Research Article:

DIETARY COMPOSITION OF ASIAN ELEPHANTS IN PARSA NATIONAL PARK: A MICRO-HISTOLOGICAL APPROACH

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ABSTRACT

The endangered Asian elephants face extreme threats from habitat loss and fragmentation, poaching for ivory, trophy hunting, and human-elephant conflicts. These mega-herbivores require ample forage and exhibit seasonal variations in their food intake. To analyze their diet, we collected vegetation samples through direct and indirect observations of signs such as feeding or damage, as well as dung samples from the core area and the buffer zone of Parsa National Park. A total of 30 species showed the most sign and damage categories in the core area, while 5 species were identified in the buffer zone. Micro-histological analysis of dung samples indicated that both monocots (excluding grasses) and dicots contributed significantly in the core area, whereas grasses and debris were comparatively more prevalent in the buffer zone. The availability of diet and nutritional preferences drive elephant movements and generate conflicts with local communities living in the buffer zone, especially when available habitat is shrinking and preferred species are limited in the core area. It is essential to manage the grasslands within the park by focusing on palatable, nutritious, and preferred species to achieve conservation goals for these endangered megafauna and minimize conflicts with local communities.

Key words: Dung analysis, foraging behavior, habitat management, human-elephant conflict, megafauna

INTRODUCTION

Asian elephants (*Elephas maximus*) are endangered (Choudhury et al., 2008), protected species under NPWC Act, 1973 in Nepal and CITES has listed this species in Appendix I. Besides poaching for ivory, trophy hunting, human-wildlife conflict, etc., they are at extreme threat also due to habitat loss and fragmentation (Naha et al., 2020; Ram et al., 2022, Sukumar, 2006; Pradhan et al., 2011). Being generalist herbivores Elephants are both grazers and browsers (IUCN, 2013), several studies on the diets of wild and domestic elephants have shown seasonal variations in their food selection across Asia and Africa (Baskaran et al., 2010; Bax & Sheldrick, 1963; Chen et al., 2006; Himmelsbach et al., 2006; Sukumar, 1990). Although Sukumar (1989, 1992; 2006) found that during the dry season, the majority of the elephant diet consisted of woody plants, while grasses comprised the majority of the elephant's diet during the wet season in Asian elephant feeding in short, tall and mixed/tall grasslands, grass dominates the diets of elephants all year round in dry deciduous and dry thorn forests (Baskaran et al., 2010). On the other hand, a seasonal fluctuation of diet composition such as a higher proportion of dicots in the dry season (February–April) compared to that of the wet season (June–September) has been reported (Koirala et al., 2016).

As food distribution and density are important factors influencing habitat selection by elephants (Shannon et al., 2006), the presence of agricultural lands near the park can significantly alter the foraging behavior of herbivores (Fox & Abraham, 2017). Crop raiding was highest during post monsoon season (June-August) in different parts of Nepal (Dangol et al., 2020; Neupane et al., 2013; Pant et al., 2016; Shrestha, 2007; Silwal et al., 2016), Assam (Wilson et al., 2015), Karnataka (Stone et al., 2019) and southern India (Rohini et al., 2016). In the foothills of the Himalayas, human-elephant conflict increases during maize or wheat maturing time (June-July) and also during paddy maturing time (September-November) (WWF, 2007).

As the largest terrestrial animal, elephants have huge demands for food, consuming as much as 150 kg of fodder per day (Vancuylenberg, 1977) and large home ranges (Alfred et al., 2012). They are a non-ruminant but have large caecum and colon for fermentation and digestion and defecate as often as 15 to 20 times per day. The need to find large amounts of food determines elephants ranging patterns and other aspects of their behavior. Elephants feed on a wide range of plant types, often showing a preference for grasses and other monocotyledons plants (English et al., 2014a, 2014b) although studies in southern China and Myanmar showed that elephants feed on nutritious foods other than grasses (Campos-Arceiz et al., 2008; Chen et al., 2006).

