Dry season forage selection by Asian elephant (*Elephas maximus*) in a fragmented landscape, northern West Bengal

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CERTIFICATE

This is to certify that **Ms. Priyanka Das** of Sálim Ali Centre for Ornithology and Natural History (SACON) has carried out an original research work titled, '***Dry season forage selection by Asian elephant (Elephas maximus) in a fragmented landscape, northern West Bengal***' in partial fulfilment of the M.Sc. (Ornithology & Conservation Biology) degree of Saurashtra University, Rajkot. This investigation was carried out under my supervision from December 2019 to August 2020. I also certify that this research work has not been submitted for any other degree to any university.

Date: 19th August, 2020
Place: Coimbatore

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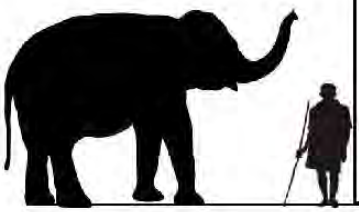

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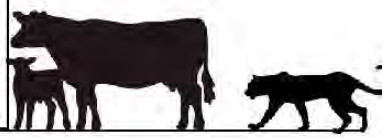

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SUMMARY

The Asian elephant is a wide-ranging species with just 51% of its range across Asia covered by forest land. Hence, it is imperative to plan conservation action in the other half comprising of multiuse landscapes. With food being an important resource determining elephant use and movement, understanding their forage selection in a heterogeneous landscape can help us prioritise allocation of limited conservation resources. I studied forage selection by Asian elephants during December 2019 to June 2020 in a tea-estate-agriculture-forest mosaic in northern West Bengal, a landscape which typifies land-use mosaics used by elephants across India. Asian elephants in the landscape consumed 132 plant species, of which 21 species constituted 85.3% of the total feeding signs recorded, while non-reproductive plant parts dominated the diet. The mean (±SE) feeding frequency was found to be highest in villages [50.15 (±22.85)] followed by forests [40.51 (±9.42)], semi-open forests [12.14 (±9.42)], tea estates [5.79 (±1.95)] and open forests [3.31(±1.44)]. However, the high variance in village indicates that elephants use villages for movement and forages occasionally. Food grain from household was consumed rarely (0.25%). Overall, they used dicots (52.73%) more than monocots (47.27%), and browse (65.23%) more than herb (34.77%). Elephants consumed more monocots in forests and tea estates whereas in semi-open forests, open forests and villages they consumed more dicots. The availability of monocots was lesser than dicots in all these land use and land cover types. In forest, they consumed more herbs, whereas browse was consumed more in all other land use and land cover types. Though herbs were more available in all the land use and land cover types, it was probably not consumed due to lack of palatability. In private land, herds used tea estates significantly more (χ^2= 6.08, df=1, $p<0.05$) than males and males used villages significantly more (χ^2=10.70, df=1, $p<0.05$) than herds leading to a difference in four of the top five species consumed by them. The difference in plant usage could be because herds use private land mostly for passage, whereas males particularly forayed to villages in search of forage. The total number of plant species available recorded was 286. From forest to semi-open forest and open forest, canopy layer tree density and total number of species decreased, whereas invasive species density increased. This could have high impact on the availability of forage species for elephants in semi-open forest and open forest and should be addressed with appropriate habitat management strategies. Of the 96 plant species for

which forage selection was assessed, 80.21% plant species were consumed more than their availability in the environment, contradictory to previous belief that elephants feed on the plants that are available in abundance. Of the plant species that had high selectivity (selection ratio>100), 31.03% of were available only in private land and 51.72% only in forest land. Hence, there are implications of this study: i). to develop appropriate strategies to offset economic loss and associated negative interactions in private land, and ii). private land plays only a subsidiary role and not a substitute for forest land in terms of forage availability for elephants. It was the first time that relative forage use and selection by Asian elephant in a heterogeneous landscape was assessed.

1. INTRODUCTION

1.1. BACKGROUND

The historical widespread distribution range of Asian elephant (*Elephas maximus*) has now shrunk to small pockets in 13 countries in south and south-east Asia (Sukumar, 1989). Consequently, the Asian elephant has been classified as 'Endangered" (Choudhury *et al*., 2008). Globally only 51% of their present range is covered by forests and 16% falls under the purview of legal protection (Leimgruber *et al*., 2003). The Asian elephant is a wide-ranging species with expansive space and resource requirements (Sukumar, 2003) and depends on vast stretches of land rather than a few forest patches (Leimgruber *et al*., 2003). This makes it imperative to focus conservation efforts for Asian elephant at a landscape level (Goswami *et al*., 2014) which provides scope for a cost-effective way to achieve a significant set of conservation goals in a timely fashion (Sanderson, 2002). However, conservation investment and planning in lands outside the Protected Area clearly needs to be based on empirical evidence (Sutherland *et al*., 2004) and prioritization (Goswami & Vasudev, 2017). One such way could be through quantifying resource selection in a fragmented landscape with mosaic land use. This is because availability and distribution of resources seem to primarily influence the occurrence and movement of elephants in a particular landscape (Bastille-Rousseau & Wittemyer, 2019) and could explain associated negative interactions with people.

