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Status of vegetation structure and composition of Mukuvisi Woodlands in Harare (Zimbabwe)

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Abstract

Vegetation structure and composition influence the suitability and availability of unique habitats for different wildlife species especially in closed environments. The main objective of this study was to establish the current status of vegetation structure and composition, in Mukuvisi Woodlands, an urban green space in Harare (Zimbabwe). Three distinct vegetation types were selected; riverine, woodland and grassland. Random sampling within the strata was employed so as to cover as much disparity in landscape as possible. A total of 15 plots measuring 20m x 30m were sampled for the woody vegetation while four 1m x 1m plots were sampled for the grasses within each of the 15 vegetation plots in Mukuvisi Woodland between February and May 2017. A total of 33 tree species were recorded in all the plots. The average tree height was 5.88m and 7.39m in woodland and riverine vegetation respectively. Dominance and evenness significantly differed between habitat types with woodlands having the highest dominance and riverine vegetation having the lowest evenness ($p<0.05$). A total of 30 grass species were recorded. Diversity and evenness of grass species was not significantly different in the three vegetation types (woodland, grassland and riverine; ANOVA, $p>0.05$). The percentage grass cover was 67.5% for woodland, 67.29% for riverine and 88.25% for the grassland. The grassland in Mukuvisi Woodland is mixed but is currently dominated by decreaser grass species of low palatability with high moribund accumulation. Active management should be applied and also aim at controlling decreaser species such as S. Pryamidallis as well as to maintain good number of grazers and browsers.

Key words: grassland, woodland, riverine, decreaser species, vlei, diversity

Introduction

Rangelands worldwide are presently undergoing widespread deterioration both in quantity and quality (Belaynesh, 2006). Mukuvisi Woodlands is also faced with its own share of rangeland associated challenges. These include lack of palatable standing biomass in hot months of the year, anthropogenic disturbances such as pollution and wood poaching (Muboko *et al.,* 2014) and universal climate change (Gibbs *et al.*,2007). The deterioration of habitat quality can be primarily attributed to adverse environmental changes resulting in low and seasonal rainfall, high moisture gathering winds, lack of or inadequate forage and grazing management, soil erosion and overstocking rates (Bolo et al., 2019; Michler et al., 2019). High temperatures, low rainfall and infertile soils are the leading causes of low rangeland productivity (van Soest, 1988). However, this is aggravated by overstocking and poor management tendencies. Increasing grazing and browsing intensity and restriction of wildlife mobility are reportedly having more serious consequences on the rangelands (Campbell, 1996; Bolo et al., 2019).

Anthropogenic and natural disturbances in protected areas may threaten the structure and composition of woody vegetation in savanna areas. Therefore, assessing structure and composition of tropical vegetation becomes more important in the face of the ever increasing threats to the tropical ecosystems (Powers et al., 2018; Addo-Fordjour et al., 2009). Given that green spaces and protected areas are the cornerstone of global biodiversity conservation (Gaston et al., 2008); our study was focused on assessing the status of woody vegetation in this important green space in Harare, Zimbabwe. This will be an important stepping stone in understanding complex ecological systems essential for basic ecological research and application (Muposhi *et al*, 2014).Understanding vegetation dynamics will help keep Mukuvisi woodlands in its best natural state and create a benchmark facilitating detection of change in the presence of human activities. It will therefore immensely contribute towards management practices aimed at maintaining the natural variability of the ecosystem. The specific objective of the study was to assess the grass and tree species composition and structure in Mukuvisi woodlands.

METHODOLOGY

Study area

Mukuvisi Woodlands, located at latitude 17°50'35S and longitude 31°5'42E, covers 274 ha (Hyde *et al.,* 2013) and is situated in the Highveld of Zimbabwe approximately 5 km south east of Harare city centre (Figure 1).

