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ECOLOGICAL DISTRIBUTION OF SAUSAGE TREE (*KIGELIA AFRICANA*) IN MURCHISON FALLS NATIONAL PARK

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ABSTRACT: *This study investigated the Ecological Distribution and Abundance of Sausage tree (Kigelia africana) in Murchison Falls National Park. Kigelia africana is one of the important Non-Timber Forest Products (NTFPs), currently providing a range of ecological and socio-economic benefits. There was a need to have a clear understanding of the distribution and abundance of the species to guide future plans for its conservation in-situ, in order to realize its full potential for sustainable exploitation. A comparison of densities, distribution patterns, structure, stem conditions in the studied area of Murchison falls national park was done. We carried out field data collection between February and April 2017. Line transect was used to sample Kigelia africana in. The diameter at breast height (dbh) of adult and sub-adult trees, height of adults, sub adults and their stem conditions, number of fruits on each fruiting sausage tree were recorded. The results revealed a significant difference in the sausage tree abundance and distribution with (24%) at distance of 500m as highest percentage and lowest abundance (3%) at distance of 700m along the transect and trees with highest fruit abundance at 42.2% (100-199) and lowest at 2% (0-4) The study identified significant differences in the dbh-size ranges with highest dbh of 36.1% (201-300) and lowest dbh of 2% 601-700, 701-800). The bell-shaped distribution curve in dbh size-rangeshad50.3% damaged stems compared to 49.7% intact. Poor seedling survival resulting primarily from herbivory, human activities and climate variability hampers sausage treemobilization. Considering the poor mobilization due to the above factors, the potential for commercialization of sausage trees in the region may not be viable. Therefore, active planting in undisturbed areas, protection of seedlings from livestock coupled with community awareness are vital to ensure better management of sausage trees, so that effective commercialization and subsistence use is realized and sustainable.*

KEYWORDS: Sausage Tree, Kigelia Africana, Murchison Falls National Park, Ecological Distribution, Non-Timber Forest Products (NTFPs).

INTRODUCTION

In developing countries, within Africa and elsewhere, a wide range of plant species have been used for both subsistence and commercial purposes. (Schumann et al 2012). Various species of plants significantly contribute to rural livelihood and have traditionally been depended upon by indigenous communities in Uganda for subsistence and trade. Marshall and Newton (2003) singled out *Kigelia africana* as one of the major Non-Timber Forest Products (NTFPs), which are particularly important for livelihood security in cash-poor households while meeting medicinal needs and providing a source of income.

Many poor and marginalized people who live in the savanna woodlands, grasslands in Uganda rely on sausage tree (*Kigelia africana*) products for their survival. As a result, local communities attach immense importance to these products. However, over exploitation and poor management of some sausage tree (Kigelia africana) products such as bark, fruits and leaves for commercial purposes will jeopardize the survival of parent trees as the trees will not be able to fully recover.

Previous studies have suggested that due to the global upsurge in demand of these NTFPs, appropriate supervision of the resources is vital in order to evade overexploitation. Hence, before sustainable harvesting of these resources is implemented, there is necessity to fully comprehend the ecological distribution of the species (Venter & Witkowski, 2010). Sausage trees *(Kigelia Africana)* belongs to the family *Bignoniaceae*. Its common names include sausage tree (Eng.); um vunguta, umfongothi (Zulu); modukguhlu (North Sotho); muvevha (Venda) (Coats-Palgrave, 1988) pandoro (West Nigeria) (Aiyelola et al., 2006) Saucissonnier; Faux baobab (Fr) Mvungunya, mwegea, mwicha, mranaa (sw) (Grace et al.,2002).

The tree grows up to 20 m tall and the bark is grey and smooth at first peeling on older trees. Its bark can be as thick as 6 mm on a 15 cm branch. The wood is pale brown or yellowish, undifferentiated and not prone to cracking (Roodot, 1992) The tree is evergreen where rainfall occurs throughout the year, but deciduous where there is a long dry season. The leaves are opposite or in whorls of three, 30 - 50 cm long, pinnate, with six to ten oval leaflets up to 20 cm long and 6 cm broad; the terminal leaflet can be either present or absent. The flowers (and later the fruit) hang down from branches on long flexible stems (2 - 6 m long).

