Journal of Forests
2025 Vol. 12, No. 2, pp. 122-133
ISSN(e): 2409-3807
ISSN(p): 2413-8398
DOI: 10.18488/jof.v12i2.4661

Effects of fire on woody vegetation structure and composition across a distance gradient from the Kanda Vlei, Kazuma Pan National Park, Zimbabwe

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Article History
Received: 24 October 2025
Revised: 28 November 2025
Accepted: 12 December 2025
Published: 31 December 2025

Keywords
Distance gradient
Fire frequency
Fire intensity
Fire prone
Structure and composition
Vlei.

ABSTRACT

Fire is a global phenomenon that influences vegetation structure and composition, shaping ecosystem dynamics in fire-prone landscapes. Despite its recognition as a key disturbance factor, little is known about its effects on woody vegetation across a distance gradient from the fire source, particularly in ecosystems characterized by vleis. To address this gap, we investigated the effects of fire on woody vegetation structure and composition across three distance gradients, replicated five times from the vlei. Fifteen rectangular plots (20x30m) were established along these gradients, with 15-20 trees selected per plot using a systematic design. A total of 509 woody plants were assessed. One-way ANOVA was used to test for significant differences in height, diameter, density, basal area, species diversity, and species richness using R software. Diversity indices, including the Shannon index for species diversity and the number of species for species richness, were calculated using the PAST4.03 software package to evaluate the composition of woody vegetation in the study area. The findings indicate a decrease in fire intensity and frequency with increasing distance from the vlei, resulting in varied fire regimes that simultaneously reduce species diversity and richness. Hayne dominates near the vlei, while fire-sensitive species such as *Terminalia sericea*, *Combretum hereroense*, *Combretum apiculatum Sond.*, and *Kirkia acuminata* prevail further from the vlei. These results highlight the importance of considering spatial patterns in fire regimes and vegetation responses for effective prescribed burning, fire management planning, and conservation strategies. This study enhances understanding of fire-vegetation relationships and informs management strategies for fire-prone ecosystems.

Contribution/Originality: This study is among the few investigations that have examined the effects of fire on woody vegetation structure and composition across a distance gradient from the fire source. By assessing changes in vegetation characteristics relative to fire proximity, the study provides insights into how fire influences savanna ecosystems.

1. INTRODUCTION

Savannas and grasslands, covering approximately 20-40% of the Earth's surface [1, 2], are prone to fires due to biomass burning [3]. Fire significantly affects vegetation structure and flora diversity [4], shaping ecosystems. Kazuma Pan National Park's ecosystem, characterized by open grasslands and mixed woodland, is susceptible to dry-season fires [5]. Understanding fire's effects on woody species is crucial for conservation and management strategies [6].

Fire influences woody vegetation structure (tree density, size distribution, canopy cover) and composition (species diversity, abundance) [7, 8], affecting habitat suitability, food availability, and ecosystem services [9]. This study investigates the effects of repeated uncontrolled dry season veld fires on woody vegetation in Kazuma Pan National Park, Zimbabwe, aiming to assess fire's impact on tree height, diameter, basal area, species diversity, and density along a distance gradient from the vlei edges.

Kanda Vlei Grassland, a unique and valuable resource within Kazuma Pan National Park, hosts a high diversity of flora and fauna species. However, recurring uncontrolled wildfires from anthropogenic and natural causes affect the woody vegetation species on the edges of the woodland and the entire woodland. This study aims to investigate the effects of these fires on woody vegetation, addressing the knowledge gap in managing fire effects on savanna ecosystems. Despite the recognition of fire as a key disturbance factor, there is a lack of research examining the effects of fire on woody vegetation structure and composition across a distance gradient from the fire source, particularly in ecosystems characterized by vleis. Another research gap covered by this study is to identify which flora species are more resilient or vulnerable to fire.

Furthermore, fire was hypothetically thought to have a significant impact on woody vegetation structure and composition. This study assumes that fire intensity, frequency, and seasonality are the sole factors affecting woody vegetation, excluding other factors such as precipitation and climate. It also assumes no confounding factors or human activities affecting the results, and that fire effects on woody vegetation are solely direct.

The research questions guiding this study are: How does fire influence vegetation structure in the woodland ecosystem? Does fire affect vegetation composition attributes in the woodland ecosystem? Which woody vegetation species are resistant and vulnerable to fire over a distance gradient? Understanding the impacts of fire on woody vegetation will provide insights into ecological processes and plant evolution [10] complex relationships between fire, woody vegetation, and savanna ecosystems. This study's findings will inform the development of effective conservation and management strategies for the sustainable use and maintenance of ecotone zones in savanna ecosystems, ensuring the sustainable use and maintenance of these unique ecosystems.

