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Impact of wildfires on browse availability in the semi-arid thornveld of South-eastern Zimbabwe

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ABSTRACT

The study aimed at investigating the impact of wild fires on browse availability on a thornveld vegetation community through assessing its effect on woody plant structure and composition. Data was collected from four randomly selected paddocks at Mahiye; a thornveld farm affected by annual wildfire outbreaks since 2000. A Point Centre Quarter technique on a line transects was used to collect the data. The records collected from the nearest woody plant (≥ 0.3 m) in each quarter included the woody species name, circumference at 30 cm height from the ground and distance from the point to that woody plant. Fifteen woody plant species were present in the study area dominated by the *Acacia* species. Out of the six hundred sampled woody plants, *Acacia nilotica* contributed 65%, *Acacia karoo* 10.8% and *Acacia robusta* 10.7% with the remainder contributed by the other twelve species. A Kruskal-Wallis non-parametric test could not provides sufficient evidence to prove that the woody plant community structure was homogenous. The height and the diameter structure had a significant variation ($P < 0.05$). This mighty be due to the presence of tall and large woody plants (height < 6m and diameter < 12 cm) within the community. Nevertheless, the Lorenz curves depicted less inequality in the height and diameter distribution within the farm (Gini coefficient 0.242 and 0.266 respectively) indicating dominance of a cohort. The histogram showed that more than 75% of the recorded stems were taller than

2.4 m and had a diameter >8 cm. Apparent from the results, the plant community had high quality browse species but the dominant size compromised accessibility of the browse. Therefore, frequent wildfires reduced browse availability in thornveld rangelands. But further research is required to unveil the amount of unavailable browse.

1. Introduction

Tropical semi-arid and arid savanna ecosystems have inherent low forage productivity but are ecologically and socio-economically important because of a large spatial coverage (Scholes and Archer, 1997). According to Richardson et al (2010), these ecosystems account for 55% of the African continent land surface. These marginal lands satisfy vast human population needs by supporting different livelihoods because of the grass and woody species co-existence. Resident smallholder farmers keep goats, sheep and cattle as an effective way of utilising the resources while game ranching mighty be common in the commercial sector.

It is however, a fact that bush encroachment is a common phenomenon in the semi-arid savanna (Wiegand *et al*., 2006) and it alters herbaceous species composition, distribution and productivity. Controlled burning as prescribed solutions to improve or maintain productivity might not be of benefit to smallholder farmers. Dependency on fire as a management tool mighty have serious consequences on the browse availability through bush thinning (Smit *et al*., 1999), because woody plants are more affected than their herbaceous counterparts (Trollope *et al*., 2002; Higgins *et al*., 2000). Use of browsers for example goats mighty be a better option (Scorings, 2011; Jeltsch *et al*., 2000; Smit et al 1999) and the method has direct economic benefit to a farmer. Many authors discussed the ecological and socio-economic services provided by woody plant species (Musemwa *et al.*, 2012; Kraaj and Ward, 2006; Smit 2005; Moyo and Campbell, 1998; Scholes and Archer, 1997). In addition, climate change effects favour the growth of woody species (IPCC, 2007; Morgan *et al*., 2007; Bond *et al* 2003). According to Smit (2005), woody plants provide high value browse during the dry season and drought years. Livestock production is the backbone of livelihoods in the developing countries (Musemwa *et al*., 2012; Thornton *et al.*, 2007). In that regard, available browse will play a pivotal role in dampening climate change shocks by sustaining livestock related livelihoods in the semi-arid areas. Annual wildfire outbreaks therefore are likely to reverse the opportunity through altering the woody canopy structure and composition that affect browse availability. Smit *et al.,* (1996) recommended future research to focus on the effect of tree thinning on browse availability. Thus the aim of this study was to investigate the effect of frequent wildfires on browse availability through assessing the resultant woody species size, height and composition in a semi-arid rangeland.

2. Materials and methods

2.1. Study site

The study was conducted at Mahiye farm (Matopos Research Institute), 30 km South of Bulawayo Zimbabwe (20°23′ S and 28°28′ E at 1340 m altitude). The area lies in the agro-ecological region IV characterised by erratic rainfalls ranging from 250-1400 mm, received between November and March (Moyo *et al*., 2011; Kennan, 1971; Thomas and Vincent, 1962). Temperature for the hottest month October is 29.4° C and the lowest is 20.9°C recorded in June.

