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The impact of bushfires on animal abundance and diversity across land tenures in Miombo woodlands, Tanzania

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Abstract. *Matimbwi L, Madoffe SS. 2022. The impact of bushfires on animal abundance and diversity across land tenures in Miombo woodlands, Tanzania. Asian J For 6: 43-51.* Southern Africa is dominated by Miombo forests (woodlands), the world's largest savanna. The purpose of this research was to examine how bushfires affect mammalian populations in Miombo woodlands under various forest tenure systems. The data was gathered through household questionnaires, a probing question checklist for key informants, participant observation, Participatory Rural Appraisal (PRA) methods, and a field inventory. We enlisted the aid of the local communities in our analysis of the PRA data we collected. Quantitative and qualitative data and information were subjected to content and structural-functional analysis. Quantitative data was examined using Statistical Package for the Social Sciences (SPSS) software. Microsoft Excel was used to examine inventory data on animal stocks. The average number of mammals collected from each forest tenure system was compared using Analysis of Variance (ANOVA) to see if there were statistically significant variations. The variety of mammal species in various forest tenure systems was measured using the Shannon-Wiener Index (H). Based on the findings, agricultural activities (44.5%), charcoal production (21.1%), and wildlife hunting (18.9%) accounted for the vast majority of bushfires in Miombo woods. It was thought that illegal logging and honey collection were the only contributing factors. Mammal populations tend to be most significant in Central Governmental Forest Reserves, then in those of the Local Government, and finally in those of the Village Government. Mildly burned sections in the Central Governmental Forest Reserve had a diversity index of 3.2. In contrast, those in the Local Government Forest Reserve and the Village Forest Reserve had indices of 2.0. There was little difference in the diversity index values of the Central Governmental Forest Reserve (2.0) and the Village Forest Reserve (2.0) for moderately burned blocks and the Local Government Forest Reserve (1.6) for unburned blocks. The Central Governmental Forest Reserve had a diversity value of 1.5 for the severely burned blocks, the Village Governmental Forest Reserve had a value of 1.4, and the Local Government Forest Reserve had a value of 1.2. Like other mammals with a low fire escape rate, bushfires hit the rock hyrax particularly hard. As a result, it is suggested that the current management regimes of Local Government Authorities be strengthened to ensure enhanced local community participation with more effective law enforcement measures to save the woods from deterioration. Similarly, communities should be given access to financing and encouragement to pursue income-generating activities to lessen their reliance on Miombo woodlands.

Keywords: Africa, fires, forest, mammals, woodlands

INTRODUCTION

Forests covered an estimated 38.8 million ha (41% of the total land area) on the Tanzanian mainland in 2011 (FAO 2011a). The combined acreage of all wild and cultivated woods is called "forested." The Miombo woodlands are some of the world's largest unbroken savannas (Desanker et al. 1997). Even though current data on the provision of products and services is underestimated due to the lack of recording of other forest products, apart from timber, such as wild fruits, vegetables, herbs, thatch grasses, and other services such as catchments and biodiversity values, the contribution of these forests to the national economy is very high (URT 2002). MNRT (1998) estimates that more than 75 million Africans call the Miombo ecoregion home and that the woodlands there are directly responsible for the well-being of more than 40 million.

The Miombo is crucial to local economies but is at risk from bushfires (Chidumuyo 2002). Large and tiny organisms can be lost in forests threatened, and a decrease in forest productivity could be caused by fire (Gleason et al. 2013; Prasetya et al. 2017; Dickman and McDonald 2020; Prestes et al. 2020; Schwartz et al. 2020,2021; Feng et al. 2021), which is a constant danger in natural and artificial forests. Most Miombo woodland species see a decline in numbers during and immediately following fires. Many creatures and vegetation perish as individuals due to fire or suffocation. Others may survive the fire but may not fare as well due to a lack of food and shelter (UNEP/SARDC 2009). Of course, some mammals make it through fires, and, like plants, they have a wide variety of strategies for adaptation (Davies 2011). It's commonly believed that fire is bad for plants and animals, yet it can also positively affect specific ecosystems.

The only feasible method of decreasing fuels in forests and woodlands is the low-fire-intensity burning of litter and undergrowth during pleasant weather conditions (Viklund 2011). Mechanically removing litter and undergrowth is one alternative strategy that has been proposed, but it is neither practical nor cost-efficient. Fire can help with land management by reducing fuel loads before they become a problem. Tasks linked to clearing brush and trimming trees, such as keeping trails clear. Fire buffers can be quite

helpful in preventing and mitigating the damage caused by natural bushfires (Stephens 2010). The seeds of some plants can only be dispersed if exposed to high temperatures or smoke. It indicates that fires are essential to the survival of some plant species and their ability to reproduce (Davies 2011).