Flowers are produced in panicles; they are bell shaped (similar to those of the African tulip tree but darker and waxier), orange to reddish or purplish green and about 10 cm wide. Their scent is most notable at night indicating their reliance on pollination by bats, which visit them for pollen and nectar (Hoyo,1997) Flowers are bisexual, very large; pedicel up to 11 (-13.5) cm long up curved at tip (Grace et al., 2002).

The fruit is a woody berry from 30 - 100 cm long and up to 18 cm broad; weighs between 5 - 10 kg hangs down on a long rope-like peduncle (Joffe, 2003). The fruit is indehiscent, with woody wall and heavily marked with lenticels at the surface. It is grey- brown with many seeded when matured. Seeds are obovoid, ca.10 mm x 7 mm with leathery testa, embedded in a fibrous pulp (Grace et al., 2002). (Mukherjee, 2004).

Sausage trees (*Kigelia africana*) form a significant basis of income, especially in the dry season and during times of drought (Duvall, 2007; Sidibe & Williams, 2001). According to Sidibe and Williams (2002), Sausage trees have an outstanding ability to survive severe drought and fire, which are two main hazards to plant life in semi-arid areas of Africa. Though sausage trees are frequentlyviewed as fruit-bearing trees, they are versatile, widely-used species with medicinal properties, abundant food uses of various plant parts, and bark fibres that are used for extensivevariety of purposes (Wickens & Lowe, 2008). Over 500 uses of the sausage trees were documented in Benin, Mali, Zimbabwe, Cameroon, Uganda, the Central African Republic, Kenya, Malawi, South Africa and Senegal across 11 ethnic groups and 4 agro-ecological zones (Buchmann, Prehsler, Hartl&Vogl, 2009).

Sausage trees have an average life span of 1000-4000 years though studies have shown that they can reach up to 7000 years (International Center for Underutilized Crops [ICUC], 2003). Radiocarbon dating of *Kigelia africana* in South Africa showed an age of about 1,493 years (www.kew.org/scienceconservation/) which largely shows how old some sausage trees can grow. According to Mashapa (2013), research by Woodborne, Hall, Basson, Zambatis and Zambatis (2011) indicates that very large specimens are not necessarily among the oldest trees, and that medium-sized individuals can also be very old, which makes it even more difficult to evaluate the ages using size. According to Gebauer et al. (2004), quick growth in diameter and height is probable under favorable conditions, reaching 2-4 m in two years and up to 12-15 m in twelve years. The sausage trees are distributed relatively unevenly and intermittently in the savanna and is regularly associated with human settlements (Schumann et al., 2012). It usually grows at low altitudes (400-700 m) and low mean annual rainfall (150-1500 mm) (Wickens & Lowe, 2007).

In spite of the gaps in the knowledge about the distribution of sausage trees, current data show that it is widely distributed in parts of western, northern, north-eastern, and southern Uganda. (Williams 2005) Sidibe, (2000) stated that the sausage trees occur naturally in most of the countries south of the Sahara and is particularly associated with the drier parts of savanna or a minimum of 350 mm of annual rainfall. Though, there are extensions of its distribution into forest areas and river banks/wetlands connected with human habitation. According to Tsy et al. (2009), phylo-geographic research shows that sausage trees originated in West Africa and spread through human-induced dispersal to the rest of Africa. It has been introduced to countries outside of Africa, including northern Australia and many Asian countries such as India, Sri Lanka, Indonesia and the Philippines and in some parts of the Middle East and the West Indies.

According to Whyte (1999), sausage trees are a keystone species with ecological significance as they offer vital ecosystem services. The trees reduce soil erosion and provide cover or shade with their canopies (Coates, 2006). The strength of this tree is extraordinary as the bark can be completely stripped from the lower trunk and still the tree is able to regenerate new bark (Palgrave, 2002). Their capacity to resist extreme stress from drought allows the sausage trees to grow on degraded or marginal lands where other species would not survive. Because of climate variability and change, weather extremes are being experienced and as such, the sausage trees resilience to such extremities such as drought (Stucker & Lopez-Gunn, 2015) makes it a very dynamic resource in fulfilling its ecological function and providing essential ecosystem goods and services.