Micro-histological analysis of feces has been widely used to study the diet of a range of wild and domestic animals from herbivores to carnivores (Alipayo et al., 1992). The basic principle of this technique is that the cuticle of the plant epidermis survives digestion and that the undigested epidermal parts in the dung can be identified by comparing them with known plant reference material (Steinheim et al., 2005). It is reliable and particularly useful in comparative studies of wild elephant food habits in many areas (English et al., 2014a, 2014b; Yamamoto-Ebina et al., 2016) since direct observation is not always feasible.

Although the dietary requirements of Asian elephants have been studied, the majority of these studies have dealt with the documentation of food plant species by direct or indirect observation, mainly in the core area however, details regarding food choice and diet composition in both core and buffer zone through micro-histological analysis of dung remain unclear. The information on elephant food habits in different habitats for Parsa National Park (PNP) is still inadequate, and further quantitative analyses are required. Thus, this study helps to fulfill the gap in understanding Asian elephant feeding ecology and food habits and diet choices in selected habitats through a micro-histological analysis of dung and the perception of stakeholders for better management of their habitat.

MATERIALS AND METHODS

Study area

Parsa national park (PNP) extends along the Himalayan foothills and consists of floodplains, Dun valleys, Bhabar tract, and Shiwalik and Chure hills in the south-central lowland of Nepal (Fig. 1). The study sites for the core area were selected in (Bhata-Laukidaha, Bhata-Amlekhgunj, Rambhouri-Ghodemasan, Bhata-Rambhouri, Bhata Range post- Dharmasala, Bhata-Devakidaha, Bhata-Jamini Khola, Bhata-Chabi Khola, and Grassland areas), and buffer zones (Pratappur and Sunachuri in Manahari Rural Municipality) were selected as high potential areas for wild elephants following recognition survey and consultation with park/local people consultation. The soil is primarily composed of gravel and conglomerates and the forest is mainly composed of tropical species.

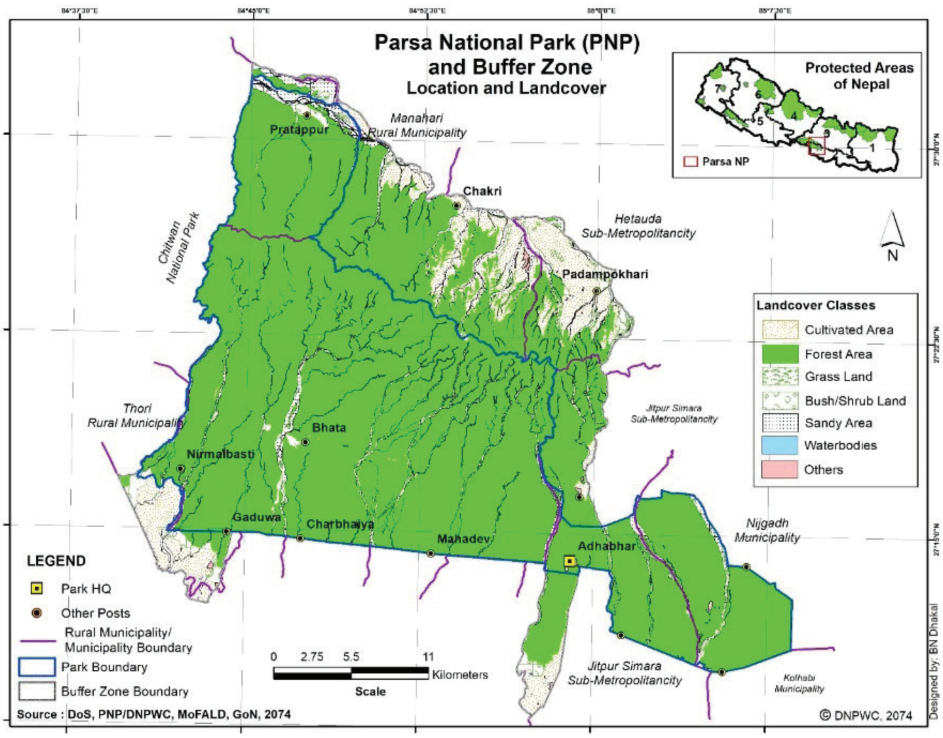


Fig. 1. Map showing core area and buffer zone of the study site

Data collection

Field Survey and sample collection

Field surveys and sample collection were done during January to May in both the core area and buffer zone to collect the vegetation samples with direct and indirect observation of signs and symptoms such as feeding or damage following recognition survey and interaction with locals/ park officials to identify the potential habitats of wild elephants. A total of 30 purposive sample plots of 10 m x10 m were established where we observed the dung, footprint, and feeding sign and symptoms, and vegetation within these plots recorded identifying characteristics of plant damage caused by elephant browse, such as debarking, branch breaking, and uprooting were recorded. These plants were collected and brought to the lab for reference plant slides for micro-histological studies.