Wildfires significantly impact the economies of many eastern and southern African countries, including Tanzania. Although the lack of long-term fire monitoring programs currently hinders attempts to estimate the spatial distribution and size of wildfires in Tanzania, the limited number of available information sources suggests that fire is a pervasive phenomenon. Around 12% of Tanzania's land was lost to fires every year between 2001 and 2007 (Archibald et al. 2010), placing the country fourth in the Southern African Development Community (SADC). About 65,000 hectares (ha) of forests and other forested areas are lost annually to forest fires (MNRT 2009). More than seventy-five percent of these fires happen in Miombo woodlands, followed by forest plantations (20%) and nature reserves (5%) (MNRT 2009).

Tanzania's forests are administered by three fire management authorities: the national, provincial, and community levels (MNRT 2009). The current study is to create data that could aid management decisions by determining the impact of bushfires on animals in Miombo woodlands under different forest tenure regimes, such as those administered by the Central, Local, and Village Government Authorities.

It is generally accepted that the increased frequency of bushfires in the Miombo woodland of Kilombero District, Tanzania, can be attributed to the influx of cattle herders and farmers from other areas searching for pastures and farming land. Due to its ability to alter the post-fire microclimate and the activity of soil biota, fire has both detrimental and beneficial direct effects on conservation. There is a vast range of variation across organisms in their reactions to and resilience against fire (Zohlo 2005).

The objectives of this research are (i) to identify the factors that contribute to the occurrence and severity of bushfires across a range of Miombo woodland tenure types, (ii) to determine how bushfires have affected the kind and number of mammals in the research areas, (iii) to assess and report on the performance of fire management techniques used in each of the study forests.

MATERIALS AND METHODS

Study area

Location

Three Miombo woodland reserves in Kilombero District, Tanzania, were selected for this research. Ihanga FR (under the District council) is located between longitude 080 25" South and longitude 36020" East, and Itundufura FR (under the Village government) is located between longitude 08018" south and latitude 360 06" East. Nyanganje FR (under the Central government) is located between 07° 56′ and 8° 4′ South and longitude 36° 39′ and 36° 50′ East, approximately 15 km north-east of Ifakara town. The district covers 14,918 square kilometers and is located at an elevation of between 300 and 1,700 meters.

Climate

In the Kilombero District, annual average rainfall typically ranges from 1200 to 1850 millimeters. The district experiences a bimodal rainfall pattern with lengthy wet seasons from March to May and short rainy seasons from October to December, with average daily temperatures between 26°C and 32°C.

Flora and fauna

In most cases, environmental factors, such as soil conditions and dynamic events like fire, determine the species mix of an area (Frost 1996). For example, tree species include *Brachystegia boehmii, Brachystegia bussei, Julbernardia globiflora, Brachystegia spiciformis, Pseudolachnostylis maprouneifolia, Pterocarpus angolensis,* and *Dalbergia melanoxylon* can be found in the Miombo woodland (Backe'us et al. Besides those mentioned above, the same woodland area in Kilombero District is home to a wide variety of other animals, including elephants (*Loxodonta africana*), buffaloes (*Syncerus caffer*), lions (*Panthera leo*), spotted hyenas (*Crocuta crocuta*), rock hyraxes (*Procavia johnstoni*), greater kudus (*Tragelaphus streps*) (Frontier Tanzania 2003).

Human population and economic activities

According to the population and housing census of 2012, Kilombero District had a population of 321,611 people, of which 169,397 were males and 162,214 were females. The growth rate is 3.4% above the National annual average of 2.1%. The main ethnic groups are Wapogoro, Wandamba, Wabena, Wambunga, and several others in small proportions. On the other hand, the main economic activities conducted by the majority of the local people include crop farming, livestock keeping, and petty trading.

Methods

Reconnaissance survey

It was essential to perform a reconnaissance study of the area before beginning the actual data-gathering procedure to pre-test the data collection gear and make any necessary adjustments to ensure they were suitable for the local conditions.

Data collection

A variety of sources, including the Kilombero District Catchment Project Office, Kilombero District Council Officials, the villagers of Kiberege, Lungongole, and Ihanga who live near the forest, and Non-Governmental Organizations, were consulted to compile the biophysical and socio-economic data used in this study. In addition, different secondary sources were tapped for more data.

Biophysical data

Field inventories were used to compare forest reserves managed by different levels of government, including the

Nyanganje Forest Reserve, the Ihanga Forest Reserve, and the Itundufura Forest Reserve, to determine differences in mammal species composition and distribution. Two local experts who understood Kilombero's fauna and I made up the survey team. The district game officer was also on board. All forest tenures were split into thirds, with each block subjected to varying degrees of fire suppression and distinct categories: minimal damage, moderate damage, and severe damage. Less than a quarter of the former's semi-evergreen forest was destroyed in fires. Open Miombo and grasslands predominated in the severely burned area, while closed Miombo prevailed in the moderately burned area, with between 25 and 50% of its area burned. Villagers' accounts of past wildfire patterns, reports from the District Forest Officer and District Game Officer, and our observations from the field all contributed to pinpointing these locations.