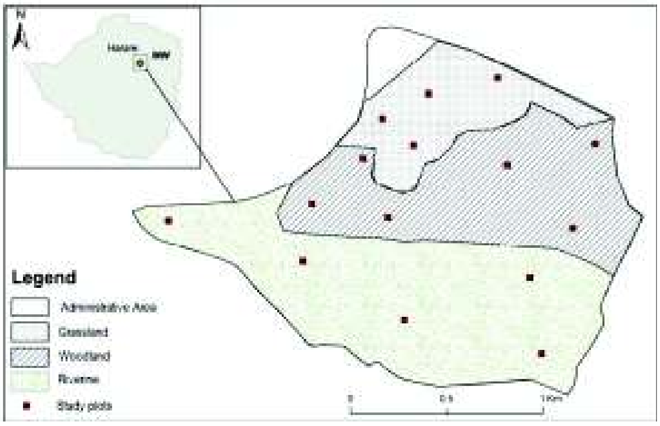

Figure 1: A map showing study plots Mukuvisi woodlands; Adapted from Muposhi *et al.,* 2014

There are two perennial water courses, Mukuvisi and Chiraura Rivers which pass through the park providing water to the animals in the park throughout the year. Mukuvisi Woodlands soils consist of sandy loams developed in stratified sand and gravel. These soils are nutrient poor, a characteristic of most of the miombo soils, as a result of the coarse-grained granite which lies beneath Mukuvisi Woodland (Baldock *et al.,* 1991; Campbell, 1996). The soils in the woody vegetation are excessively drained with rapid permeability and low water holding capacity, and are, therefore, very droughty while the riverine soils are rich and saturated (Muboko et al 2014). The 274 hectares of Mukuvisi Woodlands are zoned into segments which comprise approximately 106 ha of wildlife area, 156 ha of the public walking area and 12 ha of the interpretive and administration area. Our study was focused in the wildlife and public walking area. Mukuvisi woodlands support a diverse vertebrate fauna that includes mammals, birds, reptiles and fish. Mammals include herbivores such as Zebra (*Equus quagga*), Giraffe (*Giraffacamelopardalis*), Impala (*Aepyceros melampus*), Eland (*Taurotragusoryx*) and the introduced Blue Wildebeest (*Connochaetestaurinus*).

Study design

The study area was stratified using three vegetation types: woodland, grassland and riverine. A total of 15 plots were laid; 6 in woodland, 4 in grassland and 5 in riverine vegetation. The number of plots were proportional to the size of the vegetation type. Plot coordinates where drawn from Google earth satellite image (2012), inputted into a Global positioning system device (Garmin Etrex 20, 2001, USA) and used to locate plots on the ground. Rectangular study plots measuring 20 x 30m (0.06ha) were used following Mueller-Dombois and Ellenberg (1974). Rectangular plots were chosen owing to its least conformity to plant shape and distribution patterns (Mueller-Dombois and Ellenberg, 1974). In each plot, a quadrate was also used to get data defining characteristic features of grasses (grass name, height, and frequency of occurrence). Data collection was done from February to May 2017 a time when species were most conspicuous.

DATA COLLECTION

Trees parameters

Trees were considered to be woody species at a height of ≥3m and Circumference at breast height (CBH) ≥ 20cm i.e. 6 cm diameter at breast height (DBH) Mueller-Dombois and Ellenberg, 1974). All woody species less than 3m were regarded as shrubs. Table 1 details how the different tree parameters were measured.

Grasses species diversity and composition

Four (4) $1m^2$ quadrates were systematically placed within the plot and these quadrates formed the micro patch (Magome *et al.,* 2008). All grasses within the quadrate were identified at species level using field guides by Oudtshoorn (1999), height and frequency were also recorded (Magome *et al.,* 2008) (Table 1).

Table 1 Methods used to assess vegetation structure and composition in Mukuvisi Woodlands.

Variable	Method
Height	Tree heights (= 3m and CBH 20cm) were determined by visual estimation by consensus from the research team (Mueller-Dombois and Ellenberg, 1974: also used by Mehta et al, 2008 and Gandiwa and Kativu, 2009).
Girth	Girth was measured in (cm) with a tape measure at breast height 1.3 above ground as widely used in miombo (Martin, 1974).
Species	Vegetation species identification was done with the aid of field guides (Coates Palgrave, 1997 and Wyk and Wyk, 1997) with assistance from an experienced field technician. Unidentified plants voucher specimen were taken and preserved for later identification
Grass basal cover	Graminoids data was obtained using quadrate sampling using $1m^2$ quadrates. Grass species name, height and frequency were recorded for each grass in the quadrate. Grass species identification was done with the aid of field guides (Oudtshoorn ,1999)
Grass height	A 5m tape measure was used to measure grass height.

