

Full Length Research Paper

Feeding pattern of forest elephants in the Nki National Park and its environs, East Region, Cameroon

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Forest elephants play a vital role as keystone species in forest ecosystems, but little information is known on their feeding pattern which is a key concern for its conservation. This study was carried out in Nki National Park and the specific objective was to identify cultivated and non-cultivated plants eaten by elephants. Eleven 2 km line transects, and reconnaissance walk of approximately 40.16 km were used to identify all feeding signs of elephants. Also, administration of semi-structured questionnaires to 107 participants in 9 villages around the park was used to collect data on Human-Elephant Conflict mainly on crop raiding to identify cultivated plants eaten by elephants. Analysis was done using descriptive statistics in Statistical Package for Social Science (SPSS) version 23. Results showed that 25 wild and 18 cultivated plants from 24 families were consumed by elephants in the park and along its peripheries with diet preference of fruits (62%) and least being stems (6%). The most abundantly consumed plant families were Poaceae (*Setaria palmifolia*), Sapotaceae (*Gambeya lacourtiana*), and least being Pandaceae (*Panda oleosa*) among other families. This shows that elephants have a very diverse diet requirement which is important in the management and conservation of this critically endangered species.

Key words: Feeding pattern, wild plants, cultivated plants, conservation, *Loxodonta cyclotis*.

INTRODUCTION

Population pressure, poverty, agricultural intensification and expansion, development of infrastructure, etc., have been marked as main threats to biodiversity in the tropics (Davidar et al., 2010; Bargali et al., 2018, 2019; Vibhuti et al., 2020; Padalia et al., 2022). Merely 7% of the earth's land surface is covered by tropical forests and harbour more than half of the world's species (Wilson, 1988) and are highly threatened by human activities (Htun et al., 2011; Baboo et al., 2017; Mourya et al., 2019). The aforementioned factors have reduced the natural resources for wild life and domestic life.

Forest elephants (*Loxodonta cyclotis* Matschie, 1900)

consume all plants life forms and fruits make up a greater part of their diet with grass making a small proportion of their diet (Tchamba, 1996). Forest elephants rarely move far away from permanent drinking water, thus drinking water availability does not constrain their access to food resources, habitat selection, or long-distance movements (Powell, 1997). Forest elephants do not make large-scale migratory movements such as those exhibited in savannah elephants, this is confirmed by incipient data from telemetric studies (Powell, 1997), though, more recent telemetric studies showed that forest elephants may make movements of over 100 km when their range

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is not restricted by human activity. This is done using collars fitted with Global Positioning Systems (GPS).

Vegetation distribution and characteristics are important determinants of elephant density and distribution in African forests (Fay and Agnagna, 1991b; White, 1994a). Does drinking water availability drive the distribution and large-scale movements by forest elephants? Powell (1997) argued that the determinant of forest elephant distribution is brought about by ripe fruit availability and White (1994b) alluded that elephant may move as far as 50 km into the forest in search of super-abundant fruit patches. Forest elephants maintain a high fibre intake throughout the year consisting of leaf browse, wood, bark, roots, stems, and aquatic vegetation though fruit constitute a larger part of the diet, (White et al., 1993). Feeding ecology of African forest elephants precisely in Central Africa, has been less documented. Studies in Cameroon precisely in Santchou Forest Reserve (Tchamba and Seme, 1993), Bayang-Mbo and Korup forests (Powell, 1997) showed that different plant parts make up forest elephants' diet which include leaves, bark, wood, roots, and fruit. Despite the unavailability of quantitative data, fruits, terrestrial herbaceous vegetation (THV) and secondary woody growth, all make up very important components of forest elephant diet, at least seasonally, and may influence elephant abundance and distribution (Short, 1983).

Forest elephants also occur at high density in open canopy, including secondary forests in Central Africa (Barnes et al., 1995a, b; Powell, 1997), where the abundance of forest floor vegetation may be higher than the closed canopy forest types (Short, 1983; Barnes et al., 1991). The Marantaceae forest of the Lopé Reserve, Gabon has recorded the highest consistent density of forest elephants (3 individuals ha⁻¹) (White, 1994b), where Terrestrial Herbaceous Vegetation (THV) (Rogers and Williamson, 1987) is more abundant as compared to the herb layer. As compared to the scrub forests of Kibale, the Lopé Marantaceae forest is also in the late stage of forest succession toward closed canopy or mature forest (White and Tutin, 2001). An abundant source of herbaceous browse may also be found in swamp forest (Barnes et al., 1991), as they do for savannah elephants in East Africa (Western and Lindsay, 1984). In addition to leafy vegetation, fruit availability may also influence the density and distribution of forest elephants (Short, 1983; Merz, 1986; White, 1994c; Powell, 1997).