The following formula obtained the number of plots:

N = (TA*Si)/ (Ps*100)

Where: N=number of sampling plots, TA=total area of the forest/block, Si=Sampling intensity, and Ps=plot size. Each study forest was given a potential sampling intensity of 0.01%.

Along the transect that followed the outline of each block, strips (plots) 10 m by 30 m were set up. There was an estimated 6-kilometer distance between each transect. Each transect began at a different location, chosen at random and geo-referenced using a GPS for subsequent reevaluation; compass use was optional but helpful. In this study, each plot and transect were placed 200 meters from one another. The locations of the plots within each block were randomized.

Direct field observations of animals and indirect assessments based on feces, footprints, mammal damages, and sounds of different mammals were used to determine the species diversity and abundances in each plot (indices). For the most accurate and detailed population statistics, small mammals like rodents were captured in a live trapping technique (Sherman trap). Peanut butter was used as bait to lure the rodents into the traps. The group silently traversed the transects, tallying the number of mammals and indices on both sides. Expertise and caution were used to keep from counting the same thing twice. Moreover, to get a good average, counting was done along each transect twice daily, in the morning, in the evening, and every other week. Wildlife experts and residents from the surrounding area helped narrow down the possible mammal species. Large quantities of mammal feces and mammal damage made estimating the number of mammals easier. Estimating mammalian populations was based on the correlation between dung quantity and damage severity. The presence of more tracks and/or a noisier environment suggested the presence of more mammals.

Socio-economic data

Villages adjoining the study forests were surveyed to collect socio-economic data. Ihanga, Sagamaganga, and Kiberege were chosen because they are close to protected forests: Ihanga, Nyanganje, and Itundufura. Information was also collected from local government agencies and Non-Governmental Organizations (NGOs) in the Kilombero District. A Participatory Rural Appraisal (PRA) was conducted before the questionnaire survey. Each PRA consisted of seven to eight participants and collected data through focus groups (Lusambo 2009). Discussions in smaller groups were selected to elicit insights from participants of varying ages, genders, and professional backgrounds (Appendix 2). Kessy (1995) suggests using the PRA as a research tool to spark conversations among rural residents about specific subjects of interest.

Household heads in the research villages were given structured questionnaires with both open-ended and closed-ended questions to collect data on factors such as species abundances, causes of bushfires, areas burned, fire occurrence frequencies, control/measures taken, and fire reduction techniques (Appendix 1). In each town, 30 random households were chosen. As long as the features of the research population are adequately removed, a sub-sample size of 30 from a single observation unit is considered appropriate, as stated by Bailey (1994).

Data analysis

Biophysical data

Mammal abundance and diversity data gathered from a field inventory were analyzed using Microsoft Excel software. Mammal populations in forest reserves have been summarized by species and presented in Table 4. In addition, mammal abundances were compared between forest reserves using Analysis of Variance (ANOVA), specifically between the Nyanganje Forest Reserve, the Ihanga Forest, and the Itundufura Forest Reserve.

The number of mammal species in each forest management system was quantified using the Shannon-Wiener Index (H). In most cases, the figure is between 1.5 and 3.5, although it can go as high as 4.5 in rare cases (Kent and Coker 1992). The following formula is used to calculate the index:

$$H' = -\sum_{i=1}^{s} pi * \ln pi$$

Where;

H" Diversity index

n_i = The number of individuals in species, I = the abundance of species i.

S =The number of species, also called species richness.

pi = Proportion of individual species i^{th} and ln = Natural logarithm

Socio-economic data

There was an effort to use both descriptive and inferential statistics. Cross-tabulation was used to conduct the descriptive statistical analysis, and measures of central tendency (mean and standard deviation) and frequency and percentage distributions were determined. The data were analyzed using Statistical Package for the Social Sciences (SPSS). The socio-economic data gathered from the survey of households' completed questionnaires were coded and converted into an analyzable format.

Qualitative data or information was processed using a content analysis approach. For example, content analysis was used to dissect interviews and focus groups for recurring topics and patterns of conversation. It aided in discerning the respondent's beliefs and perspectives. According to Kajembe (1994), structural-functional analysis involves explaining social facts by how they relate to one another within the social system and the physical environment.

RESULTS AND DISCUSSION

Social characteristics of the respondents

The age distribution, gender, and marital status

Respondents with ages between 31 and 40 made up nearly half (49%) of the total, with those between 18 and 30 years old making up nearly a quarter (22%) of the sample (Table 1). If most respondents are between the ages of 31 and 40, there is a sizable population of young, active people in the area who can help out financially. A person's age influences income-generating endeavors because it influences their level of experience, wealth, and decision-making. In most cases, people over 60 who respond to a survey are not economically active. Therefore they do not engage in activities that could earn them money (Ishengoma 1998). Forest fires may become more common if people engage in economically beneficial activities like farming and hunting.