DATA ANALYSIS

Vegetation structure

Importance value index (IVI) was used to calculate and describe tree population structural dominance (Belachew, 2006; Banda *et al.*, 2008). IVI was computed using Curtis and McIntosh (1954) formula:

Vegetation diversity, richness and evenness

Species diversity was calculated using the Shannon Weiner Index formula:

$H' = \sum pi \ln pi$, where:

H' is the Shannon Index of diversity, *pi* is the proportional abundance of species *i,* and *ln* is the natural log (Mehta *et al.*, 2008). Richness was calculated by counting the number of species observed in each plot. Evenness (Equitability) defined as the relationship of observed diversity to maximum diversity (Hill, 2010) was calculated using the formula:

$E = H'/H'max = H'logS$

Where E = evenness, S= number of species and H' is the diversity index.

Statistical Analysis

Data were tested for normality using the Kolmogorov-Smirnov test. All data was found to be conforming to the normality assumptions. A one way Analysis of Variance (ANOVA, $p < 0.05$) with a post hoc Tukey Honesty Significance Difference (HSD) test was used to test for the variations in the diversity of grass and tree species in different vegetation types. Statistical analysis was conducted using SPSS version 20.0.

RESULTS

Grass diversity

A total of 33 grass species were recorded from the 15 sampled plots. We identified 21 grass species in woodland, 21 in grassland and 16 in riverine vegetation (Table 2). The dominant grass species across all vegetation types were *Sporobolus pyramidalis, Hyperthelia dissoluta, Hyparrhenia nyassae, Cynodon dactylon, Bindens pilosa, Setaria pallidifusca, Setaria homonyma*

(Table 2). However, some grass species were only dominant in one vegetation type e.g. *Phragmites australis* and *Hyparrhenia filipendula* were dominant in the riverine vegetation only. C*ynodon nlemfuensis* was dominant in the grassland near water holes and was spreading in the park. The tallest grasses were found in the riverine vegetation with some grass species recording heights of over 3m (e.g. *Phragmites australis, Hyparrhenia filipendula and Hyparrhenia nyassae)*. Other tall species recorded were *Hyperthelia dissoluta; Digitaria milanjiana, Heteropogon contortus, Sporobolus panicoides* and *Panicum maximum*. Most of the species in the grassland had the same height with the majority ranging from 0.9m to 2.5 m tall. Grasses in the woodland were relatively medium to tall with a height ranging from 0.4m to 2.5m.

Diversity and evenness of grass species was not significantly different in the three vegetation types (woodland, grassland and riverine; ANOVA, $p>0.05$; Table 3). Percentage grass cover was highest in the grassland (88.25%) compared to the other two vegetation categories (HSD, $p < 0.05$) which did not differ significantly among themselves. It was also noted that there was a lot of moribund accumulation in the grassland compared to the other two vegetation categories.

Table 2: Mean height (± SE) of grass species Sampled in Mukuvisi woodlands (February-May 2017)

	Vegetation Type					
Grass Species	**Grassland**		**Riverine**		**Woodland**	
	Height	**N**	**Height**	**n**	**Height**	**n**
Acanthospermum hispidum	_	0	_	0	0.4±0.00	12
Bewsia biflora	0.15±0.03	4	_	0	_	0
Cynodon dactylon	0.16±0.05	121	0.1±0.02	23	_	0
Cynodon nlemfuensis	0.8±0.04	54	1±0.04	24	0.45±0.17	18
Digitaria diagonalis	_	0	_	0	1.1±0.28	5
Digitaria milanjiana	_	0	2.5±0.00[a]	4	1.2±0.01	48
Elionarus agenteus	0.4±0.04	3	_	0	_	0
Eragrostis curvula	0.3±0.05	4	_	0	_	0
Eragrostis viscosa	0.9±0.01	15	_	0	_	0
Eragrostis aspera	0.8±0.02	3	_	0	0.38±0.09	15
Eragrostis rigidior	_	0	_	0	70±0.02	8
Heteropogon contortus	0.88±4.59	17	1.5±0.35[a]	11	0.8±0.10	17
Hyparrhenia filipendula	_	0	3±0.03	5	_	0
Hyparrhenia nyassae	1.9±0.85	16	3±0.72[a]	16	1.4±0.00	28
Hyperthelia dissoluta	2.1±0.65	21	2.4±0.23	11	1.5±0.60[a]	0
Loudetia flavida	1.3±0.26	6	_	0	_	0
Loudetia simplex	0.30±0.01	3	0.35±0.00	5	_	0
Melinis repens	0.6±0.02	3	1±0.57	3	0.44±0.20	31
Panicum maximum	1.2±0.01	7	1.9±0.75[a]	14	1.1±0.00	11
Phragmites australis	_	0	3.9±0.01	39	_	0
Pogonarthria squorrosa	0.76±0.61	25	0.3±0.00	4	0.5±0.17	16
Rottboellia aexaltata	_	0	_	0	0.3±0.17	6
Scleria foliosa	0.35±0.07	21	_		0.15±0.00	14
Setaria anceps	0.8±0.03	9	_	0	_	0
Setaria homonyma	_	0	_	0	0.4±0.34	87
Setaria pallidifusca	0.9±0.05	11	0.4±0.00	4	0.3±0.14	81
Sporobolus panicoides	1.3±0.14	21	1.9±0.00	4	1.4±0.18	28
Sporobolu spyramidalis	1.6±0.18	105	1.4±0.70	12	1.5±0.41	139
Sterochlaena cameronni	_	0	_	0	0.6±0.37	23
Tripogon minimus	_	0	_	0	0.12±0.01	9