2. METHODS AND MATERIALS

2.1. Description of Study Area

Kazuma Pan National Park (KPNP), located in Zimbabwe's extreme northwest corner (18°22'S 25°42'E and 18.367°S 25.700°E), is a protected area established in 1949, not 1975 [11]. As a national park, it aims to preserve and protect wildlife species, natural landscapes, and scenery for public enjoyment and education. The total area of KPNP is approximately 31,300 hectares (313 km^2), making it a small park compared to other national parks in Zimbabwe. This protected area is situated 55 km south of the Mighty Victoria Falls. Conveniently, the park is part of the larger landscape (KAZA), a unique animal migration corridor providing a vital link for wildlife to disperse and migrate. At some point, it serves as a sanctuary for a diverse range of wildlife [11]. since it is encircled by hunting safari areas, namely Kazuma Forest, Panda Masue Forest, Matetsi Unit 1, and on the western side, it shares the boundary with Botswana. The park experiences a semi-arid climate with highly variable rainfall (400-700mm per annum), with a rainy season from November to March and dry months from July to August. Temperatures range from 18℃ to 40℃ depending on the season [12]. This small prime wilderness (protected area) is renowned for its vast open grassy plains, a series of pan depressions enclosed with mixed Mopane and Zambezi teak woodland, dominated by *C. mopane and Baikiaea plurijuga* Harms species, along with other notable tree species. These tree species and a diverse array of grasses and herbs are situated on well-drained Kalahari sands, which cover the bulk of the study area, belonging to the regosol group in the amorphic soil order Nyamapfene [13] and Gambiza [14]. Moreover, the presence of two distinct hydrological systems, artificial water pans (solar pumped) and natural water systems (perennial springs and streams), together with good browse, creates conducive conditions for a diverse range of wildlife species, including

Loxodonta africana, *Syncerus caffer*, *Panthera leo*, *Ourebia ourebi*, and numerous avian species. Figure 1 illustrates the location of the study area in northwest Zimbabwe.

