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Elephant damage and tree response in restored parts of Kibale National Park, Uganda

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Elephant tree damage is a key factor in conservation and restoration efforts of African rain forests. This study was conducted between June 2009 and February 2010 to examine elephant damage and tree response in restored parts of Kibale National Park, a rain forest in Uganda. First gazetted as Forest Reserve in 1932, the area had its southern block settled and degraded through human utilization between 1970 and 1987. In 1992, the government of Uganda relocated the settled people and embarked on a restoration process. Whereas, trees such as *Ficus* species exhibited high coping abilities to elephant damage through re-sprouting, coppicing and bark recovery; *Prunus Africana* struggled because it is highly preferred by elephant for feeding and is also demanded by humans. Whereas, options that can minimize elephant damage through selective planting of less desired species may be successful, these will deflect the problem of elephant damage to local farmers through experiences of increased crop raiding as the animals search for preferred forage. A more accommodative approach that includes desirable species which can cope with damage; and the protection of endangered species that happen to be desired by both humans and elephant may be more rewarding.

Key words: Elephants, tree damage, restoration, crop raiding, tropical forest.

INTRODUCTION

Restoration is suggested as one of the best approaches to address degradation of tropical forests (Bamwerinde et al., 2006). However, the activity faces several challenges. Notably, it is expensive yet even when successfully planted the trees are susceptible to damage by, among other causes, forest fauna. This study looked at how the African elephant (*Loxodonta africana*), the largest terrestrial mammalian herbivore (Kingdon, 1979), had affected restoration efforts in an African rainforest and how trees have coped. Over the last five decades, elephants have emerged as major ecosystem engineers that influence African forests changing aspects such as forest structure and composition (Croze et al., 1981; Laws, 1970; Laws et al., 1975; Martin, 1991; Tchamba, 1996) and are sometimes the only seed dispersers for some tree species (Chapman et al., 1992). Thus, the species has positive influences on forest dynamics but may also constitute an “elephant problem” (Barnes, 1983); through, the damage it

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causes, as in the case of Kibale Forest National Park (KNP) in Uganda, and is a conservation concern. Kibale forest received ‘national park’ status in 1993 but prior to that it was a ‘forest reserve’, gazetted in 1932, with the stated goal of providing a sustained production of hardwood timber (Osmaston, 1959). A felling cycle of 70 years was initiated, on recommendation that logging opens the canopy by approximately 50% through the harvest of trees over 1.52 m in girth (Kingston, 1967). This history of logging led to varying degrees of disturbance in the forest.

The park had its southern block degraded through human settlement and cultivation between 1970 and 1987. In 1992, the government of Uganda relocated the people in order to restore the forest and declared it a national park the following year. This was done to accord it a higher protection status. The restoration programme mainly considered indigenous tree species, but also prioritized endangered species (especially Mahoganies, *Prunus africana* and *Cordia* species) (UWA, 2003). The latter are important sources of elephant food and thus the restoration paradoxically improved the elephant habitat by supplying more food. Within KNP, a number of studies have looked at elephants tree damage, but these only considered naturally growing trees and not the restored tree species (Banana and Gombya-Ssembajjwe, 2000; Struhsaker et al., 1996).

This study identified all restored tree species and documented their response to elephant damage. We also identified the various mechanisms these trees applied to cope with the damages. Results from this study have implications for the management of forest restoration at KNP and other places with similar conditions.

MATERIALS AND METHODS

Study area

Kibale National Park is located in the districts of Kabarole, Kamwenge and Kyenjojo in Western Uganda (Figure 1), between 0° 13' to 0° 41' N and 30° 19' to 30° 32' E, and is near the foothills of the Rwenzori Mountains. The park, protecting moist evergreen rain forest, covers about 766 km^2 in size and lies between 1100 and 1600 m in elevation. The mean annual rainfall in the region is 1750 mm, and the mean daily minimum temperature is about 16°C. Rainfall is bimodal, with two rainy seasons from March to May and September to November. Kibale, one of the last remaining expanses to contain both lowland and montane forests, borders Queen Elizabeth National Park to the south and wildlife moves freely within the two protected areas. It is an important ecotourism destination, popular for its population of habituated chimpanzees and other species of primates. KNP consists of mature, mid-altitude, moist semi-deciduous and evergreen forest (57%), grassland (15%), woodland (4%), lakes and wetlands (2%), colonizing forest (19%) and plantations of exotic trees (1%). This study was conducted in parts of the forest with large canopy gaps created during logging and human settlement and cultivation.