Sausage trees occur in considerable populations of mature woodlands in the western, northern, north-western and in smaller populations in the north-eastern parts of Uganda. Precisely, sausage tress in Uganda occur largely in parts of Bunyoro, Bugungu, Albertine region/Rift valley, National parks in Uganda-MFNP, Buliisa, Nwoya, Kiryandongo, Masindi and Banks of Nile basin. as their distribution is restricted by climatic conditions and altitude. The sausage trees have a valued coverage of 1.7% of the total land area in Uganda.

Indigenous plant species in Africa have the potential to play a central role in addressing livelihood concerns such insecurityas food, medicine and other associated benefits. Regardless of the available knowledge from other countries about the sausage tree (*kigelia Africana*), its multiple uses among other components, there is still a scarcity of information about the species. The data on ecological distribution and abundance don’t exist at local scale. Continued exploitation and poor management of sausage tree (*Kigelia africana*) products such as bark, fruits and leaves could endanger the survival of parent trees as the trees will not be able to fully recover thus compromising the survival of *Kigelia africana*. Therefore, it is important to accurately describe the abundance and distribution as relates to density, structure and bio-physical components. There is need to have more Knowledge and better understanding of the ecology of Sausage Trees (*Kigelia africana*) Henceforth, this study is driven by the fact that there is need to improve evidence-based monitoring through gaining initial understanding about its ecological distribution, bio-physical characteristics and significance within Murchison falls National Park.

MATERIALS AND METHODS

Study Area

The Study was carried out in Murchison Falls National Park is Uganda's largest national park. It measures approximately 3,893 square kilometers (1,503 sq mi) and lies at the northern end of the Albertine Rift Valley, where the sweeping Bunyoro escarpment tumbles into vast, palm-dotted savanna.

The park is bisected by the Victoria Nile, which plunges 45m over the remnant rift valley wall, creating the dramatic Murchison Falls, the centerpiece of the park and the final event in an 80km stretch of rapids.

The park straddles the Ugandan districts of Buliisa, Nwoya, Kiryandongo, and Masindi. Also in the park, adjacent to the Masindi-Gulu Highway, are the Karuma Falls, the location of the 600 megawatt Karuma Power Station.

This area is about 283 kilometres (176 mi), by road, north-west of Kampala, the capital and largest city of Uganda. The coordinates of the park are 02°11'15.0"N, 31°46'53.0"E (Latitude: 2.187499; Longitude: 31.781400).

Study Design and Sampling Procedure

Study Design

A descriptive cross-sectional study was conducted in the selected sites where sausage trees (*Kigelia africana*) occur in Murchison falls national park.

Sampling Procedure and Data Collection

Line transect/plot sampling method was used to sample sausage trees (*Kigelia africana*) in the purposively selected sites of woodlands, open savannah, water basins/sheds and grasslands in Murchison falls national park.

Transect line covering approximately 1000m(1km) was traversed on foot and the sausage trees sighted on the ether sides of the transect was counted, quantified and recorded in the data sheet.

Adult trees were defined as having diameter at breast height (dbh) of equal to or more than 150 cm and sub-adults with less than 150 cm and more than 1 cm in dbh following Schumann et al. (2010).

Saplings and seedlings were identified and distinguished from each other by their vegetative and morphological features such as the number of leaves and the size of the plant. Specimens were also used to do the matching. All sausage trees (adults, sub-adults and saplings) identified within each plot were counted and their heights measured. The heights of seedlings and saplings were estimated using a 1 m measuring pole.

For adult and sub-adult trees, the dbh was measured using a tape whereby the trunk was measured at 1.3 m above ground level in accordance with the international practice (www.afcd.gov.hk/).

The abundance/density was estimated using Buckland formula (1993).

$D = n / 2La$

Where;

D = Abundance/Density of sausage tree (*Kigelia africana*) per unit area

n = Number of sausage trees seen on transect

L = Total length of transect

a = Half the effective strip/tape width.

Data Analysis

The data collected was analyzed by SPSS Software version 17. The variables such as environmental factors affecting sausage tree, structure of sausage tree population, distribution and abundance were analyzed. After analysis, results were presented in tables and graphs, which are appropriate.

RESULTS

Abundance of Sausage Trees (*Kigelia africana*) Population

The sausage tree population densities in Murchison falls national park were calculated and the results are displayed in Table 1 below. Line Transect results showed that sausage tree population per plot (each 100m) did not significantly vary between the either sides of the line transect. Despite an apparent slightly higher sausage tree population of 75 trees/1000m in left side of the line transect than the Sausage tree population of 72 trees/1000m in the right side of the line transect. (fig.1).

