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Vegetation responses to fire history and soil properties in grazed semi-arid tropical savanna

Gabrielle Lebbink[1], Rod Fensham[2] and Robyn Cowley[3]
1 School of Biological Sciences, The University of Queensland, St Lucia, QLD 4072, Australia. gabrielle.lebbink@uqconnect.edu.au.
2 Queensland Herbarium, Department of Environment and Resource Management, Toowong, QLD 4066, Australia. rod.fensham@dsiti.qld.gov.au.
3 Department of Primary Industries and Resources, GPO Box 3000, Darwin, NT 0801, Australia. Robyn.Cowley@nt.gov.au.

Abstract

A long term (1993-2016) fire experiment in the grazed semi-arid savanna of the Northern Territory, was used to investigate the relative impacts of soil properties and fire history on vegetation composition and diversity in grassland and woodland habitats. Subtle variation in soil texture influenced vegetation composition and abundance independently of fire variables and was generally a more important control on floristic patterns. Irrespective of fire interval or season, fire promotes greater diversity in the understorey through its positive influence on ephemeral grasses, forbs and legumes. These findings suggest fire has a modest and temporary influence on understorey floristic patterns and fire regimes may therefore be manipulated for other management imperatives without substantial impacts on botanical values in tropical savannas. This also suggest that some savanna flora may be relatively resilient to a predicted future climate of more sever fire weather.

Keywords: fire interval, clay, fire season, germination, competition, grazing.

Introduction

Fire is used extensively in Australian tropical savannas and plays an important role in biodiversity (Woinarski *et al.* 2007), pastoral (Dyer 2001) and indigenous (Russell-Smith *et al.* 2009) management applications. In accommodating these different imperatives, fire regimes are variable and often conflicting. Further variability to fire regimes are expected under future climate projections, with increases in the frequency of extreme rainfall events and temperature predicted to increase the severity of fire events (Scheiter *et al.* 2015; Williams and Bowman 2012). In a pastoral context prescribed burning is typically infrequent, largely due to the uncertainty of follow up rain to ensure pasture growth, however some burning is often recommended to reduce woody species cover (Allan and Tschirner 2009; Cowley *et al.* 2014). Given the uncertainties in the response of Australian savannas to fire management and future climate change, it is important to understand how these various fire regimes affect the botanical composition of the savanna understory as to conserve biodiversity and encourage sustainable agricultural production.

Fire acts indiscriminately on understorey vegetation and can potentially influence plant abundance and diversity by levelling competition between species and constructing niche space (Bond and Keeley 2005; Williams *et al.* 2005a). For instance, fire can reduce the mass of perennial grass species, temporarily releasing space and resources to allow for a short-term pulse in annual forb abundance (Fensham *et al.* 2015b). Alternatively, fire can stimulate the breaking of seed dormancy and germination in some physically dormant species (Williams *et al.* 2005a). A reduction in woody cover and recruitment with burning, may also influence understorey composition via shading, development of seed barriers and competition for water and nutrients (Bowman 2000; Cowley *et al.* 2014). In a grazed system, burning may lead to intense post fire grazing of 'green pick', potentially favouring grazing avoidant species (Landsberg *et al.* 1999). When interpreting floristic responses to disturbance, it is necessary to determine the influence of edaphic conditions, such as soil properties on species composition before the effects of disturbance can be understood (Fensham and Fairfax 2007).

Here we will utilise the experimental framework of a long-term fire experiment in the Northern Territory at, 'Kidman Springs', to examine the effects of a range of fire regimes on floristic composition and diversity in the context of the edaphic environment. The following hypotheses are addressed: 1) species richness increases with more frequent fire; (2) ephemeral species and legumes increase with more frequent fire; (3) total species richness and lifeform richness differ with fire season (4) soil properties account for significant variability in species composition and diversity.

