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EVALUATION OF PLANT FUNCTIONAL TYPES RESPONSE TO GRAZING AND FERTILIZER LEVELS IN NATURAL GRASSLAND

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Abstract

We report a study on a natural grassland experiment with the objective of finding optimal plant functional types (PFTs) for the description of vegetation response to levels of grazing (ungrazed, grazed) and fertilizer (with, without). The experiment was a split-plot design in randomized blocks, with three replications and the grazing levels in the main plots. Vegetation description was based on species composition and on 12 plant morphology attributes (life-form, growth-form, stem tissue type, leaf cross section, leaf texture, leaf dorsal epidermal surface, leaf ventral epidermal surface, spininess, leaf resistance, leaf width, plant height). Cover-abundance of species was visually estimated. By using a measure of congruence, multivariate analysis and randomization testing, implemented in software SYNCSA, an optimal subset of the attributes was found (plant height, spininess and leaf cross section) that when used to define PFTs composition could express vegetation response to grazing more clearly than species composition did. The same procedure applied for the vegetation response to fertilizer could not find an optimal subset among the 12 attributes evaluated.

Keywords: exclusion, multivariate analysis, natural pasture, plant morphology attributes.

Introduction

Studies of vegetation dynamics usually require the description of community composition, which may use species or plant functional types (PFTs) as basic units. Limitations exist in comparative studies of vegetation based on species. First, species are geographically limited, hindering, in large-scale studies, comparisons between communities not sharing floras. Second, in small-scale studies relevant intraspecific variation may be lost. The description using PFTs is an adequate alternative, but the problem is how to define the types (Pillar and Orlóci 1993, Pillar 1999a).

Plant types may be defined as sets of attribute states, but the attributes need to be selected. For the types being ecologically relevant, the attributes must be responsive to environmental factors (Pillar and Orlóci 1993; Skarpe 1996; Diaz and Cabido 1997; Pillar 1999a). Pillar (1999a) suggests a preliminary choice, on the basis of existing knowledge, of a larger attribute set to define PFTs. By data analysis, an optimal subset of attributes is then selected in order to maximize the correlation between environmental variation and vegetation variation described by PFTs.

In this contribution we use the technique of PFT optimization for the evaluation of vegetation response to grazing and fertilizer levels in a natural grassland experimental setup in southern Brasil.

Material and Methods

The experiment was in a natural grassland area of Campos, in FEPAGRO’s Center of Forage Research, São Gabriel, RS, Brasil, at 30º20'27"S and 54º19'01"W, 109 m altitude. The climate is subtropical humid with hot summers. The soil is eutrophic dark red podzolic, loamy texture.

The experimental design was a split-plot arranged in randomized blocks, with three replications. The main plots (40 x 8 m) were subjected to two levels of cattle and sheep grazing: ungrazed (exclusion by fencing) and grazed. The experiment remained ungrazed from December 1996 to January 1999, when grazing started in the grazed plots. The subplots (20 x 8 m) received two levels of fertilizer (without, with fertilizer). The fertilizer subplots received in surface annually, in February of 1994, 1995 and 1996, 45 $kg.ha^{-1}$ of N (urea), 110 $kg.ha^{-1}$ of P_2O_5 (triple superphosfate) and 60 $kg.ha^{-1}$ (potassium chloride). Afterwards the areas were not fertilized.

Visual estimation of cover-abundance of species in each subplot took place in November 1999. In each subplot, species were described using a set of 12 morphological attributes (life-form, growth-form, stem tissue type, leaf cross section, leaf texture, leaf dorsal epidermal surface, leaf ventral epidermal surface, spininess, leaf resistance, leaf width, plant height). For this, only species with more than 10% frequency in the experiment were considered.

Using an optimization algorithm (Pillar 1999a), implemented in software SYNCSA (Pillar 1999b), from the initial attribute set an optimal subset was searched in order to maximize the congruence $\rho(\mathbf{D};\mathbf{\Delta})$ between vegetation variation and variation (1) in grazing levels and (2) fertilizer levels. Congruence was measured by the matrix correlation between dissimilarities of the communities described by plant types (matrix **D**) and the absolute differences (0, 1) of grazing or fertilizer level (matrix **Δ**). The data set describing the vegetation by optimal plant functional types was then treated by ordination (principal coordinates analysis – PCOA) to reveal relevant trends of variation (Pillar and Orlóci 1993) and to multivariate analysis of variance with randomization testing to evaluate the significance of vegetation response to grazing and fertilizer levels (Pillar and Orlóci 1996).