Table 1: Sausage Tree (*Kigelia africana*) Abundance and Distribution

Counts/Left of Line Transect	Distance/m	Counts/Right of Line Transect	Total Counts
9	100	12	21
8	200	6	14
7	300	5	12
10	400	8	18
15	500	21	36
10	600	4	14
2	700	2	4
6	800	4	10
3	900	7	10
5	1000	3	8
DENSITY/1000M			**147**

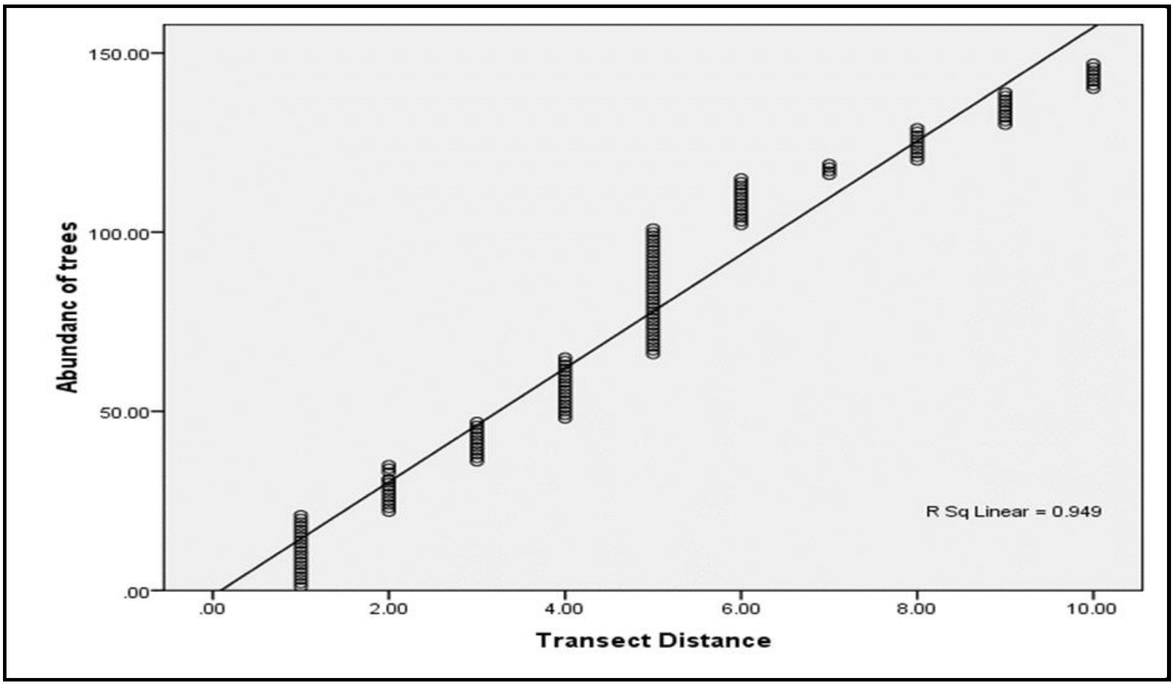

Fig.1: Comparison of Sausage Tree Abundance at Varying Transect Distance

The results showed that sausage tree abundance in each distance/plot was not evenly distributed across the habitats as some sausage tree positions were in a bunched pattern whereas some trees were more isolated. Some sausage trees especially to the left of the Line transect were more clustered whereas others were more sparsely distributed. Sausage tree stands in right side of line transect slightly exhibited a bunched distribution pattern as well. (Fig. 2). In order to reach the total of 147 sausage total population, a total area of approximately 1000m of line transect was traversed on foot which explain the observations noted above. Overall, sausage trees Murchison falls National Park generally displayed more randomly distribution patterns.

Environmental Factors Affecting the Sausage Trees (*Kigelia africana*) Population

The study findings revealed that many sausage trees saplings germinate naturally especially during the rainy season even though some of these sausage trees do not survive. However, the study findings didn't reveal the use of propagation method towards the abundance and distribution of sausage trees by the authorities of Murchison falls national park. Some of the factors that affected the survival of sausage trees were animals, insects, People and weather conditions. As shown in Table 2, animals were mentioned by the respondent (61%) as the browsers that destroy the young sausage trees.