Men and women have different social roles depending on their gender. It alludes to the nature of their bond and the societal construction of that bond (Balton 1994). The differences in how men and women are expected to act are primarily the result of social conditioning. That influences what they do and how they act inside a given group (Katani 1999). As a result, gender as a social relation significantly affects men's and women's roles in the administration and protection of ecological systems (Balton 1994).

About two-thirds (74.4%) of the participants were male, while about a quarter (25.6%) were female, according to the results (Table 1). It indicates the conventional gender roles in traditional African communities, where men head most households.

A large proportion of responders (84%) were widowed, separated, divorced, or single (16%) (Table 1). It reflects the widespread notion in African societies that a team of two people can accomplish more than one person working alone, and that married couples are more likely to have a more prosperous home than single people (Muywanga 2004). In terms of household composition, however, married and unmarried respondents represent adults.

Level of education, residence duration, and economic activities

As a means of sharing information and fostering new perspectives, education is crucial to a society's economic and social growth. Knowledge and the ability to think for oneself are only some of the many benefits of a good education. It was hypothesized that as education levels rose, more respondents in the study area would adopt the sustainable land use practices advocated by Participatory Forest Management. It is because those with higher levels of education have greater access to the technical information that enables them to participate in innovations than those with lower levels of education. The respondent's time in school was used as a proxy for their degree of education. Table 1 shows that 83% of respondents have completed elementary school, 12% have completed high school, and roughly 4% have never attended school. With an elementary education as their highest level of education, most responders may have some understanding of conservation issues.

In addition, the findings showed that 46% of respondents had been residents of the research area for more than 20 years, followed by 38% for 11-20 years and 17% for ten years or less (Table 1). It suggests that most respondents have a good grasp of the current fire situation and its effects and potential solutions to the problem of forest fires in the area.

Respondents primarily engaged in farming and small business, with a negligible percentage engaged in other economic activities (Table 1). Farmers made up the vast majority (86.7%), followed by those working in related small businesses (5.6%) and those involved in keeping livestock (3.3%). Cattle keepers use Miombo woodlands as grazing pasture for their livestock due to the floristic composition of Miombo woodlands, which has led to deforestation (Abdallah 2001; Kajembe and Kessy 2004). Many Miombo livestock farmers utilize fire to stimulate grass growth for their animals. Similarly, farmers use fire to reduce biomass when setting up farms, and this fire occasionally spreads to neighboring forests, causing damage. According to data collected by the District Forestry Office in 2011 (DNRO 2011), farmers are the primary perpetrators of forest fires in the district, followed by those who keep cattle and pasture animals.

Ethnicity and household size of respondents

Table 2 shows that Ngindo households comprised 19% of the households surveyed, followed by Ngoni families at 12% and Ndamba households at 11%, with the remaining 58% belonging to tribes other than these three. The Ngindo, Ngoni, and Ndamba prefer to live in the heart of a village. In contrast, agro-pastoralists prefer to live on the outskirts, where they can more easily access grazing and farming area and where they can also use fire to make the land more palatable for livestock.

More than half (45.6%) of the homes had six or more persons, which is higher than the national average of five people (URT 2012). Regarding household composition, families with three to five members accounted for 16.7 %. A household's ability to generate revenue and enhance its standard of living is strongly influenced by the size of its family, but large families may hasten the decline of forest ecosystem services.

Table 1. Characteristics of respondents in Ihanga, Kiberege, and Sagamaganga Villages, Kilombero District, Tanzania

Characteristics/ variable	Frequency			%
	Kiberege	Ihanga	Sagamaganga	
Gender				
Male	27	21	19	74.4
Female	14	8	7	25.6
Age group (in years)				
18-30	7	6	7	22.2
31-40	11	30	13	48.9
41-50	5	6	4	16.7
51-60	2	2	1	5.6
Above 60	3	2	1	6.7
Marital status				
Single	3	4	2	10.0
Married	26	30	20	84.4
Divorced	0	2	1	3.3
Widow	2	0	0	2.2
Education level				
Non-formal education	2	1	1	4.4
Primary education	15	40	20	83.3
Secondary education	1	3	7	12.2
Residence duration				
1-10	4	16	14	37.8
11-20	5	5	5	16.7
Above 20	22	11	12	45.6
Occupation				
Farmers	18	25	25	86.7
Petty trade	2	1	2	5.6
Livestock keeping	1	1	1	3.3
Others	2	1	1	4.4

Table 2. Ethnicity and household sizes of respondents

Characteristics/ variable	Frequency	Percentage
Ethnicity		
Ngindo	21.1	19
Ngoni	13.3	12
Ndamba	12.2	11
Other tribes	43.4	58
Size of the household		
1-2	34	37.8
3-5	15	16.7
Above 5	41	45.6