Results and Discussion

The subset of attributes that when defining PFTs maximized the congruence ($\rho(\mathbf{D};\Delta)$ = 0.73) for grazing response was plant height, spininess and leaf cross section These attributes were optimal to express vegetation response to grazing in PFT terms. In contrast,

with vegetation composition described in species terms, congruence with respect to grazing was lower ($\rho(\mathbf{D};\Delta)$ = 0,35). That is, vegetation response to grazing was more clearly expressed by the composition of optimal PFTs than by the species composition. This may be indicating that important intraspecific variation is lost when only the species identity of plant populations is used for community description. The same analytical process applied to optimize PFTs to express response to fertilizer levels did not find a high level of congruence ($\rho(\mathbf{D};\Delta)$ = 0,12).

Compositional data derived from these two cases, i.e. description by species and by optimal PFTs for response to grazing, were used in PCOA ordination (Fig 1 and 2).

When vegetation is described by optimal PFTs there is a clear-cut separation between grazed and ungrazed experimental units (Fig 2), which contrasts with a rather fuzzy separation when vegetation is described by species composition (Fig 1). Indeed, when described by optimal PFTs, ungrazed and grazed treatments differed significantly, as indicated by multivariate randomization testing (P = 0.031).

In the ordination diagrams (Fig 1, 2), the species or PFT most correlated with the axes are plotted according to the correlation level. In Fig 1, the horizontal axis is mostly reflecting the variation in the performance of *Paspalum notatum* (Pano) and *Coelorhachis selloana* (Cose). In the same Figure, the vertical axis is reflecting the variation in the performance of *Eryngium horridum* (Erho) and *Coelorhachis selloana* (Cose).

In Figure 2, the horizontal axis is mostly reflecting the variation in performances of PFTs 3 and 14, while the vertical axis is reflecting the variation in performance of PFTs 1, 6 and 4. PFTs 3 and 14, with opposite trends on the horizontal axis, and respectively characterizing grazed and ungrazed areas, differ with respect to plant height. The height of PFT 3 is 2.5-5 cm while PFT 14 is 20-50 cm. Both PFTs present the same states of spininess (none) and leaf cross section (flat). The individuals of PFT 3 belong to species such as *Paspalum notatum*, *Oxalis* sp. and *Paspalum dilatatum*, which are known to be less tolerant to shading. The individuals of PFT 14, characterizing excluded areas, belong to species such as *Melica* sp., *Panicum hians, Tephrosia asperifolia* and *Macroptilium heterophylium*, species which are usually not abundant in grazed areas; and when they are found in grazed areas they are protected by spinescent plants such as *Eryngium horridum*. Both PFTs 1 and 6 present flat leaf cross section. In PFT 1 the height is 10-20 cm, while in

PFT 6 it is 5-10 cm. The plant height in PFT 4 is 5-10 cm, and the leaves are flat with rough surfaces, belonging to *Melica* sp. and *Aspilia montevidensis*.

Based on the set of morphological attributes selected a priori for vegetation description in the experiment, the analysis could identify an optimal subset of attributes (plant height, spininess and leaf cross section) that, when defining PFTs, maximized in the data the expression of vegetation response to grazing. Furthermore, this response in terms of PFTs was better than when species were used to describe the vegetation. However, the analysis could not identify in the same set of attributes, a subset that could reveal clear-cut vegetation response to fertilizer.

