Tanzania Journal of Science 48(2): 294-303, 2022
ISSN 0856-1761, e-ISSN 2507-7961

Comparison on Vegetation Composition and Structure in Fire Prone Forest of Ilunde and Fire Suppressed Forest of Kitwe in Tanzania

Nyatwere D Mganga
Department of Biology, University of Dodoma, P.O. Box 338, Dodoma, Tanzania.
E-mail address: nyatwere2@yahoo.com
Received 31 Jan 2022, Revised 14 May 2022, Accepted 16 May 2022, Published Jun 2022
DOI: https://dx.doi.org/10.4314/tjs.v48i2.6

Abstract

Fire is among the factors influencing survival and development of plants in ecosystems. This study was conducted in frequently burnt and fire suppressed miombo woodlands of Ilunde and Kitwe, respectively. Tree stem density, basal area and composition of plants were determined. The methods used involved recording the numbers of tree stems, diameter at breast height and classifying vegetation to species level. In Kitwe forest, mean stem density of 582.7 ± 52.90 stems ha^{-} was higher than 356.8 ± 38.98 stems ha^{-} which was recorded in Ilunde forest ($t = 15.98$, $df = 29$, $p < 0.05$). Similarly, a higher mean tree basal area of 16.14 ± 1.32 m^2 ha^{-} was recorded in Kitwe forest, while 8.54 ± 0.94 m^2 ha^{-} being recorded in Ilunde forest ($t = 3.34$, $df = 14$, $p < 0.05$). Czekanowski's similarity coefficients for trees, shrubs and saplings, and herbs and grasses were 0.46, 0.34 and 0.22, respectively. Fire adapted species were recorded in Ilunde forest. Fire prone miombo woodland had lower tree stem density, basal area and dominated by fire adapted species. Similarity coefficient between the two forests was also low. Prescribed burning is recommended in miombo woodlands for sustainable species composition and tree structure.

Keywords: vegetation, composition, structure, fire prone, miombo.

Introduction

Forests and woodlands are fundamental global ecosystems which provide food, timber, medicine, clean water, aesthetic and spiritual values, in addition to environmental moderation (McKinley et al. 2011). Yet natural and anthropogenic disturbances shape forest and woodland systems by influencing their composition and structure, ultimately altering their products and/or services. Species composition and structure of miombo woodlands is fairly consistent over huge regions due to similarity in key environmental conditions (Chidumayo 1993). The woodlands consist of an upper canopy of umbrella-shaped scattered trees with no sub-canopy layer. Furthermore, shrubs and saplings form a discontinuous understorey over the patchy layer of grasses, forbs and suffrutices (Chidumayo 1993). Differences in species composition in these woodlands are more apparent at a local scale. The causes of these differences are largely fire (Backéus et al. 2006) and edaphic factors such as soil texture, soil moisture, soil nutrients, climate, grazing, logging and fuel wood extraction (Bond et al. 2005). However, fire is likely to negatively or positively influence the structure and composition of plant species depending on whether the species referred to are fire-adapted or not (Frost 1996). The varied influence of fires on plants necessitates thorough studies in forests and woodlands due to differences in underlying conditions.

High fire frequencies kill seedlings and saplings of fire-sensitive species, preventing them from growing into over storey trees

(National Institute of Disaster Management 2014, Kelly and Brotons 2017). Okello et al. (2008) argued that fire reduces the ability of fire-intolerant plants to recruit via seeds after fire. Fire-intolerant species include *Bauhinia petersiana*, *Terminalia stenostachya*, *Panicum maximum*, *Hyparrhenia hirta*, *Chrysopogon plumulosus* (Jacobs and Schloeder 2002, Zolho 2005, Ryan and Williams 2011).

Fire adapted plant species are those with protected meristems, below-ground reproductive organs, tillers (grass) stimulated by fires, thick and fissured bark and seeds that can survive fire in which heat/or smoke triggers maturation and germination by breaking the hard-seed coat dormancy (Bond and Midgley 2003, Ryan and Williams 2011, Shuman et al. 2017). Fire adapted plant species common in miombo woodlands include *Cleistochlamys kirkii*, *Crossopteryx febrifuga*, *Dalbergia melanoxylon*, *Julbernadia globiflora*, *Brachystegia microphylla*, *Acacia polyacantha*, *Millettia stuhlmannii*, *Pterocarpus rotundifolius*, *Pterocarpus angolensis*, *Burkea africana*, *Erythrophleum africanum*, *Combretum spp.*, *Afzelia quanzensis*, *Pericopsis angolensis*, *Themeda triandra*, *Diplorhynchus condylocarpon* (Trapnell and Clothier 1937, Everhan and Brokan 1996, Jacobs and Schloeder 2002, Zohlo 2005). Yet, there is limited information regarding the composition of plant species which are found in Ilunde forest which is frequently burnt and a fire suppressed forest of Kitwe.