Among some of the most important plants consumed by forest elephants are *Anonidium mannii*, *Dudoscia* species, *Panda eleosa*, *Myrianthus arboreus*, and *Gambeya lacourtiana* (Blake, 2002). The flora of Nki National Park was surveyed and found to consist of about 831 plant species belonging to 111 families (Nkonmeneck, 1998) but no study has been done in the park to ascertain the plants consumed by elephants which led to this study. A full knowledge of elephant

foraging patterns is important for understanding their habitat requirements and for assessing their habitat condition for effective management. The primary objective of this study was to establish the different varieties of both wild and cultivated plant species consumed by elephants in the Nki National Park and its surroundings.

MATERIALS AND METHODS

Description of study area

The Nki National Park (NNP) is situated between latitudes 2°05'N to 2°50'N and longitudes 14°05'E to 14°50'E. It covers a surface area of about 309,362 ha (3,093.62 km²) (Nyenty, 2016). It is situated in the East Region of Cameroon between Ngoyla sub-division in the Upper-Nyong division, Moloundou sub-division in the Boumba-and-Ngoko and Salapoumbé divisions (Figure 1).

Floristic results of the NNP revealed by Nkonmeneck (1998) and Ekobo (1998) showed the presence of 8 different types of vegetation disseminated in an evergreen, mixed and semi-deciduous forest. These include mono dominant forests of *Gilbertiodendron dewevrei*, mixed forests of *G. dewevrei* and *Raphia regalis*, forests dominated by *R. regalis*, forest clearings and swampy grasslands with or without salt licks, swampy forests of *Raphia* species, forests of *Mapania* species, forests of *Baphia leptobotrys* forests with undergrowth dominated by the family of Marantaceae. The wildlife of this region is estimated at 34 species of which large mammals are made of 11 species of primates, 12 species of ungulates and sub-ungulates including elephants and 4 species of carnivores (Ekobo, 1998).

Data collection

Data was collected in Ikwa area in the Nki National Park on eleven 2 km transect and approximately 40.16 km recce walkways and in nine villages surrounding the Nki National Park from the 18th of March to the 28th of May 2021. For this length of time, the research team went to the field twice collecting information on elephant feeding pattern. During surveys along the transects and approximately 40.16 km recce in between transects, all 'fruit fall events' of succulent fruits and pods observed along each transect and recce were recorded and identified to species where possible. Any fruit fall case was described as the fruit fall from a single plant seen on the survey route. Also, large trees, understory vegetation and vegetation on forest clearings eaten by elephants were identified.

Information on cultivated plant species eaten by elephants was collected by using semi-structured questionnaires/interviews (Bargali et al., 2007, 2009; Pandey et al., 2011; Parihaar et al., 2015; Padalia et al., 2017; Bisht et al., 2021) in nine selected villages. A total of 107 village informants were selected to get the required information for the study. Informants/Respondents were selected from the age of 16 and above and the questionnaire was based on elephant occupancy, detectability, and human-elephant conflict most especially on crop raiding to identify the cultivated plants consumed by elephants. Before the administration of questionnaires to the villagers, a pretesting was done in one of the villages (Doumzock) which was not included in the nine selected villages. This was to ensure that locals understand the questions. The nine selected villages were Dimako, Lelene, Lamson, Ngoyla-village, Mabam-Baka, Mabam-Ndjem, Nkondong II, Djadom and Bareko II.