Study site map

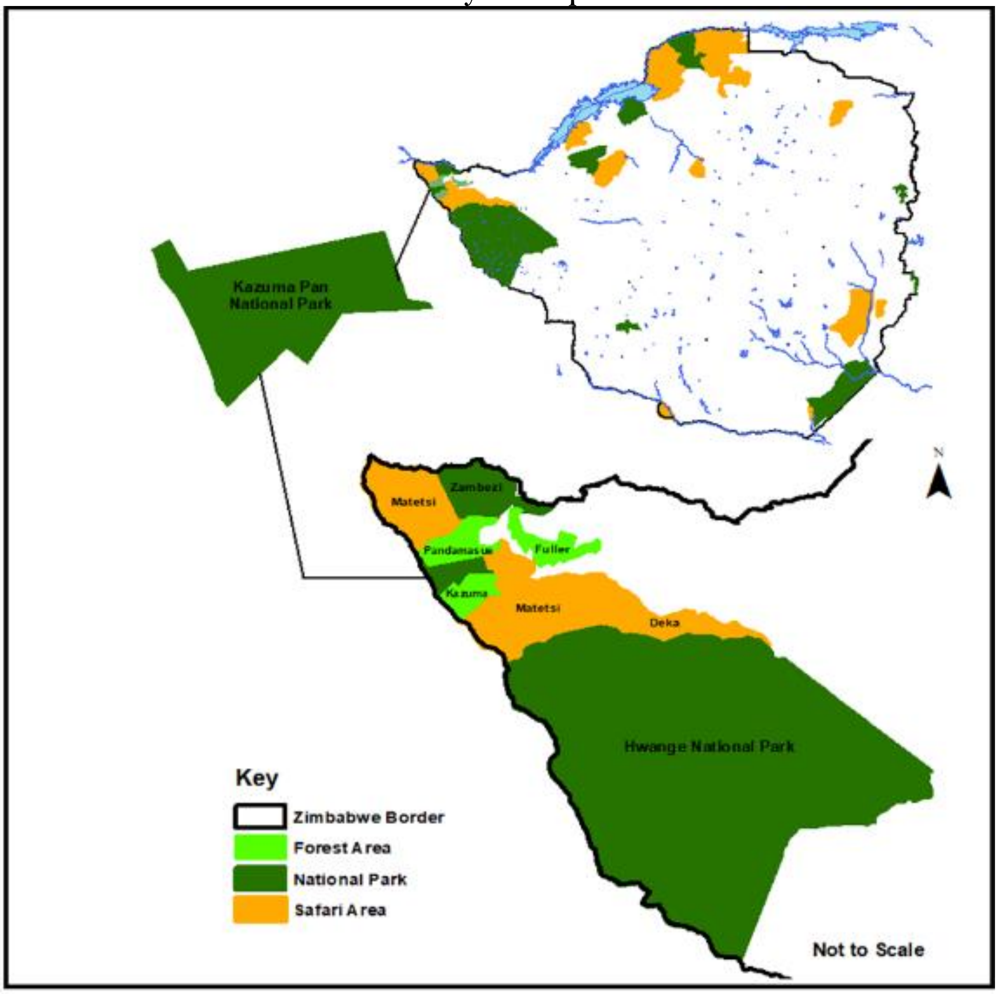

Figure 1. Location of the study area in northwest Zimbabwe.

2.2. Study Design and Field Sampling

This study investigated the effects of dry season annual fires on vegetation from the vlei, with a design comprising two treatment plots [near (at the periphery) and midway (100m away)] and a control plot [far (400m away)], replicated five times along the distance gradient. The first treatment plot was randomly assigned using a systematic random sampling method at each distance gradient. Thus, on the vlei's periphery, the first plots were established; the second 100m away (midway); and the control plot 400m away, ensuring the same vegetation type and soil type were maintained. Fifteen rectangular plots (20x30m) were pegged along the distance gradient, following Walker's [15] method, to capture at least 15-20 trees per plot. Data collection occurred in August 2023, with each plot assessed once. Variables recorded included height and diameter, where species diversity and richness were calculated using a specific software package. A tree was defined as a woody plant greater than 1.5m in height and more than 10cm in diameter. Woody species were identified using field guides [16], and species composition was observed and recorded. Tree height was measured using a 2.5m graduated pole, with visual estimates (Stick method) used for taller trees (<2.5m). Diameters were measured at breast height (1.3m) using a flexible diameter tape measure, with the tallest stem measured for multi-stemmed trees [17]. Basal area ($g=¼[pi] d^2$) and tree density ($N=\dot{n}/a$) were calculated for further analysis.

2.3. Data Analysis

To characterize the woody vegetation structure, descriptive statistics (means and standard errors) were computed for vegetation variables, including height and diameter, using Microsoft Excel. Additionally, one-way Analysis of Variance (ANOVA) was performed in R software (v. 4.3.1) to examine the significant differences within the dataset (height, diameter, density, basal area, species diversity, and species richness), that is, comparing means among the different treatment plots (near, midway, and far). Furthermore, diversity indices, including species diversity (Shannon index) and species richness (number of species), were calculated using the PAST 4.03 software package to assess the composition of the woody vegetation in the study area. By using a combination of descriptive statistics, ANOVA, and diversity indices, this study obtained a comprehensive understanding of the vegetation dynamics near the source of fire (vlei).

3. RESULTS

3.1. Vegetation Structure and Composition Attributes for Adult Trees

A total of 509 woody plants (saplings and trees) were identified, measured, and assessed in 15 sampling plots of the study. Trees located further from the vlei were taller (3.5 m) and had larger diameters (44.7 cm) than those located midway and nearer to the vlei (Table 1). Results indicate that there were no significant differences in height and diameter between the midway and near categories ($p>0.05$). There was a significant difference in average basal areas ($p<0.05$); the far category has larger diameters and basal area compared to the midway and near categories. There are no significant differences in mean densities across all distance gradients from the vlei ($p >0.05$). Furthermore, significant differences in species diversity and species richness. ($p<0.001$ and $p<0.05$) respectively, were recorded across the distance gradient from the vlei. The highest species diversity and species richness were recorded in the area further away from the vlei (Table 1).

Table 1. Woody vegetation structure and composition attributes for adult trees (dbh > 10cm) along a distance gradient from the vlei (Mean ± SE).