Laboratory Analysis

Out of the total 30 dung samples collected, a total of 10 dung samples (5 each from the core and buffer zone) were selected randomly for the analysis, following the method of Anthony and Smith (1974) and modified by Holechek et al. (1982). We kept the dung samples oven-dried at 60–70^{0}C for 6-8 hrs, grounded them well, and sieved the products using a 1-mm followed by a 0.3-mm mesh. We then retrieved a teaspoonful of sample contents from the 0.3 mm sieve and treated them with a 5% NaOH solution and boiled each until the samples became transparent. The supernatant dark fluid in the test tube was then washed with warm fresh water and absolute alcohol to remove the NaOH from the sample and to make it clear. Likewise, we prepared reference slides of the potential plant species observed in the field and listed from the literature following procedures for dung sample preparation with additional treatment with 10% concentrations of Nitric and Chromic acid solutions for at least 4 hours and placed in a hot air oven at 40^{0}C until sample became transparent. Photographs of the reference materials were taken using a digital camera attached to a stereomicroscope of the brand COSLAB Model ZSM 115 LED with a camera, COSHWIFI 5000).

Plant material identification

We identified the plant fragments following Johnson et al. (1983). The specific features of the epidermis such as cell wall structure, shape and size of cells, hairs and trichomes, shape, and size of stomata, etc. were analyzed and categorized into: (i) grass, (ii) monocotyledonous leaves other than grasses, (iii) dicotyledons leaves, (iv) woody debris. At last, each fragment was also compared with the collected reference plant material to identify the species consumed.

RESULTS AND DISCUSSION

Sign and Symptoms of Feeding/Damage

During the field visit out of a total of 30 sample plots, 26 were found showing the elephant dung, footprints, and damage whereas only dung and footprint were observed in 4 sample plots. A total of 35 species showed most of the sign and damage categories in the core area and buffer zone (Table 1).

Table 1. List of plants utilized by elephants fully/partially in study area

Local name	Scientific name	Family	Life form
	Core area		
Amala	*Phyllanthus emblica.*	Euphorbiaceae	Tree
Asna	*Terminalia alata*	Combretaceae	Tree
Barro	*Terminalia bellerica*	Combretaceae	Tree
Bhalayo	*Rhus javanica*	Anacardiaceae	Tree
Bhorla	*Bauhinia vahlii*	Leguminosae	Tree
Bot Dhangero	*Lagerstroemia parviflora*	Lythraceae	Tree
Dabdabe	*Garuga pinnata*	Bursaraceae	Tree
Gutel	*Trewia nudiflora*	Euphorbiaceae	Tree
Harro	*Terminalia chebula*	Combretaceae	Tree
Kalikath	*Myrsine semiserrata*	Myrsinaceae	Tree
Khair	*Acacia catechu*	Leguminosae	Tree
Kumbhi	*Careya arborea*	Lecythidaceae	Tree
Kusum	*Schieichera oleosa*	Sapindaceae	Tree
Kyamuna	*Cleistocalyxo perculata*	Myrtaceae	Tree
Sal	*Shorea robusta.*	Dipterocarpaceae	Tree
Sandan	*Desmodium oojenensis*	Leguminosae	Tree
Satisal	*Dalbergia latifolia*	Leguminosae	Tree
Simal	*Bombax ceiba*	Bombacaceae	Tree
Sindhure	*Mallotus phillippensis*	Bixaceae	Tree
Sissoo	*Dalbergia sissoo Roxb.*	Leguminaceae	Tree
Tanki	*Bauhinia purpurea L.*	Leguminosae	Tree
Tantari	*DilleniapentagynaRoxb.*	Dilleniaceae	Tree
Bhati	*Clerodendronviscosum*	Lamiaceae	Shrub
Bhorla	*Bauhinia vahlii*	Fabaceae	Shrub
Curry leaf	*Murraya koenigii*	Rutaceae	Shrub
Lantana	*Lanatana camara*	Verbenas	Shrub
Amriso	*Thysanolaena maxima*	Poaceae	Herb
Kans	*Saccharum spontaneum*	Poaceae	Herb
Siru	*Imperata cylindrical*	Poaceae	Herb
Thakal	*Cycas pectinate*	Cycadaceae	Herb