The study revealed that elephants and Zebras were the main browsers that consume the sausage tree leaves apart from other plant parts. Insects represented (3%) of the factors affecting sausage tree survival Twenty percent (20%) of human activities as another contributory factor affecting sausage tree survival as they remove the plants during land clearing for construction and infrastructure development16% represented extreme weather conditions such as droughts or floods as also affecting sausage tree survival.

Table 2: Environmental factors affecting sausage trees population in Murchison falls national park

		Frequency	Percent	Valid Percent
Valid	Animals	90	61.2	61.2
	Insects	4	2.7	2.7
	Human Activities	30	20.4	20.4
	Weather	23	15.6	15.6
	Total	147	100.0	100.0

Comparison of the Structure of Sausage Trees (*Kigelia africana*) Populations

Comparisons of the Size Range Distributions

The study findings recorded the largest sausage tree with 815 cm dbh in the study area of Murchison falls national park. A total of 29 sub-adult sausage trees were recorded ranging between 1 and 200 cm in dbh. The majority of the sausage trees measured were of the adult size-range within the dbh 210->800 cm.

There was a significant difference in the dbh frequency distributions of the sausage trees. The dbh size-range of 201-300 cm had highest observed values by 36.0%. Conversely, dbh ranges within the 601-700 cm and 701-800 cm had the lowest values by 2%. Figure 4 shows proportion of sausage trees within different dbh size range. In general, the largest proportion of the trees (63.8%) were within the middle size-range that extended from 201 to 500cm in dbh. Resultantly, sausage trees in the study area of Murchison falls national park displayed a bell-shaped size range distribution (Fig.4)

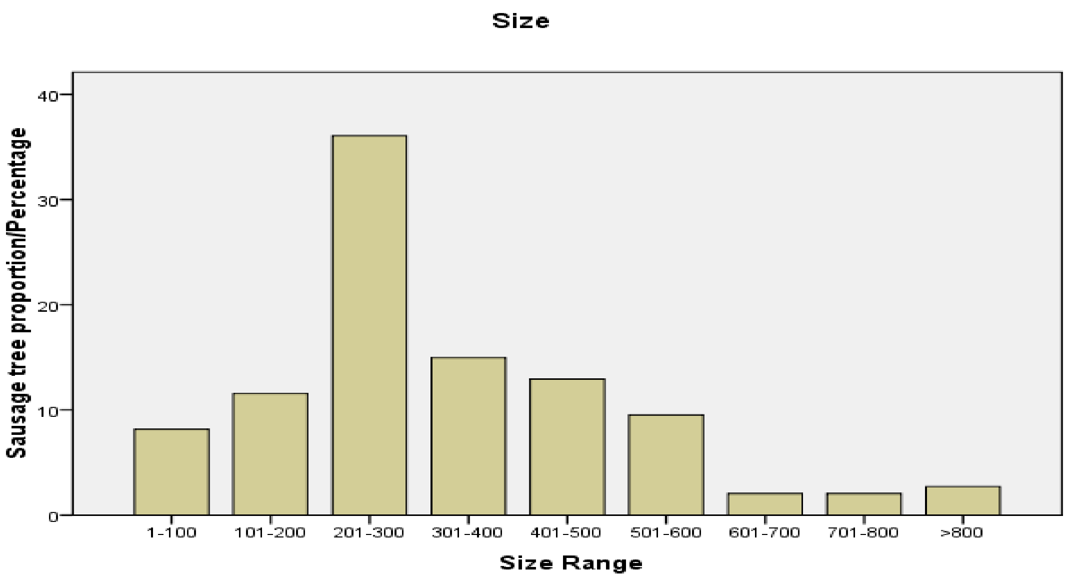

Figure 3: Comparison Sausag Tree Proportion With Size

The Comparison in Height Structure of Sausage Trees

The maximum height for adult trees in Murchison falls national park was 23m, the shortest adult trees recorded 11 m tall.

There was a substantial difference in the height frequency distribution of the sausage trees. The 11-15 m height-range had the highest observed proportion of sausage trees by 58.5%. The significant difference was also found within the 0-5m height-range that had less proportion of the sausage trees by 2.0%.

