South African Journal of Botany 92 (2014) 126–133

Contents lists available at ScienceDirect

South African Journal of Botany

journal homepage: www.elsevier.com/locate/sajb

Annual burning drives plant communities in remnant grassland ecological networks in an afforested landscape

Lize Joubert [a,*], James S. Pryke [b], Michael J. Samways [b]

[a] Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[b] Department of Conservation Ecology and Entomology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa

ARTICLE INFO

Article history:
Received 17 September 2013
Received in revised form 14 February 2014
Accepted 20 February 2014
Available online 25 March 2014

Edited by RM Cowling

Keywords:
Annual burning
Biodiversity conservation
Commercial plantation forestry
Firebreak
Grassland
Grazing
Species composition
Species turnover

ABSTRACT

Landscape ecological networks (ENs) are used to mitigate the negative effects of commercial forestry plantations on the biodiversity of southern Afromontane grasslands. Annually-burned firebreaks are fundamental to plantation forestry management, as they protect timber compartments from runaway fires. Here, we investigated the effect of annual burning with different levels of domestic cattle grazing in ENs, and annual burning without domestic cattle grazing in the adjacent protected area (PA). Sampling was conducted on three firebreak types, as well as two natural control grasslands (in the EN and PA each). The first two types (PA firebreaks and peripheral EN firebreaks) were on either side of the PA/plantation fenceline. The third type, plantation EN firebreaks, had forestry compartments on two sides and heavy cattle grazing. Although plant species richness was not significantly affected, plant communities of annually-burned firebreaks differed compositionally from those in the reference grasslands in the EN and PA respectively. Furthermore, plant species turnover was lower in annually-burned firebreaks than in reference EN and PA grasslands. Comparisons among different annually-burned firebreak types showed no difference in plant species richness. However, species composition and turnover of plant communities in peripheral EN fenceline firebreaks were similar to those of PA fenceline firebreaks, but both differed from the plantation EN firebreaks. Plant communities of longer-rotation burned grassland in the EN and PA were similar in species richness, composition and turnover. Overall, these results indicate that annual burning of firebreaks leads to homogeneous plant communities but not necessarily a reduction in species richness. High levels of cattle grazing exacerbate the effect of annual burning, as in plantation EN firebreaks. We recommend that managers should control heavy cattle grazing in annually-burned areas to maintain the natural plant communities as much as possible, while at the same time protecting the plantation blocks from runaway fires through necessary annual burning of appropriate firebreaks.

1. Introduction

In line with the global trend over the past 50 years (MA, 2005; UN, 1987; UNEP, 2007), land use change, resulting in habitat transformation, has caused biodiversity loss in the Grassland Biome in South Africa (Fairbanks et al., 2000), the second largest biome in South Africa, occupying ~21% of the country. Indeed, 47% of the biome has been transformed irreversibly (Fairbanks et al., 2000). Three of the main contributors to habitat transformation in this biome are dryland agriculture (22.6%), communal grazing (6%) and commercial plantation forestry (3.4%) (Fairbanks et al., 2000). After maize, forestry is the second largest commercial land use in South Africa (DAFF, 2010). Also, after urban development, forestry has the second highest impact on biodiversity integrity in the wetter eastern parts of the Grassland Biome (O'Connor and Kuyler, 2009).

Forestry accounts for 1.5% of the total land surface of South Africa (Fairbanks et al., 2000). However, not all of the land belonging to timber companies is planted to trees. Of the 1.8 million ha of forestry plantation in South Africa (Fairbanks et al., 2000), one third of the plantation holdings, which amounts to roughly 500,000 ha, remains permanently unplanted (Jackleman et al., 2006; Kirkman and Pott, 2002). These unplanted areas are configured as landscape ecological networks (ENs), which consist of interconnected patches of natural habitat (e.g. indigenous forest or grasslands), special landscape features (e.g. hilltops or wetlands) and managed areas (e.g. firebreaks) (Samways et al., 2010). Together, the different landscape features of an EN offset the negative effect that alien plantation trees have on local biodiversity (Kirkman and Pott, 2002; Samways, 2007), as they enable persistence and movement of individuals and propagules through the commercial forestry matrix at the landscape spatial scale.