The KNP elephant population of about 300 animals (Chiyo, 2000) is also fond of feeding from these open areas. The park, rich in a number of primates, is best known for its chimpanzees. Other resident animals include bush pigs, duikers and cats. The forest has more than 400 species of trees and shrubs, some of which are categorized as endangered (UWA, 2003).

Data collection and analysis

Sampling procedure

Data were collected between June 2009 and February 2010 in the restored area located in the southern part of KNP. From a baseline transect, laid at random, subsequent transects were laid at intervals of 100 m. In all, 24 transects were established, which ranged between 1300 to 2400 m in length. Temporary, 20 × 20 m plots were placed systematically at alternating sides of transects at intervals of 100 m by clearing a narrow trail around them using machetes. A total of 360 plots were established. These were marked and numbered using flagging tapes placed on poles in the middle of the plot. Damage caused by elephants was conspicuous. Elephants are unique herbivores and because of their size it is hard to mistake their activities with something else. To further ensure correct identification of elephant damage, a number of other factors were considered according to elephant habits for example (i) direct observation of elephant paths made through the restored area; (ii) elephant feeding signs were conspicuous, for example pulling down trees to browse on twigs, breaking branches, and pulling out roots and reducing woody cover and; (iii) association with footprints and dung as evidence of elephant presence.

Identification of tree species, damage status, survival and diameter sizes

Tree species were subsequently grouped into eight size classes defined by stem diameter: <5, 5 to 9, 10 to 14, 15 to 19, 20 to 24, 25 to 34, 35 to 44 and > 44 cm. Trees were identified to species level with the aid of protocols described by Katende et al. (1995) and Hamilton (1981). The Diameter sizes at Breast Height (DBH) were measured using a pair of Vernier calipers and the values recorded in the data sheets. All trees within plots were assessed for elephant damage (Table 1).

Characterizing trees basing on the type, extent of elephant damage and tree response

Tree damage was categorized into three major categories:

Category one (not damaged)

These are trees with no damage at all.

Category two (damaged but coping)

These had evidence of elephant damage and signs of recovery. Recovery was identified through signs such as: (i) coppicing - when growth was observed as a response of the tree to elephant damage; (ii) sprouting - when a tree had any new growth of a plant such as a new branch or a bud as a counter response to elephant damaged parts; and (iii) bark healing - when the damaged part of the tree trunk bark grew again and repaired, and covered the damaged and exposed areas.

Category three (damaged and dead)

Category three comprised of trees with evidence of elephant damage to tree parts (the crown or the trunk) and was drying or dead. These had no evidence of recovery after damage. For all damaged trees, the extent of damage was assessed and assigned categorical scores based on how far the elephant went to damage the tree from the outer bark into the deep parts of the inner vessels.