As depicted in Figure 5, there was a gradual increase in the proportion of trees with increasing height-ranges before a decrease in trees with the tallest height-range (20.1-25 m). More trees were recorded within the 10.1-25 m height classes than within the <10 m and >15.1m height-ranges.

Overall, the highest proportion of trees (58.5%) recorded in Murchison falls national park were within the 10.1-15m range while the lowest tree proportion (2.0%) were within the 0-5m height-range (Table 4). In general, the height frequency distribution patterns of sausage trees were more negatively skewed as the highest proportions of trees were within the taller height-ranges.

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Table 4: Comparison of proportions of sausage trees within different height range

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5	3	2.0	2.0	2.0
	5.1-10	9	6.1	6.1	8.2
	10.1-15	86	58.5	58.5	66.7
	15.1-20	30	20.4	20.4	87.1
	20.1-25	19	12.9	12.9	100.0
	Total	147	100.0	100.0	

Comparison of the Stem Condition

There was a significant difference in the stem condition of the sausage trees within the studied area of Murchison falls national park. There were much higher observed counts of intact individual stems by 13%. The number of stems with other disturbances (such as termite infestation, man induced cuts and natural holes) were fewer by 10.8%.

The study revealed 50% of the total number of sampled sausage trees were found to have intact barks. These were the trees that had not been exposed to some kind of visible damages or stem disturbances. All the sub-adult trees had good stem condition (intact). Some of the trees had some cuts on the stem while the other one had evidence of de-barking. Thirty-six (36%) of the trees that were sampled had evidence of de-barking whereas Other type of disturbances like burning identified on the sausage trees stems were on only 12% of the sampled sausage trees. This shows that Murchison falls national park had fewer sausage trees de-barked and burnt than and had even fewer trees with other stem disturbances (2%) which had visibly hollow trunks, which could have been either human made or natural occurrence.

Table 5: Proportions of Sausage Trees with Varying Stem Conditions

Parameters	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	73	49.7	49.7	49.7
Intact	53	36.1	36.1	85.7
De-barked	18	12.2	12.2	98.0
Burnt				
Others	3	2.0	2.0	100.0
Total	147	100.0	100.0	

Comparison of Fruit Production

There was statistically significant difference in number of fruits produced per tree at Murchison Falls national Park. Figure 6 shows that the highest proportion of trees in Study area of Murchison falls national park (42.2%) had 100 to 199 fruits. The lowest proportion of trees that had lowest fruit yield (0-4 fruits) was recorded with (2%) and a few trees had lowest proportion of (>300)) fruit range at (4.1%).

The study also found out that some adult trees which had reached the reproductive stage did not have fruits while some tree measuring less than 100 cm in dbh were already producing fruits.

Figure 6: Comparison of sausage tree fruit production

DISCUSSION

Factors such as herbivory, agricultural activities and land development affected the sausage tree abundance as some trees were destroyed through trampling or browsing in the pastures and during land clearing for construction and infrastructure developments. The high levels of land use developments taking place in Murchison falls national park affected the survival and consequently the abundance and distribution of sausage trees in the area. According to Edkins et al. (2010), Ecological distribution patterns and abundance of sausage tree can be attributed to herbivory, human activities, droughts or soil character requirements. Additionally, Venter and Witkowski (2009) suggested that sausage tree abundance/densities are affected by a number of factors such as animal facilitated seed dispersal, soil characteristics and topography.

The study also revealed some of insects as contributory factor affecting sausage tree survival such as termites, grasshoppers and beetles. When the sausage trees are attacked by such insects, they tend to reduce the rates of shoot and root growth. This will then increase the susceptibility of plants to disease and mortality (Venter & Witkowski, 2013). According to Sidibe and Williams (2002), in Ghana, an unidentified black beetle damaged and eventually destroyed the sausage tree branches by girdling. Additionally, a caterpillar (Gonimbrasia herlina) is known to feed on the sausage tree seedling and leaves (Sidibe & Williams, 2002).

A study conducted in Gonarezhou National Park (GNP) in Zimbabwe on the structure of sausage trees across different soil types showed that the highest frequency of young trees was found on granophyres soil group stratum than on malvernia and rhyolite soil group stratum (Mashapa et al., 2013). This explains that edaphic factors such as soil type, texture, depth and drainage capacity has an influence on sausage tree abundance as they grow on a wide range of well-drained soils, from clays to sands, but not on deep unconsolidated soils, where the species is unable to obtain sufficient moisture or anchorage (Mashapa et al., 2013).