- Means the species was not found at the corresponding vegetation type; superscript letters indicate values that significantly differ within the same row

Table 3: Diversity attributes (Mean± SE) of grass species sampled in 15 plots (in three vegetation types) in Mukuvisi woodlands, February –May 2017.

Attribute	Vegetation type		
	Grassland	**Riverine**	**Woodland**
Shannon	1.80±2.52	2.02±2.677	2.08± 2.84
Evenness	0.74±0.515	0.72±0.727	0.74±0.611
Dominance	0.20±0.132	0.19±0.089	0.15±0.0814
Average height(m)	1.30±0.836	0.78±1.587	0.92±0.684
Percentage Grass cover	88.25[a]	67.29	67.55

Superscripts letter indicates significant different values within the same row (LSD, p < 0.05)

Woody Species Diversity

A total of 33 tree species were recorded in 15 sampling plots in Mukuvisi woodlands (Fig.2). The average tree height was 5.88m and 7.39m in woodland and riverine vegetation respectively. *Lantana camara, Jacaranda mimosifolia* (outside plots) and *Psidium guajava* inside the plots were recorded. Only dominance and evenness significantly differed between habitat types with woodlands having a higher dominance and riverine vegetation having a lower evenness (T test, p<0.05, Table 4). IVI results (Table 5) shows that *Julbernadia globiflora* is the highly dominant species followed by *Parinari curatefolia* and *Brachystegia spiciformis* respectively. The most dominant species were from the family Caesalpinioideae. *Friesodielsia obovata* was the least important tree species followed by *Gardenia ternifolia* and *Cussonia arborea* with Importance Value Indices of 1.27; 1.54 and 1.72 respectively.

