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Selectivity Of Forest Tree Species For Debarking By Elephants In Rabongo Forest-Murchison Falls National Park, Uganda

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ABSTRACT

Selectivity of the different forest tree species for debarking by elephants in a forest ecosystem is an important phenomenon for understanding the interactions between the large herbivores and the woody community in the tropical forest ecosystem.

Here we present a long term investigation on elephant preference to forest trees debarking in Rabongo Forest spanning 20 years since 1992 in seven (7) one hectare plots established in 1992 distributed over 46 hactare in Rabongo Forest which is an important habitat for most large herbivores in Murchison Falls National Park.

Diospyros abyssinica; *Holoptelea grandis*; *Trichilea prieuriana* and *Cynometra alexandri* were the most debarked/preferred tree species and also the most abundant in the forest in Rabongo Forest although the number of the debarked trees ≥ 10cm dbh reduced by 4%.

Synthesis. There should be close monitoring of the number of elephants that visit Rabongo Forest over the years to relate with the number of stems debarked over the years to guide on the need to maintain the right elephant carrying capacity for the forest. We also recommend for further investigation for what attributes make the above tree species be preferred by elephants in Rabongo Forest

Key Word: Debarking, scars, resilience, selectivity, preference

1. INTRODUCTION

Woody species supply sufficient quantity of African elephants' diet and the selectivity of the tree species for debarking change with seasons (Owen-Smith and Chafota 2012) and this is the determinant of tree structure, function and composition (Hisashi, *et al.,* 2006). Forest disturbance by large vertebrates such as elephants (L*oxodonta africana*) play a role in determining vegetation cover through their feeding ecology and social behahours O'Connor (2006). The tree species which experience such disturbances must adapt in order to survive. Forest tree debarking can be so severe threatening their survival although some are resilient to such damages (Norden, *et al.,* 2009). Forest trees are quite often broken down, uprooted, pushed down, scarred, trampled upon or browsed by the elephants. Tree species loss due to the increasing stem debarking by elephants in the tropics has been registered (Addo-Fordjour and Rahmad, 2015). Nonetheless, their survival depends on the intensity of the impact over time.

Elephant activities in the forest may cause canopy gaps which are later on filled by other trees making them both resilient and resistant to change (Thompson, *et al.,* 2009). Elephants select forest trees for debarking for diet change during dry season when there is little browse (Addo-Fordjour and Rahmad, 2015). Tree stem debarking by elephants in African tropical forests are recorded by various researchers (Sheil and Salim 2004; Nampindo 2005) and such trees must cope with frequent debarking for their continuity (Schoonenberg *et al.*

2003). Rabongo forest (46 Ha) is situated within the elephants' feeding range within Murchison Falls National Park and this puts its trees at a high risk to be selected for browse, debarking and uprooting by elephants. Although other scholars suggest that elephants are less selective in their feeding in order to provide sufficient intake (English 2014), a small forest patch like Rabongo puts the trees in danger of being selected for debarking.

Tropical forest mosaic occurs in many places within the home range of forest elephants such as tropical forest ecosystem of East and West Africa (Blake, 2004). Forest trees are browsed, large quantities of fruits are eaten whenever available and various parts of trees like leaves and the bark make 75% of elephants' diet (Turkala and Fay 2001). Most of these feeding methods have varying impacts on tree growth and survival. Breaking or uprooting trees will automatically lead to their death and in some cases ring barking result into infections by pathogens and other pests causing death. Stem damage is also known to reduce mean tree life time (Sheil and Salim, 2004).

Ssali *et. al.,* (2013) found that elephants were selective in Bwindi Impenetrable National Park, depending on where, how and what tree stems they damaged. Other researchers (Sheil and Salim 2004, O 'Connor *et al*., 2006) studied forest trees scarring by elephants listed the damaged tree spices with factors determining forest tree debarking by elephants. Elephants being heavy browsers and through their social interactions greatly damage forest trees (Hisashi *et al.,* 2013). They characteristically select green grasses and herbs during the rainy season (Osborn, 2004) when all food types are abundant though browse is eaten throughout the year with increasing intake towards the onset of dry season. Tree barks and tree forage consumption increase towards the end of the dry season when browse foliage begins to fall causing serious damage on the trees (Holdo, 2003). The fact that Rabongo Forest lie within Murchison Falls National Park, aggravate the likelihood of forest tree debarking by elephants leaving such damaged trees at the mercy of their struggle for existence. Schoonenberg *et al.,* (2003) noted that tree species that cannot cope with such damages can easily be eliminated from the population.