	Buffer zone		
Maize	*Zea mays*	Poaceae	Herb
Paddy	*Oryza sativa*	Poaceae	Herb
Kans	*Saccharum spontaneum*	Poaceae	Herb
Amriso	*Thysanolaena maxima*	Poaceae	Herb
Simal	*Bombax ceiba*	Bombacaceae	Tree

Joshi and Singh (2008) reported tree species like *Mallotus phillipinensis*, *Acacia catechu*, *Dalbergia sissoo*, *Tectona grandis*, *Zizyphus mauritiana*, *Aegle marmelos*, *Ficus bengalensis*, *Ficus glomerata*, *Grewia oppositifolia*, *Bombax ceiba*, *Lannea grandis*, *Bauhinia variegata*, *Lagerstroemia parviflora*, *Kydia calycina*, *Syzygium cumini*, *Flacourtia indica* and *Ehretia laevis* to which elephants fed up on in Rajaji National Park. Besides these species, elephants also used various grasses and shrubs as their food resources, which included *Dendrocalamus strictus*, *Helictere sisora*, *Saccharum munja*, *Saccharum spontaneum*, *Cynodon dactylon*, *Eulaliopsis binata*, *Tinospora malabarica* and *Neyraudia arundinacea*. It was observed from the present investigation that from January to March, elephants mainly utilized the bark of different trees (*Shorea robusta*, *Bauhinia variegata*, *Mitragyna parvifolia*, *Schleichera oleosa, Lagerstroemia parviflora, Cordia obliqua, Tectona grandis, Holophramitis* spp., and *Bombax ceiba*) as their food. Elephants preferred to feed extensively on the bark and twigs of *Tectona grandis* at the onset of summer whereas they were observed to eat the bark of *Bombax ceiba* tree during the very hot season, also observed by Koirala et al. (2016) in the elephants of Parsa National Park and Chitwan National Park.

Diet composition

The diet of elephants in the forest as well as in the buffer zone was differentiated into four food categories; dicots, monocots, grasses, and debris (Fig. 2). In general, monocots comprised of dung, are higher in both forest core areas and buffer zone. The pair-wise comparison between both habitats shows that the contribution of the monocot in the dung was slightly higher in the core area than in the buffer zone. However, the contribution of the dicot in the forest was significantly higher (Table 2) than in the buffer zone whereas grasses and debris were higher in the buffer zone. As these samples were collected in the rainy season, a similar finding was obtained by Koirala et al., (2016).

Table 2: Pair-wise comparisons (chi-sq) test for food categories in forest and buffer zone

Food Categories	Chi-sq	*Df*	*p*-value
Dicot	153.61	1	0.000
Monocot	14.656	1	0.000
Grass	212.84	1	0.000
Debris	45.505	1	0.000

The availability of the diet and nutritional preference drive elephant movements, and generate conflict with humans, especially when available elephant habitat is shrinking due to forest fragmentation, and degradation, proximity to forest, availability of water (Ram et al., 2022; Rode et al., 2006). The abundance and availability of the different types of vegetation in the core forest exceeded the dicots in the buffer zone. Forests are rich in preferred woody species in comparison to the buffer zone and this might be the reason for the high contribution of dicot in the forest area. The grasses generally have higher digestibility than browse (Van Wieren & Van Langevelde, 2008), which is mainly due to the content of lignified fiber in the grass (Hummel et al. 2006). Elephants mainly feed on green, nutritious grasses in the early wet season (Cerling et al., 2006) and high grazing pressure in the core area might be a reason for the high grasses content in their diet in the buffer zone.