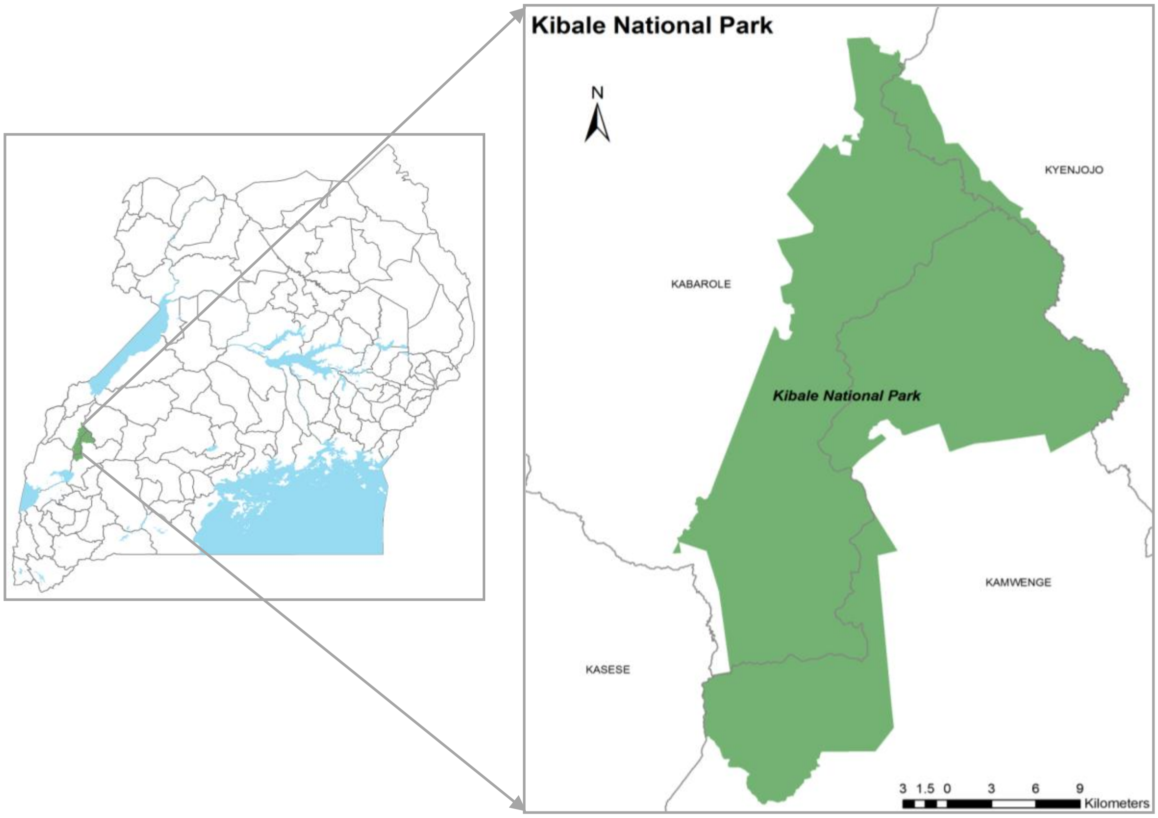

Figure 1. Location of Kibale National Park in Uganda.

Table 1. Codes developed to record data on tree conditions to examine type of elephant damage in Kibale National Park, Western Uganda.

Code	Tree condition	Definition of tree condition
GC	Good condition	No evidence of physical damage observed
DT	Damaged twigs	Twigs have been eaten by elephants
DB	Debarked	Part of the stem stripped of bark exposing wood underneath
BS	Broken stem	Stem dead or broken by pushing over by elephants
UR	Uprooted	Tree uprooted
BB	Broken branches	Tree branches have been broken by elephants
BT	Broken top	Crown completely broken off
TF	Tree fallen	Tree completely fallen down
TP	Trampled	Tree trampled on the ground by elephants
LB	Leading shoot broken	Leading shoot completely browsed off leaving only branches.

Habitat types were classified based on the dominant vegetation in the sampled plots, and elephant damage to different tree species in different habitats and in different diameter size classes was recorded. Various habitat types were encountered in the plots: elephant grass dominant (EGD), *Albizia* dominant (ALD), *Bridelia* dominant (BRD), *Lantana* dominant (LAD), *Acanthus* dominant (ACD), shrub dominant (SHD), herbaceous plant dominant (HPD), *Sapium* dominant (SAP). Damage was recorded according to codes in Table 1.

We recorded causes of damage and response for example re-sprouting, coppicing along the remaining stem, coppicing from the rootstock in order to record tree resilience. We later categorized trees as resilient or non-resilient and scored coping abilities to elephant herbivory.

Data analysis

Qualitative data on the characteristics of trees depicting tree condition were tabulated and used to generate graphs of species; their relations and diameter classes. In order to assess whether elephant damage to trees varied with species, habitat type and diameter size class, Chi-square tests were performed at a 5% level of significance. The tree conditions or damage codes were tallied and converted to percentage occurrence and used to deduce the

Table 2. List of tress species planted for restoration of degraded parts of Kibale Forest National Park, western Uganda (1996 to 2002).