As elephants spend 70-90% of their time foraging (Wyatt & Eltringham, 1974; Guy, 1976) and consume 1.5% to 2% of their body weight as dry forage daily (Sukumar, 2003), food could be the most important resource in this regard. At a landscape scale, elephants have been found to show strong selection for areas of high foraging opportunities besides water (Bastille-Rousseau *et al*., 2020) and their densities correlate with fruiting season of specific plants (Short, 1983; White, 1994). Although, forage use by Asian elephant is well documented (McKay, 1973; Olivier, 1978; Sukumar, 1990; Chen *et al*., 2006; Varma *et al*., 2008; Roy, 2009; Baskaran *et al*., 2010; Mohapatra *et al*., 2013), very less is known about forage selection (English *et al*., 2014; Koirala *et al*., 2016). Moreover, our knowledge is mostly from savannah habitat and tropical dry forest and very less is known about tropical moist forests, despite the fact that forage use of elephants greatly varies across habitat

types (Sukumar, 2003). Outside the confines of forest land, our understanding is exclusively restricted to crop depredation patterns (Sukumar, 1990; Sitati *et al*., 2005) and not relative forage use in a heterogeneous land use matrix.

Understanding forage selection by elephants at a landscape level has various implications for their conservation. Crop raiding by elephants is the primary form of negative interaction between humans and elephants (Shaffer *et al*., 2019) with an estimated damage of 0.8–1 million hectares of crops every year in India (Rangarajan *et al*., 2010). Understanding elephant forage selection in human use areas would help to quantify the actual loss and develop better mitigation strategies by prioritising crops and areas that require protection and initiating fodder plantation in degraded forest land and fallow areas. Knowledge on forage selection is the first step towards understanding various ecological aspects about elephants as well: i). carrying capacity of a landscape as the availability of food resources is a major determinant (Bi *et al.*, 2016), ii). role in seed dispersal in a habitat type (Campos-Arceiz & Blake, 2011), and iii). if a particular population is undergoing nutritional stress (Trites & Donnelly, 2003).

The Asian elephant population of northern West Bengal is the western most extension of the north-east Indian population (Sukumar, 1989). The landscape has fragmented moist tropical forests in a mosaic of tea plantations and agricultural land with previous evidence of upto 57% of land outside Protected Area being used by elephants (Kshettry *et al*., 2020). It experiences one of the highest negative interactions between humans and elephants in Asia (Sukumar, 2003) with an estimated number of humans killed and injured annually by elephant being 47 and 164 respectively, while annual crop damage by elephant being 2078 hectares between 2006 and 2016 (Naha *et al*., 2019). Hence, this landscape was deemed ideal to understand conservation strategies for Asian elephants by quantifying dry season forage selection in a heterogeneous land use matrix. Furthermore, the landscape provides additional opportunities to address the paucity of knowledge on foraging ecology of Asian elephant in moist tropical forests.

1.2. OBJECTIVE

The aim of the study was to understand dry season forage selection by Asian elephant in a multi-use landscape with fragmented patches of forests.

The objectives of the study were the following:

a. Assessing forage use across different land use and land cover types.
b. Assessing the availability of plant species across different land use and land cover types.
c. Assessing forage selection across different land use and land cover types.