Causes of bushfire in Miombo woodlands

The causes of bushfires in Miombo woodlands are depicted in Figure 1. The top causes include agricultural preparation (44.5%), charcoal manufacturing (21.1%), hunting (10%), cigarette remnants (5.6%), illegal logging (4.4%), local beliefs (4.4%), honey harvesting (1.1%), and miscellaneous causes (8.9%). As a result of the region's strong population growth and low GDP per capita, slash-and-burn agriculture in the Miombo zone is widely practiced for subsistence (Chidumayo 1997; Luoga 2000). These findings corroborate those of FAO (2011b), which found that unchecked human activities, such as the preparation of agricultural fields, are the leading cause of bushfires in Miombo and grassland ecosystems. Wildlife hunters are another vital contributor; they may intentionally light fires to clear regions of biomass or lure game back to places that have been burned so they can easily capture them in the regenerating grass. Wildfires on the Tanzanian mainland can also be caused by honey-seeking and collecting. When gathering honey, some beekeepers set fires to smoke the bees, but they don't always put out the fires afterward, which might cause unintended or accidental fires. In addition, livestock farmers will intentionally burn grasslands to increase forage quality and, in some cases, to get rid of parasites like ticks and tsetse flies.

There is evidence that charcoal production in Miombo woodlands is a significant human activity that degrades forests, especially within a 200-300 km radius of major urban sites. To prevent unintentional fires from pedestrian smokers and arson, forest plantations, game reserves, and national parks may engage in activities such as mining, pit sawing, and controlled burning (regulated biomass burning) at the start of the dry season. Despite this, most fires are set by individuals for the reasons listed above. However, some people do ignite fires only for amusement (cultural beliefs, e.g., *in Tanzania, some tribes believe that if one starts the fire and it ends up gutting and spreading to a large extent, such a person is bound to live a long life*).

Bushfire occurrence and intensities in Miombo woodlands

Instances of wildfires were recorded from 2005 to 2011 in Table 3. The results demonstrated the frequency and intensity of fires vary yearly due to the multiple elements that contribute to bushfires, such as the forest biomass, the causes of fires, and the weather. VFR typically had the fewest fires and the lowest fire intensities, while LGFR typically had the most. The number and strength of CGFR were about average.

The degree to which people felt ownership of their land (as measured by tenure and financial incentives) may have contributed to the number and severity of fires. The Food and Agriculture Organization of the United Nations (2010) states that many factors have a role in whether or not a government decides to implement tenure reform. Changing tenure patterns with more variety is essential to improve circumstances for achieving forest management goals. The goals of saving mammalian populations and diversity are related to Sustainable Forest Management and improved economic consequences.

Results demonstrated statistically significant differences between the means of blaze occurrences in the CGFR and the VFR, with the difference between the two being 0.956 ± 0.337 and 1.556 ± 0.334, respectively ($p < 0.05$), indicating a higher frequency of bushfire occurrences in these forest reserves. Miombo woodlands are home to a wide variety of mammal species, so all forest reserves must work to prevent bushfires. Better strategies for managing wildlife and, by extension, minimizing the negative impact of wildlife on natural resources can be attained by encouraging local and higher governmental authorities to adopt community development plans, enforce regimes to emphasize risk mitigation, and fire-smart principles (British 2010).

