Synergizing livestock management and grassland ecology for enhanced biodiversity and soil health

Schossler, D[1]; Garcia, S[2]; Medina, A[3]; Widmaier, G[4]

[1]Alianza del Pastizal/Aves Uruguay, Canelones 1198 esquina Z. Michelini. Montevideo. 11100. Uruguay, alianzadelpastizaluy@gmail.com; [2] Laboratorio Sosei, Av. a la playa 62 Canelones, 1500, Uruguay, silvipgarcia@gmail.com; [3]Alianza del Pastizal/Aves Uruguay, Canelones 1198 esquina Z. Michelini. Montevideo. 11100, Uruguay, agus.medina@avesuruguay.org.uy; [4] Alianza del Pastizal/Aves Uruguay, Canelones 1198 esquina Z. Michelini. Montevideo 11100, Uruguay, gus.widmaier@gmail.com.

Key words: bird diversity; grassland conservation index (GCI); soil microorganism; active carbon; phosphatase activity

Abstract

This study investigated the relationship between soil health and biodiversity in grasslands, under the hypothesis that better livestock management practices result in a healthier balance between fungi and bacteria, greater carbon sequestration potential, higher bird diversity, and better coverage of forage species. Six farms were selected, and within each, variables were determined at farm and paddock level. At farm level, floristic variables related to pasture degradation as coverage of forage species, coverage of invasive exotic species, proportion and height of the upper stratum were assessed to form the Grassland Conservation Index (GCI) and Bird Monitoring Strategy. At paddock level, a representative pasture was chosen based on the dominant soil group. Two transects were established in these pastures along which soil was sampled for analyses of microbiologically, chemical and physical attributes. Fungal abundance, the fungi-to-bacteria ratio (F), enzymatic activities (beta-glucosidase and phosphatase), and active carbon (AC) were determined. These variables were used to construct the Microbiological Soil Health Index. Chemical analyses included nutrient content, micronutrients, pH, and bases. At the farm level, principal component analysis (PCA) revealed that the main and the second axis explained 39,4% and 24% respectively, of the variability, distinguishing two samples. AC and phosphatase, crucial for the soil health index, were determinant in this separation. These two samples showed higher total phosphorus (P total), AC, and phosphatase activity, suggesting that soils rich in total P can sustain a greater abundance of P-solubilizing microorganisms. Although the number is low and much more studies are needed to correlate the ecosystemic trophic chains and their relationships, this case study leaves lessons learned and trends of the relationships between ecosystemic services of rangelands.

Introduction

The Río de la Plata grasslands are among the largest, most diverse, and least transformed temperate subhumid to subtropical grasslands in the world, spanning central-eastern Argentina, Uruguay and southern Brazil (Soriano et al. 1991; Paruelo et al. 2022). These grasslands provide crucial ecosystem services, including food provisioning, biodiversity conservation (Bilenca and Miñarro 2004; Medan et al. 2011), and carbon sequestration (Modernel et al. 2016). Given climate change and increasing market demands, there is an urgent need to identify indicators that reconcile livestock production with environmental protection.

Evidence suggests that biological indicators, such as bird species richness and microbiological and biochemical indicators, offer a more precise assessment of soil health and functional potential than physicochemical indicators. Soil microorganisms perform essential functions for plants (Newsham et al. 1995; Smith and Read 2008; Mendes et al. 2013; Rillig et al. 2016) and serve as valuable bio-indicators. These include the abundance of beneficial organisms, the fungi-to-bacteria biomass ratio (H:B), enzyme activity crucial for nutrient cycling (Pérez Guzmán et al. 2021), and active carbon content, which reflects the carbon available to microorganisms and is sensitive to practices that sequester carbon in the soil (Hurisso et al. 2016).

Within Uruguay, El Paso Centurión and Sierra de Ríos is a protected landscape important for biodiversity. The main activity here is livestock farming on natural grasslands, which requires effective management based on scientific data. Our approach emphasizes that healthier soils promote better plant growth, that supports livestock production and plant diversity, which in turn sustains greater bird diversity and serves as bioindicators of environmental health.

Our main objective was to establish a baseline of environmental health indicators in the Paso Centurión and Sierra de Ríos Protected Landscape, generating information to propose management recommendations for biodiversity conservation. Specifically, we aimed to assess i) the health status of six livestock farms using soil, vegetation, and bird health indicators, and ii) the correlation between these health indicators at different spatial scales (farm and paddock).

Methods

This study was carried out in Paso Centurión and Sierra de Ríos, a protected landscape which is in the northeast of Uruguay. In November 2023 we selected 6 livestock establishments (named from A to F). At farm spatial scale we study percentage of natural pasture, vegetation cover index by satellite, bird abundance, bird richness species.