Variable	Far (400m)	Midway(100m)	Near(periphery)	P Value
Height (m)	3.59 ± 0.34^{a}	2.33 ± 0.23^{b}	2.09 ± 0.19^{b}	*
Diameter (cm)	44.7 ± 3.31^{a}	23.8 ± 3.38^{b}	25.3 ± 3.62^{b}	*
Basal area	15.7 ± 1.64^{a}	3.14 ± 2.40^{b}	3.31 ± 2.13^{b}	*
Density (stems/ha)	353 ± 52.2^{a}	310 ± 131.1^{a}	150 ± 55.0^{a}	NS
Species diversity	1.65 ± 0.11^{a}	0.62 ± 0.09^{b}	0.13 ± 0.13^{c}	**
Species richness	7.4 ± 0.74^{a}	2.4 ± 0.24^{b}	1.2 ± 0.2^{b}	*

Note: Mean values with different letter superscripts (a, b, c) within column for each variable denote significant difference. NS (Not significant) = $P > 0.05$; * = $P < 0.05$ and ** = $P < 0.001$.

3.2. Sapling Abundance and Species Diversity

There were significant differences in mean sapling abundance and species diversity across the distance categories ($p<0.05$), with the highest species diversity and abundance being recorded at 100m away (midway) from the vlei (Table 2).

Table 2. Sapling abundance and species diversity along a distance gradient from the vlei (mean ± SE).

Variable	Far (400m)	Midway (100m)	Near(periphery)	P value
Abundance	11.2 ± 0.86^{b}	31.6 ± 1.63^{a}	12.8 ± 2.24^{b}	*
Species diversity	0.57 ± 0.15^{ab}	0.89 ± 0.15^{a}	0.08 ± 0.08^{b}	*

Note: Mean values with different letter superscripts (a, b) within columns for each variable denote significant differences. * = $P < 0.05$.

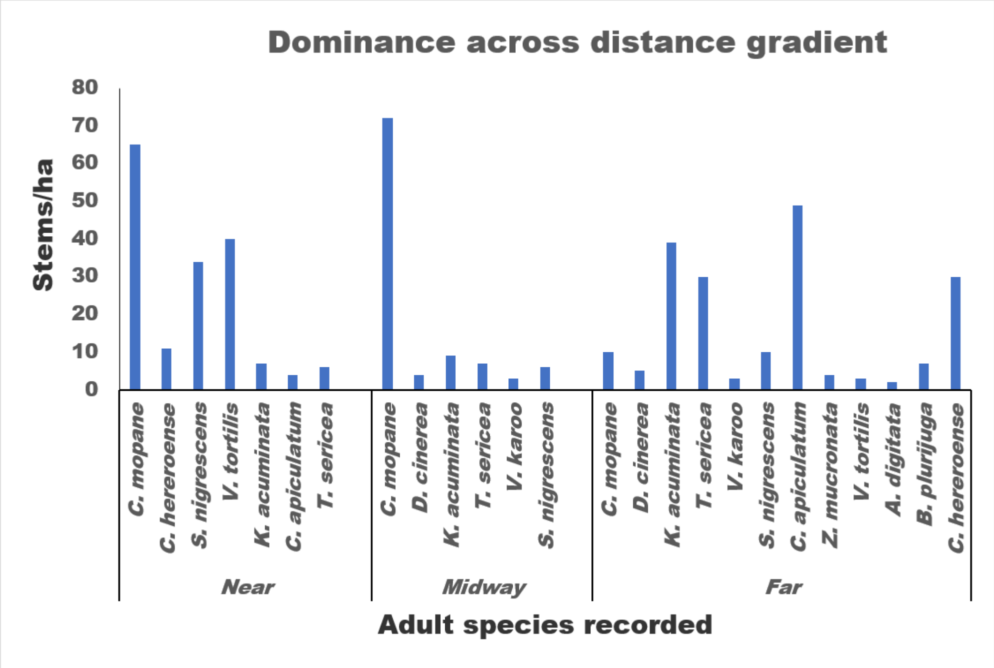

Figure 2. Adult species recorded across a distance gradient.

3.3. Adult Species Recorded

Figure 2 shows the total number of adult species recorded across distance gradients (near, midway, and far). It clearly shows that the fire-adapted species (*C. mopane, S. nigrescens, and V. tortilis*) dominated the near category, while the fire-sensitive species (*T. sericea, K. acuminate, C. apiculatum, and C. hereroense*) prevailed further away from the vlei. Table 3 presents the Importance value index for adult species recorded.

Table 3. Importance value index for adult species recorded.