The soils are clays derived from epidiorite and related schist rock types. Acacia species dominate the plant community hence called thornveld or acacia tree bush savanna (Rattray, 1961/2; Kennan, 1971). The common acacia species include *A. nilotic*a, *A.karoo*, *A. rehmanniana* and *A. gerrardii*. Dominant grass species include *Hyperrhenia sp*, *H. contortus*, *S. incrassata*, *T. triandra*, *C plurinodis*, *U. mossambicensis* and *P maximum* (Chirara, 2002; Moyo, 1998; Ward *et al*., 1979). Mahiye farm was affected by wildfires annually from 2000 to 2012.

2.2. Data collection

The woody plants attributes were collected from five randomly selected paddocks using a Point Centre Quarter technique (PCQ) (Kumarathunge et al 2011; Cottam and Curtis, 1956) on a line transect. Three 100 m transects at an angle of 120^{o} to each other were laid at the estimated centre of the paddock with the direction of the first transect randomly selected. Each sampling point was placed at 10 m interval along the 100 m transect and four quarters formed as prescribed (Dahdough-Guebas and Koedam 2006; Cottam and Curtis 1956). Six hundred live woody plants were sampled from five paddocks. The data collected included distance from the point to the centre of the tree formation, tree circumference at 30 cm trunk height, plant height and species.

2.3. Data analysis

The Cottam and Curtis (1956) formulae were used to calculate relative basal area and absolute tree density in the study area. Species richness, relative abundance and summary statistics were calculated using Statistical Package for Social Sciences (SPSS version 17). Kruskal-Wallis non-parametric test was used to determine the effect of fire on the variations in height and diameter within the farm. For further investigation, a Lorenz curve (Sandras and Bongiovanni, 2004; Damgaard and Weiner, 2000; Weiner and Solbrig, 1984) was used to assess the height and diameter inequality. The two analyses were done using GenStat (2011). Microsoft excel (2007) histogram function (Bin range of 2cm for diameter and 1 m for height) was used to assess class concentrations.

3. Results

3.1. Woody Species composition and absolute density

The vegetation survey recorded fifteen (15) woody plants in the farm, a generally poor species composition. A larger proportion of the observed woody plant samples were *Acacia nilotica* (65%) plants, while *Acacia karoo* and *Acacia robusta* (second and third) combined had less than 25% of the total woody plants abundance (10.8% and 10.7). Other browse species observed in a descending order include *Acacia gerrardii*, *Ziziphus mucronata*, *Dichrostachys cineria* and *Fleuggea virosa*. *Sclerocarya birrea*, *Combretum imberbe* and *Combretum hereroense* were the broadleaved plants present in the study area. The absolute woody plants stem density was estimated at 240 stems per hectare.

3.2. Community Structure

3.2.1. Canopy height class

Canopy structure was heterogeneous with an absolute mean height more than 1.5 m. The Kruskal-Wallis nonparametric ANOVA showed a significant inter paddock height variation. Lorenz curve in Fig 1 had a Gini coefficient of 0.242 that indicates low inequality in the stature of the wood plants community. Furthermore, Fig 2 depicted a positively skewed height distribution in the farm with a modal plant height class of 2.5 m to 3.4 m. The community had few live stems less than 1.4 m and more than 6.5 m. The mean height of the first five most abundant browse woody plants were as follows, 3.342 m (*A. nilotica*), 3.165 m (*A.karoo*), 3.866 m (*A. robusta*), 2.919 m (*A gerrardii*) and 2.919 m (*Z. mucronata*).

3.2.2. Diameter class distribution and basal area

The results showed a heterogeneous woody plant diameter distribution and the dominance of relatively mature plants relative to the vegetation type under consideration. Kruskal-Wallis nonparametric analysis of variance confirmed the variation ($p < 0.05$). Nevertheless, the Lorenz curve shown in Fig 3 had a Gini coefficient of 0.266 showing less inequality in the community. In addition, the histogram shown in Fig 4 represented a positively skewed diameter distribution across the farm with a modal class of 9.5 cm to 10.4 cm. In addition, present in the community were a small percentage of larger trees with diameter more than 30 cm and those less than 2cm (Fig 4). Absolute stem basal area was 110.19 ± 8.47 cm².