* Corresponding author at: Tel.: +27 82 650 9814; fax: +27 21 808 4807.
E-mail addresses: lizejoubert@gmail.com (L. Joubert), jpryke@sun.ac.za (J.S. Pryke), samways@sun.ac.za (M.J. Samways).

http://dx.doi.org/10.1016/j.sajb.2014.02.009
0254-6299/

After forestry compartments, firebreaks are the most extensive regularly maintained biotope type in these production landscapes. The primary purpose of firebreaks is to protect forestry compartments from runaway wild fires. Therefore, firebreaks surround and dissect forestry plantations. They are burned annually before the start of the dry winter season. Similar to road verges in other parts of the world (Eversham and Telfer, 1994; Ries et al., 2001; Saarinen et al., 2005; Vermeulen, 1994), firebreaks form an extensive network throughout the landscape, which potentially enables them to contribute to biodiversity conservation in the timber production landscape. Indeed, mown firebreaks among timber compartments in the lower-lying Zululand provided early-successional habitat necessary for the survival of three grasshopper species that did not occur anywhere else in the EN (Bazelet and Samways, 2011).

One of the first steps for understanding how grassland biodiversity is affected by annual burning of firebreaks is to determine how the plant community is affected, as plants are the primary producers underpinning survival of higher trophic levels in terrestrial ecosystems. Although fire can affect higher trophic levels directly, for example, through exposure to flames (Swengel, 2001), studies have reported an indirect effect of fire on arthropods and birds through changes in vegetation structure (Jansen et al., 1999; Little et al., 2012). Still others have reported a direct link between the plant community and arthropods at the species level. In the KwaZulu-Natal Midlands, for example, flower-inhabiting arthropods persisted in a landscape as long as their host plants were present, irrespective of the level of disturbance to which they were subjected (Bullock and Samways, 2005). A study comparing firebreaks with biennially-burned grasslands in the southern Drakensberg region found a significant difference in plant species composition, but not for species diversity (O'Connor et al., 2004). Another study conducted in montane grassland in the Drakensberg reported that autumn burning had a smaller effect on plant species composition than winter or spring burning (Uys et al., 2004). Ultimately, the effect of annual burning on plant communities will determine the degree to which firebreaks can contribute to biodiversity conservation in timber production landscapes.

The overall aim of this study is to determine the effect of annual burning with different levels of domestic cattle grazing in ENs, and annual burning without domestic cattle grazing in the adjacent protected area (PA). For this reason, three annually-burned firebreak types that differ in the level of grazing were identified. Here we asked: 1) Do plant species richness, composition and turnover of annually-burned firebreaks differ from that of longer-rotation burned (reference) grassland in the EN and PA, respectively? 2) Are firebreaks with different levels of grazing similar in terms of species richness, composition and turnover? Here, we expect annual burning to cause a shift in plant species composition, but not necessarily a reduction in plant species, while the level of cattle grazing drives differences among different firebreak types. This allowed us to determine the extent to which the annually-burned firebreaks, necessary for plantation protection, have conservation value.

2. Methods

The study took place in the Midlands of KwaZulu-Natal (29°38′S; 29°58′E) in three commercial forestry plantations, and the adjacent iMpendle Nature Reserve. In this region, pockets of indigenous forest occur within an expansive matrix of Southern KwaZulu-Natal Moist Grassland (880–1480 m.a.s.l.), Midlands Mistbelt Grassland (760–1400 m.a.s.l.) and Drakensberg Foothill Moist Grassland (880–1860 m.a.s.l.) (Mucina et al., 2005, 2006). These grasslands were structurally similar, but they differed in terms of botanical composition, which was the result of differences in the abiotic environment (Mucina et al., 2006).

