Do we really need to burn the bushes? 29 years of the Kidman Springs Fire Experiment, NT

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Abstract

Australia's tropical savannas are well adapted to fire, but in grazed areas fire frequency is now often lower than when under traditional Aboriginal management. To test the assumption that fire should be applied on pastoral land to manage the tree-grass balance and keep pastures productive, the Kidman Springs Fire Experiment has monitored the impact of fire frequency and seasonal timing on pasture yield and woody cover on a grassland and a Eucalypt woodland. We examine the impact of fire interval (two, four and six yearly vs. control) and season (early in June vs. late in October) on woody cover, and of woody cover on pasture yield. The experiment coincided with an unusually wet period for the region. Woody cover increased through time on all burnt and unburnt treatments, but the increase was lower on the woodland with two and four yearly fires and late dry season fire, and with any fire on the grassland. Two recent consecutive very dry years in 2019 and 2020 halved woody cover across all burnt and unburnt treatments in the woodland, suggesting fire may not be required to manage the tree-grass balance. However on the grassland, despite some decline in tree basal area, canopy cover was unaffected by the dry years, except on burnt treatments. Pasture yields declined with higher woody cover on the grassland, but less so on the woodland. Managed fire has many purposes in grazed systems, including: the removal of rank pasture to improve diet quality for livestock, promoting a more even grazing pattern, opening up the landscape for ease of mustering, and the prevention of uncontrolled wildfires. But in our less productive woodlands fire may not be needed to manage woody cover.

Keywords

Fire, savannas, grazing, woody encroachment, tree-grass competition

Introduction

Woody plant encroachment in global savannas is a natural process in response to environmental and biotic drivers (Archer *et al.* 2017), but it is seen as less desirable on pastoral land where it can reduce pasture growth (Scanlan 2002) and subsequent carrying capacity for livestock production (Dyer and Stafford Smith 2003). Potential drivers of woody thickening on pastoral land in north-western Australia include an increase in rainfall since the 1970s, higher levels of CO_2, and a reduction in the frequency of fire following the removal of traditional burning practices, and lower fuel loads due to grazing. Reintroducing fire to pastoral landscapes has been recommended to manage woody encroachment (Cowley *et al.* 2014). However, anecdotal reports of widespread tree death in the drier years of 2019 and 2020, suggested periods of low rainfall may be equally, if not more effective at managing woody cover, as observed elsewhere (e.g. Fensham *et al.* 2019). Competition between the over- and understorey varies with site fertility, rainfall and species (Scanlan 2002). This study examines the long term fire experiment at Victoria River Research Station, 400km south of Darwin (Cowley *et al.* 2014) for evidence of competition between trees and grass, and the effect of the driest period since the study began on levels of woody cover.

Methods

The grazed fire experiment in the semi-arid tropical savannas (July to June median 1970 to 2020 rainfall 752mm) has native pastures on a Eucalypt woodland on limestone derived red calcarosol soils and an open grassland on grey alluvial vertosol soils. Dominant overstorey species include *Corymbia terminalis*, *Eucalyptus pruinosa*, *Carissa lanceolata* and *Hakea arborescens* on the woodland and *Terminalia volucris* and *Bauhinia cunninghamii* on the grassland. Replicated fire treatments (approximately 2.6 ha) at each site have a fire interval of two, four and six yearly with unburnt controls. Fires were lit in early (June) or the late dry season (October). Total herbage dry matter yield was visually estimated in June using Botanal. Canopy cover and tree basal area of woody plants were assessed using a Bitterlich gauge at every third pasture quadrat in 2009, 2017, 2019 and 2021. Oblique aerial images were used to assess plot woody canopy cover in 1995, 1997, 2000, 2005, 2009, 2001 and 2013 (see Cowley *et al.* 2014 for full description of methods, including image analysis).

Repeated measures ANOVA with a balanced control was used to examine the effect of season and interval of fire on woody cover through time. Relationships between woody cover and understorey yield were examined on recently burnt plots only (two years or less) using general linear models regression. Bonferonni tests were used for post-hoc pair-wise comparisons of means. Woody cover was transformed to normalise variance and model residuals were checked to ensure transformations were appropriate. All analyses were done with the STATISTICA data analysis software system, version 12.5 (StatSoft Inc. 2014).