Species category		
Pioneer	**Intermediate**	**Climax**
Bridelia micrantha	*Cordia africana*	*Chrysophyllum albidum*
Croton megalcarpus	*Cordia mellinii*	*Lovoa brownii*
Croton macrostarchys	*Mimusopsis bagshawei*	*Uvariopsis congensis*
Sapium elipticum	*Prunus africana*	*Diospyros mespiliformis*
	Warbugia ugandensis	
	Spathodea campanulata	
	Erythrina abyssinica	
	Dassylepsis egglingii	
	Strobozia sclefferi	

type and extent of damage inflicted on trees by elephants.

RESULTS

Tree species and damage status

A total of 1520 individual trees belonging to thirty seven (37) indigenous tree species were encountered (Table 2). Of these, 17 were planted for restoration and 20 were naturally growing. Following Moles and Westoby (2000), restored species were categorized into functional groups of pioneers, intermediate and climax species (Table 2). Whereas, restoration records state that there were equal planting of the species in all categories, we found very few climax species, but many pioneers and the intermediates (Table 3). The two most frequent species *Bridelia micrantha* (22%) and *Sapium elipticum* (15%) are pioneer species. Other species constitute less than 10% each. In terms of damage, of the 37 tree species recorded, more than 60% was constituted by 14 species each of which had individuals damaged by elephants. Moreover, ten of these were species involved in the restoration process (Figure 2). The least damaged trees species included *Blighia unijigatus*, *Markhamia lutea*, *Allophyllus abyssinica*, *Maesa lanceolata*, *Chrysophyllum albidum*, *Croton macrostachyus*, *Spathodia campanulata*, *Vernonia amygdalina*, *Acacia sieberiana*, *Celtis africana*, *Melicia dura*, *Warbugia ugandensis*, *Antidesma membranaeceum*, *Erythrina abyssinica*, *Rauvolfia vomitaria*, *Tabernaemontana holstii* and *Funtumia africana*.

The trees that were not damaged included *M. dura*, *Kigelia africana*, *Olea welwitschii*, *Diospyros abyssinica*, *Mentena undata*, *Entanda abyssinica* and *Cordia africana.* Out of the seven non-damaged trees only one species was involved in the restoration process.

Type of elephant damage and tree response

Elephants were the major cause of tree damage, accounting for damage of about 61% of the damage observed in sampled tree population (Figure 2). The highest and common form of damage was debarking, followed by breaking of branches, broken stems and broken leading shoots. Of the trees damaged by elephants, 58% were coppicing, 29% showed no signs of recovery but were still alive while 13% were dead (Table 4). In addition to species specific intrinsic resilience traits, the extent of the wound also influenced tree recovery. There was a significant negative association between extent of tree wound and coppicing capacity ($p < 0.01$). Elephant damage was significantly associated with habitat type ($\chi^2 = 72$, d.f. = 7, $p < 0.01$). Habitats dominated by the elephant grass had most tree damage, followed by *Albizia* spp dominated habitats and then *Bridelia* sp dominated habitats. Habitats dominated by *Sapium* sp had the lowest damage. On comparing all the habitats, it is evident that elephant damage to tree species related to presence of their preferred food ($p<0.01$), thus, the high prevalence of damage in habitats dominated by elephant grass and *Albizia*. When we looked at tree damage in relation to size, the greatest damage (81%) was observed among trees with less than 5 cm DBH. Trees with larger diameters seemed resilient.

Most of these large trees were partly debarked and had scars suggesting that they were survivors of damage at some stage in their development. Trees that survived elephant damage generally had many wounds and disfigurements.

Tree recovery modes and coping mechanisms after elephant damage

In general, the trees exhibited three major responses to elephant damage - coppicing, sprouting and bark repair. There were inter-species variations in mechanisms used. For example, Ficus species coppiced, sprouted and generally showed signs of bark repair after damage. The species also produced sticky exudates immediately after injury. In particular, *Ficus* seemed to be the most resilient to elephant damage among all the species. *P. africana*

Table 3. Numbers and composition of enumerated trees species and proportion of elephant influenced damage in the restored area of Kibale National park, western Uganda. Data collected between June 2009 and February 2010.