Distance gradient	Species	Relative density	Relative frequency	Basal area	IVI	Rank
Near	*C. mopane*	217	65	1.39	283	1
	S. nigrescens	113	34	0.361	168	2
	V. tortilis	133	40	0.439	63.7	3
	C. hereroense	36.6	11	0.209	47.8	4
	K. acuminata	23.3	7	0.439	30.3	5
	T. sericea	20	6	0.030	26.0	6
	C. apiculatum	13.3	4	0.027	17.3	7
Midway	*C. mopane*	240	72	0.757	313	1
	K. acuminata	30	9	0.161	39.2	2
	T. sericea	23.3	7	0.027	30.4	3
	S. nigrescens	20	6	0.021	26.0	4
	D. cinerea	13.3	4	0.02	17.4	5
	V. Karoo	10	3	0.017	13.0	6
Far	*C. apiculatum*	163	49	1.1	213	1
	K. acuminata	130	39	0.697	170	2
	C. hereroense	100	30	0.57	131	3
	T. sericea	100	30	0.116	130	4
	C. mopane	33.3	10	0.516	43.9	5
	S. nigrescens	33.3	10	0.035	43.4	6
	B. plurijuga	23.3	7	0.083	30.4	7
	D. cinerea	16.7	5	0.056	21.7	8
	Z. mucronata	13.3	4	0.051	17.4	9
	V. tortilis	10	3	0.032	13.0	10
	V. Karoo	10	3	0.017	13.0	11
	A. digitata	6.67	2	0.173	8.84	12

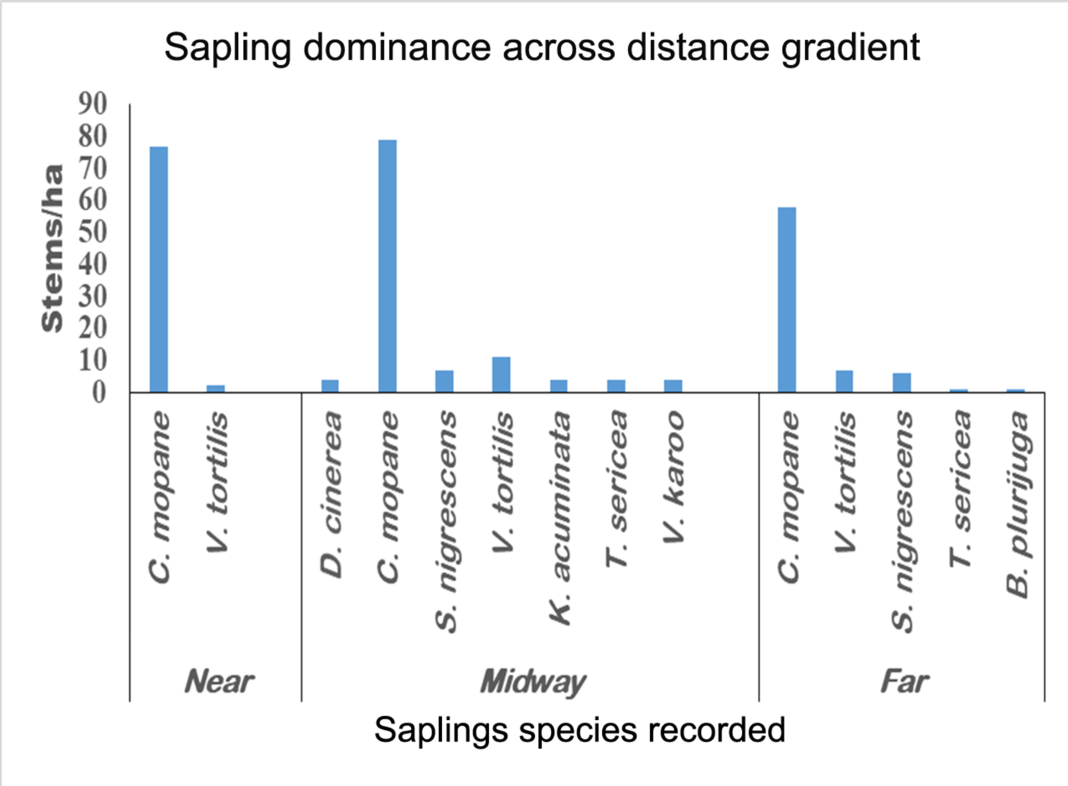

Figure 3. Sapling species recorded across the distance gradient.

3.4. Saplings Species Recorded

Figure 3 shows the total number of saplings for each sapling species recorded across the three distance categories (Near, Midway, and Far). However, the trend clearly shows that Mopane saplings dominate all three categories, having the highest numbers. Table 4 presents the Importance Value Index for sapling species recorded.