2. MATERIALS AND METHODS

2.1 STUDY AREA

The study was carried out from Rabongo Forest (Murchison Falls National Park) in mid-western Uganda. Rabongo Forest lies between 1º57' N to 2º 35' N and 31º 22' E to 32º 08' E. The forest lies in the district of Bulisa situated within the western rift valley bed in the biodiversity rich region of Albertine rift region, North East of Lake Albert, South East of Murchison Falls National Park and North East of Budongo Forest (UWA 2014). The forest covers an area of approximately 4 km^2 within Murchison falls Conservation Area lying just 20 km to the North East of Budongo Central Forest Reserve. Rabongo Forest lies within an undulating terrain sloping gently towards Lake Albert with an altitude range of 700-1000 m above sea level.

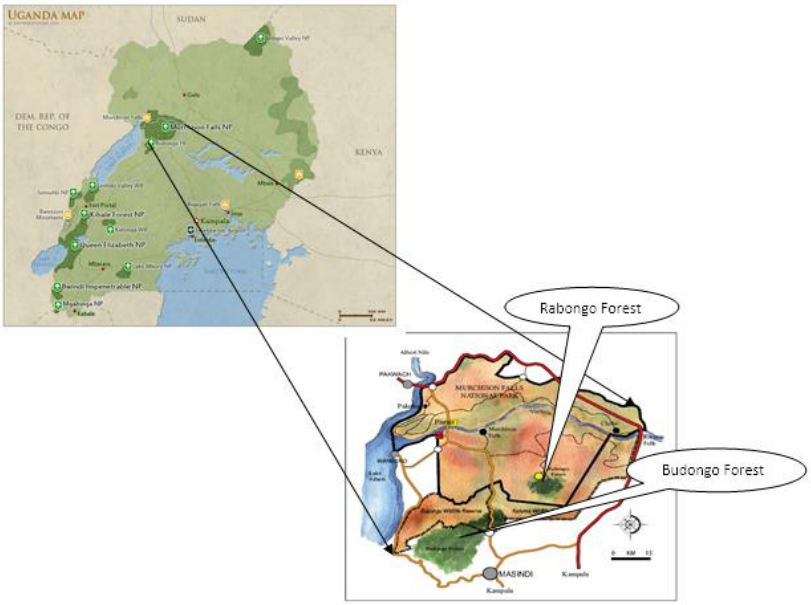

Figure 1: Map of Murchison Falls Protected Area indicating the position of Rabongo Forest in relation to Budongo Forest (UWA 2014)

2.2 GEOLOGY AND SOILS

Rabongo Forest is mostly underlain by *precarrbrian* origin consisting of *gneiss*, *schists* and *granuli* rocks. Soils of Rabongo Forest are *ferralitic* representing final stage in tropical weathering which are deep with little differentiation into clearly defined horizons. Weatherable clay materials or the lattice type (*caoline*) are associated with important quantities of iron oxide and occasionally hydrated oxides of aluminum. *Murram* is abundant in the form of concretion or sheet stone. The latter cover some high grounds such as hill tops. It's under lain by *quartzite* rocks and generally variable from red loams containing small quantities of iron concretions which support forest vegetation to cellular iron sheets (UWA 2014).

2.3 FLORA AND FAUNA

Rabongo Forest supports quite a distinct vegetation type characterized by abundance of *Diospiros abyssinica*, *Holoptelea grandis* in association with C*ynometra alexandrii* in the upper story and *Trichilea prieuriana* and *Tapura fischeri* in the under storey (Sheil and Salim 2004).

Elephants, bufalos and primates visit the forest patch making it unique for subsidizing the fauna diet occasionally during stress periods (UWA 2014).

2.4 WEATHER

The minimum temperature varies from 23^{o} C to 29^{o} C while maximum ranges from 29^{o} C to 32^{o} C. Low temperatures are between December and February during the Southern summer.

The annual rainfall varies between 1000 mm to 1,250 mm on 50-100 rainfall days. Thunderstorms and hailstorms are frequent. Most rains fall between April and June and between September and November. The

two rain fall seasons are separated by two dry seasons from December to March and June to August, the first being very severe. During the dry seasons, relative humidity varies between 45% and 50% during very wet rainy days (UWA 2014).

