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Where to Graze? An Edaphic Grassland Perspective of Grazing Management in Grassy Ecosystems

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Grassy ecosystems have long been ignored, misunderstood, and undervalued (Parr et al., 2014). Strategies for managing, preserving, and restoring grassy ecosystems are in striking difference of those for forests, so misconceptions have become pervasive in the ecological literature. Recently, Baggio et al. (2021) (hereafter BEA2021) have called the scientific community to debate the role of grazing in promoting conservation and sustainable use of grassy ecosystems in Brazil. They emphasize that management strategies of grassy ecosystems fundamentally differ from the dominant forest-centric and tree-centric paradigms so that to some degree, disturbance can effectively be used to manage biodiversity in open ecosystems. Here, I call the attention that not all grassy ecosystems are equal, and grazing regimes are likely to have different effects on different types of grassy ecosystems. Thus, the assumptions and generality of the claims by BEA2021 should not be immediately accepted without criticism. To contribute to that debate, I discuss the potential impacts of grazing in edaphic grasslands.

In edaphic grasslands, poor drainage (seasonally saturated or inundated soils), extremely low moisture-holding capacity (shallow and rocky soils), or exceptionally low soil fertility preclude dense tree cover, even in the absence of frequent disturbances (Buisson et al., 2019). Vegetation in edaphic grasslands is primarily driven by soil factors (e.g., Xavier et al., 2019) and secondarily, by climate and disturbance. Extreme soil physical and chemical soil properties create particular conditions that make edaphic grasslands ecologically different from disturbance-maintained grasslands. Thus, management strategies are expected to differ between edaphic and disturbance-maintained grasslands.

Campo rupestre, the most biodiverse grassy ecosystem of Brazil, is a widely distributed edaphic grassland across all regions of the country (Miola et al., 2021), and a key ecosystem priority at the national level (Fernandes et al., 2020). Nearly 40% of *campo rupestre* plant species are endemics and micro-endemics (Colli-Silva et al., 2019), the highest plant endemism rate in Brazil (Zappi et al., 2015). There are both theoretical and empirical reasons to assume that grazing in *campo rupestre* is unlikely to succeed as a management strategy (Figure 1A).

First, for the *campo rupestre*, and for many areas in the core Cerrado, there is no evidence to support the BEA2021 statement that "we have clear evidence that exclusion of grazing animals, combined with fire suppression and a wetter climate, cause strong and rather fast changes in vegetation structure, especially encroachment of woody vegetation and losses of characteristic species of open ecosystem." Actually, modeling the palaeo-range of *campo rupestre* based on the distribution of 1123 endemic plants using climatic and edaphic variables shows that the current area of *campo rupestre* has remained virtually unchanged during the Pleistocene (Rapini et al., 2021). Vegetation stability during the Pleistocene does not support the idea that grazers played key roles in the vegetation palaeodynamics of *campo rupestre*. Consequently, BEA2021 statement that "the grassy biomes need grazing animals and/or fire to maintain their biodiversity and ecological characteristics" may not largely apply to *campo rupestre*.

Second, *campo rupestre* has extreme low resilience (Buisson et al., 2019), so the effects of trampling on its fragile vegetation and on its endemic species are expected to be remarkably detrimental (Figure 1B). Third, extreme low-quality forage of *campo rupestre* forbs, grasses, and graminoids (Figure 1B; Silveira et al., 2016) is unlikely to sustain economic return without additional nutritional supplementation. Fourth, few *campo rupestre* grasses present grazing-related traits including stoloniferous and

