

Is phosphorus a limiting factor for the productivity of Campos grasslands?

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Abstract

The *Campos* are natural grasslands covering 350,000 km² across Uruguay and southern Brazil, and mainly used for animal production in extensive grazing systems. These grasslands are characterized by soils with low phosphorus (P) availability and limited water storage capacity. Therefore, climatic variability and nutrient deficits are considered to be major limitations to their aerial net primary productivity (ANPP). To evaluate this phosphorus limitation, we (1) compiled ANPP results from 109 paired P fertilizer vs control plots, from experiments carried out throughout Uruguay between 1970 and 2015, and (2) analysed nitrogen-to-phosphorus (N:P) ratio in more than 250 herbage samples collected between 1990 and 2002 from *Campos* distributed across Uruguay. These two databases span different soil types and years with variable precipitation: ANPP of control plots ranged from 400 to 6,000 kg dry matter ha⁻¹ y⁻¹. P fertilization generally increased ANPP, but the magnitude was low and stable across the gradient of ANPP (mean: 450 kg DM ha⁻¹ y⁻¹). No differences were detected either between soil types or fertilizer sources. Almost all herbage samples had N:P ratio lower than 16 (92% had N:P lower than 14). Together, these results suggest that P deficiency is a minor determinant of annual ANPP of *Campos* grasslands in Uruguay.

Keywords: natural grasslands, campo natural, phosphorus limitation, ANPP, N:P ratio

Introduction

Campos grassland is an extensive ecosystem spread over a wide variety of soils in Uruguay and southern Brazil (Allen *et al.*, 2011), characterized by low fertility and limited water storage capacity. These natural grasslands, a hotspot of biodiversity with more than 3,000 species of temperate and subtropical plants, are mainly used for animal production in extensive grazing systems, and provide several ecosystem services (Modernel *et al.*, 2016). Climatic variability is considered to be the main limitations for productivity, and nutrient deficiencies are also widespread (Berretta *et al.*, 2000). Average available soil P (Bray-Kurtz), for instance, is typically lower than 5 ppm (Hernández *et al.*, 1995), which would indicate that aerial net primary productivity (ANPP) may be limited by P deficiency. The N:P ratio of plant biomass could be used as an indicator of the relative limitation of N, P or both. A N:P ratio less than 10-15 identifies a N-relative limitation, while a ratio more than 20 to 25 indicates a clear P relative limitation in grassland (Güsewell, 2004). The aim of this study is to evaluate the hypothesis that available soil P is one of the major limitations of ANPP of *Campos* grasslands.

Materials and methods

We compiled ANPP from 109 short- and long-term experiments with paired P-fertilized vs control treatments, carried out in Uruguay between 1970 and 2015. This dataset included 15 soils of different origin from 3 pedologic regions (Basaltic, East and Sedimentary), P rates from 6 to 140 kg P ha⁻¹ y⁻¹, different fertilizer sources and interannual variable precipitation. Further, we compiled a separate dataset of nitrogen-to-phosphorus (N:P) ratio in more than 250 herbage samples collected between 1990 and 2002 from well managed to overgrazed (degraded) *Campos*. Statistical analyses were performed with Infostat (Di Rienzo *et al.*, 2015).

Results and discussion

ANPP of control plots varied greatly, from 400 to 6,000 kg dry matter (DM) ha⁻¹y⁻¹, mainly due to interannual variability of precipitation. Increases in ANPP on P-fertilized plots were relatively significant ($P < 0.05$), but little and stable across the gradient of ANPP and soil types: on average 443 kg DM ha⁻¹ y⁻¹ (Figure 1). Annual or cumulative P rate used as fertilizer had no effect on forage yield production. No significant difference was also detected between more soluble vs more insoluble P fertilizer sources (482 and 422 kg DM ha⁻¹ y⁻¹, respectively).

The N:P ratio data further support the idea of little P deficiency in these grasslands: more than 90% of herbage samples had N:P ratios lower than 14, and less than 5% of the samples had N:P ratios higher than 16 (Figure 2). This suggests a more important N limitation than P limitation in these grasslands (Güsewell, 2004).

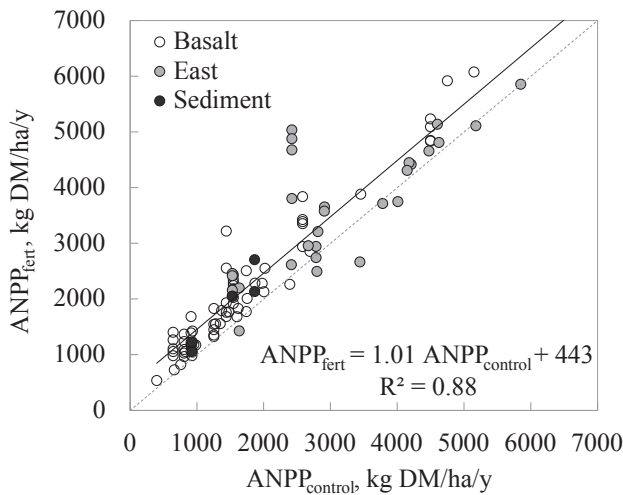


Figure 1. Relationship between ANPP of control and P-fertilized plots. White, grey and black symbols indicate sites from Basaltic, East, and Sedimentary pedologic regions.

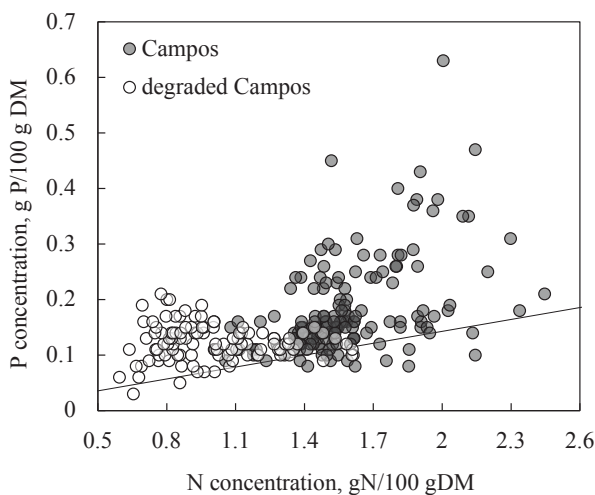


Figure 2. Relationship between N and P concentration (on a % of dry matter basis), for Campos grasslands. The line indicates the N:P ratio = 14.

Conclusions

In spite of low available soil P levels, as indicated by available P, primary productivity of Uruguayan *Campos* grassland appears not to be largely limited by P availability.

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