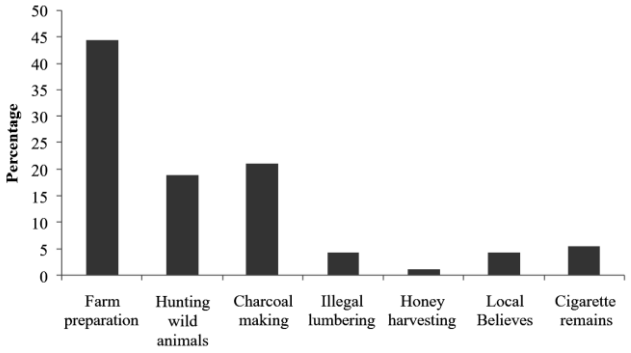

Figure 1. Causes of bushfire in Miombo woodlands

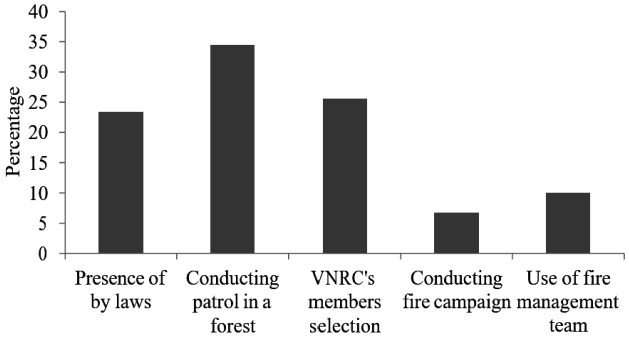

Figure 2. Bushfire management strategies in Miombo woodlands

Table 3. Bushfire intensities in Miombo woodlands

Year management regime	Number of fires occurred	Fire intensity
2005 Nyanganje FR	1	Low
Ihanga FR	2	Moderate
Itundufura FR	1	High
2006 Nyanganje FR	2	High
Ihanga FR	5	High
Itundufura FR	1	Moderate
2007 Nyanganje FR	3	Moderate
Ihanga FR	6	High
Itundufura FR	1	Moderate
2008 Nyanganje FR	1	Low
Ihanga FR	3	High
Itundufura FR	2	Moderate
2009 Nyanganje FR	2	High
Ihanga FR	1	High
Itundufura FR	1	Moderate
2010 Nyanganje FR	2	High
Ihanga FR	4	High
Itundufura FR	2	Low
2011 Nyanganje FR	1	Low
Ihanga FR	2	High
Itundufura FR	2	Low

Bushfire management strategies in Miombo woodlands

Even though Miombo woodlands employ a multitude of wildfire control mechanisms to prevent bushfires from occurring, fire still poses a hazard to the survival of mammals there. The use of by-laws (23.3%), conducting bushfire campaigns (6.7%), conducting forest patrols (34.4%), choosing VNRC members to serve as critical implementers of participatory forest management (25.6%), conducting forest patrols (34.4%), and conducting fire management teams (10%) are among these strategies (Figure 2). In addition, the Strategic Bushfire Management Plan (SBMP) outlines the strategies and concrete steps communities, and the government can take to manage bushfires better and lessen the damage. Those damages would cause property, human life, and the environment need to manage now and in the future, including potentially catastrophic events (Corbell 2009). However, 34.4% of respondents to this poll claimed no fire management plans in their villages, while 65.6% said there were fire management procedures in the area. It demonstrates that the local communities near forests do not effectively adopt the policies, which results in poor forest conservation.

PFM was used as a fire management strategy in the Miombo woods. The results showed that 63.3% of the households believed PFM significantly reduced the number of fires in the Kilombero Forest Reserves. However, inadequate institutional capacity in terms of technical and professional employees and financial resources, according to FAO (2011c), failed to manage the fires appropriately. In light of this, it is important to promote community involvement, engagement, and collaboration in integrated fire management. About 32.2% of the households said that PFM does not help to reduce fire occurrences, while 4.4% said they knew nothing about PFM (Figure 3).

According to the statistical analysis, there is no statistically significant difference ($p < 0.05$) between the fire suppression tactics used in the forest under the CGFR and LGFR (0.00 ± 0.125) and VFR and CGFR (0.033 ± 0.125), respectively. It demonstrates how different management regimes for forests have varied fire management practices.

Status of mammals due to forest fire

About 71% of respondents claimed that fire-related extinctions of mammal species in the Miombo woodlands had occurred, whereas 29% claimed that mammal species had not changed. Forest fires change the energy, nutritional, and water fluxes between the soil, plants, and atmosphere by reducing plant biomass and litter. These changes could affect the vegetation's productivity and long-term nutrient status, ruining other mammals' habitats (Frost 1996). Additionally, fires cause individual creatures to perish, injure or destroy living tissues, altered growth and reproduction rates, alter resource availability and utilization, and change competitive and other connections between organisms. Mammals are also vanishing because of hunting, and some are escaping from their specialized habitats.

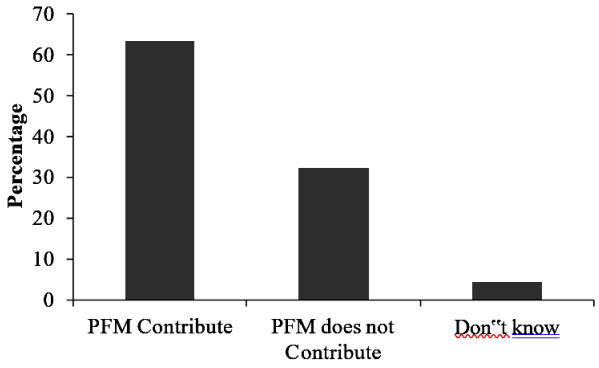

Figure 3. Contribution of PFM in alleviating bushfire problems

Effect of fire regimes on mammal species diversity in different forest tenure

In moderately burned forest blocks, the Shannon Wiener diversity index value was 2.0 under the control of the Central Government (Nyanganje Forest Reserve) and 1.6 under the control of the Village Government Authority (Itundufura Forest Reserve) (Figure 4). For badly burned blocks, the CGFR (Nyanganje Forest Reserve), Village Government Authority (Itundufura Forest Reserve), and Local Government Authority (Ihanga Forest Reserve) had diversity values of 1.5, 1.4, and 1.2, respectively. In the CGFR (Nyanganje Forest Reserve), under VFR (Itundufura Forest Reserve), and Forest Reserve under Local Government Authority (Ihanga Forest Reserve), respectively, the Shannon Wiener index for blocks that had just moderately burned was 3.2, 2.0, and 1.6.