At the paddock spatial scale, two representative points within the dominant soil type were sampled in each establishment. For the study of chemical, physical and biological indicators of the soil, two composite soil samples from the first 15cm were taken, following two 60 m transects. We determined total P, micronutrients, total bases and organic matter according to MEHLICH - I; Sulfochromic Oxidation and soil physical analysis were performed with Bouyoucos Densimeter. In laboratorio Sosei we estimated biological variables such as Fungi and bacterial biomass to estimate the H:B ratio, and abundance of protozoa were determined by direct microscopy; phosphatase activity and betaglucosidase activity were measured by spectrophotometry and active carbon was determined by oxidation of potassium permanganate. To investigate the health of the vegetation, the cover of forage species, the cover of exotic species and the structural heterogeneity were assessed in these sample points. Using vegetation variables, we construct the Grassland Conservation Index at farm scale, which represents individual contribution of producers (at the level of rural establishments) to the conservation of natural grasslands. Integrating data of functional microbiological variables, the Microbiological soil health Index (MSHI) was constructed. To study the

correlation between the different indicators at paddock scale, simple linear regression analyses were carried out between the different variables studied, as principal component analysis (PCA), standardizing different variables at paddock scales.

Results

Results at farm scale

Site C had the lowest ICP and, together with site F had a low number of birds compared to the other sites surveyed (Figure 1)

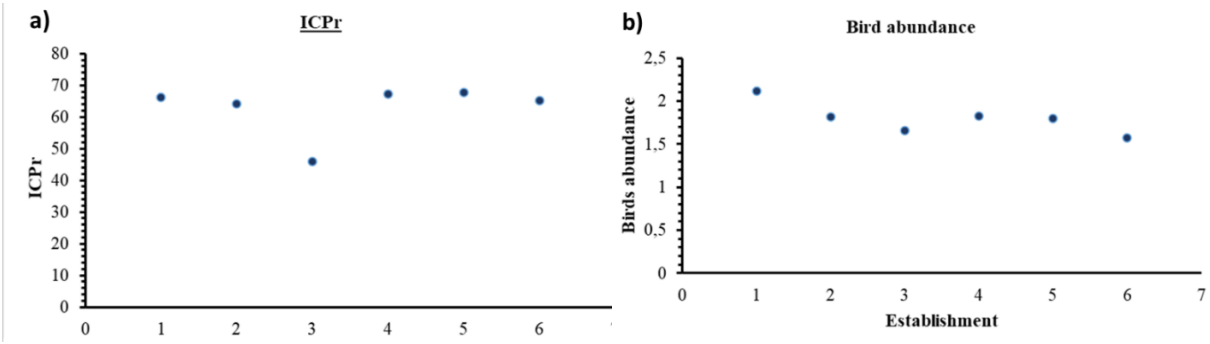

Figure 1. ICP value (a) and bird abundance (b) in the establishments studied.

Results at paddock scale

The abundance of the different microbial groups and as the H:B ratio, was relatively homogeneous among study sites (ranged 0.01-0.4). We found differences in soil microorganism functioning variables between sampled points. The principal component analysis separated samples A1 and C2 (samples with greatest MSHI) from the rest at paddock scale. The active carbon, phosphatase activity and total P in soil were important in explaining this grouping of sample points. (Figure 2).

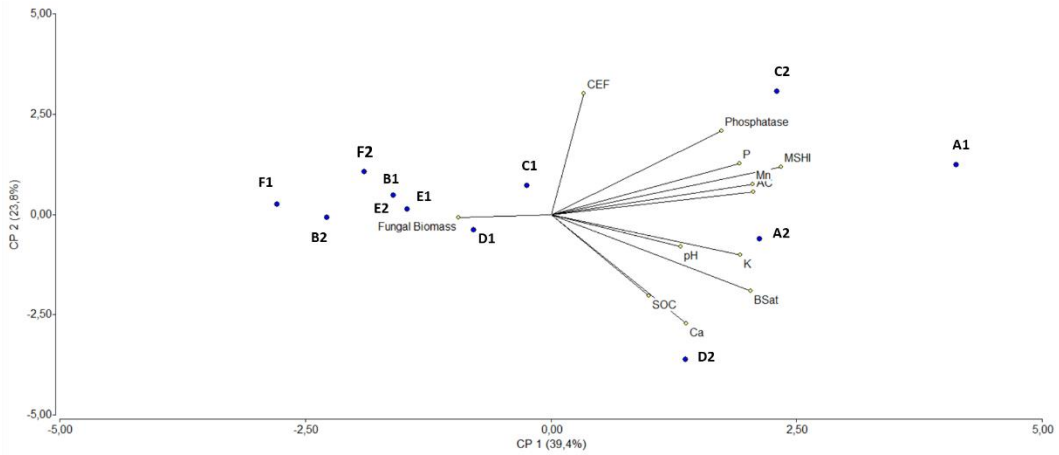

Figure 2. Principal component analysis performed with variables standardized at paddock scale. A1 and A to F1 and F2 are points 1 and respectively sampled and within paddock A to paddock F; MSHI: Microbiological soil health Index; AC: active carbon; Bsat: bases saturation; SOC: soil organic carbon; CEF: coverage of forage species.

In terms of grassland vegetation, all sites had a high total ground cover (70-98%), an índex of forage species cover between 1.6 -3.4 and no exotic species were recorded. Contrary we expected, the relationship between MSHI and forage species cover was weak (Fig 3).