Specie	Species count	Percentage composition	Number damaged	Proportion damaged (%)
Bridelia micrantha	340	22	63	17
Sapium elipticum	227	15	41	18
Warbugia ugandensis	94	6	9	10
Funtumia Africana	86	6	11	13
Albizia gummifera	84	6	46	55
Rauvolfia vomitaria	74	5	4	5
Erythrina abyssinica	52	3	3	6
Spathodia campanulata	52	3	9	17
Diospyros mespiliformis	50	3	2	4
Uvariopsis congensis	42	3	30	71
Prunus africana	41	3	35	85
Maesa lanceolata	38	3	10	26
Albizia zygia	34	2	17	50
Mimusops bagshaweii	30	2	17	57
Ficus branchipoda	28	2	18	64
Markhamia lutea	26	2	9	35
Croton megalocarpus	25	2	21	84
Vernonia amygdalina	23	2	4	17
Antidesma membranaceum	22	2	2	9
Chrysophyllum albidum	20	1	5	25
Ficus vivas	20	1	15	75
Croton macrostachyus	17	1	4	24
Acacia sieberiana	14	1	2	14
Celtis africana	14	1	2	14
Acacia hockii	12	1	10	83
Blighia unijigatus	10	1	4	40
Tabernaemontana holstii	10	1	0	0
Ficus natalensis	9	1	6	67
Albizia coriaria	5	0.3	3	60
Lovoa brownie	5	0.3	3	60
Melicia dura	5	0.3	0	0
Allophyllus abyssinica	3	0.2	1	33
Kigelia africana	3	0.3	0	0
Olea welwitschii	2	0.1	0	0
Entanda abyssinica	1	0.1	1	-
Mentena undata	1	0.1	1	-
Diospyros abyssinica	1	0.1	1	-

and *S*. *campanulata* responded to damage through bark repairs. In these species, fresh bark started to form within two weeks after injury. *Cordia mellinii*, *E*. *abyssinica*, *Mease lanceolata*, *Crysophyllum albidum*, *F*. *africana*, *Markamia lutea* and *V. amygdalina* responded to damage by coppicing. However, some trees had no indication of recovery after damage. This was common with *B. micrantha*, *Albizia* spp, *Croton* spp, *S*. *elipticum*, *Uvariopsis congensis* and *Acacia hockii*.

DISCUSSION

This study importantly identifies elephant preference for candidate restoration species and differences in these species' ability to respond to damage. A restoration programme that deliberately selects species less preferred