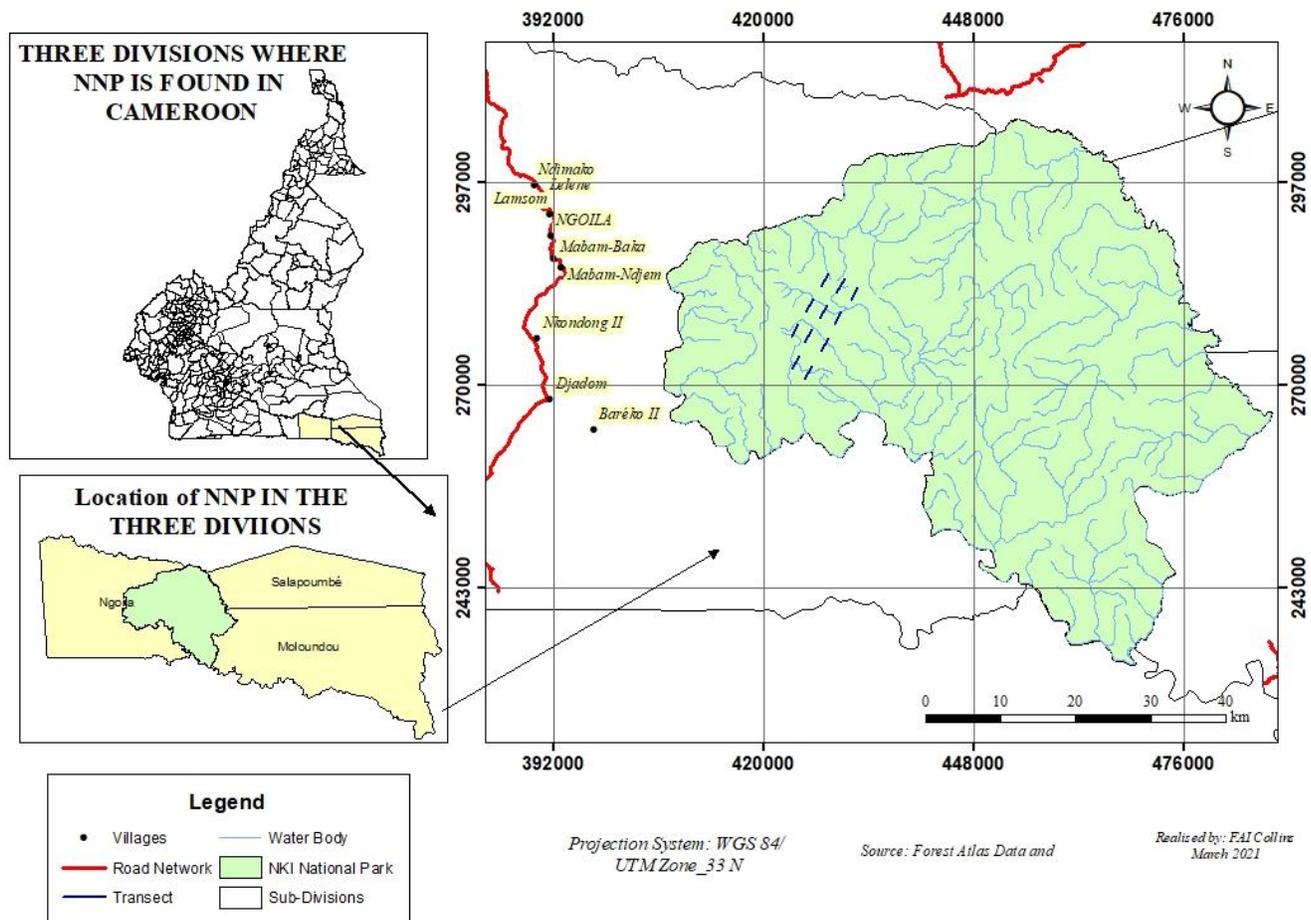


Figure 1. Map of Nki National Park (Njoka, 2021).

Plant identification

Plant identification was done in the field using morphological characters. Plant samples, videos and images of plant characters were recorded for later identification by Mr. Bellinga Bana Jean Paul (botanist at WWF-Jengi Tridom in Ngoyla) and an inventory of these plants was made.

Data analysis

Inventory was made of the collected and identified plants showing their families, species and the part of the plant consumed by elephants. These plants were also grouped into monocots and dicots and descriptive statistics were used to compare various variables using Statistical Package for Social Sciences (SPSS) software version 23 and the results presented in three tables and four figures.

RESULTS

Species of plants eaten by elephants in the Nki National Park and its peripheries

During the survey on transects, recesses and interviews,

several species of wild and cultivated plants were recorded. 25 wild plants and 18 cultivated plants were identified to be fed upon by elephants in the Nki National Park. These plants were grouped into 24 families with different plant parts consumed: leaves, stems, bark, fruits, seeds, and pulp (Table 1).