It is reported that frequent fires change vegetation structure mainly by killing individuals of the small size classes (Staver et al. 2020). However, this is the opposite of what was reported by North et al. (2009) and Ryan and Williams (2011) that individuals with large size classes were mainly affected by wildfires. Thus, different species responses occur because of different allometry and defense mechanisms (Ma et al. 2020). Stem density usually defines the density of a stand and it shows the degree of disorderliness of stems in a given area (Njana 2008). In Mozambique, Williams et al. (2008) reported higher stem density in miombo woodlands that were previously disturbed through burning for more than 20 years than in the protected miombo woodlands. However, in Mozambique 574 stems ha^{-} were recorded in "machambas" (Mozambican-Swahili word meaning small, subsistence farming plots) that were abandoned for more than 20 years (previously slashed and burnt), while in protected miombo woodlands there were 373 stems ha^{-} (Williams et al. 2008). In Tanzania, stem densities in miombo woodlands range between 616 and 980 stems ha^{-} (Zahabu 2001, Giliba et al. (2011).

Apart from stand stem density, basal area, which is the total area of all trees or specified classes of trees per hectare, is a very useful measure of structure (Lowore et al. 1994). It has been reported that generally in miombo woodlands, the basal areas range between 7 and 25 m^2 per ha (Lowore et al. 1994, Malimbwi and Mugasha 2001, Backéus et al. 2006). In Zimbabwe and Mozambique, low ranges of basal area were recorded in the frequently burnt miombo woodlands (Ryan and Williams 2011). The high frequencies of fire in Ilunde forest might be influencing stem density and basal area.

Therefore, the present study aimed to investigate structure and composition of plant species structure and composition in a frequently burnt forest of Ilunde in Uvinza District. A fire suppressed forest of Kitwe found in Kigoma District was used as a control site.

Materials and Methods

Description of the study area

Kigoma is one of the regions of the United Republic of Tanzania (URT) located along the shore of Lake Tanganyika. The region is nestled under the hills of the western arm of the Albertine Rift Valley on the edge of the Lake. The region has an area of 45,066 km^2, of which 8,029 km^2 are covered by water (URT 2008). According to URT (2016), the altitude of the entire region varies from the level of Lake Tanganyika that is 773 m to almost 2000 m above sea level. Kigoma is characterized by tropical rainy climate and experiences one long wet season lasting from November to May and one long dry season. The region as a whole receives modest amount of rainfall varying from 900 mm to1050 mm with some parts receiving relatively close to 2000 mm in the high elevations.

The average annual air temperature for Kigoma region is 24 °C. The soils are predominantly red laterite, although in the flat-lying lowlands black cotton soils dominate (URT 2016). Vegetation typology of Kigoma Region was once characterized by pristine forests of miombo woodlands (Chepstow-Lusty et al. 2006); however, in recent years severe anthropogenic disturbances have altered the plants therein (Personal Communication). The forests in Kigoma Region have valuable tree species such as *Pterocarpus angolensis* (mninga), all species of *Khaya* (mkangazi), *Afzelia quanzensis* (mkola), *Brachystegia spiciformis* (mtundu) and *Pterocarpus tinctorius* (mkurungu) (URT 2008).

The present study was confined to two forested ecosystems, namely Ilunde and Kitwe found in Uvinza and Kigoma Urban Districts of Kigoma Region, respectively. Ilunde Forest Reserve forms the eastern topography of the Kigoma Region which is characterized by low and undulating hills and swampy areas. Yet, this forest has been reported to be frequently burnt. For example, the Moderate Resolution Imaging Spectroradiometer (MODIS) Satellite Imagery of Ilunde forest which was taken from the year 2001 to 2012 indicated that the average number of fires per year was 35 (Mganga and Lyaruu 2016). On the other hand, Kitwe which is dominated by mountainous hills was used as a control since it had been protected from wildfires for more than fifteen years by the collaboration of the United Republic of Tanzania (URT) and United States Agency for International Development (USAID) under the management of the Jane Goodall Institute (Personal Communication).

Ilunde forest is located between latitudes 5º 00 and 6º 00 S, and longitudes 30º and 31º E; while Kitwe forest is located between latitudes 4º 54' and 4º 55' S, and longitudes 29º 36' and 29º 37' (Figure 1). Uvinza District had 383,640 inhabitants, while Kigoma Urban District had 215,458 people (URT 2013).