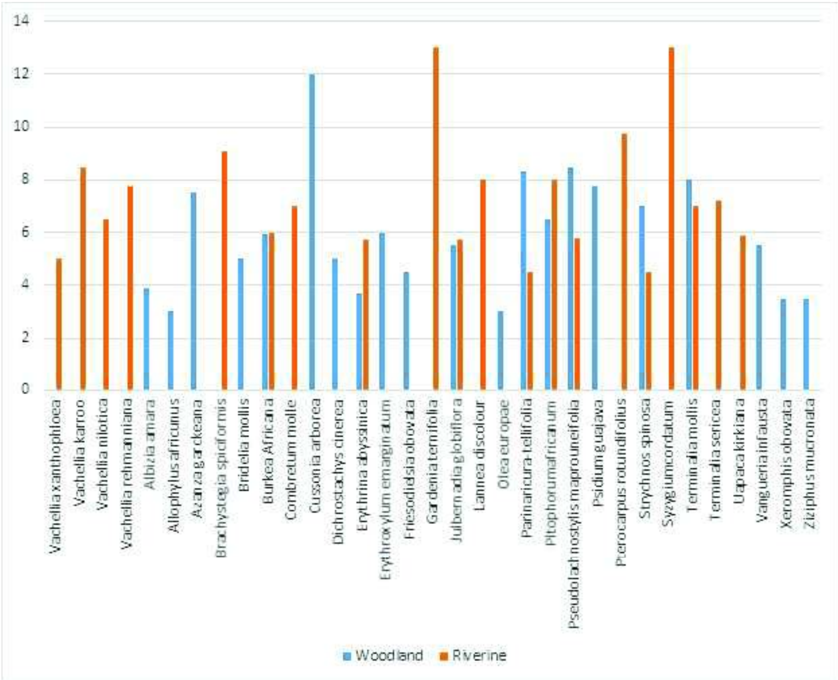

Figure 2. Mean height of tree species identified in Mukuvisi Woodlands

Table 4: Diversity attributes of woody species sampled in two strata in Mukuvisi woodlands February –May 2017

Diversity indices	Woodland	Riverine
Species Richness	21	27
Individuals	117	103
Dominance_D*	0.2882	0.05703
Shannon_H	2.032	3.042
Simpson_1-D	0.7118	0.943
Evenness_e^H/S*	0.3632	0.7757

***indicate that values significantly differed within the same row (T test, p < 0.05)**

Table 5: The 10 most important and the 10 least important woody species (determined by Important Value Index (IVI) recorded in Mukuvisi woodlands green space

Woodland	Family	Relative dominance	Relative frequency	Relative density	IVI
10 Most Important tree species					
Julbernadiaglobiflora	Caesalpiniaceae	33.76	60.87	28.22	122.85
Parinaricura-tefolia	Chrysobalinaceae	34.50	7.81	3.60	45.91
Bragstegiaspiciformis	Caesalpiniaceae	25.21	4.85	15.35	45.41
Erythrinaabyssinica	Fabaceae	19.85	5.36	2.65	27.86
Pterocarpusrotundifolus	Fabaceae	10.55	8.62	4.92	24.10
Combretummolle	Combretaceae	10.03	8.62	4.92	23.58
Uapakakirkiana	Euphorbiaceae	12.18	5.48	2.84	20.49
Terminalia sericea	Combretaceae	9.80	4.85	2.84	17.49
Acacia nilotica	Mimosaceae	4.40	7.77	4.55	16.71
Syzygiumcordatum	Myrtaceae	13.03	0.97	0.57	14.57
10 Least Important tree species					
Lanea discolour	Anacardiaceous	1.41	1.94	1.14	4.49
Albiziaamara	Fabaceae	2.98	0.85	0.38	4.21
Dichrostachyscinerea	Mimosaceae	0.88	1.94	1.14	3.96
Ziziphusmucronata	Rhamnaceae	0.42	1.71	0.76	2.89
Olea europae	Oleceae	0.09	1.71	0.76	2.55
Acacia amythethophylla	Mimosaceae	0.80	0.97	0.32	2.09
Allophylusafricunus	Sapindaceae	0.76	0.97	0.29	2.02
Cussoniaarborea	Araliaceae	0.18	0.97	0.57	1.72
Gardenia ternifolia	Rubiaceae	0.00	0.97	0.57	1.54
Friesodielsiaobovata	Annonaceae	0.04	0.85	0.38	1.27

The invasive tree species identified were, guava (*Psidium guajava)*, *Jacaranda mimosifolia* and *Lantana camara.* These species are mainly observed in the riverine and woodland areas.

DISCUSSION

The grassland in Mukuvisi Woodland is dominated by grass species such as *Sporobolus pyramidalis, Hyperthelia dissoluta, Hyparrhenia nyassae, Cynodon dactylon* and*Cynodon nlemfuensis*. All these species are considered to be increase species of low palatability which invade disturbed land (Bothma *et al.*, 2005). Increaser species have low nutritive value and they over-compete preferred grasses and this could be associated with graze problems in Mukuvisi woodlands (Mukuvisi, pers. comm). Furthermore, as indicated in our results the grasses are tall in all the different vegetation types and tall grasses do not make good graze as most savannah animals prefer short grasses (Bothma *et al.*, 2004). *S. pryamidallis* is an indicator of low soil fertility and unlike most other grasses can tolerate and thrive on soils with very low nutrition levels, poor drainage and highly compacted soils (Barnes *et al*., 2014).