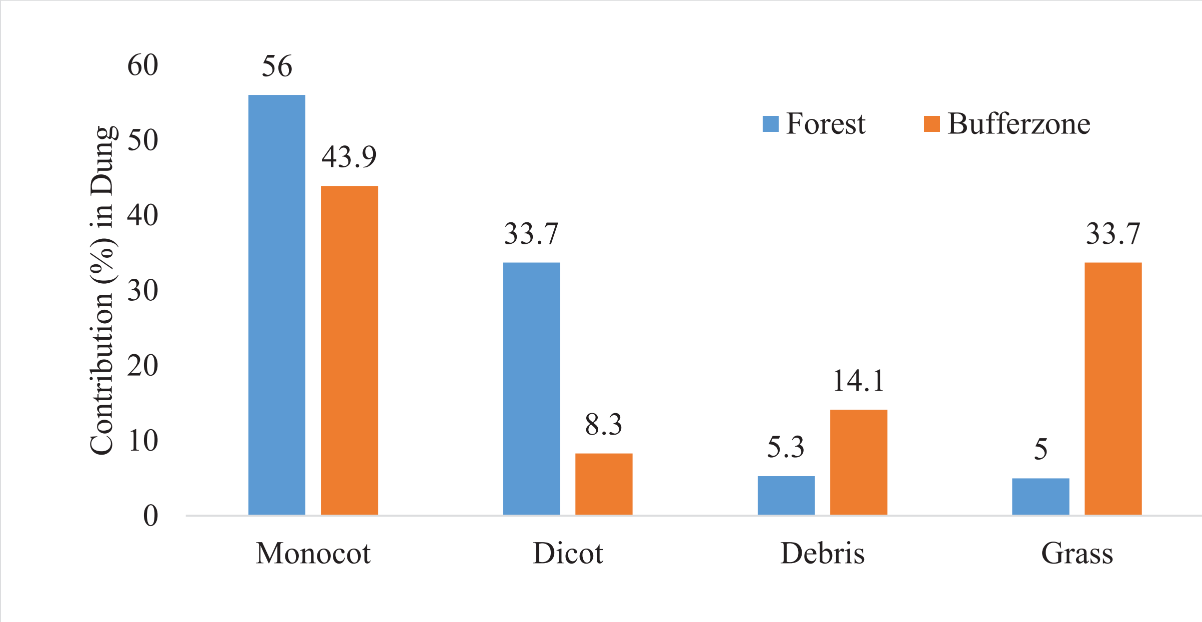
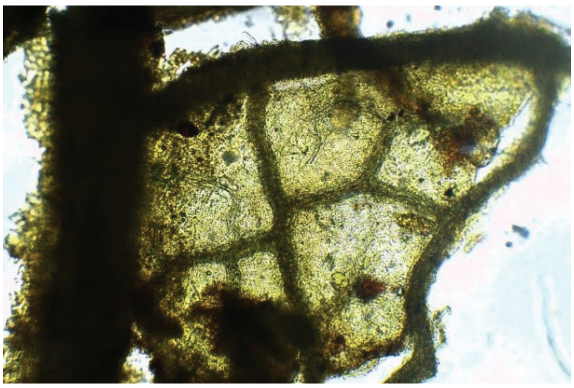
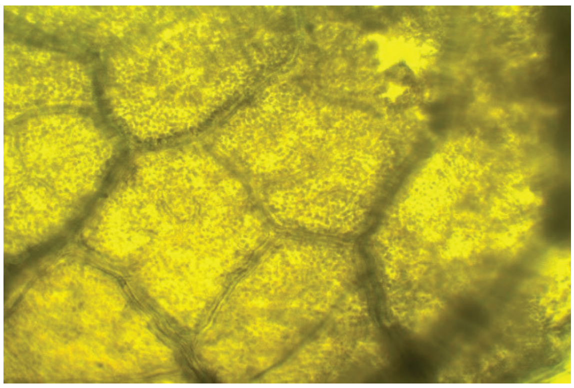