Table 4. Importance value index for sapling species recorded.

Distance gradient	Species	Relative density	Relative frequency	IVI	Rank
Near	*C. mopane*	256.67	77	333.67	1
	V. tortilis	6.67	2	8.67	2
Midway	*C. mopane*	263.33	79	342.33	1
	V. tortilis	36.67	11	47.67	2
	S. nigrescens	23.33	7	30.33	3
	D. cinerea	13.33	4	17.33	4
	K. acuminata	13.33	4	17.33	4
	T. sericea	13.33	4	17.33	4
	V. Karoo	13.33	4	17.33	4
Far	*C. mopane*	193.33	58	251.33	1
	V. tortilis	23.33	7	30.33	2
	S. nigrescens	20	6	26	3
	T. sericea	3.33	1	4.33	4
	B. plurijuga	3.33	1	4.33	4

4. DISCUSSION

In this study, results for mean height show a clear difference in woody vegetation structure across the distance gradient from the vlei. A significant increase in mean height as distance from the vlei increased was observed, with the far distance showing the tallest woody vegetation, followed by the midway distance, and the nearest distance showing the shortest vegetation. These findings clearly show that the pattern in vegetation height was influenced by proximity to the vlei and potential fire effects. The fact that trees get taller as you move away from the vlei is consistent with findings from other studies. For instance, Smith [6] found the same patterns in savannas, where trees were growing taller as you moved away from the water sources. This occurs because of differences in resource availability, which may become scarcer as you move away from the vlei [18]. But for this study, it's a different scenario. In areas where fires are more frequent and intense, soil nutrients and moisture availability can be depleted by extreme heat, resulting in limited resources near the vlei compared to further from the vlei. However, this results in shorter woody vegetation near the vlei compared to areas that are farther from the source of fire (vlei), as observed in this study.

The shorter vegetation height observed near the vlei indicates that there are more frequent or intense fire regimes in these areas. According to Bond and Keeley [19], fire is known to exert selective pressure on vegetation, favoring species with traits that enable them to survive or recover from fire damage. In grassland or vlei ecosystems, frequent fires can suppress the growth of taller woody vegetation, resulting in shorter vegetation near the vlei, where fire occurrences may be more frequent due to proximity to the source of fires or higher fuel loads. Other studies conducted by Enslin et al. [20] and Gandiwa and Kativu [5] support that frequent fires and/or repeated burning have damaging effects, including top kill of woody plants. However, Hoffmann et al. [21] and Ryan and Williams [22] also agree that repeated top kill of small trees makes them particularly susceptible to the 'fire trap,' which prevents recruitment into adult size classes.

In addition, the present study showed significant differences in height between distance categories; near categories had more frequent fires than other categories. The results oppose those of Tafangenyasha [23], which showed that trees are taller in heavily burnt areas than in unburnt areas. However, the results support those of Trapnell [24], Spence and Angus [25], Strang [26], Gandiwa [27], and Gandiwa et al. [17].

The results for diameter show a similar trend to that observed for mean height. The far distance shows the largest diameter compared to the midway and near distances. However, this suggests that the size (diameter) of the woody vegetation is affected by the proximity to the vlei and probably fire disturbance. The larger diameter trees farthest from the vlei may be older and more established, having more time to grow and develop thicker trunks over time, simply because of lower fire frequencies and intensity [28]. Additionally, a farther distance from the vlei may provide favorable conditions for growth, such as fewer fires, allowing the development of larger individuals. Since trees in the far distance are taller than those in the near and midway distances, the canopy spread acts as a barrier for reducing undergrowth. Therefore, there will be less grass (fuel load) growing under tall trees, resulting in fewer fires. This means that trees in the far distance experience less disturbance than those near the vlei, which have more fuel load.

Conversely, the smaller diameters observed at the nearest and midway distances from the vlei may be due to fire. Referring to Mbow et al. [29], more frequent and intense fires negatively affect woody vegetation by scorching their bark and damaging the growth tissue, thus reducing soil moisture and nutrients. This may lead to smaller diameters. The reason behind this thesis is the proximity to the ignition source or a larger fuel load reservoir for fires. Furthermore, competition among woody species for resources such as water and nutrients may also contribute to the observed differences in diameter across the distance gradient. The competition results from the fact that fires may exhaust resource availability. Another reason for smaller diameters near the vlei is that species in the near category are less resistant to fire disturbance than those in the far category, which are more adapted and resistant and able to grow in larger diameters [30].

