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Policy Forums

Moving from forest *vs.* grassland perspectives to an integrated view towards the conservation of forest–grassland mosaics

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In this paper, we discuss some key aspects for the maintenance of biological diversity in grassland–forest mosaics in southern Brazil (*Campos Sulinos*) not explored yet. *Campos Sulinos* are grasslands distributed throughout the Pampa and the Atlantic Forest biomes. Since these grasslands remain from past dryer and colder climatic conditions, they are acknowledged as native rather than anthropogenic ecosystems (Pillar and Velez, 2010). The grasslands form mosaics with shrubby and forest physiognomies belonging to *Araucaria* and seasonal forests in southern Brazil, owing to climatic conditions suitable for forest expansion (Oliveira and Pillar, 2004). Thus, these ecosystems compete for spatial representativeness and resources in mosaics (Innes et al., 2013). Grasslands need specific attention and policies to proper management, conservation and sustainable use, since the ecological processes maintaining their biodiversity greatly differ from those driving diversity in forest ecosystems (Pillar and Velez, 2010; Overbeck et al., 2013). In ecosystems where climate favors woody vegetation, ecological disturbances are important for the temporal and spatial maintenance of grassy physiognomies (Bond and Parr, 2010; Pillar and Velez, 2010). Livestock grazing and burning at intermediary to high levels prevent woody encroachment and consume dry leaf biomass, enabling the co-occurrence of forbs and prostate graminoids and consequently increasing herbaceous diversity (Bond and Parr, 2010). However, these disturbance levels are expected to maintain the grassy physiognomy to the detriment of establishment of shrublands and forest patches. On the other hand, woody plant encroachment and forest expansion through edge dynamics are promoted when disturbance ends (Duarte et al., 2006).

In forest–grassland ecotones, shrubby physiognomies consist of unstable states leading to either forest or grassland, which represent alternative stable states relying on a given set of environmental conditions and disturbance frequency to coexist (Bond and Parr, 2010). After disturbances decrease or cease, grassland vegetation composed by herbaceous species is replaced by tussock, shrub and tree species (Overbeck et al., 2005; Duarte et al., 2006) (Fig. 1). The intermediary phase, the shrubland, is an unstable state with high probability of replacement by either forest or grassland (Oliveira and Pillar, 2004). The lack of or weak anthropogenic disturbance allows

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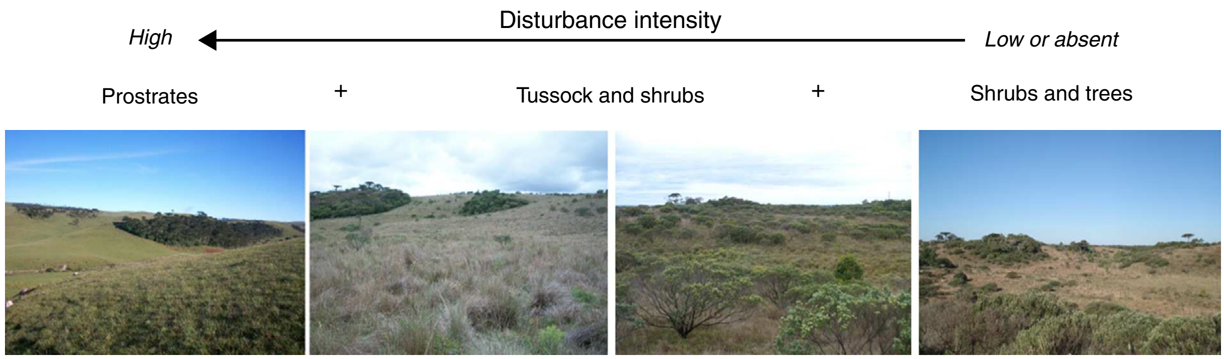

Fig. 1 – Physiognomic changes occurring in mosaics according to disturbance intensity, from grassy physiognomies (left) to shrublands with scattered forest patches (right).

grassland–forest bi-stability (spatial co-occurrence of both physiognomies), while strong human interference enables the occurrence of only one state (Innes et al., 2013). Within such dynamics, only strong environmental disturbances have potential to make the system to oscillate and produce shrubby physiognomies.

Disturbance levels evenly distributed across the landscape are likely to decrease regional levels of biodiversity in forest–grassland mosaics of *Campos Sulinos*, because such homogeneity of conditions is expected to preclude the occurrence of unstable states (Hobbs and Huenneke, 1992). Disturbance regimes applied within private lands homogenizes the regional diversity in forest–grassland mosaics, because they are continuous in space and generally imposes overgrazing or too frequent burning. Anthropogenic disturbance prevents the occurrence of tussock and shrub strata, which are very important habitats for many plant species relying on woody vegetation cover to establish (Duarte et al., 2006) and for animal species depending on tussock and woody vegetation cover for feeding, building nests, roosting, breeding and protecting against predation (Pedó et al., 2010; Azpiroz et al., 2012). Therefore, these intermediary vegetation types should be taken into account in conservation plans.