Results

Rainfall was at or above the long term median in 24 of the last 29 years (Figure 1). The first consecutive years with below median rainfall during the fire experiment were in 2019 and 2020. This was followed by rainfall in the top 10% of all years in the 2021 wet season.

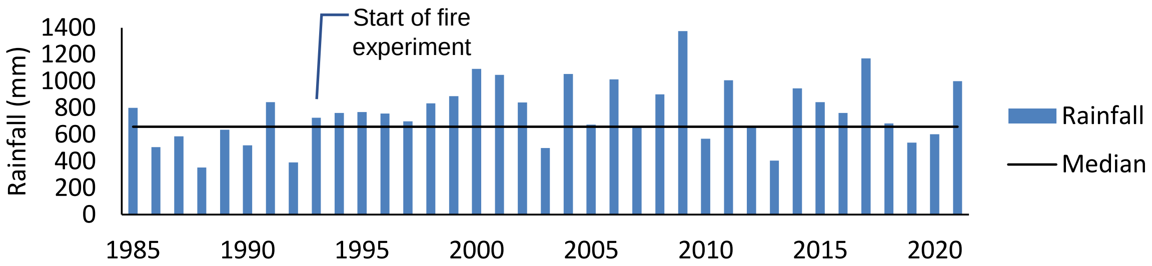

Figure 1: July to June rainfall and median rainfall (1900 and 2020) at Kidman Springs.

Tree-grass relationships

The grassland pasture yield was often significantly negatively correlated with tree basal area and woody canopy cover, but this was rarely the case for the woodland (Figure 2). The relationship between woody cover and yield varied between the grassland and woodland sites (significant site x woody cover interaction) for tree basal area across all years pooled ($P<0.0001$) and in 2017 ($P<0.001$) and 2019 ($P<0.05$) and for canopy cover across all years pooled ($P<0.001$) and in 2017 ($P<0.001$).

Change in woody cover through time

Woody canopy cover increased between 1995 and 2019 on all burnt and unburnt treatments, but the increase was lower on the woodland with two and four yearly fires (vs. unburnt or 6 yearly fires $P<0.01$) and with late dry season fire (compared to early dry season fire $P<0.001$), and with any fire on the grassland ($P<0.01$, Figure 3).

Declines in woody cover after the very dry years of 2019 and 2020 were more pronounced on the woodland than the grassland. Between 2019 and 2021 the woodland tree basal area declined to 2009 levels or lower for all burnt and unburnt treatments (declined by 54% on burnt sites and 50% on unburnt sites, P<0.05). Woodland canopy cover declined by 58% to 1995 levels (from 22.7 to 9.5%, P<0.05) for burnt and by 35% to 2017 levels for unburnt sites (27.1% to 17.5%, P<0.05). The canopy cover on the grassland declined on burnt treatments by 32% to 2009 levels (from 10.8 to 7.4%) but was unchanged on unburnt controls (mean 16.6%, P<0.05), whereas tree basal area declined to 2017 levels on burnt (declined 41% by 1.0 m^2/ha, P<0.05) and unburnt sites (declined 24% by 0.8m^2/ha, P>0.05).