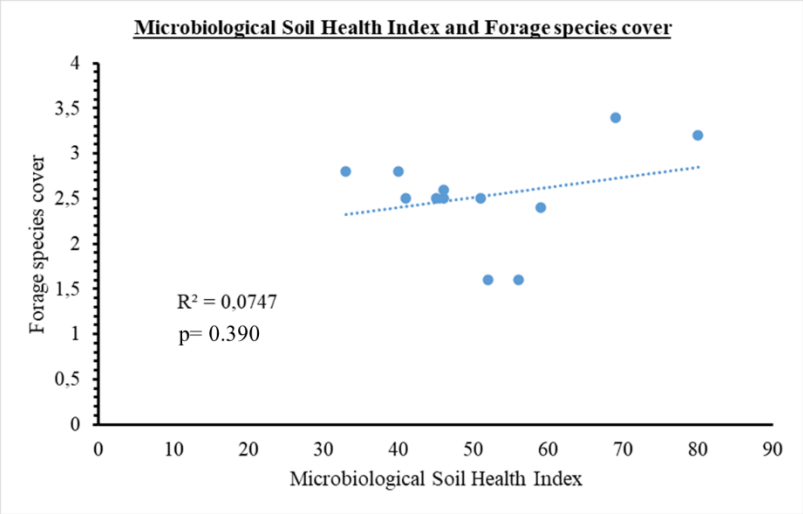

Figure 3. Relationship between the Microbiological soil health Index and coverage of forage species.

Discussion

Our research is the first to report values for soil microbial indicators in grasslands and shows that exist an association between soil and vegetation health in this ecosystem. The points with the highest MSHI were those with the highest levels of total P. This could be explained due to soils with more total P could support a greater abundance of P-solubilising microorganisms, as evidenced by a higher activity of the enzyme phosphatase. Contrary we expected we did not find a relationship between the MSHI and forage species cover, probably due to the small number of replications. Larger sampling efforts would be needed to explore this relationship further. A more comprehensive avian survey, including statistical modelling, is needed to establish a stronger, statistically significant link between bird diversity and ecological indicators. Identifying indicators that reflect the health of the different components of the natural field and how they relate to each other under different productive management is a fundamental step in creating incentives and promoting policies for the conservation of our most important ecosystem.

Acknowledgements

We thank the producers and the landscape authorities of El Paso Centurión.

References

Bilenca D and Miñarro F. (2004) Identificación De Áreas Valiosas de Pastizal (AVPs) en las Pampas y Campos de Argentina, Uruguay y sur de Brasil (Buenos Aires: Fundación Vida Silvestre Argentina).

De Vries FT. Hoffland E. van Eekeren N, Brussaard L, Bloem J. Fungal/Bacterial ratios in grasslands with contrasting nitrogen management. *Soil Biol. Biochem.* 38, 2092–2103

Hurisso TT, Culman Horwath SW, Wade J, Cass D, Beniston JW, Bowles TM, Grandy AS, Franzluebbers AJ, Schipanski ME, Lucas ST. Ugarte CM. (2016) Comparison of Permanganate-Oxidizable Carbon and Mineralizable Carbon for Assessment of Organic Matter Stabilization and Mineralization. *Soil Sci Soc AmJ.* https://doi.org/10.2136/sssaj2016.04.0106

Mendes R, Garbeva P, Raaijmakers, JM (2013) The rhizosphere microbiome: Significance of plant beneficial, plant pathogenic, and human pathogenic microorganisms. *In FEMS Microbiology Reviews* 37, (5), pp. 634–663. https://doi.org/10.1111/1574-6976.12028

Modernel P, Rossing WAH, Corbeels M, Dogliotti S, Picasso V, and Tittonell P (2016) Land use change and ecosystem service provision in Pampas and Campos grasslands of southern South America. *Environmental Research Letters*, 11(11). https://doi.org/10.1088/1748-9326/11/11/113002

Paruelo JM, Oesterheld M, Altesor A, Piñeiro G, Rodríguez C, Baldassini P (2022) Grazers and fires: Their role in shaping the structure and functioning of the Río de la Plata Grasslands. *Ecología Austral*, 32(2bis), 784–805. Available from: https:// doi. org/10. 25260/ ea. 22. 32.2. 1. 1880

Proyecto MapBiomas Uruguay – Colección 1 de los mapas anuales de cobertura y uso del suelo (2024), available at [LINK] [Accessed 25.10.2024]

Rillig M C, Sosa-Hernández M A, Roy J, Aguilar-Trigueros CA, Vályi K, Lehmann A (2016) Towards an integrated mycorrhizal technology: Harnessing mycorrhiza for sustainable intensification in agriculture. *Frontiers in Plant Science*, 7(OCTOBER2016), 1–5. https://doi.org/10.3389/fpls.2016.01625

Soriano A, León RJC, Sala OE, Lavado RS, Deregibus VA, Cauhépé MA (1991) Río de la Plata grasslands. In: "Natural grasslands. Introduction and western hemisphere". (Ed RT Coupland). pp. 367–407. (Elsevier: Amsterdam)