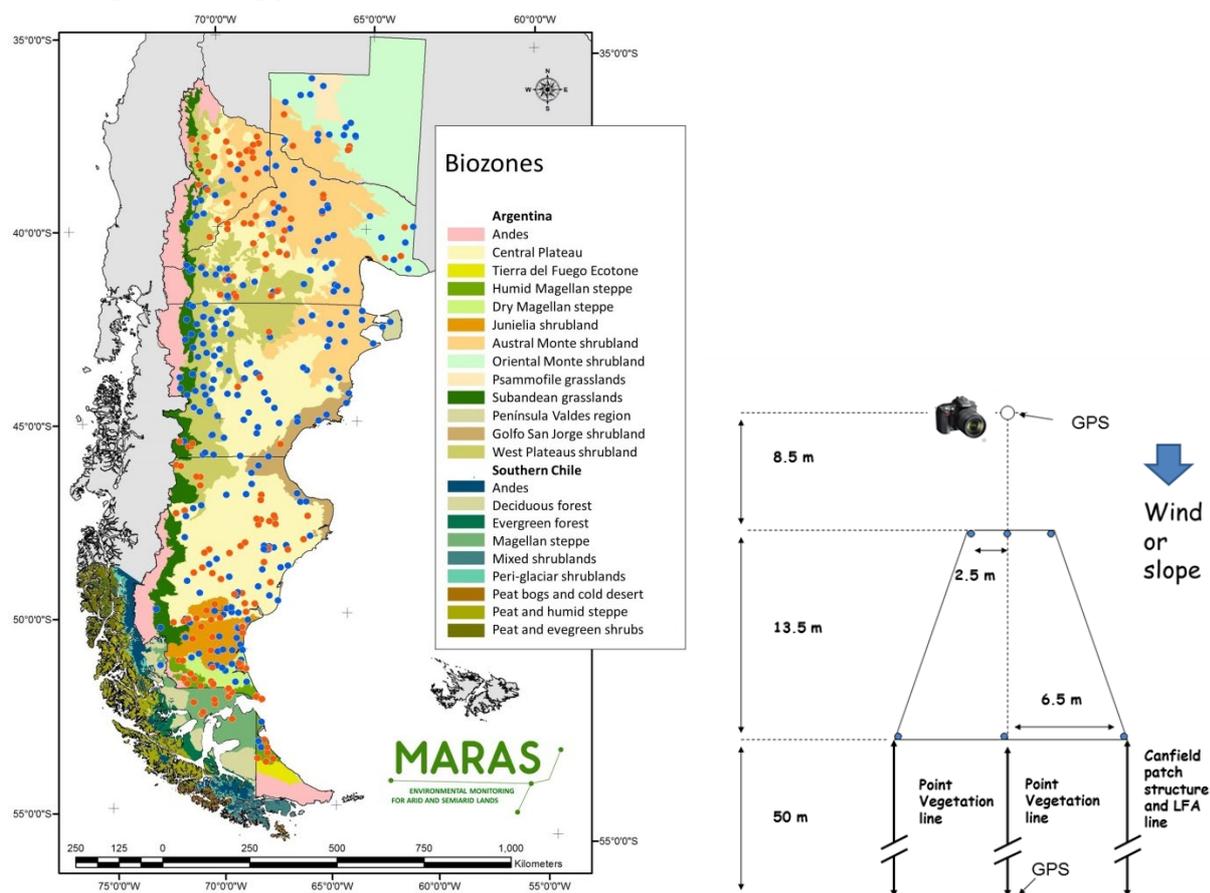
Location of monitoring plots

Figure 1. Left: Map of the MARAS network in Patagonia as of September 2019. Dots represent monitors: those in blue have been surveyed twice, red ones have surveyed only once. Right: Diagram of the monitoring plots based on permanent steel poles. Three 50-m transects were surveyed using graduated tapes and ropes were used to outline the trapezoid - shaped photographic plot. All tapes and lines were removed after assessment.