Plant parts consumed by elephants

The identified plants species were grouped according to the different parts consumed by elephants; fruits and seeds, leaves, stems, bark, and whole plant (Table 2). From the identified plants eaten by elephants, the highest proportion of the plant part eaten were fruits and seeds (62%) and the least was stem (6.0%).

Forest elephant's diet composition by life form

Elephants fed more on trees which accounted for 56% of their food from plant life form, followed by monocotyledons with 23% of species and the least was fern with 2% (Figure 2).

Table 1. Plant species and parts fed upon by elephants.

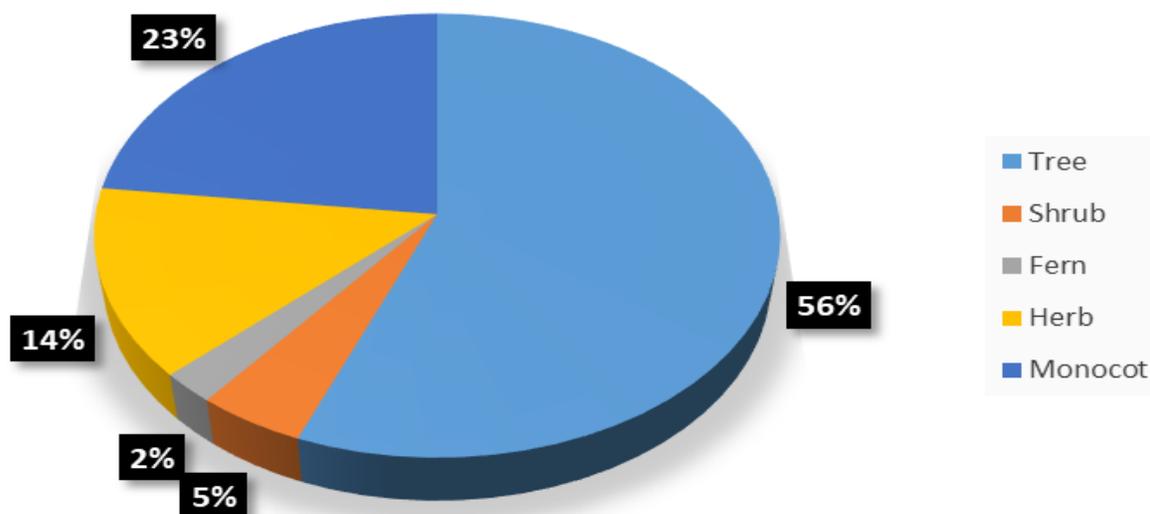
Family	Scientific name	English name or commercial name	Plant part eaten
Wild Plants			
Annonaceae	<i>Anonidium mannii</i>	Wild soursop /ebom	Fruit
	<i>Xylopiya athiopica</i>	Okola	Fruit
Sapotaceae	<i>Gambeya lacourtiana</i>	Abam vraï	Fruit
	<i>Omphalocarpum elatum</i>	Navel fruit tree/mebememgono kosso	Fruit
	<i>Baillonella toxisperma</i>	Moabi	Fruits
	<i>Autranella congolensis</i>	Mukulungu tree	Fruit and bark
Combretaceae	<i>Terminalia ferdinandiana</i>	Kakadu plum/bush Plum	Fruit
Invirgiaceae	<i>Irvingia robur</i>	African mango	Fruit
	<i>Irvingia gabonensis</i>	Bush mango	Fruit
	<i>Klainedoxa gabonensis</i>	Eveuss	Fruits
Arecaceae	<i>Raphia monbuttorum</i>	Raffia	Pulp, young bamboos and nuts
Moraceae	<i>Myrianthus arboreus</i>	Giant yellow mulberry/monkey fruit	Fruits
Clusiaceae	<i>Garcinia kola</i>	Bitter kola	Bark and fruits
Pandaceae	<i>Panda oleosa</i>	afan(e)	Bark and fruits
Anisophyllaceae	<i>Poga oleosa</i>	African Brazil nut/Afo/ ovoga	Bark and fruits
Malvaceae	<i>Duboscia macrocarpa</i>	-	Fruits
Mimosaceae	<i>Tetrapleura tetraptera</i>	Aridan fruit/four corners (akpa)	Fruits
Poaceae	<i>Setaria barbata</i>	Corn grass	Whole plant
	<i>Setaria palmifolia</i>	Palmgrass	Whole plant
	<i>Pennisetum purpureum</i>	Elephant grass	Stem and leaves
Marantaceae	<i>Ataenidia conferta</i>	Emviali	Whole plant
	<i>Haumania danckelmaniana</i>	Sel	Whole plant
	<i>Megaphrynium macrostachyum</i>	Okoe	Whole plant
Meliaceae	<i>Lovoa trichiliodes</i>	Dibetou	Fruit
Cultivated plants			
Curcubitaceae	<i>Cucumeropsis edulis</i>	Egusi/Ngon	Fruit and seeds
	<i>Cucurbita pepo</i>	Pumpkin	Whole plant
Poaceae	<i>Zea mays</i>	Maize	Whole plant
	<i>Saccharum officinarum</i>	Sugar cane	Whole plant
Musaceae	<i>Musa paradisiaca</i>	Banana	Pith, leaves and fruit
	<i>Musa sapientum</i>	Plantain	Pith, leaves, and fruits
Anacardiaceae	<i>Mangifera indica</i>	Mango	Fruit
Burseraceae	<i>Dacryodes edulis</i>	Plum	Fruit
Lauraceae	<i>Persea americana</i>	Pear	Fruit
Myrtaceae	<i>Psidium guajava</i>	Guava	Fruit
Arecaceae	<i>Elaeis guinensis</i>	Palm tree	Pulp and nuts
	<i>Cocos nucifera</i>	Coconuts	Leaves and nuts
Annonaceae	<i>Annona muricata</i>	Cultivated Soursop	Fruit