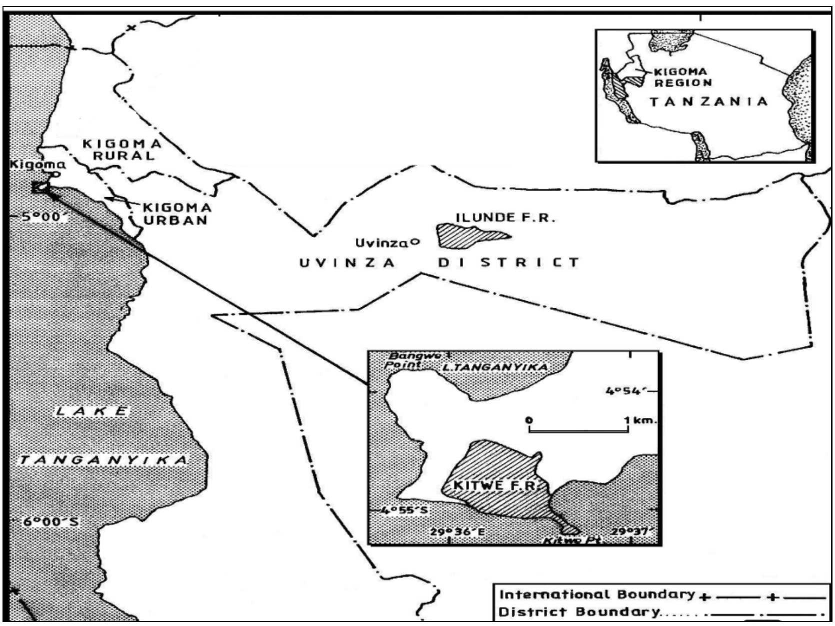

Figure 1: Locations of Ilunde and Kitwe forests in Kigoma region. Source: Field work.

Study design

The inventory design which was used in this study was systematic random sampling. The sampling intensities for Ilunde and Kitwe were 0.03% and 2.4%, considering their area coverage of 6144 ha and 87.78 ha, respectively. Thirty circular concentric plots were established in each forest of Ilunde and Kitwe. The distance between concentric plots was 150 m and 100 m in Ilunde and Kitwe forests, respectively on the basis of their area coverage (Vesa et al. 2010).

Data collection

In each concentric plot, data for determination of stand structure were collected by measuring trees with diameter at breast height (DBH) ≥ 20 cm using caliper in radius with 15 m, radius with 10 m was used to sample trees with DBH ≥ 10 cm but less than 20 cm and radius with 5 m was used to sample trees with DBH ≥ 5 cm but less than 10 cm as recommended by Vesa et al. (2010). In the present study, a tree is defined as a woody species with DBH of ≥ 5 cm as adopted from studies carried out in miombo woodlands of the Eastern Arc Mountains of Tanzania (Zahabu 2008) and in Mozambique (Ryan and Williams 2011). For forked trees, when the forking point was below the breast height, the tree was recorded by giving a unique stem number for each fork, and all stems got the same tree number. If the forking point was above the breast height, a tree was recorded as one stem (Vesa et al. 2010). To determine composition of species; herbs, grasses, shrubs, saplings and trees were sampled using the previously established concentric plots though with some modifications. That is, a radius with 15 m was used to sample trees, a radius with 10 m was used to sample shrubs and saplings and a radius with 2 m was used to sample herbs and grasses. Scientific names and total number of individuals per plot were recorded in the field. All measured trees were identified to species level in the field with an aid of a plant taxonomist. Voucher specimens for species which were difficult to identify in the field were pressed and transported to the herbarium of the Department of Botany at the University of Dar es Salaam for proper identification using respective flora or by matching with dried herbarium specimens of known identity.

Data analysis

The composition of plant species (grasses, herbs, shrubs, saplings and trees) in the two forests was compared using Czekanowski coefficient (Cz). This is because Czekanowski's similarity coefficient is the most powerful, since it incorporates quantitative and qualitative data. Its coefficient values range between 0 (complete dissimilarity) and 1 (which is total similarity) (Magurran 1988). Czekanowski coefficient was calculated using species' abundances per forest pair (Kent and Coker 1992). It is important to assess the composition of plant species in the two forests so as to take immediate interventions to protect fire sensitive plants before losing them. The tree stem density (stems per hectare) (N) which is a useful parameter for defining stocking if it is accompanied with information on diameter was used. Besides, basal area (m^2/ha) was calculated from measured DBH for all trees in all plots. Tree stem density and basal area give information about the amount of trees per unit area of land, thus the stability of vegetation. Tree stem density and basal area in the two forests were assessed using GraphPad InStat software.