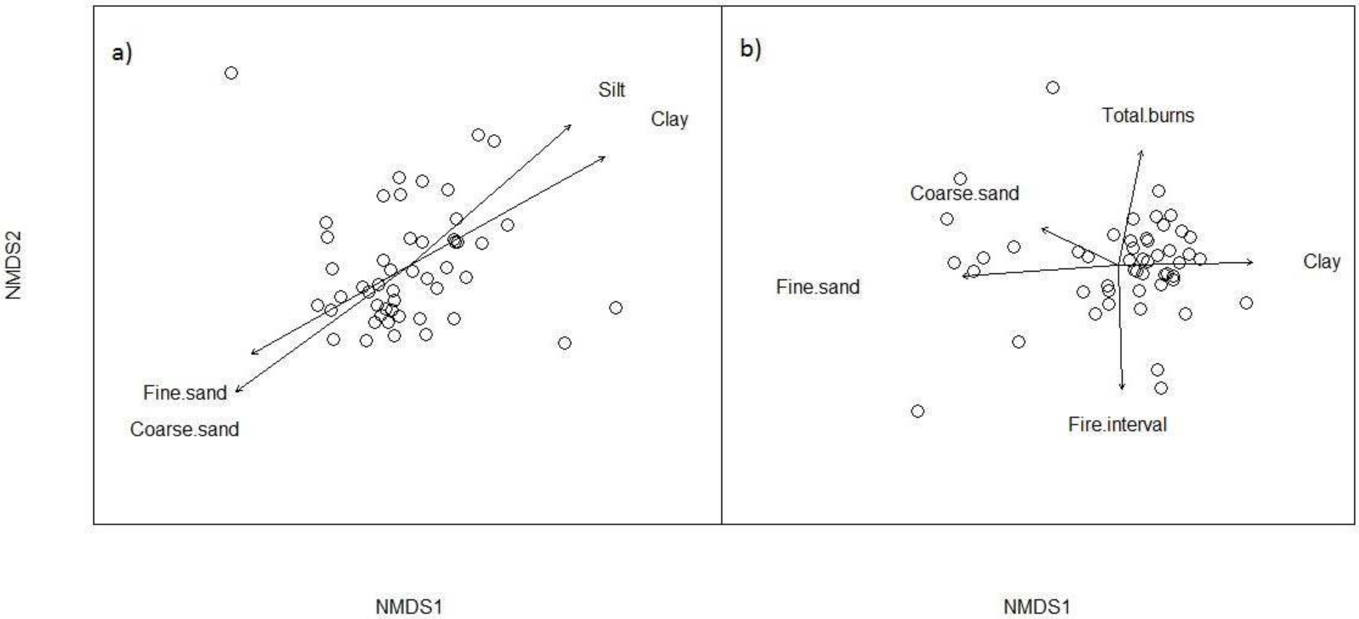

Fig. 1. Significant soil and fire vectors through a two-dimensional ordination based on species composition data for all plots from (a) woodland and (b) grassland. Stress values are 0.160 and 0.137 for woodland and grassland habitat respectively. All vectors are significant at P=<0.01 with the length of the arrow proportional to the strength of the correlation. The circles represent individual plots.

Methods

Floristic and soil data were collected within twelve, 2.6 ha treatment blocks, in two habitats; grassland and woodland. Per habitat, two blocks were allocated to one of the four fire treatments (early (EDS) or late dry season (LDS) burn, every 2, 4 or 6 years) and two blocks allocated as unburnt controls. Detailed methods for the collection of floristic and soil data and statistical analysis are described in Lebbink *et. al* (2017), currently under review in The Rangeland Journal.

Results

All soil texture variables were significant vectors in the woodland ordination space (P<0.01), while clay, coarse sand, fine sand, total years burnt and fire interval were significant vectors in the grassland ordination (P<0.05) (Fig. 1a, 1b). PERMANOVA results indicate no significant differences in species presence/absence or abundance with fire season in either grassland or woodland habitats.