1.3. LITERATURE REVIEW

1.3.1. Status and distribution of Asian elephant

Asian elephants formerly ranged from West Asia along the Iranian coast into the Indian subcontinent, eastward into Southeast Asia, including Sumatra, Java, Borneo, and into China at least as far as the Yangtze-Kiang, which covered an area of 9 million km^2 (Sukumar, 2003). At present, they are distributed in pockets of 13 countries: India, Bhutan, Nepal, Bangladesh, China, Vietnam, Laos, Myanmar, Sri Lanka, Indonesia, Malaysia, Thailand and Cambodia (Sukumar, 2003). Habitat loss and fragmentation have been found to be the main cause for decline in Asian elephant range. Only 51% of the present range constitutes of wild land of which just 16% is under legal protection (Leimgruber *et al*., 2003). As a result, today the Asian elephant represents one of the most endangered species of large mammal in the world (Sanitiapillai, 1997). Only 14 of 59 present ranges have conservation areas larger than the minimum viable area for long term conservation of the Asian elephant population (Leimgruber *et al*., 2003). In India, the Asian elephant population has been estimated to be 27,312 individuals, and they are distributed across four separate geographical regions which are south India, north-west India, north-east India and central India within a total forest area of 1.10 lakh km^2 (MoEFCC, 2017). The north-east Indian population was contiguous till the turn of the previous century, but is now present in 14 discrete pockets due to loss of forest as a result of various anthropogenic activities (Choudhury, 1999). The northern West Bengal population is the western most extension of this north eastern Indian population, and ranges from the Sankosh to Mechi Rivers (Roy, 2009).

1.3.2. Landscape species

Landscapes are defined as spatially heterogeneous areas, typically with an extent at least a few kilometres across (Forman, 1995). Landscape species are defined as biological species

that use large, ecologically diverse areas and often have significant impacts on the structure and function of the natural ecosystem (Sanderson *et al*., 2002). Conservation based on landscape species is focussed on those whose life history characteristics and spatial and temporal biological requirements is particularly useful for identifying when and where human uses of the landscape may compromise the ecological integrity of the overall landscape (Sanderson *et al*., 2002). Conservation of landscape species will lead not only to the conservation of other sympatric species, but presumably also the conservation of the structure of the landscape, including the ecological functions dependent on that structure (Sanderson *et al*., 2002). The Asian elephant has been recognized as a landscape species for the following reasons: i. dependency on areas outside Protected Areas due to their expansive space and resource requirements, ii. susceptibility to threats from poaching and negative interactions between human and elephant that can potentially limit their occurrence in human-dominated areas and iii. their significant influence on ecosystem structure and function (Goswami *et al*., 2014). However, conservation investment and planning in lands outside Protected Areas needs to be based on empirical evidence vis-à-vis their conservation value and current and emerging conservation conflicts (Sutherland *et al*., 2004).

1.3.3. Resource selection

Resource selection studies have played a significant role in our attempts to understand the distribution of animals in the environment (Bastille-Rousseau & Wittemyer, 2019). Moreover, even the occurrence of Asian elephants in a particular region seems to be primarily influenced by the availability and distribution of resources (Sukumar, 2003). Selection is defined to be strictly a binary decision with outcomes of use or non-use of a resource unit, when encountered (Lele *et al*., 2013). Resource use is defined as the quantity of the resource that is utilized by an animal or population of animal in fixed period of time and resource availability is the quantity accessible to the animal (or the population of an animal) during that same period (Manly *et al*., 2002).

1.3.4. Feeding ecology of elephant

Extensive understanding exists on the foraging ecology of Asian elephants across its range: south India (Sukumar, 1990; Baskaran *et al*., 2010), central India (Mohapatra *et al*., 2013),

north-east India (Roy, 2009; Sarkar *et al*., 2012) Sri Lanka (Mckay, 1973), Myanmar (Campos-Arceiz *et al*., 2008), Nepal (Pradhan *et al*., 2008; Koirala *et al*., 2016), China (Chen *et al*., 2006), Borneo (English *et al*., 2014; Suba *et al*., 2018), Malaysia (Olivier, 1978) and Vietnam (Varma *et al*., 2008). This is not a comprehensive list and there are other studies as well. From these studies, we know that elephants are versatile feeders and forage on a range of plant families and plant parts. They spend 70-90% of their time foraging (Wyatt & Eltringham, 1974; Guy, 1976). Asian elephants in particular, can consume a daily equivalent of 1.5% to 2% of their body weight as dry forage (Sukumar, 2003). Although the forage species differs with habitat, the majority of our understanding has been from the tropical dry forest and very less from tropical moist forests (Sukumar, 2003). Asian elephant's diet in dry thorn forest and grassland comprised of 88 species of plants (McKay, 1973), deciduous and thorn forest comprised of 112 plant species (Sukumar, 1990) and in moist forests of Buxa Tiger Reserve, 150 plant species were recorded to be eaten by elephants (Roy, 2009). Seasonal changes in diet may involve complete shifts to different vegetation communities with evidence of browse dominant diet in the dry season and herb dominant diet in the wet season (Sukumar, 2003). Asian elephants may feed on over a 100 plant species in an area but plants from just a few botanical families may account for most of their total intake (Bi *et al*., 2016). However, our understanding of forage selection is very limited (English *et al*., 2014; Koirala *et al*., 2016) because of the logistical difficulties involved in assessing availability of plant species in a landscape (Sukumar, 2003). This knowledge is nonetheless crucial for Asian elephant conservation in terms of habitat management and human–elephant conflict mitigation (Koirala *et al*., 2016).