Results and Discussion

The composition of plant species in Ilunde and Kitwe forests

The result presented in Table 1 summarizes Czekanowski's coefficients of similarity of all plant species that were recorded in Ilunde and Kitwe forests. Similarity in the composition of plant species between the two sites was fairly low. The highest similarity coefficient of 0.46 was for trees, the lowest being 0.22 for herbs and grasses. This means that tree species in Ilunde and Kitwe forests were similar by 46%, while herbs and grasses were similar by only 22%. On the other hand, the coefficient of similarity in shrubs and saplings was 0.34. This implies that the two forests were a bit similar in trees compared to herbs and grasses.

Table 1: Comparison of plant species composition in Ilunde and Kitwe forests

Plant form	Czekanowski's similarity coefficient
Herbs and grasses	0.22
Shrubs and saplings	0.34
Trees	0.46

The values of Czekanowski's similarity coefficients of species composition were low in that none reached 0.5. The low similarity coefficients in the composition of plant species between the frequently burnt and fire suppressed forests suggest low resemblance. This reveals a complex community, since presence of many species allows a large assemblage of the different species in each site. According to Paré et al. (2010), patterning of species in a forest is believed to maintain varied types of species at the landscape level. The lowest similarity in composition of herbs and grasses between the two forests could have resulted from loss of fire-intolerant species thereby enhancing non-indigenous plants to occupy vacated spaces. In Ilunde forest utilisation of herbs and grasses as fuels during repeated burning enhanced their flourishing and fire adaptation potential. This result is in agreement with Williams et al. (2008) who reported low coefficients of similarity in composition of plant species between disturbed and protected woodlands of Mozambique.

Furthermore, in Ilunde forest, herbs and grasses were mainly different species when compared to a fire suppressed forest of Kitwe. Newbery and Huston (1995) proposed that high fire frequencies promote high species richness of the herbaceous layer by preventing competitive exclusion by woody plants. Shade-intolerant plant species require fire to open gaps in the vegetation canopy that will later on let in light, allowing their seedlings to compete with the more shade-adapted seedlings of other species (Kalaba 2012). As a result, the shade intolerant species take over (United States National Park Service 2006). According to Leach and Givnish (1999), high species types in fire-prone areas result from intermediate resource availability that reduces dominance and elimination of all forms of plants. Dense canopy cover does not favour regeneration since only shade adapted plants can sustain the associated competition (Ryan and Williams 2011).

In Ilunde forest, the most abundant species were the non-miombo defining species, namely *Diplorhynchus condylocarpon*, *Pterocarpus angolensis* and *Strychnos pungens*. The results of this study are in agreement with Ribeiro et al. (2015) who reported that in secondary regrowths of miombo woodlands, the miombo defining species are less abundant following severe disturbance. Miombo defining species *viz. Julbernadia globiflora* and *Brachystegia spiciformis* are fire-adapted and were supposed to be abundant in Ilunde forest. Lawton (1978) reported on *Julbernadia globiflora* and *Brachystegia spiciformis* to be only fire-adapted during the older age, while during the sapling stage required protection from wildfires. In Ilunde forest during the sapling stage of miombo defining species there was no protection from wildfires; it is likely that the species were negatively affected by wildfires thus ultimately lowered in abundance. Williams et al. (2008) did not report any miombo defining species in previously slashed and burnt regrowths in miombo woodlands of Mozambique. On the contrary, Chidumayo and Frost (1996) insisted that after disturbance, for example by wildfires, regeneration is expected to be from stumps/root suckers/shoots and recruitment from old stunted seedlings. In Kitwe forest, of the two most abundant tree species were the miombo defining species *viz. Julbernadia globiflora* and *Brachystegia microphylla*. Also, in Kitwe forest, fire suppression and large accumulation of litter have had rendered vacated niches for fire-intolerant and shade-requiring species. For example, *Podocarpus milanjianus*, a shade adapted species (Department of Water Affairs and Forestry (DWAF) 2005), fire-intolerant species such as *Bauhinia petersiana* and *Panicum maximum* were only recorded in the area.

In Ilunde forest where there were frequent fires the canopies remained open, possibly facilitating seed germination of light-requiring plant species such as *Strychnos* spp., *Albizia gummifera*, *Pterocarpus angolensis* (also fire-adapted) and *Uapaca nitida*. *Themeda triandra*, a grass adapted to frequent burning was only recorded in Ilunde forest. After disturbance in forests by wildfires, there is an increase of insolation reaching the forest floor due to removal of canopies hence favourable germinating conditions and triggering regeneration of light demanding species (Peters 1994).