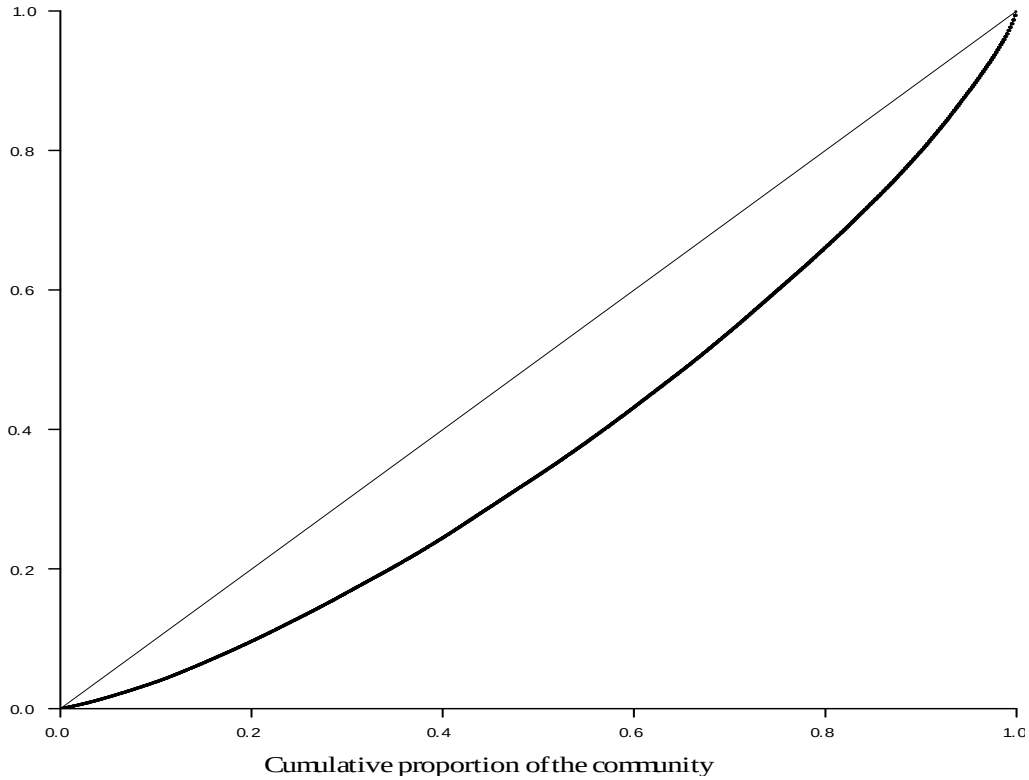

Fig. 1. Lorenz curve showing height inequality in the farms

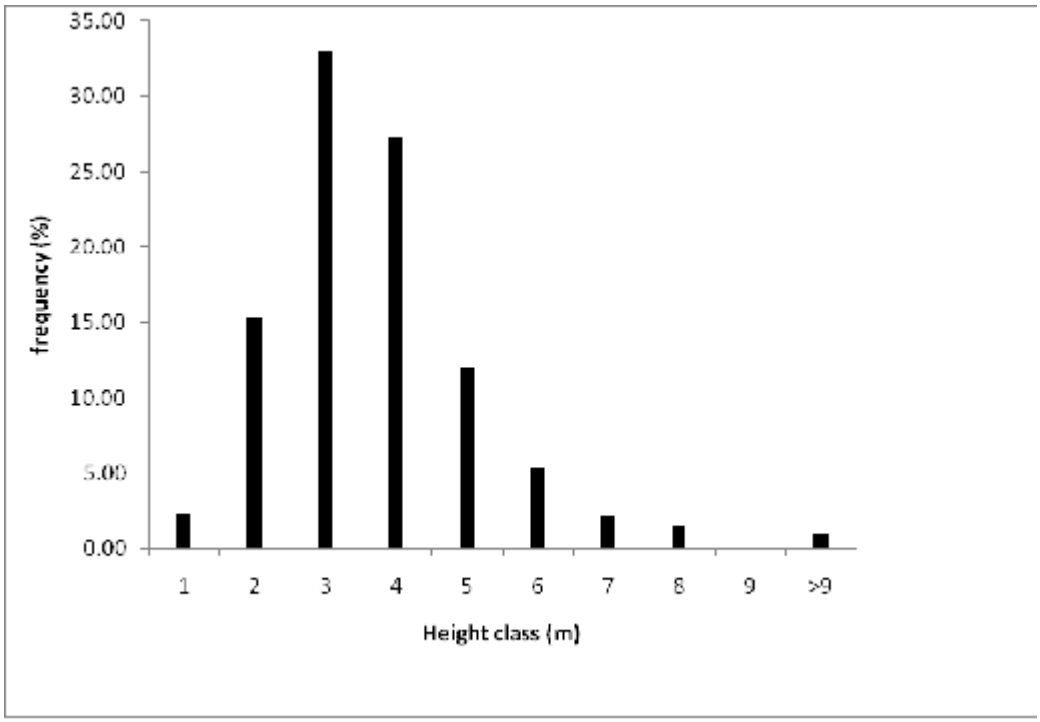

Fig. 2. Woody species height class frequency as a percentage of the sample size (600).