Linear mixed effect models revealed species richness to decrease with increasing clay content and fire interval across both habitats. Forbs, annual grass and legume richness and abundance had a significant negative relationship with fire interval (P<0.05). Annual forb richness and abundance had a significant negative relationship with clay content (P<0.05). Perennial grasses showed no relationship with clay content or fire interval. Tukey's *post-hoc* pairwise comparison of total and lifeform mean richness with fire season and interval indicate no significant differences between two and four yearly or early and late blocks, but both pair were generally more rich than unburnt blocks (P<0.05) (Fig. 3, Table 1).

Discussion

Subtle variation in soil texture influenced vegetation composition and abundance independently of factors related to fire, and was more important than fire in driving floristic patterns. Soil properties have been highlighted previously as a confounding factor influencing floristic composition relative to disturbance regimes in other environments (Fensham *et al.* 2015b). A decrease in species richness with increasing clay content may reflect inherent differences in the water and nutrient holding capacity of different soil textures which are favouring a limited number of adapted species (Silva *et al.* 2013).

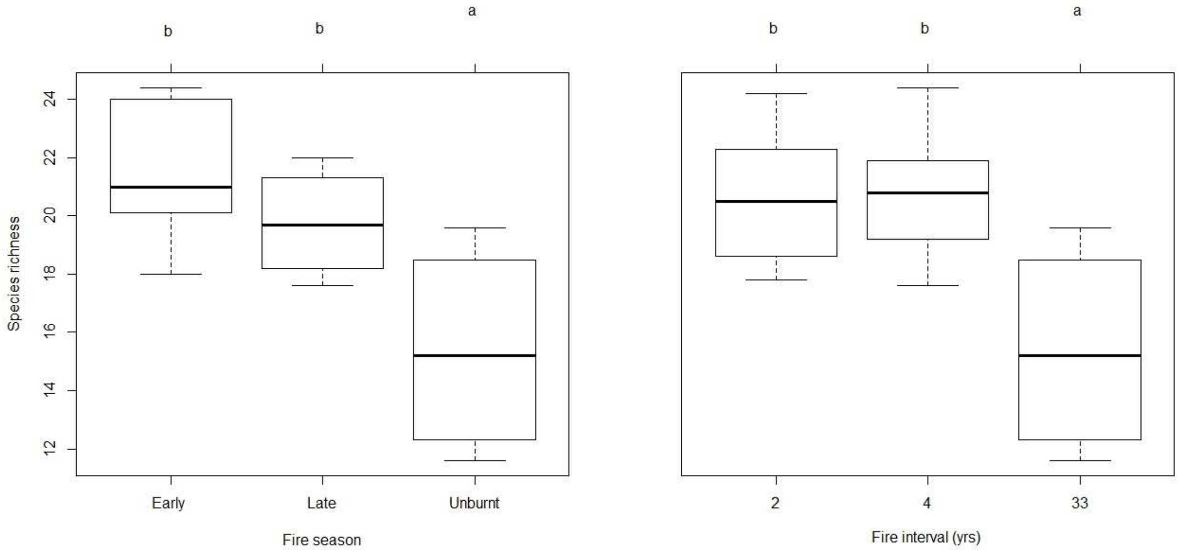

Fig. 2. Box plots and Tukey HSD post-hoc test showing the difference in total species richness between fire intervals and seasons. Within each graph, treatments that differ significantly are indicated with a different letter (P<0.05). Midline shows the median, box shows the 25th and 75th percentiles, error bars show minimum and maximum values.