3. METHODS

3.1 RESEARCH DESIGN

We identified the need to re-assess the very seven 1 ha plots established by Douglas Sheil in 1992 and first assessed by Simon Nampindo in 2001(10 years later) since another 10 years had elapsed (2011).

The following sequence of actions were taken: Identified the problem; generated and tested the research objectives; generated the research topic; mobilized the necessary research funds, tools, equipments and staff; carried out data collection from the field; analyzed field data and compiled the research report.

3.2 SAMPLE SELECTION AND SIZE

We used the very sample selection and size as in Sheil and Salim (2004) and Nampindo (2005) due to the need to re-assess the very plots after 20 years. We identified the very Permanent Sample Plots (PSPs) using old reference maps, Global Positioning Systems (GPS) together with the knowledge of the UWA field Rangers and research assistants. Search for any sign of the corner trenches and trace of paint on the trees at the point of measure (Sheil and Salim 2004 and Nampindo 2005) guided the search. Whenever the paint was identified on trees, it indicated that the research team was already in the middle of the plot. Further tracing of the corner trenches to ascertain the actual lay out of the plots was then done. The plots were then re-demarcated within their original locations according to earlier sampling methods. External plot boundaries were re-opened by cutting a straight line to the next corner trench, and this continued till the whole sides (100 m by 100 m) of the plot(s) were completed (Figure 2).

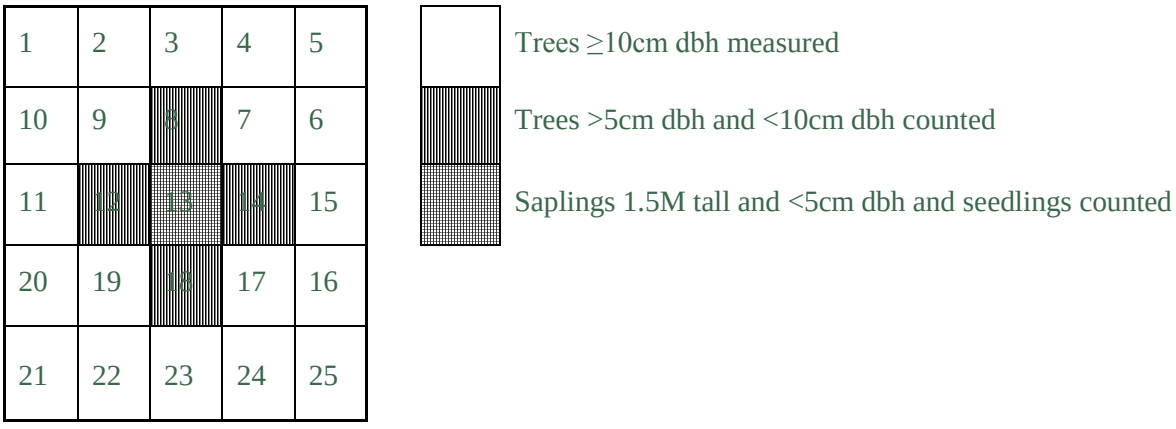

Figure 2: Permanent Sample plot lay out according to (Alder 1992)

Subsequent quadrant lines were then re-opened at 20m intervals running north-south and then east-west forming quadrants of 20 m by 20 m, to form 25 quadrants per plot following Alder (1992). This same process was followed throughout all the 7 plots (175 subplots/quadrants) for re-assessment.

For the control plot in Budongo Forest, the location of Research Plot 7 in compartment N15 was traced following the tie line from Royal Mile up to the first plot corner mound. Corner trenches were followed to guide the extent of the plot for re-opening. In total, 7 ha out of the 46 ha of Rabongo forest was re-assessed as a representative area of Rabongo Forest. A control plot from Strict Nature Reserve (Budongo RP7) was assessed to compare forest tree species diversity and abundance with those of Rabongo Forest.

3.3 INSTRUMENTATION AND PLOT ESTABLISHMENT

Instrumentation

We employed measuring tapes to establish quadrants, diameter tapes to measure tree diameter, pangas for reopening plots and quadrant line, brushes and paint for writing tree numbers and strip along the point of measure. While camera for photographing, field data book were used to record data, protective gears, hoes and spades were used to reopen the trenches and re-heaping corner mounds.