Overall, the Shannon Wiener diversity index values (H) showed that the CGFR had the maximum diversity, followed by the VFR. In contrast, the LGFR had the lowest diversity (Figure 4). These results are consistent with those made by Zahabu (2008), who found that managed forests had a higher species diversity than unmanaged ones. In Tanzania, the woods managed by the Central Government are typically better than those by LGFR. Because of a combination of law enforcement and nearby local populations' participation in forest resources, species variety is more significant in the woods managed by the Central Government. The most significant concern to the Eastern Arc Mountain forests, according to Madoffe and Munishi (2005), is wildfire, which can have a catastrophic impact on biodiversity and water conservation. According to the Shannon Index, there was no discernible difference (p 0.05) in how bushfires affected the mammal species found in forest tenure regimes. The roughly parallel fire regime lines suggest that bushfires in Miombo woodlands under various forest tenures have more or less identical effects on mammals.

Effect of fire regime on mammals abundance under different forest tenure

The number of animal species found in the forests under various tenures is depicted in Figure 5. Mammal abundance is directly impacted by forest tenure and fire management practices. In the mildly burnt site, the distribution of mammals in terms of their numbers per hectare revealed that the numbers were 45, 22, and 20 for CGFR, LGFR, and VFR, respectively. The corresponding CGA, LGA, and VFR numbers for a moderately burned site were 28, 23, and 24. Mammal counts for the severely burned site were 25, 23, and 10 for CGFR, VFR, and LGFR, respectively. Mammal populations in the VFR and LGFR were often substantially lower than those in forests owned by the Central Government. Due to improved habitats in the CGFR as a result of better management, the number may be higher. The Central Government has a consistent budget, more patrols, and better law enforcement (Madoffe and Munishi 2005).

Mammals leave the LGFR for protection because the surrounding communities have significantly encroached on the Local Government forests, and they don't feel safe. In addition, protecting forests overcomes rural poverty and helps to ensure the long-term survival of mammals and the trees that serve as their habitat (Penn 2010). A total of 16 animal species were found in the three studied forests. Table 4 lists the dominant mammal species found, including *Kobus vardoni, Madoqua kirki, Colobus angolensis sharpie, Phacochoerus africanus*, and Rodents. With roughly 43.3% of all species counted, the *Colobus angolensis sharpie* species dominate CGFR, LGFR, and VFR forests.

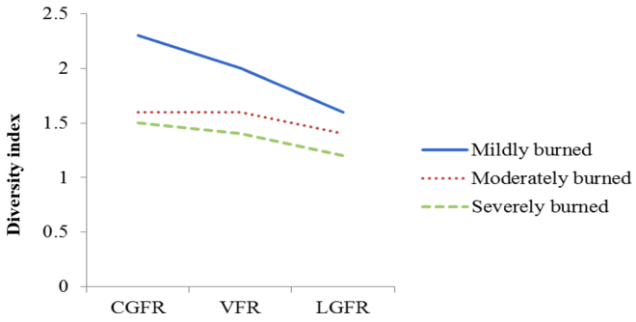

Figure 4. Effect of fire regime on mammal species diversity in different forest tenure, Kilombero District, Tanzania

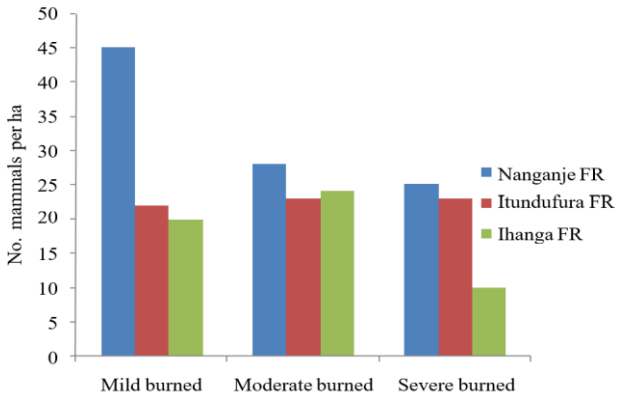

Figure 5. Mammals abundance in forests under different tenure

Table 4. Mammals species in different forest tenure, Kilombero District, Tanzania