On the other hand, in Kitwe forest close canopy due to fire suppression and enormous accumulation of litter could explain the absence of light-requiring species such as *Albizia gummifera* and *Uapaca nitida*. According to Kikula (1985), *Uapaca* species is normally eliminated by miombo species when the canopy becomes dense. *Albizia gummifera* apart from being light-requiring species is less fire-adapted and thus, was expected to be abundant in Kitwe. The canopy species in Kitwe forest comprised of *Pericopsis angolensis*, *Burkea africana*, *Crossopteryx febrifuga*, *Afzelia quanzensis* and *Ozoroa insignis* which are known associates of miombo species. The low similarity coefficients of plant species between the frequently burnt and fire suppressed miombo woodlands observed in the present study is in agreement with the findings of Williams et al. (2008). The high abundance of fire-adapted species in frequently burnt areas has been reported in several studies (Jacobs and Schloeder 2002, Zolho 2005, Ryan and Williams 2011).

Tree stem density, basal area and size class contribution of trees in the study areas

The results shown in Table 2 show that mean stem density ± SD of 356.8± 38.98 (stems ha⁻) was recorded in Ilunde forest, while that of 582 ± 52.9 was obtained in Kitwe forest. The results of t test showed that tree stem density was higher in Kitwe forest than in Ilunde ($t = 15.98$, $df = 29$, $p < 0.05$). Likewise, basal area of 8.54 ± 0.94 (m^2 ha⁻) was recorded in Ilunde forest, and 16.14 ± 1.32 being recorded in Kitwe forest. The result of t test revealed that tree basal area was again higher in Kitwe forest than in Ilunde forest ($t = 3.34$, $df = 14$, $p < 0.05$).

Table 2: Tree stem density and basal area in Ilunde and Kitwe forests

Parameter	Ilunde	Kitwe
Basal area (m^2 ha⁻)	8.54 ± 0.94	16.14 ± 1.32
Stem density (stems ha⁻)	356.8 ± 38.98	582 ± 52.9

Furthermore, the stem density of different diameter size classes revealed an inverse J-shaped structure in Ilunde and Kitwe forests (Figures 2 and 3).

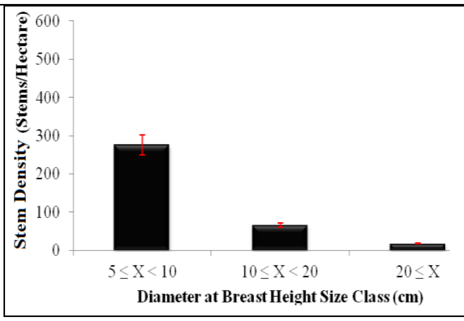

Figure 2: Stem density of different size classes in Ilunde forest. X = Size of diameter at breast height (cm)

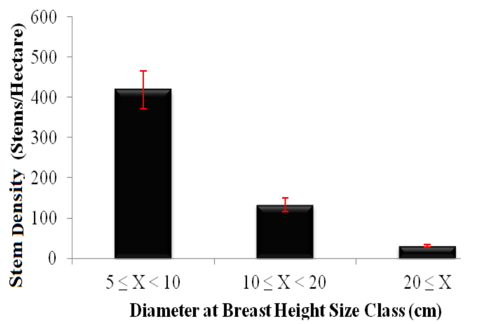

Figure 3: Stem density of different size classes in Kitwe forest.

In this study, trees with DBH of 5 cm but less than 10 cm comprised of 77% and 74% of all trees in Ilunde and Kitwe forests, respectively (Figures 4 and 5). Furthermore, trees with DBH of 20 cm and above constituted 5% in each of Ilunde and Kitwe forests (Figures 4 and 5).

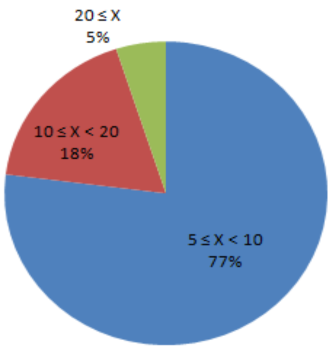

Figure 4: Percentage contribution of different size classes in Ilunde forest.

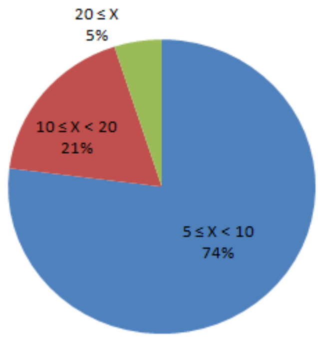

Figure 5: Percentage contribution of different size classes in Kitwe forest.