Plot establishment

We maintained the plot design of the seven square 1 ha plots established by Douglas sheil in 1992 in Rabongo Forest (Sheil and Salim 2004). The forest area was stratified into forest types according to the disntict canopy textures identified from aerial images. A grid was laid over this classified image and random number Cartesian coordinate pairs were generated to objectively select sites in each forest types at resolution c*a* 5 m. These locations were found on the ground by reference to features visible on the images and a further pair of random numbers was used to offset the first plot corner to avoid local systemic biases.

The plots were laid at 100 m by 100 m. and subdivided into subplots of 20 m by 20 m where trees were re-assessed for different parameters. The Budongo Forest Research Plot 7 was established at 100 m by 186 m in 1950s in Nyakafunjo block 15, a strict Nature Reserve to study long term ecological changes in an undisturbed forest. The research plot was divided into 30 m by 30 m sub plots which were also assessed by this research as a control plot.

3.4 DATA COLLECTION

Within all the subplots, data collection proceeded from the first quadrant of every plot to the last (25^{th}) where all trees ≥10 cm dbh were enumerated and assessed for any sign of debarking on the stem up to 4.5 m tall. The following were recorded under this section: any ambiguous signs of bark removed from the stem, number of coppicing stems and species, healing from the scars, Seeding/fruiting or premature/early flowering and seedlings within the crown diameter of the damaged trees to indicate species regeneration after elephant

damage. Codes ranging from '0' (no any recovery sign) to '5' (fully recovered from the damage) were used to describe qualitative characters such as healing from scars. All the forms of recovery or coping mechanism by the damaged tree stems were recorded to correlate the types of resilience employed by the different trees in Rabongo forest.

Voucher specimens were prepared for those tree species whose identification was not possible in the field for later identification at Makerere University herbarium. Diameter at Points of Measure (dPoM) of all stems ≥10 cm dbh was measured from the very points measured by Sheil and Salim (2004) and Nampindo (2005). At the PoM removal of all moss, algae, soils and ferns was done before re-painting with oil paint in a ring around the trees. Each tree number was re-painted and recruits without tree numbers were assigned unique numbers in line with the previous numbering system (Sheil and Salim 2004 and Nampindo 2005). Tree DBH were measured at 1.3 m above the stem base for normal stems and slightly above buttresses or flutes at point of measure (PoM) using a light ladder. Any forked or branched trees below PoM were considered as separate trees following Huang *et. al.*, (2003). From the middle quadrants 8, 12, 14 and 18, all the poles >5 cm dbh and <10 cm dbh were sampled. Saplings 1.5 m tall and <5 cm dbh were sampled from the most middle quadrant (13), seedlings >0.6 m and <1.5 m tall were sampled from quadrant 13 from 4 strips 1m wide running East West.

For the elephant's damage, assessment for any scars was made including old/ healed scars as judgment whether the scar was of elephant activity or not was difficult. According to Sheil and Salim (2004), a scar was defined as any unambiguous sign of tusk damage to the stem, even if the stem had subsequently healed. I was able to judge if such scarring was associated with feeding and/or other aspects of elephant behavior by observing any sign of elephant tusk on the tree stem up to 4.5m above the ground.

Table 1: Descriptions of scar ranks

Ranks	Degree of bark loss
0	No clear damage
1	Localized, remains 75% unringed within 4.5m high
2	Semi-ringed, less than 75% to 25% unringed a round the stem
3	Less than 25% unringed at any point of the stem within 4.5m high
4	Total ringing somewhere or 75% ringed area
5	Total bark stripping 1m wide all the way round the stem

Scores 0-5 were given to describe scarring effect (table 3.1). Trees broken from the stem and those uprooted or pushed down were counted to indicate the degree of impact caused. Trees with broken trunks and/or fallen down from their roots through foraging were recorded as fatally damaged and those with foraged shoots only were recorded as having survived damage.

4. DATA ANALYSIS

We collected data on tree species debarked by elephants over the 20 decades (1992-2011) and analyzed graphically to show the trend of number of each tree species debarked over the period

Patterns of forest trees Damage/scarring in Rabongo Forest

We employed rank correlation to compare the scarring effects of 2011, 2001 and 1992 to see if there were any similarities.

Damage intensity of the size classes and damage ranks (0-5), were analyzed using Systat 7.0. Comparisons were made for the censuses of 1992, 2001 and 2011 to assess the trend of elephant impacts in 20 years broken into 10 years' intervals.