Forest tenure, Fire regime	Common name	Scientific name	No. of mammals
CGFR			
Mild	Puku	*Kobus vardoni*	1
	Buffalo	*Syncerus caffer*	5
	Elephant	*Loxodanta africana*	3
	Reedbuck	*Redunca arundinum*	2
	Eland	*Taurotrugus oryx*	1
	Colobus monkeys	*Colobus angolensis sharpie*	12
	Hartebeest	*Alcelaphus bucelaphus lichensteinii*	3
	Sable antelope	*Hippotragus niger*	1
	Waterbuck	*Kobus ellipsiprymnus*	1
	Zebra	*Equus quagga*	1
	Rock hyrax	*Procavia johnstoni*	2
	Dik dik	*Madoqua kirki*	4
	Lion	*Panthera leo*	1
	Warthog	*Phacochoerus africanus*	2
	Rodent	Rodentia (1)	5
	Greater Kudus	*Tragelaphus strepsiceros*	1
Moderate	Elephant	*Loxodanta africana*	2
	Colobus monkeys	*Colobus angolensis sharpie*	5
	Waterbuck	*Kobus ellipsiprymnus*	1
	Rodents	Rodentia (2)	3
	Rock hyrax	*Procavia johnstoni*	2
	Dik dik	*Madoqua kirki*	1
Severely	Elephant	*Loxodonta africana*	2
	Colobus monkeys	*Colobus angolensis sharpie*	37
	Waterbuck	*Kobus ellipsiprymnus*	8
	Rock hyrax	*Procavia johnstoni*	6
	Dik dik	*Madoqua kirki*	4
	Warthog	*Phacochoerus africanus*	6
	Rodents	Rodentia (3)	12
VFR			
Mild	Elephant	*Loxodanta africana*	2
	Reedbuck	*Redunca arundinum*	2
	Colobus monkeys	*Colobus angolensis sharpie*	7
	Hartebeest	*Alcelaphus bucelaphus lichensteinii*	2
	Rock hyrax	*Procavia johnstoni*	2
	Dik dik	*Madoqua kirki*	2
	Lion	*Panthera leo*	1
	Warthog	*Phacochoerus africanus*	2
Moderate	Colobus monkeys	*Colobus angolensis sharpie*	7
	Waterbuck	*Kobus ellipsiprymnus*	3
	Rock hyrax	*Procavia johnstoni*	4
	Dik dik	*Madoqua kirki*	5
	Warthog	*Phacochoerus africanus*	4
Severely	Colobus monkeys	*Colobus angolensis sharpie*	12
burned	Waterbuck	*Kobus ellipsiprymnus*	1
	Dik dik	*Madoqua kirki*	2
	Rodents	Rodentia (4)	4
	Rock hyrax	*Procavia johnstoni*	2
	Warthog	*Phacochoerus africanus*	2
LGFR			
Mild	Colobus monkeys	*Colobus angolensis sharpie*	7
burned	Hartebeest	*Alcelaphus bucelaphus lichensteinii*	4
	Rock hyrax	*Procavia johnstoni*	2
	Dik dik	*Madoqua kirki*	2
	Warthog	*Phacochoerus africanus*	4
	Rodents	Rodentia (5)	9
Moderate	Hartebeest	*Alcelaphus bucelaphus lichensteinii*	2
	Waterbuck	*Kobus ellipsiprymnus*	3
	Warthog	*Phacochoerus africanus*	2
	Rodents	Rodentia (6)	3
Severely	Colobus monkeys	*Colobus angolensis sharpie*	9
	Hartebeest	*Alcelaphus bucelaphus lichensteinii*	3
	Waterbuck	*Kobus ellipsiprymnus*	2
	Rodents		10

The study demonstrated how different forest management systems have very different distributions of animal species. The widespread occurrence of these species may have been caused by wildfires, which are not favorable to their continued existence. Rodents and monkeys, who have strong fire escape rates, were not significantly impacted by fire, although sluggish/slow animals like rock hyrax may have been. Fire may also indirectly affect mammals, especially if it clears out habitats and destroys their food sources and niches. While elephants and giraffes need tall trees or plants to eat on and for shade, some species, like lions, need tall grass to hide from their prey. In contrast, a temperate forest might support green grass growth, which would favorably affect the environment for population expansion.

In conclusion, the study examined the impact of different forest tenure systems on the abundance of animals in Miombo woods. The following conclusions are drawn from the study's results. (i) The study unequivocally shows that agricultural preparation, charcoal production, and wild animal hunting are the primary causes of bushfires in Miombo woodlands. Cigarette ashes, illegal wood harvesting, folklore, and honey gathering also cause some fires. (ii) It was discovered that CGFR had the most diversity of mammals, followed by VFR, while LGFR had the least diversity. Similar numbers of mammals were present in areas that had been burned lightly, moderately, and least in areas that had been severely burned. (iii) The discrepancies in the numbers of mammals found in the various forest regimes can be attributed to differing local community involvement and strict law enforcement. It indicates that conservation is most successful in the CGFR, then the VFR, and least effective in the LGFR. (iv) Several fire control measures, including patrol, PFM, and law enforcement, are used in the research region but only in the CGFR. (v) In addition, social and economic characteristics, particularly the respondents' education level, gender, and length of residency, had a favorable, significant impact on forest conservation, particularly in reducing fire incidences.

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