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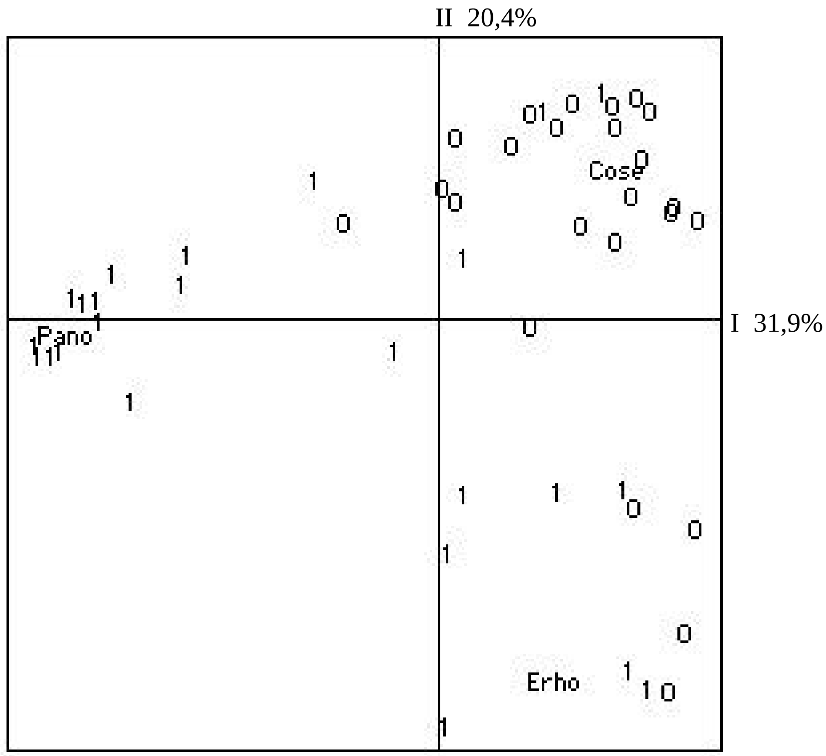

Figure 1 - PCOA ordination of experimental units (subplots) described by species, on natural grassland, São Gabriel, RS, Brasil. Ungrazed subplots are identified by 0, grazed ones by 1. Axes 1 and 2 contain respectively 31.9% and 20.4% of the total variation. Species (abbreviations in the text) having higher correlations (| r | > 0.5) with the two ordination axes are plotted at their correlation levels rescaled accordingly to the ordination diagram scale.

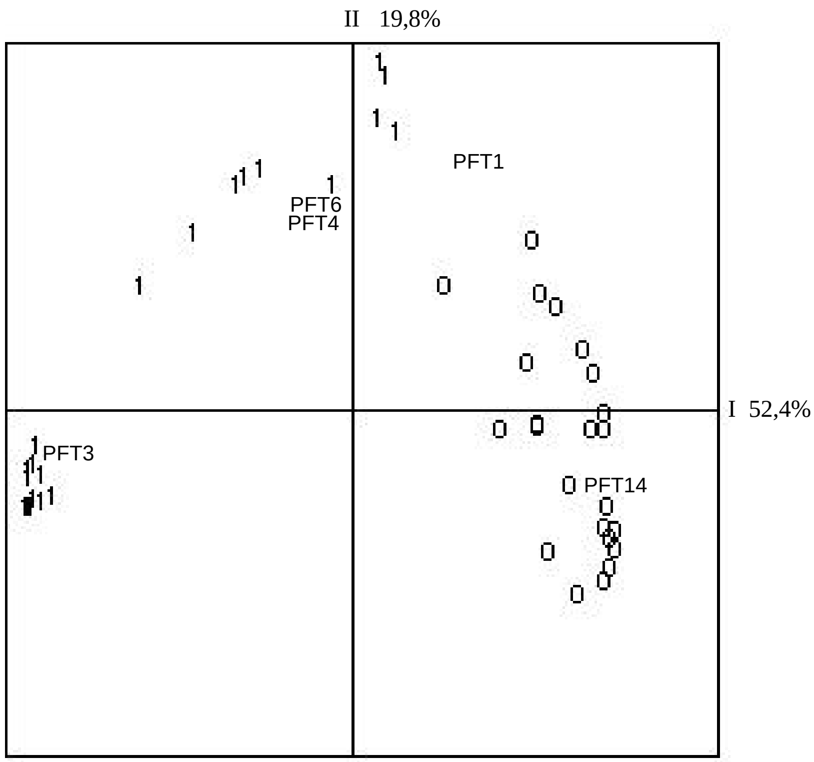

Figure 2 - PCOA ordination of experimental units (subplots) described by optimal PFTs, on natural grassland, São Gabriel, RS, Brasil. Ungrazed subplots are identified by 0, grazed ones by 1. PFTs were defined by plant height, spininess and leaf cross section. PFTs with higher correlations (| r | > 0.5) with the two ordination axes are plotted at their correlation levels as explained in Figure 1.