The diameter size class distribution in all the studied forests depicted an inverse J-shape which has higher number of individuals in the small size class than in the large size class. This structure reveals developing and regenerating forest communities. It is possible that both forests (the frequently burnt and fire suppressed forests) are now recovering from past disturbance. Lejju et al. (2001) suggested that an inverse J-shaped population structure is an indication of a growing group of trees that may have experienced a past disturbance. The presence of mango (*Mangifera indica* L.) in Kitwe forest in several plots signified that there were human settlements and/or practicing agriculture at one time (personal communication). Mango was dispersed from its origin in Myanmar to East Africa by human beings for domestication purpose (Mukherjee 1951).

Furthermore, the highest percentage of trees with the smallest DBH in the two forests suggests a low extraction rate of this size class. On the other hand, a relatively low proportion of trees with the largest DBH in Ilunde forest probably indicates that repeated fires could be limiting small trees to transform to large sizes. Basal areas that were recorded in Kitwe and Ilunde forests were within the ranges of basal area values that had been recorded in other miombo woodlands. However, the basal area values that were recorded in Ilunde forest were comparatively low. An increase in mortality leads to a decrease in tree density and size through a decrease in average longevity, both of which lead to a decrease in basal area (Prior et al. 2009).

Likewise, the higher stem density was recorded in Kitwe forest than Ilunde forest. Probably this suggests that frequent fires create micro-habitats ranging from those in which plant species are burnt and eliminated to those affected by their parts only, while others withstanding such disturbances. This is a form of secondary ecological succession in which burned forests progress through continuous and directional phases of colonization following the destruction caused by the fire (Begon et al. 1996). The result on low stem density in a frequently burnt forest when compared with a fire suppressed forest is contradictory to what was reported by Skarpe (1992). The discrepancy with the present study could be caused by limited trees coppicing in the frequently burnt forest of Ilunde due to repeated fires. The structure of plant species obtained in the present study is in agreement with other studies (Chidumayo 1997, Isango et al. 2007, Munishi et al. 2008).

Conclusion and recommendations

In Ilunde and Kitwe forests similarity in composition of all plant forms was fairly low suggesting distinct microclimate though in the same region. Fire adapted plant species were mainly recorded in a frequently burned forest of Ilunde, while fire-sensitive species found in Kitwe forest. Also, stem density and basal areas were low in the frequently burnt forest compared to the one protected against fires. In forests and woodlands, fires are responsible for increasing the richness of fire adapted species. The depicted structure and composition of plant species may also be explained by other growth conditions like soil moisture and genetic constitution, or it may be a result of edaphic, genetic, topographic, old age senescence, diseases, wind throw and natural succession (González-Rivas et al. 2006, Traoré et al. 2008). However, all these factors were not assessed in this study, therefore recommended for future studies. Also, prescribed burning is recommended in miombo woodlands for sustainable species composition and tree structure.

References

Backéus I, Petterson B, Strömquist L and Ruffo C 2006 Tree communities and structural dynamics in miombo (*Brachystegia-Julbernadia*) woodland, Tanzania. *Forest Ecol*. *Manag*. 230: 171–178.

Begon M, Harper JL and Townsend CR 1996 Ecology, Individuals, Populations and Communities. Blackwell Scientific Publications, Oxford. pp 958.

Bond WJ and Midgley JJ 2003 The evolutionary ecology of sprouting in woody plants. *Int . J. Plant Sci.* 164(S3): S103–S114.

Bond WJ, Woodward FI and Midgley GF 2005 The global distribution of ecosystems in a world without fire. *New Phytol*. 165(2): 525–538.

Chepstow-Lusty A, Winfield M, Wallis J and Collins A 2006 The importance of local tree resources around Gombe National Park, western Tanzania: Implications for humans and chimpanzees. *Ambio*: 35: 124–129.

Chidumayo EN 1993 Silvicultural Characteristics and Management of Miombo Woodlands. Paper Presented in the Conference on International Symposium on Ecology and Management of Indigenous Forest in Southern Africa, Victoria Falls Zimbabwe, July 27 to 29, 1992.

Chidumayo EN 1997 Miombo ecology and Management: An introduction. Stockholm Research Institute, Stockholm, Sweden.

Chidumayo EN and Frost P 1996 Population biology of Miombo trees. Bogor, Indonesia, Center for International Forestry Research.

Department of Water Affairs and Forestry (DWAF) 2005 Environmental Monitoring and Auditing Protocol. Integrated Environmental Management Sub-Series No.1.7. Second Edition. Pretoria, South Africa.