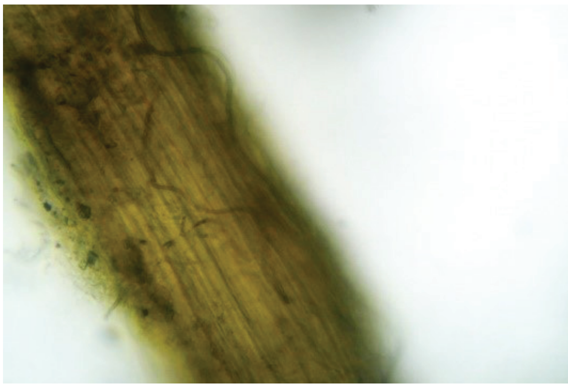
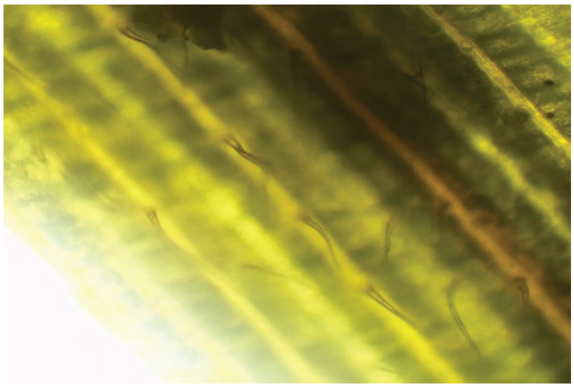
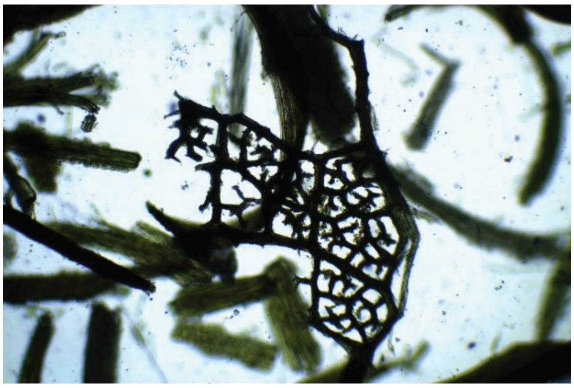
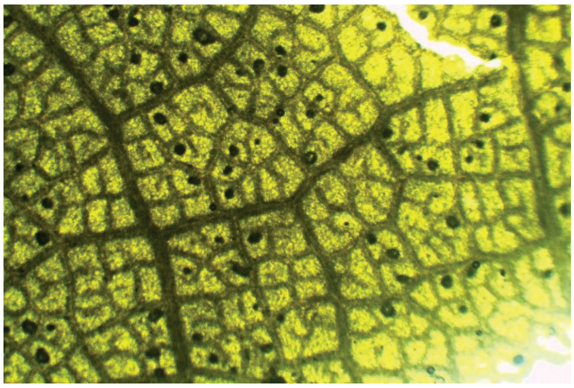
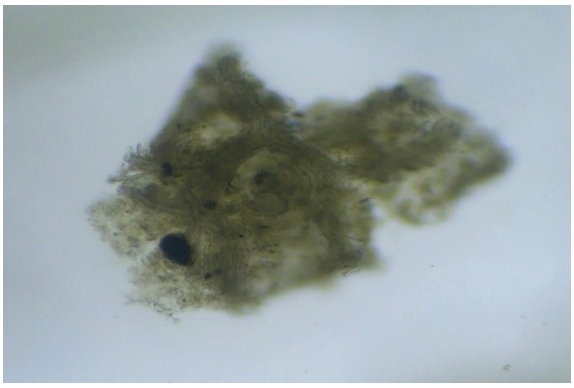
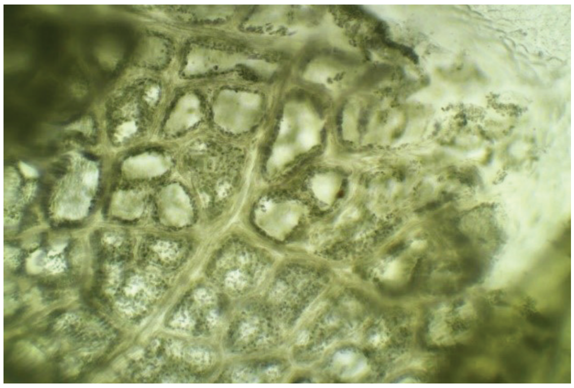
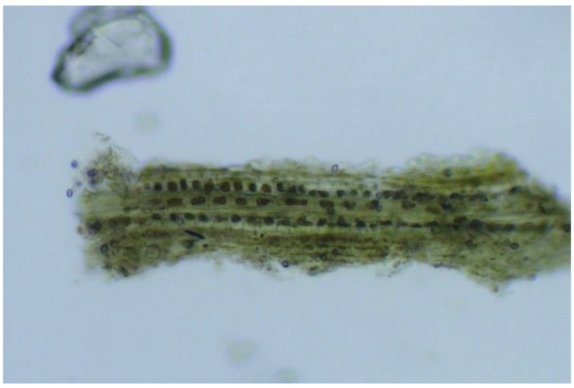
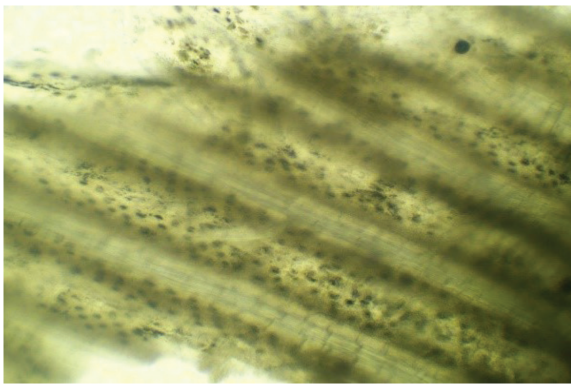
Fig. 2. Comparison of elephant diet composition between core and buffer zone