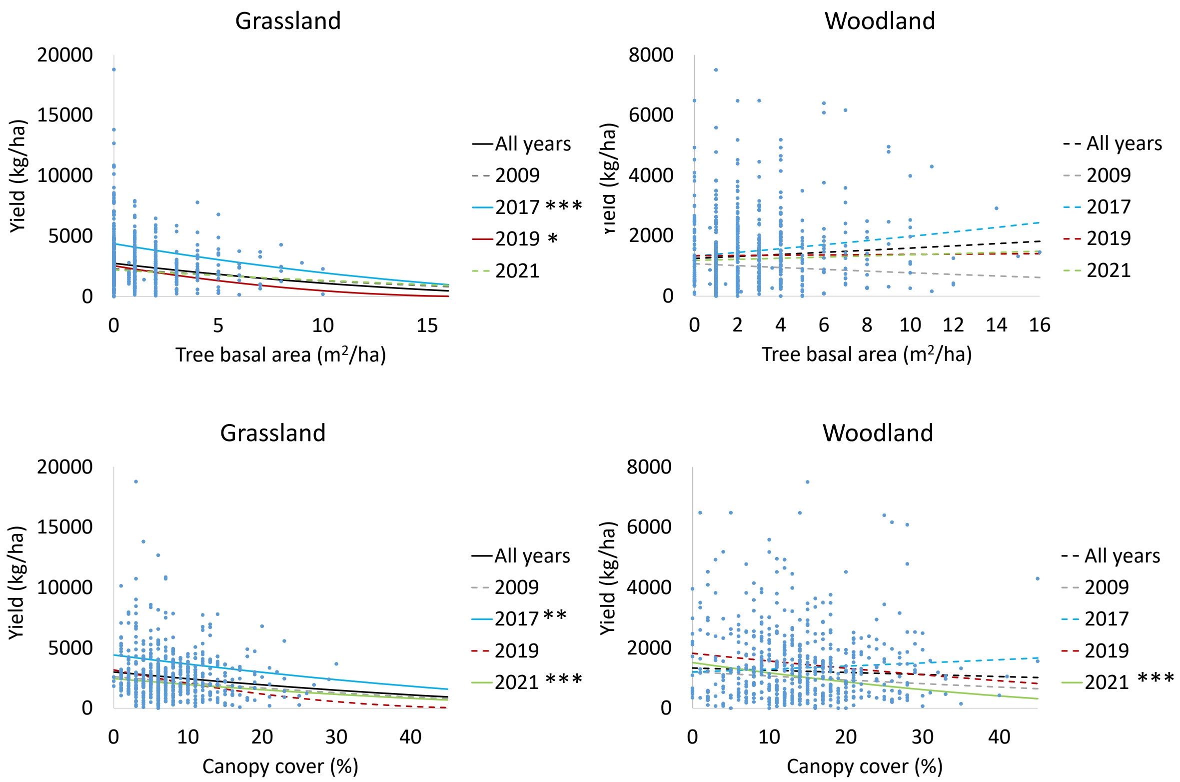

Figure 2: Trends of yield with tree basal area (top) and woody plant canopy cover (bottom) on the grassland and woodland at Kidman Springs. Significant correlations are indicated by solid lines, others by broken lines. * P<0.05, ** P<0.01, *** P< 0.001

Discussion

The woodland has lower potential pasture growth than the grassland, with lower nitrogen uptake by the pasture layer and less than half the water holding capacity of the grassland (Cobiac 2006). Despite the lower woody cover of the grassland, there was more evidence for competition between the woody and pasture layer than for the woodland. The lack of correlation between woody cover and yield on the lower fertility woodland site occurred in both high and low rainfall years. The exception was in the wet year of 2021 which followed below average rain in 2020 and 2019. When growth is water limited in dry years, this can increase the nutrients available to plants in the following year. Hence nutrients may be limiting pasture growth in most years on the woodland. In low nutrient sites, litter from the woody canopy layer can increase soil nutrients and benefit pasture growth (Landsberg *et al.* 2011). Woodland trees may also have access to water in deeper layers on the limestone derived calcarosols, which could reduce competition for water with the pasture layer in most years.

Unlike eastern Australia, north-western Australia has not experienced multiyear droughts since the early 1990s. Increases in woody cover at the fire experiment corresponded with decades of above average rainfall. After the dry years in 2019 and 2020, reductions in woody cover on the grassland have been modest with no decline in canopy cover on unburnt sites. In contrast, the declines in woody cover on the woodland were more consistent with drought induced mortalities observed elsewhere (Fensham *et al.* 2019). It appears woodland trees and shrubs, which had higher cover levels than on the grassland, were more heavily impacted by the drier years.