Assessment of change

The 255 reassessments showed significant changes (P<0.05 paired T test) for: increase in perennial vegetation cover (%), plant species richness (number of species), decrease in bare soil (%) (Fig. 2). The mean length of bare soil interpatches was 157 cm and decreased -42 cm (data not shown). Land function indexes of Stability, Infiltration and Recycling showed small non-significant changes (Fig. 2). Laboratory soil analysis for vegetated patches showed significant increases in conductivity, pH, Organic matter, and sand % (Fig. 2). Finer soil particles decreased non-significantly. Bare soil interpatches had 1.4% organic matter and also increased 0.33%, and clay, that initially was 9.3% reduced -2.3% (data not shown).
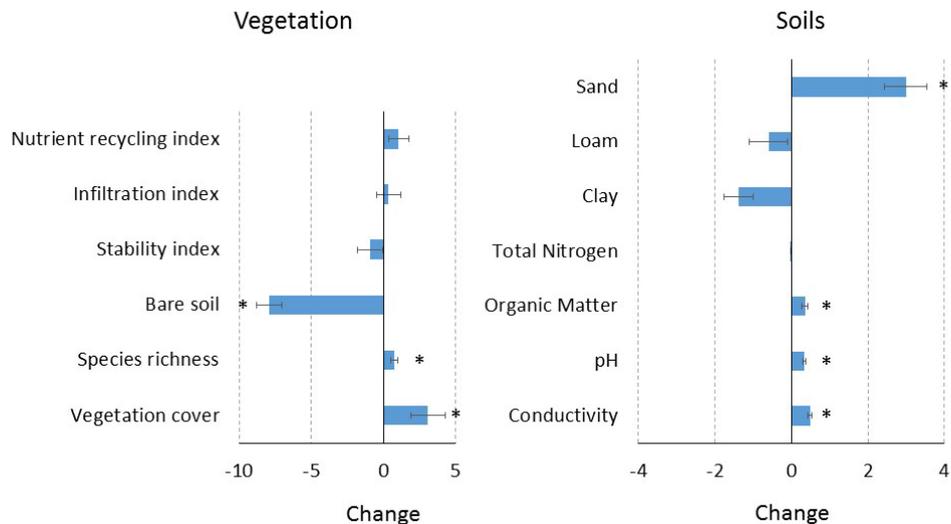

Figure 2. Left: change (value at reassessment- value at installation date) of 255 MARAS monitoring plots reassessed in Patagonia. Vegetation cover (%), Species richness (nº of species per monitoring plot), Bare soil (%), Stability, Infiltration and Nutrient Recicling indexes (Tongway y Hindley 2004). Right: change in values of laboratory analysis of soil samples including soil sand, loam and clay fractions (Bouyoucos hydrometer), total N Kjeldahl (%), Organic matter Walkley - Black (%), pH 1:2.5, and conductivity (dS/m). Asterisks indicate significant changes in paired T test (P<0.05).

Discussion

Changes observed indicate that vegetation cover at regional scale in Patagonia significantly increased in the period 2014-2019. Bare soil was reduced and a small but significant increase in diversity, evaluated through species richness has also been found. The main Land Function indicators remained without significant changes. This increase in vegetation cover is the result of a complex interaction between climate, as both dry spells and favourable periods were experienced in this vast region, and the effects of improved management with lower sheep stocks and farm abandonment, as regional sheep stocks that reached 20 M in the 1950's fell to 7 M in the last two decades. Soils show an increase in sand, that probably reflects on-going erosion of the finer particles of loam or silt in this region subjected to intense wind storms. Total Nitrogen did not vary and the tendency to increase pH and conductivity is hard to explain. A positive trend in organic matter accumulation of 0.34% that demonstrates that the region is acting as a carbon sink, and could offset the CO_2 equivalent emissions of the sheep industry. As a conclusion, Patagonia is apparently recovering from past degradation, and the MARAS monitoring network provides hard data that should be further analysed in combination to remotely sensed data and at a biozone scale to interpret changes and intra-regional trends.

Acknowledgements

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