Animals in Mukuvisi woodlands therefore usually graze near the viewing platform where there are short grasses which are usually clipped by management. The grass swards have ground cover of above 67% (Table 2), composed of both moribund and live grass. Moribund grass hinders regrowth and can further complicate graze availability. The relatively lower percentage grass cover in woodland and riparian vegetation could be related to the high tree density and canopy area of woody species that tend to induce shading and reduce herbaceous vegetation establishment. These findings are similar to those by Peterson and Reich (2008), and Tedder *et al.,* (2014) who reported that spatially variable shading from over storey trees affected the grass sward.

The dominant tree families *Caesalpinioideae* and *Fabacae* show that Mukuvisi woodlands is a typical miombo ecosystem which is dominated by the *Caesalpinioideae* and *Fabacae* family. The woody species density (708-1305/ha) was also similar to those recorded in other studies in Miombo ecosystem, 700-1038 trees/ha (Isango, 2007) and 74-1041/ha (Bakéus *et al.*, 2006). While the *Caesalpinioideae* and *Fabacae* families dominated the vegetation in Mukuvisi woodlands, several other species from other families such as *Mimosaceous, Myrtaceae, Euphorbiaceous, and Combretaceae* were recorded. This is expected of Miombo ecosystems which are known to have high species diversity (Munishi *et al.*, 2011) and consequently provide adequate habitat for different animal species. Despite this huge advantage of increased plant species diversity, Mukuvisi woodlands' downside is that of tree heights. The average tree height in the Woodland vegetation in Mukuvisi woodlands was 5.88m and the riverine vegetation had an average height of 7.39m. This presents a major challenge in browse provision as these heights are beyond the browse heights of savanna browsers. The browse height for Impala is known to be less than 1.5m; Kudu and Elands 1.5m-2m and giraffe is known to be 2m-5m (Gaiballa and Lee, 2012).

While the prevalence of invasive species is said to be on the increase (EMA Report, 2012), invasive species were recorded at low frequencies in Mukuvisi woodlands. For instance *Jacaranda mimosifolia* and *Lantana camara* were not recorded in all our plots but were observed to be occurring within the park. *Psidium guajava (*which was recorded within plots) does not present an ecological problem (Obiri, 2011).The lower tree species dominance and higher evenness in riverine vegetation can be attributed to favorable soil conditions and water availability in the riverine sections of the park. This is also evidenced by taller trees (average height- 7.39m) in riverine vegetation. Water availability has long been known to be the major driver controlling biological activity and regulating productivity in savanna ecosystems (Walker et al., 1981; Maranga *et al.,* 1983; Maranga, 1986). As such the continuous availability of soil moisture in the riparian parts of Mukuvisi woodlands are favorable to the vegetation growing in these areas.

CONCLUSION

The grass species composition indicates that there is a high level of disturbance in the park. Disturbance is usually associated with improper stocking rates. There is therefore a need to maintain proper stocking rates in the Park to avoid overutilization and depletion of feed resources especially during the critical hot dry seasons. Supplementary feeding in the hot dry season may be necessary to ensure that the crude protein levels do not decline below threshold levels. Mukuvisi woodlands park management should focus on the restoration of the park's grasses to a short sward through active management and also aim at controlling increase species such as *S. pryamidallis*. Increaser species can be controlled by various ways i.e. chemical, biological, and mechanical. Hay bailing of grass before flowering will help reduce dominance of increaser species and also maintain high species diversity and medium grass height which is preferred by animals (Muposhi *et al.*, 2014). These hay bales can be used in hot dry seasons when standing biomass is depleted or can be sold to other game ranchers. Close monitoring of the availability of the grass component favored by the animals and continuously monitoring the diet profile shift and quality of these animals is recommended.

Fire management is needed in Mukuvisi woodlands to sustain and restore the health of the ecosystem and its component biota, and to protect on-site and off-site infrastructure and lives from wildfire. The vegetation of Mukuvisi Woodlands is comprised largely of fire-prone types e.g. *Heteropogon contortus* and *Hyparrhenia spp* (Motzkin*et al.,* 1999). However, if fire is to be used as a management tool there is need for proper smoke management considering the proximity of Mukuvisi woodlands to Harare City center. Smoke from fires can become a nuisance to people downwind, and can cause serious visibility hazards on public roads. While invasive woody species are not yet a major problem in Mukuvisi woodlands, there is need to stop the possibility of their increase in the near future.

Competing interests: The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

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