	Unburnt	2	4	Unburnt	Early	Late
Lifeform abundance						
AH	13.9 ± 2.7 [a]	24.4 ± 2.3 [ab]	23.0 ± 2.2 [b]	24.4 ± 2.8 [a]	13.9 ± 2.31 [b]	23.0 ± 2.3 [ab]
PH	7.2 ± 1.2 [a]	12.8 ± 1.2 [b]	12.2 ± 0.8 [b]	7.2 ± 1.2 [a]	12.8 ± 1.2 [b]	12.3 ± 0.8 [b]
AG	4.0 ± 0.9 [a]	7.0 ± 0.7 [b]	8.5 ± 0.6 [b]	4.0 ± 0.9 [a]	7.0 ± 0.7 [b]	8.5 ± 0.6 [b]
PG	7.9 ± 1.9 [a]	6.6 ± 1.1 [a]	6.7 ± 1.2 [a]	7.8 ± 1.9 [a]	6.6 ± 1.1 [a]	6.7 ± 1.2 [a]
LG	5.1 ± 1.3 [a]	9.5 ± 1.1 [a]	8.7 ± 0.9 [a]	5.1 ± 1.31 [a]	9.5 ± 1.07 [a]	8.7 ± 0.94 [a]
Lifeform richness						
AH	5.5 ± 0.8 [a]	9.4 ± 0.7 [b]	8.4 ± 0.6 [b]	5.5 ± 0.8 [a]	9.4 ± 0.6 [b]	8.4 ± 0.7 [b]
PH	2.8 ± 0.4 [a]	4.6 ± 0.4 [b]	4.3 ± 0.3 [b]	2.8 ± 0.4 [a]	4.6 ± 0.4 [b]	4.3 ± 0.3 [ab]
AG	1.5 ± 0.2 [a]	2.3 ± 0.2 [b]	2.6 ± 0.2 [ab]	1.5 ± 0.2 [a]	2.3 ± 0.2 [ab]	2.6 ± 0.2 [b]
PG	2.7 ± 0.7 [a]	2.3 ± 0.7 [a]	2.3 ± 0.4 [a]	2.7 ± 0.8 [a]	2.3 ± 0.4 [a]	2.3 ± 0.4 [a]
LG	2.0 ± 0.5 [a]	3.8 ± 0.4 [a]	3.2 ± 0.4 [a]	2.0 ± 0.5 [a]	3.8 ± 0.4 [b]	3.3 ± 0.5 [ab]

Table 1. Mean lifeform abundance, richness and standard error for fire interval and seasons categories. Significant differences between treatment pairs annotated with a different letter (Tukey's *post-hoc* test $P < 0.05$).

The positive response of ephemeral species and perennial forbs to fire has been demonstrated previously and is often attributed to a reduction in competition from large perennial grasses (Cowley *et al.* 2014; Fensham *et al.* 2015b). Although perennial grass abundance and richness did not respond significantly to fire in this study, perennial grass herbage mass is reduced immediately post fire at the site (Cowley *et al.* 2014), which may reduce competition sufficiently to allow for a flush in these other lifeforms. The well documented seed dormancy release and increased germination of legumes and other ephemerals in response to fire, may have also contributed to an increase in these lifeforms with burning (Moreira and Pausas 2012). The non-response of species to season suggests these influences may not be a significant control on species richness and composition in this habitat, despite impacts on vegetation structure with more frequent, intense fires in the LDS (Andersen *et al.* 2005; Cowley *et al.* 2014).

Floristic composition and abundance were more responsive to soil texture than the influence of fire interval and fire season, suggesting edaphic factors need to be understood when investigating the effects of disturbance regimes on floristic composition (Fensham *et al.* 2015b). Irrespective of fire interval or season, fire promotes greater diversity in the understorey through its positive influence on ephemeral grasses, forbs and legumes. These findings suggest fire has a modest and temporary influence on understorey floristic patterns and fire regimes may therefore be manipulated for other management imperatives, such as fauna conservation, carbon sequestration and pastoral productivity without substantial impacts on botanical values in tropical savannas. An understanding of post-fire floristic responses will be essential to achieving these desired management outcomes. Further, these results suggest that species may be relatively resilient to increased fire intensity and frequency as a consequence of climate change. The effects of fire on botanical composition has only been studied in limited areas of northern Australia and these generalisations need further testing in a range of tropical savanna environments. Perhaps the greatest threat to future fire regimes at present, is the continual spread of high biomass exotic grass species and this should be at the forefront of fire management in a changing climate.

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