Everhan EM and Brokan NVL 1996 Fire and plants: Population and community. Biology series 14. *Bot*. *Rev*. 62: 113–183.

Frost P 1996 The ecology of miombo woodlands. In: Campbell B (Ed) *The miombo in transition*: *Woodlands and welfare in Africa*. CIFOR, Bogor, Indonesia. pp11-57.

Giliba RA, Boon EK, Kayombo CJ, Musamba EB, Kashindye AM and Shayo PF 2011 Species composition, richness and diversity in miombo woodland of Bereku Forest Reserve, Tanzania. *J. Biodivers.* 2(1): 1–7.

González-Rivas B, Tigabu M, Gerhardt K, Castero-Marin G and Odén PC 2006 Species composition, diversity and local uses of tropical dry deciduous and gallery forests in Nicaragua. *Biodivers. Conserv.* 15(4): 1509-1527.

Isango JA, Varmola M, Valkonen S and Tapaninen S 2007 Stand structure and tree species composition of Tanzania Miombo woodlands: A case study from Miombo woodlands of community based forest management in Iringa District. In: *Proceedings of the 1st Mitimiombo Project Workshop* (pp. 43-56). Finnish Forest Research Institute.

Jacobs MJ and Schloeder CA 2002 Fire frequency and species associations in perennial grasslands of south-west Ethiopia. *Afr. J. Ecol.* 40(1): 1–9.

Kalaba F 2012 Carbon storage, biodiversity and species composition of Miombo woodlands in recovery trajectory after charcoal production and slash and burn agriculture in Zambia's Copperbelt. *Centre for Climate Change Economics and Policy***,** *Working Paper No. 119*; *Sustainability Research Institute Paper No.* 40. pp 1–39.

Kelly LT and Brotons L 2017 Using fire to promote biodiversity. *Science* 355(6331): 1264–1265.

Kent M and Coker P 1992 Vegetation Description and Analysis, A Practical Approach. Belhaven Press, 25 Florida Street, London.

Kikula IS 1985 The influence of fire on the composition of Miombo woodland of SW Tanzania. *Oikos* 46: 317–324.

Lawton RM 1978 A study of the dynamic ecology of Zambian vegetation. *J. Ecol.* 66: 175–198.

Leach MK and Givnish TJ 1999 Gradients in the composition, structure, and diversity of remnant oak savannas in southern Wisconsin. *Ecol Monogr*. 69(3): 353–374.

Lejju JB, Oryem-Origa H and Kasenene JM 2001 Regeneration of indigenous trees in Mgahinga Gorilla National Park, Uganda. *Afr. J. Ecol.* 39: 65–73.

Lowore JD, Abbot PG and Werfen M 1994 Stackwood volume estimations for miombo woodlands in Malawi. *Commonw. For. Rev.* 73: 193–197.

Ma R, Xu S, Chen Y, Guo F, Wu R 2020 Allometric relationships between leaf and bulb traits of *Fritillaria przewalskii* Maxim. grown at different altitudes. *PLoS One* 15(10): e0239427.

Magurran EA 1988 *Ecological Diversity and its Measurement*. Princeton: Princeton University Press.

Malimbwi RE and Mugasha AG 2001 *Inventory Report of Kitulangalo Forest Reserve in Morogoro, Tanzania*. Ministry of Natural Resources and Tourism, Forest and Beekeeping Division, Dar es Salaam.

McKinley DC, Ryan MG, Birdsey RA, Giardina CP, Harmon ME, Heath LS, Houghton RA, Jackson RB, Morrison JF, Murray BC and Patakl DE 2011 A synthesis of current knowledge on forests and carbon storage in the United States. *Ecol. Appl.* 21:1902–1924.

Mganga ND and Lyaruu HVM 2016 Plant species diversity in western Tanzania: Comparison between frequently burnt and fire suppressed forests. *Int. J. Pure Appl. Biosci.* 4(3): 28–44.

Mukherjee SK 1951 The origin of mango. *Indian J. Genet. Plant Breed.* 11(1): 49–56.

Munishi PKT, Philipina F, Temu RP and Pima NE 2008 Tree species composition and local use in agricultural landscapes of west Usambaras Tanzania. *Afr. J. Ecol.* 46: 66–73.

National Institute of Disaster Management 2014 Ministry of Home Affairs, Government of India First Edition. New Delhi.

Newbery DM and Huston MA 1995 Biological diversity: the coexistence of species on changing landscapes. *J. Trop. Ecol.* 11(4):568–568.