Species identified from Microhistological analysis of dung

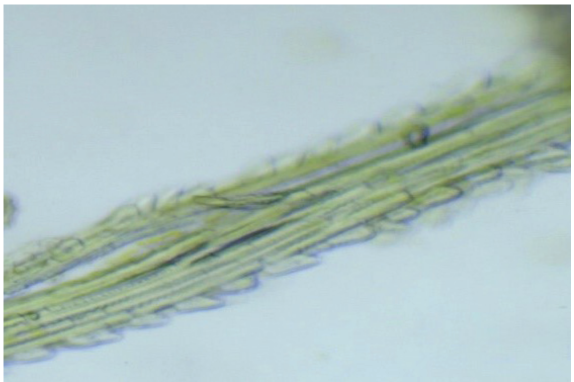
The specific features of the epidermis (cell wall structure, shape and size of cells, hairs and trichomes, shape, and size of stomata) of the reference plant material were photographed and compared with the fragments of dung sample and found the species Garuga (*Garuga pinnata),* Sal *(Shorea robusta)*, Sissoo *(Dalbergia sissoo)* Bot dhangero *(Lagerstroemia parviflora)* Bamboo *(Dendrocalamus sp.)* in the core area. Maize *(Zea mays)* was dominant in the sample of the buffer zone whereas Amriso *(Thysanolaena maxima)* and Kans *(Saccharum spontaneum)* were common in both samples (Fig. 3).

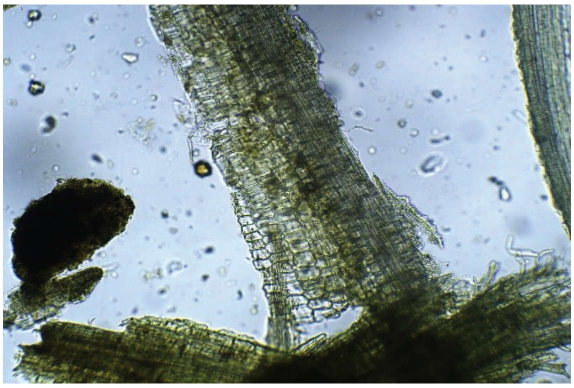
Fig. 3 Identification of dung samples comparing with reference slides