Impact of elephant damage/scarring to tree stem growth and survival

We employed non parametric test (Mann- Whitney U Test) to ascertain whether there were any differences in the survival and growth of the scarred and the non scarred trees. Chi-square test (X^2) was also used to determine the relationship between forest tree species damages and their coping/recovery mechanism which maintain Rabongo Forest ecosystem to its current state damaged stems.

5. RESULTS

Comparison of elephant scarring effects in Rabongo forest plots

The tree stems which were observed having any signs of elephant task were recorded and the total scarred stems per plot and compared (Figure 4.1). This gave a clear indication of elephant activities the different locations in Rabongo Forest.

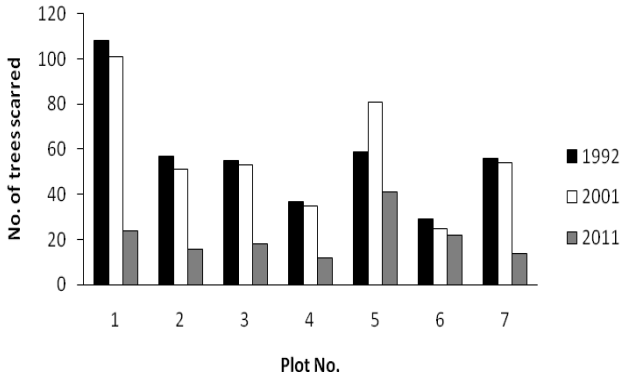

Figure 3: Number of stems (≥10cm dbh) scarred in Rabongo Forest plots

The number of stems debarked by elephants decreased in all the plots (figure 3). Plot 1 and 5 maintained a higher number of trees debarked as compared to the rest of the plots. Plot 6 had uniform scarring effect

throughout the measurement regimes. Meanwhile plot 1 registered a marked drop in the number of trees scarred from 101 trees in 2001 to 24 trees in 2011 measurement. We went ahead to assess the number of the debarked stems in the different diameter size classes (figure 4)

Scarring effect differentiation among the diameter size classes across all plots

We identified the most preferred size class and tree species over the 20 years (figure 4). We observed a higher preference in the lower diameter size classes than in the higher diameter size classes. There was also a general drop in the scarring effect across all the diameter size classes between 1992 and 2011. Diameter size class 1 (10-19.9cm dbh/PoM) dropped from 280 trees to 87 trees while diameter size class 2 (20-29.9 cm dbh/PoM) dropped from 65 to 17 trees.

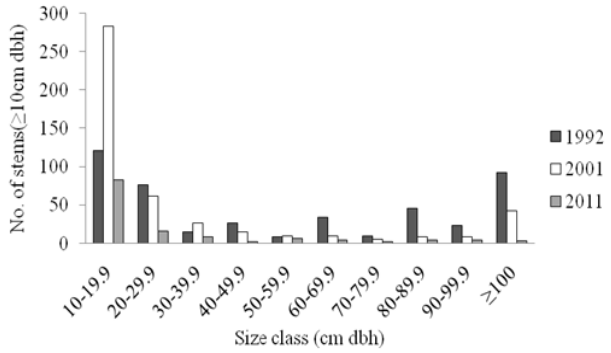

Figure 4: Selection among trees of different diameter size class (≥ 10cm dbh) in Rabongo in 1992, 2001 and 2011

Species preferred for debarking by elephants in Rabongo Forest

The scarring effect was generally spread though out all the diameter size classes though in decreasing rates (figure 4). *Holoptelea grandis* (28.9% - 2001 and 22.7% -2011), *Diospyros abyssinica* (36.9% - 2001, 18.6% - 2011), *Trichilia prieuriana* (19.6%) and *Cynometra alexandri* (11.7%) were mostly selected as compared to other species (Figure 5).