Njana AM 2008 *Arborescent species diversity and stocking in miombo woodlands of Urumwa forest reserve and their contribution to livelihoods, Tabora, Tanzania*. Master of Science Dissertation, Sokoine University of Agriculture, Morogoro-Tanzania.

North M, Hurteau M and Innes J 2009 Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions. *Ecol*. *Appl*. 19: 1385–1396.

Okello BD, Young TP, Riginos C, Kelly D and O'Connor TG 2008 Short- term survival and long-term mortality of *Acacia drepanolobium* after a controlled burn. *Afr. J. Ecol.* 46(3): 395–401.

Paré S, Savadogo P, Tigabu M, Ouadba JM and Odén PC 2010 Consumptive values and local perception of dry forest decline in Burkina Faso, West Africa. *Environ. Dev. Sustain.* 12(2): 277–295.

Peters CM 1994 *Sustainable Harvest of Non-timber Plant Resources in Tropical Moist*

Forest: An Ecological Primer. Washington DC. http://www.harmlesscoconut.com/resources/14 Retrieved on Wednesday 22nd December, 2021.

Prior LD, Murphy BP and Russell-Smith J 2009 Environmental and demographic correlates of tree recruitment and mortality in North Australian savannas. *Forest Ecol. Manag*. 257(1): 66–74.

Ribeiro NS, Syampungani S, Matakala NM, Nangoma D and Ribeiro-Barros AI 2015 Miombo woodlands research towards the sustainable use of ecosystem services in Southern Africa. In: Lo Y, Blanco JA and Roy S (Eds.) *Biodiversity in Ecosystems-Linking Structure and Function* vol. 17 (pp 475–491), IntechOpen, London.

Ryan CM and Williams M 2011 How does fire intensity and frequency affect miombo woodland tree populations and biomass? *Ecol. Appl.* 21: 48–60.

Shuman JK, Fisher R, Koven C, Knox RG, Andre B and Kluzek EB 2017 Coexistence of Trees and Grass: Importance of climate and fire within the tropics NASA Astrophysics Data System (ADS). In: American Geophysical Union, *Fall Meeting*, abstract #GC43L-05.

Skarpe C 1992 Dynamics of savanna ecosystems. *J. Veg. Sci.* 3(3): 293–300.

Staver AC, Brando PM, Barlow J, Morton DC, Paine CT, Malhi Y, Murakami AA and Pasquel J 2020 Thinner bark increases sensitivity of wetter Amazonian tropical forests to fire. *Ecol. Lett*. 23: 99-106.

Traoré YN, Ngoc LBT, Vernière C and Pruvost O 2008 First report of *Xanthomonas citri* pv. *citri* causing citrus canker in Mali. *Plant Dis.* 92(6): 977-977.

Trapnell CG and Clothier JN 1937 *The Soils, Vegetation and Agricultural Systems of North Western Rhodesia: Report of the Ecological Survey*. Government Printer, Lusaka.

URT (United Republic of Tanzania) 2008 *Kigoma Region Socio-Economic Profile*. The Planning Commission, Dar es Salaam and Regional Commissioner’s Office, Kigoma.

URT 2013 *2012 Population and Housing Census*. National Bureau of Statistics Ministry of Finance, Dar es Salaam and Office of Chief Government Statistician President’s Office, Finance, Economy and Development Planning, Zanzibar.

URT (United Republic of Tanzania) 2016 Kigoma Region Socio-Economic Profile. President’s Office, Regional Administration and Local Governments. Dar es Salaam.

United States National Park Service 2006 Management policies 2006. Washington, DC: U.S. Government printing. http://www.nps.gov Retrieved on Monday 20th December, 2021.

Vesa L, Malimbwi RE, Tomppo E, Zahabu E, Maliondo S, Chamuya N, Nssoko E, Otieno J, Miceli C and Daisgaard S 2010 National Forestry Resources Monitoring and Assessment of Tanzania. FAO-Finland Forestry Program, Forestry Department, FAO.

Williams M, Ryan CM, Rees RM, Sambane E, Fernando J and Grace J 2008 Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. *For. Ecol. Manag*. 254: 145–155.

Zahabu E 2001 *Impact of charcoal extraction to the Miombo Woodlands: The case of Kitulangalo area, Tanzania*. Master of Science Dissertation, Sokoine University of Agriculture, Morogoro-Tanzania.

Zahabu E 2008 *Sinks and sources: a strategy to involve forest communities in Tanzania in global climate policy*. PhD Dissertation, University of Twente, Netherlands.

Zolho R 2005 *Effect of fire frequency on the regeneration of miombo woodland in N’hambita, Mozambique*. Master of Science Dissertation, University of Edinburgh, United Kingdom.