1.3.5. Implications of feeding ecology

A basic knowledge on Asian elephant feeding ecology will help us understand the following:

Habitat carrying capacity: The availability of food resources is a major determinant of the carrying capacity of a given habitat and can affect the distribution of Asian elephants in a given area (Bi *et al*., 2016).

Human- elephant negative interaction: Crop raiding is the primary form of human-elephant negative interaction (Shaffer *et al*., 2019) as elephants forage in agricultural fields to meet dietary requirements (Sukumar, 1990; Sitati *et al*., 2005). In India, elephant related conflict

alone has been estimated to damage 0.8–1 million hectares of crops every year (Rangarajan *et al*., 2010). Understanding elephant forage selection in human use areas will help us quantify the economic loss faced in terms of plants or food grains consumed by elephants in human use areas. This in turn will help us to develop mitigation strategies to guard these plants or avoid accidental attacks when elephants come to forage on them.

Seed dispersal: Only animals with an ability to traverse and utilise multi use landscape provide true net colonisation benefits to a plant species and this service is highly essential especially when ecological landscapes have become increasingly fragmented (Spennemann, 2020). Elephants are effective seed dispersers and are likely to play an important role in long-distance dispersal (Corlett, 2009). However, the importance of elephants as seed dispersers varies across habitats, taxa, and continents (Campos-Arceiz & Blake, 2011). The seed dispersal distance is shorter in Asian elephants as compared to African elephants (Campos-Arceiz & Blake, 2011). However, it is not possible to understand the effectiveness of a particular population of elephants in seed dispersal without fundamental knowledge in foraging patterns.

Nutritional stress: Nutritional stress is a negative physiological and/or behavioural state resulting from sub-optimal quantity or quality of food available to an animal (Trites & Donnelly, 2003). Its effect on terrestrial and marine mammals include reduced body size, reduced birth rates, increased neonate mortality, increased juvenile mortality, behavioural modifications (e.g. longer foraging bouts), and changes in blood chemistry and body composition (Trites & Donnelly, 2003). Knowledge on the fodder plant species and the quantities consumed is essential for estimating their nutritional composition and comparing it with optimal nutrition requirements for elephants (Sukumar, 2003).

2. STUDY AREA

2.1. LOCATION & HISTORY

The study area lies in northern West Bengal and comprises of an area of 908.81 km². It is a multi-use landscape that includes the Protected Areas of Chapramari Wildlife Sanctuary (9.6 km²) and Gorumara National Park (88 km²), Reserved Forests of Jalpaiguri Forest Division and Kalimpong Forest Division (41.73 km²), tea estates, agricultural land and human settlements (Fig.1). The study area is bordered by Chel river on the western side, Diana river on the eastern side and Bhutan on the northern side. Multiple factors led to the forest fragmentation in the landscape, like clearing of natural forest for timber plantations and tea estates by the erstwhile British rulers, settlement of Taungya cultivators in the 19th century (Gruning, 1911), the establishment of army units in the 1960s (Roy, 2009) and biotic pressure from the growing human population. At present, the once contiguous low land forest is present as 27 disjoint forest patches (Roy, 2009). Remote sensing study has shown that between 1987 and 2019, there has been reduction of areas like vegetation, agriculture and plantation, whereas area under built-up (6.44%), barren land (2.71%) and water body (1.29%) has increased (Chamling & Bera, 2020).