Since basal area is derived from diameter, a significant difference was observed in basal areas across distance gradients from the vlei, with the far category having the highest values and the near category having the lowest values. This agrees with a study done by Gandiwa et al. [17], which showed a significant difference in basal areas between the burnt and unburnt sites. The unburnt site or in areas with less frequency of fires exhibits higher basal areas and height, as compared to those on the burnt sites. The main reason behind these findings is that higher basal areas and diameters at a far distance are attributed to reduced intensity of fires due to fewer moribund (dry grasses), which are the main source of fuel load in the study area. However, the opposite is true for nearer or midway distances to the vlei. Therefore, closer to the vlei, there are more frequent and intense fires, leading to reduced growth and survival of woody plants. Enslin et al. [20] also support the findings of this study, stating that the dry season's annual hot fires probably produced more extreme top kill, resulting in basal coppicing, which is the killing of above-ground parts of plants and the generation of smaller plants with narrower basal areas on the burnt site. The stem density of woody vegetation remained consistent across the distance gradient from the vlei, despite variations in tree height, diameter, and basal area. This clearly shows that woody vegetation adapts to changes in its environment and fire disturbance without changing its density.

Sometimes, the impact of fire on the ecosystem may result in a lack of significant differences in stem densities. The study done by Bond and Keeley [19] supports the idea that fire plays a key role in shaping the structure and composition of woody vegetation by influencing seed germination, seedling growth, and competition among species. Moreover, the consistent stem density across the distance gradient reveals that fire may be responsible for maintaining a balance in new stem growth and mortality. However, Higgins et al. [18] show that the balance indicates a level of stability, where the woody vegetation community compensates for any changes in the population size or density. Additionally, woody plants can also develop some adaptive strategies to survive, especially in fire-prone areas. Taking this from Pausas and Keeley [31], woody species have evolved strategies such as re-growing from roots, releasing seeds only after fires, or having fire-resistant bark, allowing them to withstand fires. The following studies also support the findings of this study, in the sense that fire had little effect on stem density. Gandiwa, et al. [17]; Tafangenyasha [23] and Strang [26]. Moreover, fire disturbance in this study did not have a significant influence on tree density. Heinl [32] agrees with these ideas by providing reasons that fires in the African savanna can influence the size, structure, and biomass of tree populations but not tree density. This is attributed to resprouting after burning, and typically, savanna vegetation is fire-adapted and resilient. Furley et al. [33] also agree with this present study and other researchers, such as Heinl [32]. In contrast, Pausas and Keeley [31] prove that an increase in the frequency or severity of fires is likely to change the tree density and basal area. The significant differences observed in species diversity across all distance gradients from the vlei provide an understanding of the relationship between environmental gradients, fire disturbance, and woody vegetation composition. The results showed a clear pattern that species diversity decreases as you move closer to the vlei.

According to Higgins et al. [18], fire regimes can create a diverse landscape with different habitats and niches, allowing for a diverse range of plant species to coexist, each adapted to different fire regimes or environmental conditions. Therefore, in this study, a greater species diversity was observed farther away from the vlei, showing that fire disturbance near the vlei had a significant impact on species composition. Thus, there was high fire frequency and intensity closer to the vlei.

The decline in species diversity near the vlei may be attributed to increased fire frequency or intense fires in the area, leading to the dominance of fire-adapted species or a decline in more sensitive species. According to Bond and Keeley [19], repeated fires favor species that can resprout, have fire-resistant seeds, or grow quickly, leading to a decrease in species diversity over time. Since the vegetation is the potential source of these recurring fires, species diversity is likely to decrease in the surrounding areas. Other factors, such as soil moisture levels or nutrient availability, may also contribute to the observed patterns in species diversity. This is because areas with hot or frequent fires often result in the loss of major nutrients such as nitrogen, phosphorus, and organic carbon, while cooler fires facilitate the release of nutrients from organic matter into the soil. A study conducted in Angola showed that in intensely burned areas, nutrient levels are much lower than in areas with less frequent fires. Stellmes et al. [34] and Wallenfang et al. [35]. However, woody species farther from the vlei may have access to more favorable environmental conditions, allowing for the coexistence of a greater variety of species adapted to different ecological niches [36].