Table 1. Contd.

Rutaceae	<i>Citrus latifolia</i>	Lime fruit	Fruit
	<i>Citrus aurantifolia</i>	Lime fruit	Fruit
	<i>Citrus sinensis</i>	Orange fruit	Fruit
Bromeliaceae	<i>Ananas comosus</i>	Pineapple	Fruit
Caricaceae	<i>Carica papaya</i>	Paw-paw	Fruit
Total = 24	43		

Table 2. Proportions of plant parts eaten by elephants.

Plant part	Number	Percentage
Whole plant	8	16.0
Bark	4	8.0
Stem	3	6.0
Fruits and seeds	31	62.0
Leaves	4	8.0
Total	50	100.0

**Figure 2.** Forest elephant's diet composition by plant life form.

Monocotyledons and dicotyledons' percentage consumption by elephant

Plant species eaten by elephants were grouped into monocotyledons and dicotyledons for both wild and cultivated plant species and for the entire plant species collected (Table 3). Among the wild plants collected, 68.0% were dicots while 32.0% were monocots. Cultivated plants showed 44% dicots and 56% monocots but overall, 58% dicots and 42% monocots plants are consumed by elephants (Figure 3).

Plant species eaten by elephants classified according to family

The different plant species eaten by elephants were classified according to families to identify which family had the highest number of species eaten by elephants (Figure 4). Many families had the same number of plants that were consumed by elephants. Poaceae was the family with the most abundant plant species consumed by elephants, followed by Sapotaceae and lastly by Pandaceae among many other families. Many families

Table 3. Grouping of plants into monocots and dicots.

S/N	Monocotyledons	Dicotyledons
Wild plants		
1	<i>Raphia monbuttorum</i>	<i>Anonidium mannii</i>
2	<i>Setaria barbata</i>	<i>Xylopia athiopica</i>
3	<i>Setaria palmifolia</i>	<i>Gambeya lacourtiana</i>
4	<i>Pennisetum purpureum</i>	<i>Omphalocarpum elatum</i>
5	<i>Ataenidia conferta</i>	<i>Baillonella toxisperma</i>
6	<i>Haumania danckelmaniana</i>	<i>Autranella congolensis</i>
7	<i>Megaphrynium macrostachyum</i>	<i>Terminalia ferdinandiana</i>
8	<i>Pteridium aquilinum</i>	<i>Irvingia robur</i>
9		<i>Irvingia gabonensis</i>
10		<i>Klainedoxa gabonensis</i>
11		<i>Myrianthus arboreus</i>
12		<i>Garcinia kola</i>
13		<i>Panda oleosa</i>
14		<i>Poga oleosa</i>
15		<i>Duboscia macrocarpa</i>
16		<i>Tetrapleura tetraptera</i>
17		<i>Lovoa trichiliodes</i>
Total	8	17
Cultivated plants		
1	<i>Cucumeropsis edulis</i>	<i>Mangifera indica</i>
2	<i>Cucurbita pepo</i>	<i>Dacroydes edulis</i>
3	<i>Zea mays</i>	<i>Persea americana</i>
4	<i>Saccharum officinarum</i>	<i>Psidium guajava</i>
5	<i>Musa paradisiaca</i>	<i>Annona muricata</i>
6	<i>Musa sapientum</i>	<i>Citrus latifolia, Citrus aurantifolia</i>
7	<i>Elaeis guinensis</i>	<i>Citrus sinensis</i>
8	<i>Cocos nucifera</i>	
9	<i>Ananas comosus</i>	
10	<i>Carica papaya</i>	
Total	10	8
Grand total	18	25