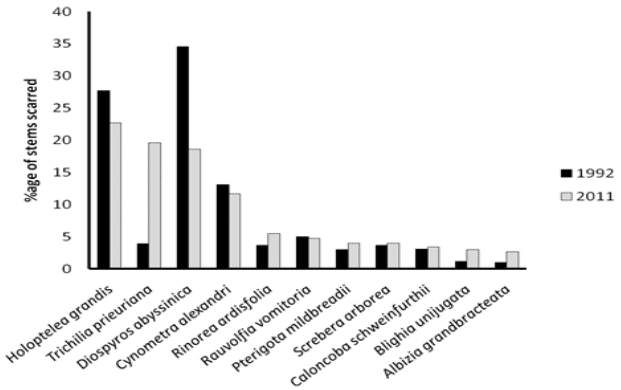

Figure 5: Tree species preference by elephants in Rabongo Forest between 1992-2011

Forty two tree species were debarked over the period but with preference to eleven species throughout the two decades. The percentage of *Diospyros abyssinica* scarred dropped from 36.9% to 18.9% and *Holoptelea grandis* (28.9% to 22.7%) in 2011 but that of *Trichilia prieuriana* increased from 4.1% to 19.6% indicating a higher elephant preference in 2011.

There was a general increase in stem abundance of *Trichilia prieuriana, Cynometra alexandrii, Tapura fischeri* and *Diospyros abyssinica* and stem decrease of Caloncoba *schweinfurthii* and *Xylopia parfolia, Blighia unijugata, Antiaris toxicaria* and yet these were not the most affected species by elephants in Rabongo Forest.

6. DISCUSSION

Patterns of scarring amongst trees of different locations

The total number of tree stems found with signs of tree damages or scars per plot decreased over the last decade, however, Plots 5, 1 and 6 had higher effects due to their closeness to grasslands areas where elephants and other herbivores could easily browse. Trees were scarred, ring barked, broken or pushed down. Nampindo (2005), recorded plots 1, 5 and 7 as the most disturbed by the elephants in 2001 while Sheil in 1992 (Sheil and Salim, 2004) recorded plots 1, 5 and 2. This gives a clear indication that plots 1 and 5 were the most prone sites for elephant damage over the last 2 decades, yet they had the highest stem abundance, species diversity and basal area increase. The result therefore agrees with (Sheil, 1996 and Nampindo, 2005) that forest disturbance increases stem density and species diversity. Although (Sheil and Salim, 2004 and Nampindo, 2005) noted that elephant damaged trees in locations where stem density was high, we discovered that the elephants only selected sites where there were trees species composition of their preference for debarking. This minimized their energy budget on movement looking for single species in different locations for debarking. A single site with all the required combination of tree species for debarking made a preferred site where the elephants could return to year after year.

Patterns of scarring amongst trees of different sizes

The lower diameter size classes were most selected than the larger diameter size classes (Nampindo 2005, Sheil and Salim 2004). The preference for the lower diameter size classes could have been due to the tender nutritious tissues which were easy for digestion. The younger plants have high moisture content and therefore easy to be browsed than the larger diameter size classes which would require more energy budget to browse and digest yet they had low nutrient contents. It also takes lesser efforts to browse younger tender stems than the older and mature stems with less reward to the browser. Across the diameter size classes, there was a reduced number of stems debarked which could have been due to the resilience mechanism of the damaged tree stems that could have healed faster.

Scarring rank distribution across the diameter size classes was quite categorical and unique in the lower and larger size classes. We observed that the elephants employed less strength by only inflicting lower scar ranks of 1 or 2 to size class ≤49.9cm dbh and the higher scar ranks on the larger diameter size classes of ≥50cm dbh with scar ranks 3-5. This implied that to remove a reasonable portion of a bigger tree required an extra strength.

In earlier observations, scar rank 1 spread to the larger diameter size classes but still remaining concentrated in the lower diameter size classes. Critical observations revealed that the lower scar ranks in the larger diameter size classes were actually originally larger scar ranks which greatly healed and only remained a smaller portion to close up. On the other hand, scars on the smaller diameter size classes were most recent damages which were just trying to heal.

For elephants to remove a portion of tree bark from a larger size classes with well established stem, a little more strength is applied against the stem. The bark then pealed to a reasonable height roughly 4.5 meters high due to the stronger fibers. These took long to heal or had low resilience because, in most cases, even the cambium cells were affected by the greater force applied by the elephants which left tusk marks against the stems. Other damage effects in smaller diameter size classes included stem breaking, pollarding and extirpation by the mature bulls.