Free-ranging cattle can also affect the forest side of the mosaic, since ungulates depress the forest litter layer and increases the openness and deterioration of understory structure by consuming and trampling seedlings, herbs and ferns, which precludes the occurrence of small mammals and other understory animals (Pedó et al., 2010). In Africa, for example, small mammals diminished in density and recruitment in response to overgrazing and trampling, because ungulates seemed to decrease resources and damage habitat structure for small herbivores (Keesing, 1998). In Australia, long-standing overburning and grazing have caused extreme population declines and species' range contractions, being one of the leading processes causing extinctions over the last decades (Andersen et al., 2012). Small mammals seem to be resilient to sporadic fire events with fast recolonization and temporal turnover caused by changes in habitat quality (Briani et al., 2004). However, they are unable to use habitats under frequent and intense disturbances, whereas only few opportunistic and non-resident species can support degraded habitats (Pedó et al., 2010). Loss of mammal species may drastically affect ecological services (Ceballos and Ehrlich, 2009), such as regulation of plant and arthropod communities through seed dispersal and predation, nutrient cycling and the prey availability for predators (Duffy, 2003; Nichols et al., 2009). In general, low levels or the absence of disturbances make the habitat suitable for a wide range of animal and plant taxonomic groups relying in dense, taller, and shading vegetation, whereas more intense levels of disturbance benefit a great diversity of grassy and forb species inhabiting grasslands. The conservation of various vegetation states in mosaics ensures high levels of regional biodiversity and consequently the maintenance of ecological processes (Loyola et al., 2006).

Strategies reconciling the temporal and spatial maintenance of high biodiversity levels in forest–grassland mosaics of *Campos Sulinos* at the regional scale are urgently needed. Distributing cattle raising activities and burning events unevenly across landscapes may guarantee high levels of biodiversity and ecosystem functioning due to the coexistence of grassy, shrubby and forest physiognomies at broader scales. Burning and grazing should be welcome in areas large enough to include many patches subject to different disturbance regimes. Nonetheless, extensive disturbances may prevent the occurrence of patches free of perturbations, which serve as source-areas for recolonization or colonization of new areas (Hobbs and Huenneke, 1992). Such spatial heterogeneity is important for the maintenance of diversity of many taxa such as woody plants (Carlucci et al., 2012), small mammals (Pedó et al., 2010), and many other animal groups (Tews et al., 2004).

Decades ago, the landscapes of *Campos Sulinos* were composed by large extensions of grassy, shrubby and forest mosaics (Rambo, 1956). Disturbances occurred in minor landscape portions due to aggregated behavior of herbivores and fire patchiness. Nowadays, areas of grasslands previously used for livestock have been rapidly converted to agriculture or exotic tree plantation (*ca.* 1000 $km^2\,yr^{-1}$; Cordeiro and Hasenack, 2009). These conversions have made the management of small and isolated remnants more intense, which has become a critical threat to biodiversity and to challenged actions seeking to increase landscape heterogeneity. To make it worse, cattle herds are increasing in spite of the reduction of areas for livestock, which either intensifies the management of native grassland remnants or leads to the conversion of these grasslands into artificial pastures (Crawshaw et al., 2007).

The existence of both strictly and sustainable use protected areas as well private lands are of outmost importance for mosaic heterogeneity and biodiversity conservation at large scales (Metzger, 2010; Soares-Filho et al., 2014). Recent proposals concerning ecosystem management and conservation have been tested using adaptive management (Van Wilgen et al., 2011). In a regional context, many of the goals of adaptive management are already considered by the land protection categories of the Brazilian National System of Protected Areas (SNUC, Law 9985, July 18th 2000, Brazil – available at http://www.planalto.gov.br/ccivil_03/leis/l9985.htm). In this regard, regions – not localities – should pursuit areas including and excluding human activities (*e.g.* private and strictly protected areas, respectively). Disturbance-based management is appropriate in private areas or in protected areas targeted for sustainable use (IUCN categories III, IV, V and VI, according to Dudley, 2008). Such protected areas urge to be created in ecologically relevant mosaic areas in Pampa and Atlantic Forest biomes. These categories aim to preserve natural features, either by active productive management or sustainable use of natural resources. Traditional cattle ranching can be maintained in these areas, combining mosaic conservation with economic production.

Strictly protected areas should be considered as species-sources and reference areas for restoration and conservation of different vegetation states with minimal human interference. Similarly to other South American grasslands, the conservation of *Campos Sulinos* has been neglected, since they have historically received minor attention from Brazil's conservation agenda (Overbeck et al., 2007). Only 0.15% of the total area covered by grasslands in Rio Grande do Sul are included in strictly protected areas (Develey et al., 2008), representing the few remnants of grasslands, shrublands and forest mosaics practically free of disturbances. Any human intervention in strictly protected areas should be justified by the accurate identification of specific environmental thresholds (*e.g.* Hoffmann et al., 2012 and references therein) besides fire and herbivory – *e.g.* droughts, edaphic conditions and species' traits. Importantly, we need to elaborate efficient systems of fire control in strictly protected areas. In areas under high burning risk, careful monitoring coupled with periodic mowing, firebreaks, windbreaks and even the presence of natural forest patches may prevent fire to spread across extensive areas. On the other hand, grassland management in SNUC's strictly protected areas (IUCN's categories Ia, Ib and II), if necessary, should be done with precaution and rigorous scientific criteria, under the cost of severe and unknown losses in fauna and flora diversity. Adaptive management has shown inconsistent results, with sites under different disturbance regimes showing contrasting patterns of diversity, which makes some practices suitable for a given locality while not applicable to others (Van Wilgen et al., 2011). Although adaptive management may improve our learning about grassland–forest dynamics, the current state of knowledge about restoration and conservation supports the use of passive management and the precautionary principle.

We highlighted the need to move from forest *vs.* grassland perspectives to an integrated view towards the conservation of forest–grassland mosaics, because we believe that grassy, shrubby and forest physiognomies should be equally valued for conservation purposes. Finally, we hope that our appointments call attention of scientists and conservationists to the importance of moving from a focus on fine-scale diversity of grassland or forest to a landscape/regional-scale approach to better understand and conserve forest–grassland mosaics. Support from government and society is urgently needed to create protected areas in grassland–forest mosaics in *Campos Sulinos*.

Conflicts of interest

The authors declare no conflicts of interest.

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