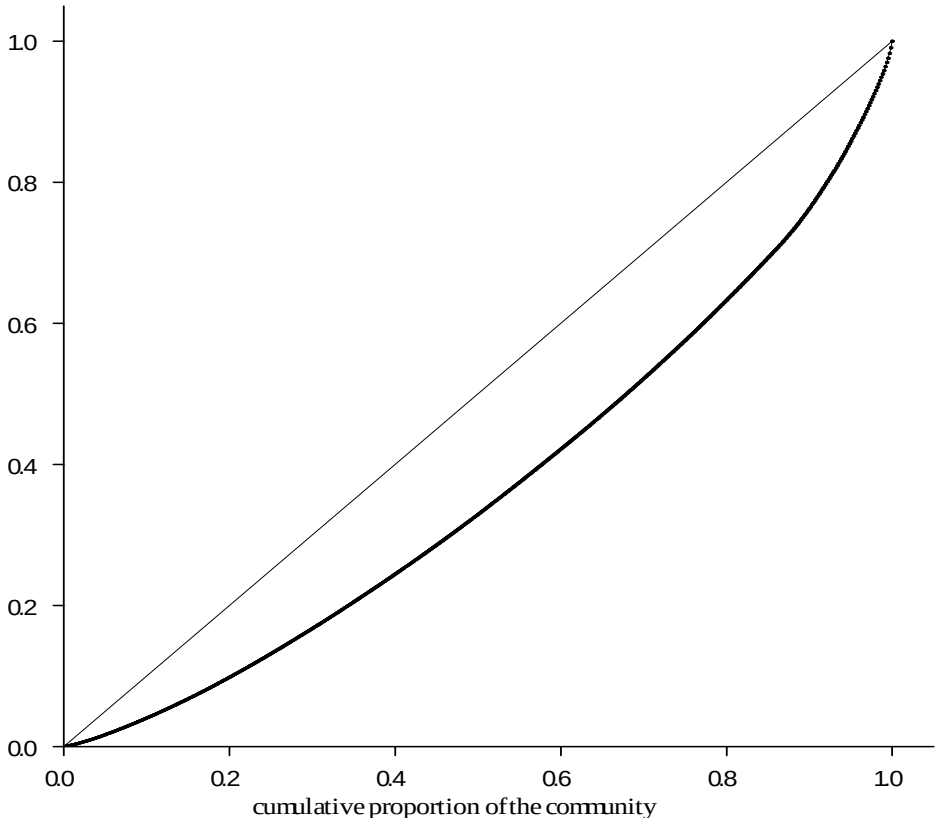

Fig. 3. Lorenz curve showing diameter inequality in the farm.