The preferred trees species by elephants in Rabongo Forest

A number of tree species were debarked by elephants in Rabongo forest over the last 20 years (1992-2011). Elephants mostly preferred *Diospyros abyssinica*, *Holoptelea grandis*, *Trichilia prieuriana* and *Cynometra alexandri* for debarking. These tree species played a major contribution towards the elephants' woody plants dietary selectivity for Rabongo Forest over the last 20years. The long term monitoring of the elephants' feeding ecology on forest trees in Rabongo Forest clearly proved preference for such species. There was reduction in the percentages of *Diospyros abyssinica* from 36.9% to 18.9% and *Holoptelea grandis* (28.9% to 22.7% stems) while *Trichilia prieuriana* had a higher preference from 4% to 19.6%. The abrupt rise in *Trichilia prieuriana* was a clear indication of woody species dietary change in the elephants' feeding behavior in Rabongo Forest over the later decade. We also observed that the percentage of *Trichilia prieuriana* scarred increased in 2011, meanwhile the percentages of *Diospyros abyssinica* and *Holoptelea grandis* scarred reduced, which could be due to changing preference with time. Individuals with extreme damage sprouted/coppiced, this facilitated the overall resilience of the forest in that the forest cover increased through multiple re-sprouts. The selected coppicing species were kept at browsing level while the non selected species grew to canopy heights maintaining a multistory forest canopy stratum (O'Connor, 2000). Some tree species are known to be exhibiting chemical defense and poor quality to the elephants that could have limited their selectivity (English 2014). Elephants selected tree species whose attributes predisposed them to pollarding,

uprooting or scarring. The selected species remained more less the same over the 20 years' assessment with *Trichilia prieuriana* being highest in 2011. The most damaged tree species were also the most abundant tree species in Rabongo Forest that complemented most of the elephants' woody species diet. Elephants preferred browsing on the tree species with higher stem density than those with less stem density (Sheil and Salim 2004, Nampindo, 2005). In this case, one could wonder why the abundance of the species didn't reduce over the last two decades of browsing if the tree species were not resilient to the elephant damages. This leaves more opportunity for further research on the attributes making these tree species most preferred or whether the elephant disturbance caused their abundance.

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7. REFERENCES

Alder, D., and Synnott, T.J., 1992. Permanent Sample plot Techniques for mixed Tropical Forest. Tropical Forestry Papers No. 25

Blake, Stephen and Clement Inkamba-Nkulu. 2004. Fruit, minerals and forest elephant Bolivia, Canada. Journal of Forest Resources 33:330-338.

Botes, A., McGeoch, M.A., Van Rensburg, B..J., 2006. Elephants and human induced changes to dung beetle (Coleoptera: Scarabaeidae) assemblages in the Muputaland Centre of endemism. Biological Conservation 130: 573-583.

Eggeling, W.J. 1947 Observations of the Ecology of Budongo rainforest, Uganda. Journal of Ecology.

Hisashi M., Peter L., and Jum Rafia Abd. Sukor 2013. Utilization of Macaranga trees by the Asian elephants (*Elephas maximus*) in Borneo. Mammal Study 31:115-118 (2006)

Holdo, R.M., 2003. Woody plants damage by African elephants in relation to leaf nutrients in Western Zimbabwe. Journal of the Tropical Ecology 19: 189-196.

Huang W.,Pohjonen,V,Johansson,S., Nashanda,m., Katigula, mil and Luukkanen,O (2003). Species diversity, forest structure and species composition in Tanzanian tropical forests. Forest Ecology and Management 173:11-24.

Megan English, Graeme Gillespie, Marc Ancrenaz, Sulaiman Ismail, Benoit Goossens, Sen Nathan and Wayne Linklater (2014). Plant selection and avoidance by the Bornean elephant (Elephas maximus boeneensis) in tropical forest: does plant recovery rate after herbivory influence food choices? Journal of Tropical Ecology, 30, pp 371-379 doi:10.1017/s0266467414000157

Nampindo, S., 2005. The role of elephants (*Loxodonta africana* Blumenbach) in forest savanna vegetation change in Rabongo forest, Uganda. Msc. Thesis Makerere University.

Norden N, Chazdon R.L, Chao A, Jiang Y.H, Vilchez-Alvarado B. Resilience of tropical rain forests: Ecology Letter 2009 12(5): 385-94.

Norman Owen-Smith and Jonas Chafota (2012) Selective feeding by a mega herbivore, the African elephant (Loxodonta africana) Journal of Mammalogy 93(3):698-705.

O'Connor, T.G., 2006,. A functional hypothesis of the threat of local extirpation of woody plant species by elephants in Africa. Centre for African Ecology, Witwatersrand South Africa.

Osborn, F.V., 2004. Seasonal variation of feeding patterns and food selection by crop-raiding elephants in Zimbabwe. African journal of Ecology 42: 322-327.