Forty-five sites were spaced out throughout the EN and PA over a maximum linear spatial scale of 17 km (Fig. 1). We differentiated between longer-rotation burned grassland and annually-burned firebreaks. Longer-rotation burned grasslands were burned every 1–3 years on an ad-hoc basis in winter (June to August) for grazing and biodiversity conservation purposes. Firebreaks, on the other hand, were narrow, linear strips that had been burned annually in autumn (April to May) for the past ~20 years to protect timber compartments from runaway fires during the dry winter season. All sites were burned during the 12-month period prior to sampling. Grazing by domestic cattle, belonging to local human communities, was taken as an embedded factor for all EN sites. PA sites were only grazed by naturally-occurring indigenous herbivores.

We differentiated among five types of sites that varied in fire frequency and level of grazing (Table 1). They were (1) longer-rotation burned grassland within the PA without cattle grazing (= first longer-term set of reference sites for comparison with annually-burned sites) ($n = 8$), and (2) longer-rotation burned grassland within the EN with cattle grazing (= second set of reference sites for comparison with annually-burned sites) ($n = 13$) (Table 1). On either side of the PA/plantation fenceline, we found (3) annually-burned firebreaks in the PA without cattle grazing (PA firebreaks; $n = 8$) and (4) annually-burned firebreaks on the periphery of the plantation with light cattle grazing (peripheral EN firebreaks; $n = 8$) (Table 1). This enabled a fenceline contrast of annually-burned plant communities with and without cattle grazing. Lastly, (5) firebreaks in the EN with pine compartments on two sides (plantation EN firebreaks; $n = 8$) served as a conduit for cattle movement and were, consequently, heavily-grazed (Table 1). This presented an opportunity to determine the combined effect of annual burning and heavy cattle grazing on plant communities in firebreaks.

Grazing intensity in the different grassland and firebreak types was estimated from the proportion of times that cattle were encountered at any one site out of 10 site visits (high: >70%, moderate: 30–60%, low: <10%) and proportion of bare ground as a result of trampling (high: >10%, low: <10%) (Table 1). The proportion of bare ground (i.e. % cover at 10 randomly-position 1 m^2 quadrats) was estimated at all sites during a one week period in November 2012, approximately five months after last burn for longer-rotation burned grassland and seven months after last burn for firebreaks.

All EN firebreaks were adjacent forestry compartments, within the 30 m edge zone that was previously determined for invertebrates (Pryke and Samways, 2012). In contrast, PA firebreaks were inside the core zone, which was found >30 m from the pine compartment edge. We compared annually-burned firebreaks on either side of the PA/plantation fenceline to determine whether plant communities inside the edge zone were similar to those inside the core zone. All longer-rotation burned grassland sites were in the interior of the PA, and in wider corridors in the EN >30 m from the pine compartment edge.

In the EN, annually-burned firebreaks and longer-rotation burned grasslands were represented by an equal number of sites in each vegetation type. However, in the PA, all longer-rotation burned grassland sites were in Drakensberg Foothill Moist Grassland, because the Midlands Mistbelt Grassland section was not burned in the year preceding the study (Table 1).

Vegetation was sampled from January to March 2013. Sites were spaced ~400 m apart. At each site, there were six randomly-orientated (30 m) vegetation transects, and twenty-four randomly-spaced vegetation quadrats (1 m^2). Vegetation quadrats were positioned randomly, but within 5 m from vegetation transects. The vegetation sampling method followed that of O'Connor et al. (2004). Unlike findings on tallgrass prairie in North America, where spatial scale of measurement determined magnitude of change caused by fire and grazing on plant communities (Collins and Smith, 2006), the effect of fire frequency and burning season on plant communities in South Africa was consistent at different spatial scales (1 m^2 and 100 m^2) (Uys et al., 2004). In each vegetation quadrat, we determined the identity and abundance (% cover) of each plant species as well as the proportion of bare ground