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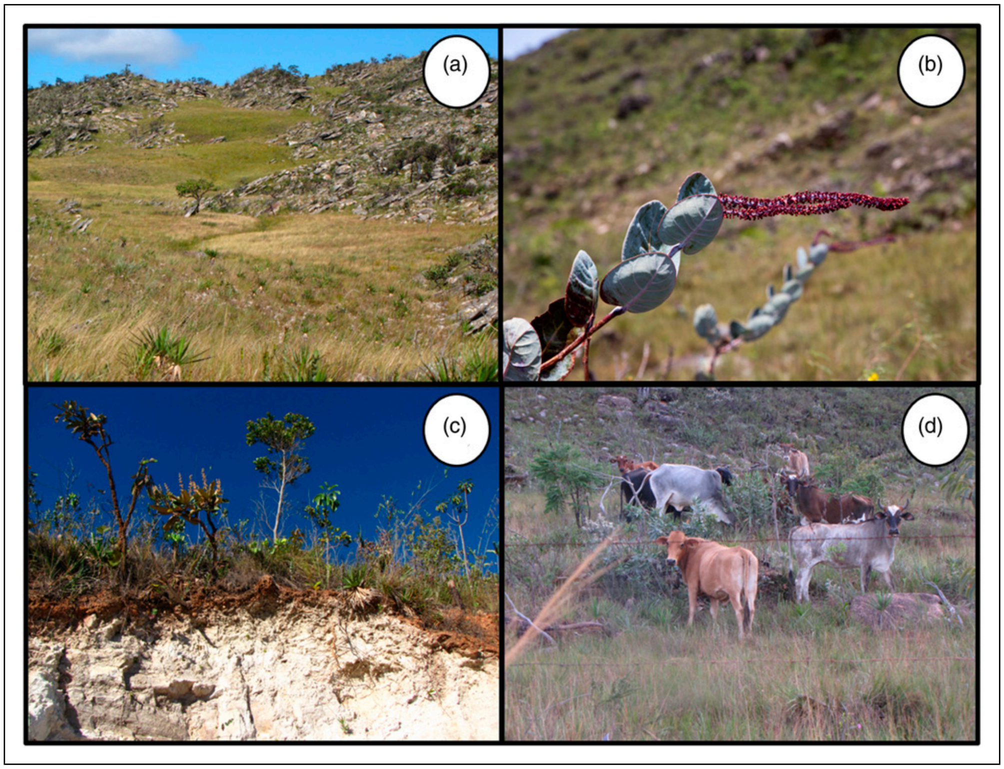

Figure 1. *Campo rupestre* is a typical example of an edaphic grassland. A preserved *campo rupestre* site illustrating the high environmental heterogeneity (A). Endemic species such as *Coccoloba cereifera* (B) produce highly sclerophyllous leaves and are adapted to shallow and extremely-impoverished soils (C). Endemic species can be threatened by trampling, defoliation, fertilization and invasive species resulting from grazing (D).

rhizomatous habit. Finally, as an extremely impoverished ecosystem (Figure 1B), dung fertilization may increase invasiveness (see Barbosa et al., 2010) and as discussed by BEA2021, could shift plant community strategies from resource-conservative to resource-acquisitive species. *Campo rupestre* species are adapted to sandy and extremely impoverished soils (Oliveira et al., 2015; Abrahão et al., 2020), and changes in the functional signature of the communities mediated by increasing soil fertility are likely to reduce biodiversity (Seabloom et al., 2021).

The effects of grazing in *campo rupestre* are largely unknown, but available data suggest that cattle alters soil parameters and has long-lasting negative impacts on vegetation and on the survival of native species (Kolbek & Alves, 2008; Figure 1D). BEA2021 state that the greater the abiotic limitations of the system, the more sensitive to grazing intensity the system should be. That is precisely why extreme caution should be taken in proposing grazing as a management strategy for edaphic grasslands. Defoliation has been shown to constrain seedling establishment (Archibald et al., 2021) and deplete resources from underground storage organs (Morris, 2021). Altogether, evidence suggests that if mismanaged, vertebrate herbivory may threaten vegetation regeneration and compromise ecosystem services such as belowground carbon storage.

I agree with the statement that studies allowing for the definition of grazing strategies that promote major conservation objectives are urgently needed in grassy ecosystems. Such studies should simultaneously quantify both negative and positive effects of grazing. Data on vegetation dynamics in core areas of the Cerrado are also likely to contribute to this debate. One potential benefit of grazing management is the protection of the fire-sensitive forest archipelagos (Coelho et al., 2018). Cattle usually reduces the flammable biomass near the forested sites, thus maintaining the canopy integrity (F.S. Neves, unp. data). Since grazing effects in *campo rupestre* are largely unknown, I recommend extreme caution for extreme ecosystems.

BEA2021 offers valuable lessons to both researchers, stakeholders, and land managers who need to rethink the idea that disturbance is essentially detrimental to biodiversity. I applaud their efforts to begin this critical discussion, but I caution that embracing the diversity of grassy ecosystems is a fruitful pathway to support a diversity of management strategies for grassy ecosystems. We should celebrate the diversity of Brazilian grassy ecosystems and provide robust frameworks to support their long-term sustainability using management strategies tailored for edaphic grasslands as well (Fernandes et al., 2020).

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