Schoonenberg, T., M. Pinard, and S. Woodward. 2003. Responses to mechanical wounding and fire in tree species characteristic of seasonally dry tropical forest of Bolivia. Can. J. For. Res. 33: 330–338.

Sheil, D. and Salim, A. 2004. Forest trees persistence elephants and stem scars. BIOTROPICA 36(4): 505-521

Ssali, F. Sheil, D. and Nkurunungi J. B., 2013. How selective are elephants agents of forest tree damage in Bwindi Impenetrable National Park, Uganda. African Journal of Ecology volume 51, Issue 1. Pp 55-65 2013

Thompson, I., B. Mackey, S. McNulty, and A. Mosseler. (2009). Forest resilience, biodiversity, and climate change. a synthesis of the biodiversity/ resilience/stability relationship in forest ecosystems. Technical Series No. 43. Montreal: Secretariat of the Convention on Biological Diversity.

Uganda Wildlife Authority (2014). Murchison Falls National Park, Bugungu Wildlife Reserve, Karuma Wildlife Reserve (Murchison Falls Protected Area). General Management Plan, July 2013 – June 2023

8. APPENDICES

***Appendix 1**: Tree species preference by elephants over 20 years in Rabongo Forest-Murchison Falls National Park*

Species	Total No. of stems 1992	Percentage debarked 1992	Total No. of stems 2001	Percentage debarked 2001	Total No. of stems 2011	Percentage debarked 2011
Affania cinerea	0	0	3	0	5	0.7
Albizia grandbracteata	0	0	0	0	16	2.7
Albizia gummifera	0	0	0	0	3	0.7
Antiaris toxicaria	5	0.1	8	0.2	8	1.4
Blighia unijugata	13	0.2	30	0.4	36	2
Caloncoba schweinfurthii	107	2.1	164	2.3	91	3.4
Celtis zenkeri	9	0.7	26	1.4	45	1
Chrosophyllum albidum	3	0.6	3	0.6	2	0
Coffea canephora	12	0.2	17	0.2	13	0
Cola gigantea	4	0.2	1	0	1	0
Cordia africana	8	0.2	3	0.2	2	0
Cynometra alexandri	64	12.1	120	11.6	273	11.7
Dichrostchys cinerea	18	1.2	24	0	7	0.7
Diospyros abyssinica	820	33.6	970	34.7	830	13.6
Erythrophyllum fischeri	13	0	12	0	10	0.7
Ficus exasperata	2	0.2	3	0.2	3	0
Ficus sansibarica	15	0.5	13	0.4	13	0
Holoptelea grandis	549	27.7	657	29.7	582	18
Kigelia africana	23	0.2	28	0.2	10	0.7
Maerua duchensii	0	0	2	0	3	1.4

Majidea fosteri	1	0	1	0	1	0.7
Margariteria discoideus	37	0.5	41	0.4	39	0.7
Markhamia lutea	24	1	18	1.2	0	0
Milicia excelsa	7	0.2	8	0.2	18	0.2
Monodora angolense	7	0.9	8	0.8	4	0
Monodora myrstica	1	0.2	1	0.2	4	0
Oxyanthus speciosus	33	0.5	48	0.6	1	0
Premna angolense	68	0.2	100	0.6	5	0.7
Pseudospondias microcarpa	1	0.2	1	0.2	1	0
Pterigota mildbreadii	5	0.7	7	0.8	4	2
Rauvolfia vomitoria	115	5	133	3.7	2	2.8
Rinorea ardisfolia	58	3.7	83	4.5	64	5.5
Rothmannia ucerllifomis	26	2.1	28	0.6	20	0
Screbera arborea	33	1.7	21	0.2	23	2
Tapura fischeri	26	0.4	95	0.4	126	1.4
Terminalia sp	0	0	0	0	1	0.7
Tetrapleura tetraptera	9	0	14	0	12	0.7
Trichilia prieuriana	19	1.5	111	2.1	139	19.6
Turrea floribunda	6	0.3	19	0.2	25	0.7
Vangueria madagascariensis	0	0	1	0.2	4	1.4
Vernonia amygdalina	9	0.5	13	0	3	0
Xylopia parvifolia	31	0.2	73	1	61	0.8
Zahna golungensis	1	0.4	0	0	7	1.4
Total percentage		**100**		**100**		**100**