As discussed by Rocky and Mligo (2012), the bell-shaped distribution is an indication that plant populations are likely to crush if any kind of intensive disturbance continues. Where already at least two fallen aged sausage, trees were encountered and more particularly where increased developments are taking place that may in the future affect the survival of even the large size categories. Main threats such the practice of hollowing trunks, burning as well as debarking with continuous poor species regeneration may probably lead to population and abundance collapse. Mashapa (2012) pointed out that sausage tree losses make the areas less visually appealing and unattractive to tourist as well as affect the biodiversity and ecosystem function where these losses occur.

Apart from the natural drivers, Human beings contribute to the sausage tree mortality which imply that humans bring in various activities such as developmental projects and bush burning activities that tend to affect the survival and abundance of sausage trees. Mwavu and Witkowski (2007) stated that human land-use activities influence growth conditions for plants by altering various abiotic factors such as nutrient availability and water supply. According to Schumann et al. (2010), human activities alter demographic parameters such as germination, seedling and sapling growth, survival and mortality rates and alter the structure and stability of populations. According to Hean and Ward (2012), African savannas are subject to frequent herbivory and the occurrence of fire is highly variable. Therefore, human land-use activities such as construction and infrastructure when the land is being developed have a greater influence on the survival of sausage trees and ultimately on the population and distribution of the sausage trees.

The rarity of the sausage trees in parts of Murchison falls national park could have been due to the sausage tree abundance being highly dependent on rare favorable conditions. According to Venter and Witkowski (2010), low recruitment rates and bell-shaped or positively skewed size-class distributions which are typical of sausage tree populations across Africa have raised concern about the maintenance of sausage tree populations. However, this may be of less concern due to the long-lived nature of sausage trees low adult mortality rate (Venter & Witkowski, 2010). This opinion was also expressed by Wickens and Lowe (2009) who pointed out that the longevity of sausage trees means a few recruits are necessary to maintain the current population distribution of trees. Hofmeyer (2001) also concluded that there were sufficient sausage trees in reproductive size-categories in Kruger National Park and as such, low number of small trees simply indicated a poor recruitment phase. Poor recruitment could be an indication that sausage trees have lost importance for people in recent years as seen in West Africa where no planting or active protection of the animals and anthropogenic activities from livestock are practiced (Duvall, 2007). This is not happening in Uganda, which could explain why the sausage tree is losing importance in the study area. It appears that people are just satisfied by seeing large sausage trees in reproductive stages around.

CONCLUSIONS

Overall, the results show that there were significant structural differences of sausage tree populations. Despite the land conversions that took place in Murchison falls National Park, the area still has large-sized sausage trees which are explained by the fact that the land developers deliberately leave out adult trees during any developments. Other factors responsible for the structural differences included the land-use type, soil characteristics and ecological and climatic conditions. Elephants are not the only cause for concern in the study site which shows that other factors other than elephants influence the population structure.

The bell-shaped size-range distribution shows that there is poor recruitment which was postulated to be mainly hampered by animal browsing. This explains that the sausage trees that grow on areas that are not protected from animals such as grazing areas are not likely to survive into mature stages and this according to Schumann et al. (2010) could indicate a population in decline. Apart from animal browsing, human development and extreme weather conditions due to climate change maybe foreseen to be the main causes of sausage tree mortality in the near future if proper action is not taken. For example, the current developments and expansion of the Murchison falls tourist hotels and rest houses is likely to encroach into those areas where sausage trees had better chances of surviving if well protected. The median fruit abundance did not differ significantly which explains that these study site experienced similar ecological and biological patterns that enabled or limited pollination, fruit abortion, resource availability or the trees to have enough reserves after leaf flush. Stem conditions were significantly different in study area, higher proportions of sausage trees were intact while debarked or other kinds of stem disturbances were slight lower compared to trees which were intact. The higher proportions of sausage trees that were de-barked and other stem disturbances were found within the grasslands as it shows that animals tend to de-bark the trees when they fail to access other sources of food during dry periods.

Due to poor sausage tree reestablishment, efforts should be made by the Uganda Wildlife Authority (UWA) and Uganda National Forestry Authority (UNFPA)to encourage sausage tree propagation including planting away from Animal and Human dominated areas to limit interference.

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