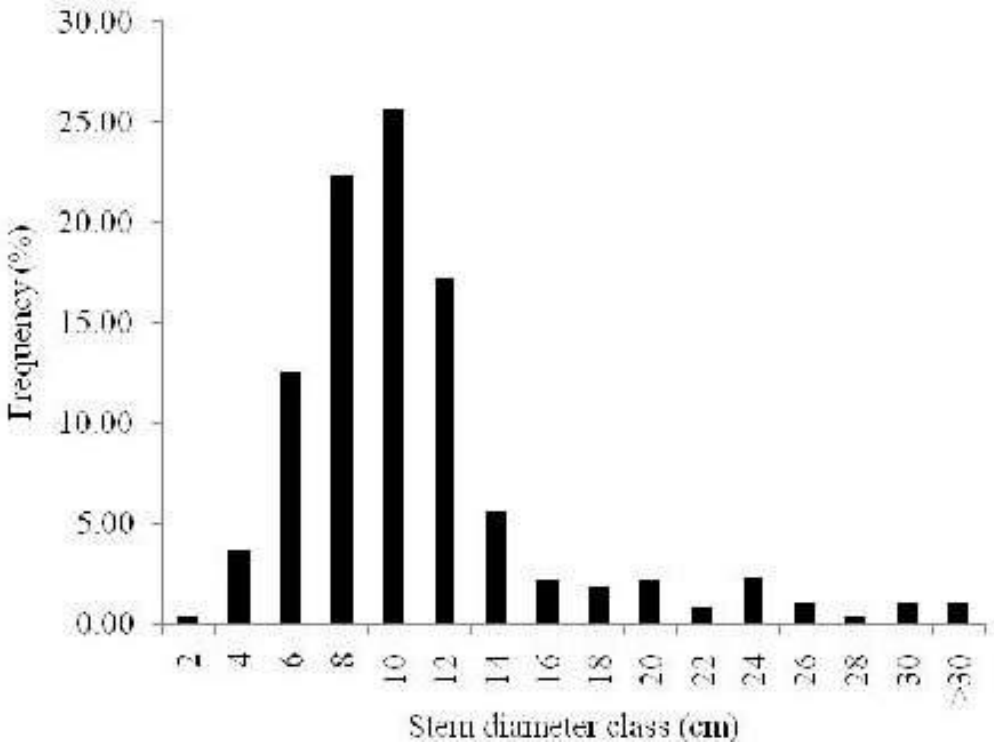

Fig. 4. Woody species diameter class frequency as a percentage of the sample size (600).

4. Discussion

4.1. Species richness and composition

Species compostion results obtained were comparable to the site description by Moyo *et al*., (2011); Kennan, (1971) and Rattray, (1961/2). Species composition of a community affects the quality of browse while the plant densities affect the quantity of the browse. Ecologically, species composition was poor because *Acacia nilotica* abundance was almost two thirds of the total woody plants abundance in the area with the fourteen species contributing a third. This compromises the resilience of the ecosystem. On the other, both the dominant and rare species in the community produce high quality browse. Since Dube (2003) found that nitrogen retention was high in goats fed on a mixture diet of *Acacia nilotica* and *Acacia karroo browse*. According to Smith *et al*., (2008) the *Acacia nilotica* and *Dichrostachys cineria* pods have the potential to improve goat performance in communal areas during the dry, the period of nutritive deficiency in grass species. In addition, *Ziziphus mucronata* and *Acacia karoo* produce high value foliage favoured by browsing livestock and wildlife. In that regard, the browsable species observed were of high browse quality. Based on the comments from Mukungurutse (2002) density of the palatable woody plants also has an impact on intake as it affects the available browse quantity and intake. However, this study could not confirm the adequacy of the available browse provided at a density of 240 woody plants per hectare.

Inference from the species composition and the absolute plant density indicated the presence of a factor that gave *Acacia nilotica* a competitive advantage over others. Rattray (1961/2) described an *Acacia nilotica* dominated community as a fire climax. Levick, *et al.,* (2012) observed low woody canopy cover in area affected by frequent fires than the low frequent counterparts. Therefore, fire disturbances have an upper hand as cause for observed species composition.

4.2. Community structure

In addition to the effect of plant species and plant density, actual available browse is a function of the community structure in question. Both age and height has an effect through influencing the accessibility of the browse (Mukungurutse, 2002). As the plant mature, the canopy diameter widens making most of the browse inaccessible by herbivores hence reducing available browse. Arzai and Aliyu (2010) found a linear relationship between plant height and trunk size in trees found in the savannah region of Nigeria. Height affect the general browse level estimated at 1.5 m for goats and browse above the level is usually not accessible. In comparison with the results from this study, most of the browse produced was inaccessible by goats. In contrast, Gandiwa (2011) found that frequent fires promoted the dominance of short plants. A difference that might be due to the initial physiognomic structure and fuel load as the later site had low fuel load due to the sparse herbaceous species. According to Trollope *et al*., (2002), the apical position of the meristems in wood species predisposes them to destructive effects of hot fires, an effect that decreases with increase in the height hierarchy. Trollope, (1999), stated that juveniles and saplings are more susceptible to hot fire effect than mature species. Grundy *et al*., (2012), Weiner and Lynda (2013) further supports fire as a major cause because, it suppress seedling establishment and resprouting especially in the dry areas promoting persistence of mature trees The facts are evident from Figure 3 and 4 that show a homogenous diameter and height class in the farm with poor recruitment.

In addition, naturally trees have two age dependent growth stages, the long vegetative growth and reproductive growth stage. According to Thomas (2011) reproductive growth declines vegetative growth hence mature trees might not produce as much available browse as seedlings, saplings and coppices. In fire prone areas, head fires exacerbate the problem through destroying the lower branches that are easily accessed by browsers and pods production as the fires concise with the flowering period of acacia species.

5. Conclusion

Fires promoted the dominance of mature and tall acacia species that are not easily accessible by the browser. This has a negative impact on the available browse in a rangeland implying low protein intake by the browsers during the dry season hence low performance. Further research is required on burning frequencies that balances bush suppression, grass production and browse availability. Alternatively burning can be replaced with the use of mixed goats and cattle effects on woody plants structure.

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