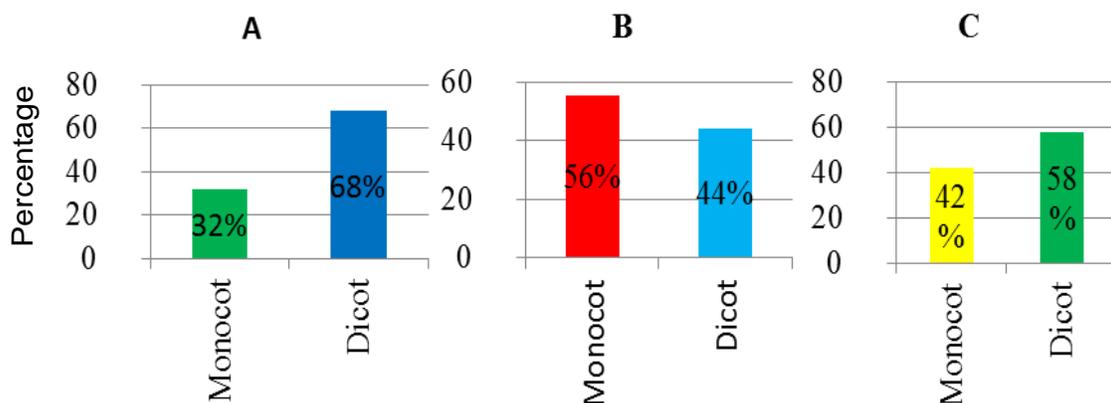


Figure 3. Proportions of monocotyledons and dicotyledons consume by elephants within wild plants (A), cultivated plants (B) and whole study (C).

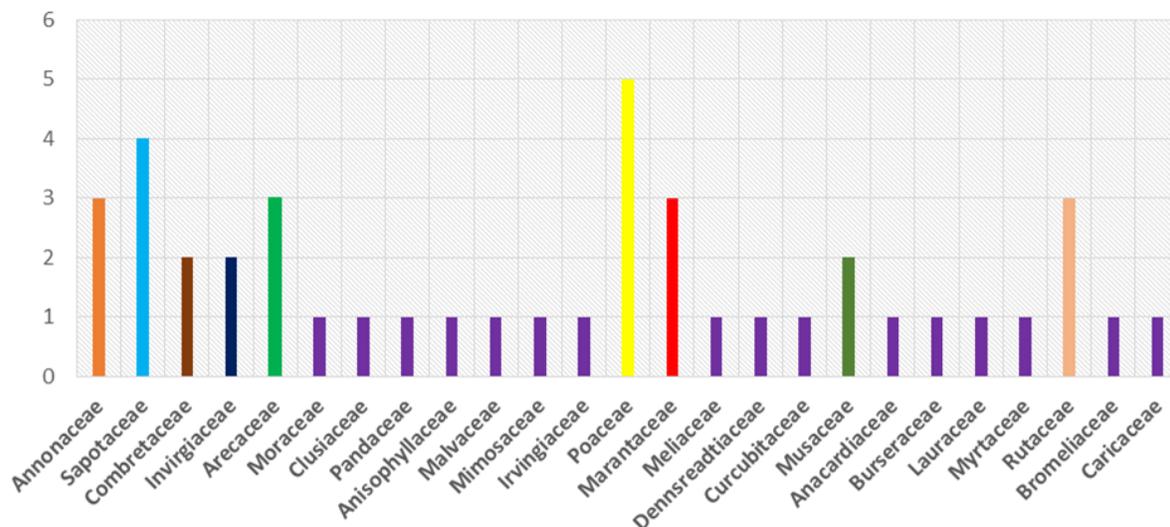


Figure 4. Proportions by family of plants consumed by elephants.

had the same number of plants that were consumed by elephants.