Gandiwa et al. [17] also highlighted that the difference in species diversity across the distance gradients might be because some species were lost to burning and replaced by some relatively fire-tolerant species. Enslin et al. [20] and Govender et al. [37] in their studies, they discovered that there was no significant change in species composition after burning in Kruger National Park, South Africa. But some studies conducted by Heinl [32] and O'Connor [38] clearly showed that frequent fires have negative effects on species diversity, and it has been recorded in several fire experiments. That is the reason why species diversity decreases as we move closer to the source of fire. The data on species richness show a significant difference across a distance gradient away from the vlei, with a sharp decrease in species richness near the vlei. This pattern indicates that the closeness to the vlei and the fire disturbance have a major impact on the diversity and composition of woody species in the study area.

The higher species richness observed further away from the vlei implies the presence of a more diverse variety of plant species. This could be due to a number of variables, including decreased fire frequency and intensity or more favorable environmental conditions that support a wider range of plant species [19]. Since frequent or hot fires are detrimental to soil, it might be possible that, far away from the source of fires (vlei), conditions are likely to be conducive for species richness. According to Stellmes et al. [34] and Wallenfang et al. [35], hot fires often result in the loss of major nutrients and moisture availability in the soil. Scientifically, fires make soils prone to erosion, leading to the washing away of nutrients with the soil. Fire disturbance can function as a selective pressure in fire-prone ecosystems, favoring species with fire-resilient features like resprouting ability or fire-resistant seeds [18]. As a result, the lower species richness found closer to the vlei may indicate the dominance of fire-adapted species that can remain or regenerate when there are recurring fires. The fall in species richness approaching the vlei could be potentially driven by frequent and intense fires facilitated by too much accumulation of fuel loads. Only fire-dominant species can survive in these areas; thus, the less-adapted species will slowly disappear over time.

Findings in this study show significant differences in both sapling abundance and species diversity across distance gradients from the vlei. This agrees with findings by Smith et al. [39] and Jones and Brown [40]. Midway distances exhibiting higher sapling abundance and species diversity than near and far plots clearly demonstrate that the impact of fire on vegetation structure and composition decreases with distance from the vlei. The higher sapling abundance and species diversity at midway distances support predictions of the Intermediate Disturbance Hypothesis (IDH). Thus, according to Connell [41] and Staver et al. [3], moderate disturbance can promote species coexistence and biodiversity by allowing for colonization and reducing competition. In the context of this study, the intermediate fire disturbance experienced by midway plots may have led to the establishment and persistence of a variety of woody species, resulting in more regeneration and species richness than plots closer to or farther from the vlei.

There is lower sapling abundance and species diversity in the extremes, far and near distances. Limited exposure to fire and disturbance, reduced opportunities for colonization and growth, and dominance of established plants in the far distance resulted in a decrease in sapling abundance and species diversity. However, the near distance experienced high fire frequency and intensity, high disturbance levels, and increased competition from fire-adapted species, which affected the regeneration status. The following sapling species were recorded during the study*: C. mopane, D. cinerea, S. nigrescens, V. tortilis, K. acuminate, V. karoo, T. sericea, and B. plerijuga*. However, mopane had more regeneration across all distance gradients. Mopane trees are well-adapted to semi-arid conditions, making them resistant to hot, frequent fires near the vlei. They also managed to thrive in the midway category because there was moderate disturbance, which also promoted colonization and reduced competition [42]. This also shows that mopane species are the ones that colonize the area after fire. However, these species also managed to dominate in the far distance because of less frequent fires, effective dispersal ability, and tolerance to shade.

5. CONCLUSION

In conclusion, this study demonstrates the significant impact of fire on woody vegetation structure and composition across a distance gradient from the vlei. The findings show that fire intensity and frequency decrease with increasing distance, resulting in varied fire regimes and vegetation responses. Species richness and diversity decrease with distance from the vlei, with fire-adapted species dominating near the vlei and fire-sensitive species prevailing at greater distances. These results highlight the importance of considering spatial patterns in fire regimes and vegetation responses for effective fire management and conservation efforts. To manage fire-prone ecosystems effectively, a landscape approach should be adopted, recognizing the distribution patterns of fire and vegetation to inform prescribed burning, fire management planning, and conservation efforts accordingly. This should be complemented by establishing monitoring programs, engaging local stakeholders, and dividing the giant Kanda vlei into sections (fireguards) to contain and manage fires. Ultimately, fostering collaboration across disciplines, including ecology, fire science, land management, and indigenous knowledge, is necessary to promote ecosystem resilience and balance conservation.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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