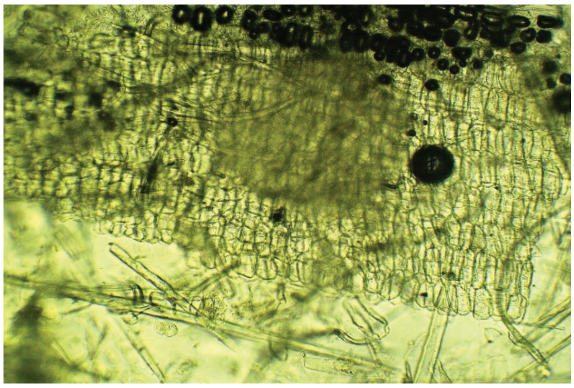
Fragments of dung samples	**Fragments of reference material**
	
Bot dhangero (*Lagerstroemia parviflora*)	Bot dhangero (*Lagerstroemia parviflora*)

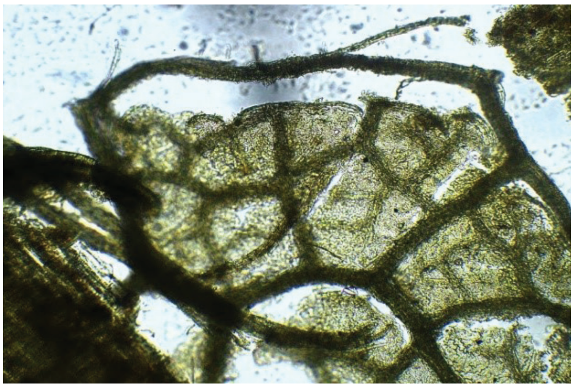
 Bamboo (*Dendrocalamus sp.*)	 Bamboo (*Dendrocalamus sp.*)
 Dabdabe (*Garuga pinnata*)	 Dabdabe (*Garuga pinnata*)
 Sissoo (*Dalbergia sissoo*)	 Sissoo (*Dalbergia sissoo*)
Fragments of dung samples	**Fragments of reference material**
 Amriso (*Thysanolaena maxima*)	 Amriso (*Thysanolaena maxima*)

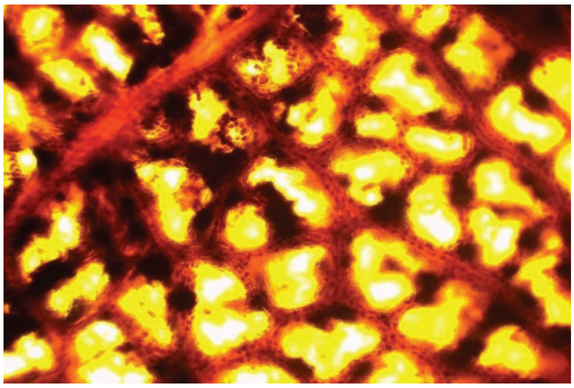

Kans (*Saccharum spontaneum*)


Kans (*Saccharum spontaneum*)


Maize (*Zea mays*)


Maize (*Zea mays*)


Sal (*Shorea robusta*)


Sal (*Shorea robusta*)

Implications for management

For many large herbivores, phenological changes in plant nutrient content play a strong role in determining the timing and frequency of crop-raiding behavior (Chiyo et al., 2005; Osborn, 2004) mainly around the buffer zone of the protected areas resulting in conflict. Among the causes of human-wildlife conflicts, food-and diet-related factors are believed to be the prominent drivers (Can et al., 2014; Coogan & Raubenheimer, 2016). Elephants raid cropland because natural food in the forest is draining as a result of increasing human encroachment and settlement near the forest (Chen et al., 2016; Das & Mrinmay, 2020). It has been found that elephants are known to rely heavily on grass family in the wet season and almost exclusively on woody plants during the dry season so these things should be considered in planning and management for better output in the goal of conservation.

CONCLUSION

Elephants are generalist feeders, consuming a large number of plant species, and show a wasteful mode of feeding. Although elephants prefer monocots in the rainy season, they do not have more options of eating dicots and monocots other than grasses in the core forest. Diet and nutritional preference are the two most important factors that drive elephant movements in buffer zone. Hence, it is obvious to manage the grasslands within the park focusing on palatable, nutritious, and preferred species to achieve the conservation of such endangered megafauna and minimize the conflict with local people.

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