DISCUSSION

The flora of Nki National Park is diverse with about 831 plant species belonging to 111 families of which 544 are in the undergrowth and 287 have diameters greater than or equal to 10 cm (Nkonmeneck, 1998). Of this great diversity, this study recorded only 25 wild plants in the park and 18 cultivated plants along the peripheries of the park known to be eaten by elephants in this park. In the Santchou reserve, Tchamba and Seme (1993) identified only 39 plant species consumed by forest elephants out of which 17 were fruits. Blake (2002) recorded 351 different plant species from 73 families in Ndoki National Park. The comparatively large food list for elephants in the Ndoki National Park may have more to do with the focus and long duration of the study and not a difference in the forest elephant diet.

It is ascertained that forest elephants consume more fruits compared to savannah elephants (Alexandre, 1978; Gautier-Hion et al., 1985; Dudley et al., 1992; Tchamba and Seme, 1993; White et al., 1993; Feer, 1995; Powell, 1997). This study indicated that fruits accounted for the highest proportion (62%) of plant part consumed by elephants. This aligns with an extensive study on the role of forest elephants as seed dispersers in Bayang-Mbo and Korup forests Cameroon (Powell, 1997) who isolated 93 different species of germinating seedlings in elephant dung piles. This was further confirmed by the study of Blake (2002) in the Ndoki National Park where elephants consumed a minimum of 96 species of fruit from 35 families, and fruit was present in 94.4% of dung piles.

Overall, trees mostly dicots (58%) were the most heavily consumed plant life form. Grass was rarely eaten by elephants in the forest though the most abundant plant family (Poaceae) recorded were grasses, but their consumption rate was low. This same pattern was reported by Blake (2002) in the Ndoki National Park in neighboring Congo where forest elephants fed mostly on tree products than grasses. Information on food selection of forest elephants by life form is limited. Tchamba and Seme (1993) reported that in the Santchou reserve, elephants feed mostly by either grazing or stripping off fruit' which constituted 45 and 38% of their records, while only 6% of feeding observations were recorded of elephants eating leaves and twigs. The Santchou reserve has many vegetation types; savannah, swamp forest and farmland, and forest elephant rates of feeding may vary by vegetation type and these data may not reflect overall life form selection rates of elephants. Other published studies of forest elephant feeding ecology give no information on the relative frequency with which the different plant life forms are eaten but rather species lists by life form is used as an indicator of the importance of each plant species (Merz, 1981; Short, 1981; White et al., 1993). All these studies show that, in terms of number of species, small dicotyledonous trees are the most commonly eaten plant type. This present study shows 68% dicots and 32% monocots consumption of wild plants, a 56%:44% monocots and dicots consumption pattern of cultivated crops along the peripheries of the park and an overall 58% dicots and 42% monocots consumption rate of all identified plant species. Based on plant life forms, this study showed that trees (57%) were the most consumed, then monocots (23%), herbs (14%), shrubs (4%) and least consumed was ferns (2%). An abundant monocotyledon remains (excluding grasses) in

dung samples was found throughout the year in the Lopé Reserve (White et al., 1993), though neither Merz (1981) nor Short (1981) listed a single monocotyledon food species in their study sites, even though these species were present in the understory.

Across all plant life forms, fruits and seeds constituted 62% of all feeding events, though when elephants find themselves on cultivated land, most crops are consumed whole. Other studies have not focused on identifying the different cultivated plant species raided by elephants where human-elephant conflict is prevalent. This study identified 18 species of cultivated plants consumed by elephants on farmlands.

This study recorded Poaceae as the family with the most abundant plant species consumed by forest elephants though their proportion of consumption was very small. The Nki National Park is made of different vegetation types, and since feeding ecology of elephant is influenced by habitat type, grasses may compensate for low fruit availability in some habitat types or during seasonal decrease in fruit availability.

Conclusion

The findings of this study showed that forest elephants feed on a diverse diet of different plant species consisting of 25 wild plants and 18 cultivated plants with their diet preference mainly consisting of fruits in the Nki National Park and its surroundings. This knowledge on elephant feeding requirements is essential for the conservation of this Critically Endangered Species. Plant species such as *A. mannii*, *G. lacourtiana*, *Duboscia macrocarpa*, *Iringia gabonensis* and *Baillonella toxisperma* among many others which are consumed maximally by elephants should be propagated/regenerated and managed *in-situ* at higher level/quantity so that elephants could not face any paucity of the food.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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