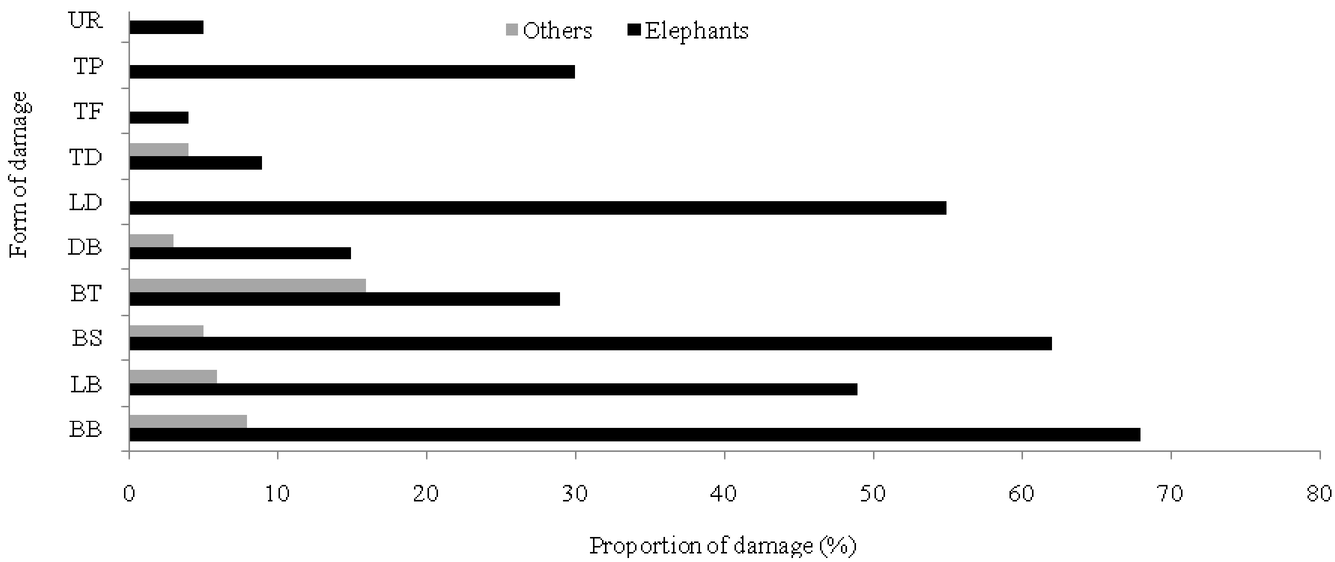

Figure 2. Observed different forms of damage and corresponding proportion damage in percentage. BB represents broken branches, LB = broken leading shoot, BS = broken stem, BT = broken top, DB = debarked, LD = dried upper leaves, TD = dried top, TF = tree fallen, TP = trampled and UR = uprooted. Others represent forms of vertebrate damage other than elephants for example, buffalos, duikers, bush pigs and primates.

Table 4. Status of surveyed tree species and their response to damage in Kibale Forest Park.

Damage and response	Abundance	Relative abundance
Undamaged trees	607	39
Elephant damaged and coppicing	550	35
Elephant damaged, not coppicing but living	275	18
Elephant damaged and dead	63	4
Damaged by diseases	28	2
Damaged by insects	18	1
Damaged by other herbivores	15	1

by elephants as has been done in Swaziland (Mtui and Owen-Smith, 2006) may thus be more successful. An equally successful strategy may be selection of species that we identify to respond well to elephant damage. In this respect, species like *Ficus vivas* which showed exceptional characteristic of good sprouts following elephant browsing are more desirable in such situations. Moreover, *F. vivas* is fed on by a wide range of ungulates (Ndawula et al., 2011; Tweheyo et al., 2010) and may thus have multiple benefits. Complementary human care mechanisms to prevent herbivory could be used. Examples include guarding and fencing in the first five years of the restoration process since older trees are more resilient (Makhabu et al., 2006). *P. africana* topped the list of species preferred by elephants in the restored region. The species contains iron levels exceeding 250 ppm and can satisfy the iron requirements of elephants (Arnold and Townson, 1998). Similar observations of elephants selecting trees to damage according to species have been made (Calenge et al., 2002).

From our discussions with park management and the local people, the same species also tops the list of species preferred by human beings. This is confirmed by our field observations that the species had far more signs of human collection of bark than all the other species. Species like *P. africana* and *Lovoa* spp, which hardly geminate after deforestation, are on high demand for human utilization yet are prone to herbivore damage. These are also endangered species (UNEP-WCMC, 2010) and deserve prioritisation in forest management.

Conclusion

It is clear that elephants present antagonistic relations to forest restoration. Whereas, there are tree species that are less favoured by elephants for herbivory, some are well adapted through coping mechanisms as in the case of *Ficus* sp. However, as the case of *P. africana* demonstrates, it may not be an optimal restoration strategy to go for the former species. Therefore, an active programme that manages rather than prevents elephant damage may be more preferable. Moreover, prevention techniques such as the planting of undesirable species may help but only to push the problem to the local people as elephants may frequently find themselves visiting local gardens for food. Mackenzie and Ahabyona (2012) estimate an average farmer around KNP to lose around US$74 (1.5% of median household capital asset wealth). Whereas, baboons are the most frequent raiders in this area, they are closely followed by the elephants which moreover cause more damage per event (Mackenzie and Ahabyona, 2012; Naughton-Treves et al., 1998). Elephant damage is thus both a conservation and livelihood concern that needs to be carefully managed so that conservation of the flora and fauna is promoted in ways that are also compatible with the livelihoods of the local people.

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