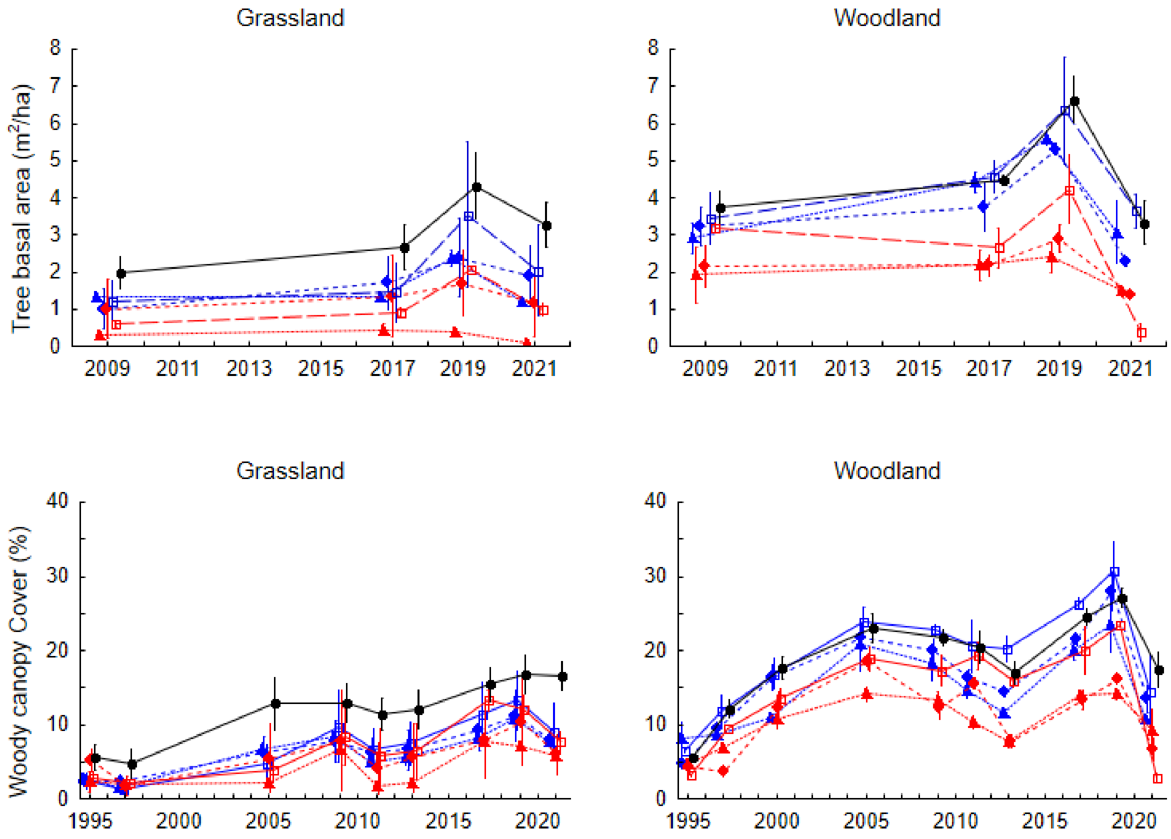

Figure 3: Mean tree basal area (top) and woody canopy cover (bottom) through time with fire treatment and site. Treatments are 2, 4, 6 yearly intervals of E, early or L, Late fire. (Bars represent s.e. of mean). E2 L2 E4 L4 E6 L6 Unburnt

Conclusion

Implementing fire can be dangerous and requires considerable planning and skill. Spelling paddocks to ensure effective fuel loads and post-fire spelling to promote pasture recovery can take burnt areas out of production for a year. Targeting fire to where there will be the best return for this investment in lost production and resources makes sense. Given that pasture growth on the more productive grasslands is reduced by woody cover, and that dry years appear to be relatively ineffective in managing woody encroachment, fire would seem to be a useful tool to maintain the tree-grass balance in these pastorally important landscapes. Maintaining these naturally open grasslands is also important for grassland dependent native species. We have found that burning early in the dry season, every four years, is an effective strategy to prevent woody encroachment of productive grasslands.

Conversely, given the relative lack of competition between the pasture and tree layers in woodlands, and the ameliorating effect of dry years on woody cover, fire may be less critical to maintain pasture productivity in this part of the landscape.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgements

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Summary text for the Range Management Newsletter

Wetter decades saw up to five-fold increases in the woody cover of plants in 25 years at a long-term, grazed fire experiment in the semi-arid tropical savannas of the Northern Territory. However two consecutive dry years in 2019 and 2020 halved woody cover on a Eucalypt woodland but had little effect on an alluvial grassland, except in burnt treatments. There was little competition between the pasture and tree layer in the woodland, but more on the grassland. This suggests that fire should be used to keep our natural grasslands open and productive, but that it may be less important to burn woodlands when they have natural fluctuations in woody cover in response to climate, and the tree layer has less effect on pasture growth.