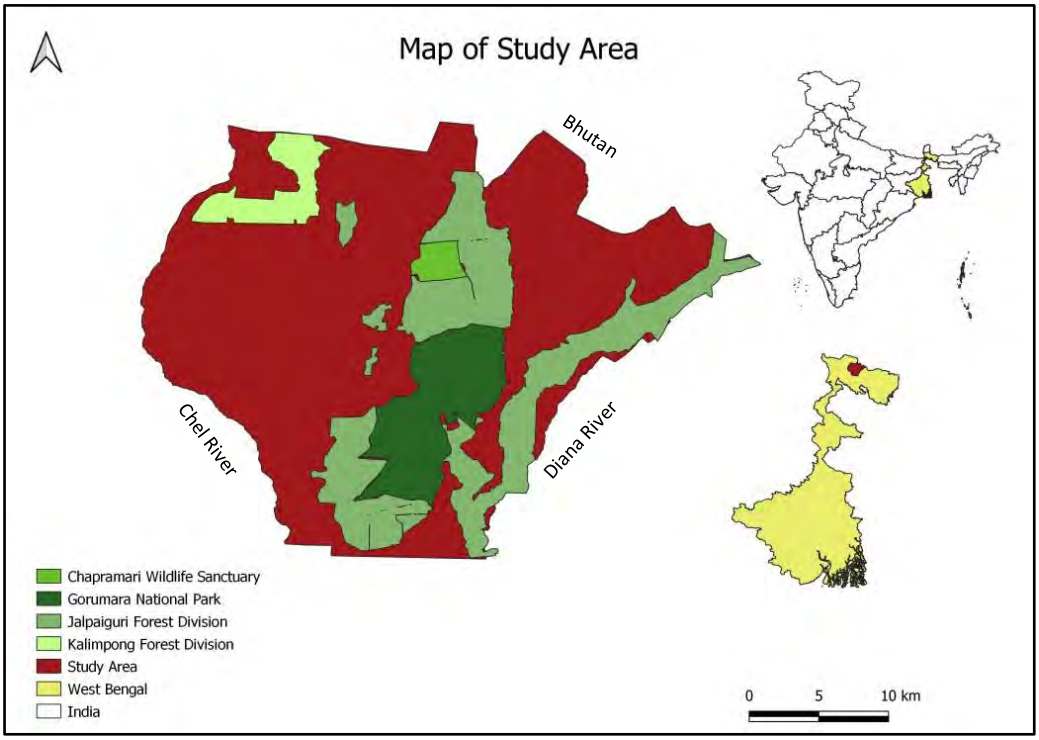

Fig. 1: Study area in northern West Bengal bounded by Chel river in the west, Diana river in the east and Bhutan in the north

2.2. CLIMATE, PHYSICAL FEATURE, FLORA & FAUNA

The annual temperature in the study area ranges between 7.8^{o}C and 37.9^{o}C (http://jalpaiguri.gov.in/html/disprof.html, accessed July 2019) and annual rainfall is 3160 mm (Kshettry *et al*., 2017). The northern West Bengal elephant range is spread over sub-Himalayan foothills in the north and alluvial plain in the south dissected by multiple rivers that originate in the Himalayas and drain into the Brahmaputra–Gangetic river basins (Roy, 2009). The region is part of the East Himalayan biodiversity hotspot (Myers *et al*., 2000). The major forest types are northern tropical semi-evergreen forest and tropical moist deciduous forest and the grassland type is east Indian alluvial grassland (Champion & Seth, 1968). Apart from natural forest, there are monocultures and mixed plantations which mostly comprises of *Tectona grandis*, *Shorea robusta*, *Lagerstroemia speciosa*, *Ailanthus integrifolia* and *Acacia catechu* among others. The study area is rich in mammal (Bhattacharjee & Parthasarathy, 2013), reptile, bird, amphibian, and insect diversity (Barua & Bist, 1996).

2.3. PEOPLE & ECONOMY

Jalpaiguri district has a high human population density of 701 people per km^2 (http://jalpaiguri.gov.in/html/census.html,census2011.co.in/census/district/1-darjiling.html, accessed August 2019). The major communities inhabiting this area are tribals from Chotanagpur plateau and the erstwhile Santhal Pargana who were brought here by the British rulers to work in the tea plantations; the Rajbangshi, Muhammadan, Nepali, Bhutia, Bengali, Marwari and Mech communities (Gruning, 1911) whose main occupation are farming, livestock rearing and work in the tea estates (Kshettry *et al*., 2017).

2.4. ASIAN ELEPHANT POPULATION OF NORTHERN WEST BENGAL

The elephant population of northern West Bengal is the western most extension of the north-eastern Indian population and ranges from the Sankosh river at Assam-West Bengal border to Mechi river at Indo-Nepal border (Roy, 2009). The present Asian elephant population in North Bengal is comprised of around 488 individuals spread across a forest area of 1933 km^2 (MoEFCC, 2017). However, around 57% of the area outside the Protected Area has been found to have evidence of usage by elephants and it was distinctly higher in the land between two adjacent forest patches (Kshettry *et al*., 2020). This landscape

experiences one of the highest negative interactions between human and elephant in Asia (Sukumar, 2003) with an estimated number of humans killed and injured annually by elephant being 47 and 164 respectively and annual crop damage by elephant depredation events account for 2078 hectares between 2006 and 2016 (Naha *et al*., 2019). The 161 km long Siliguri–Alipurduar railway track that runs through three Protected Areas is a major threat for free movement of the elephant population with a total of 39 elephant deaths reported during the period of 1958–2008 (Roy *et al*., 2009).

3. METHODS

3.1. STUDY DESIGN

For assessing the forage selection, type I design where measurements are made at the population level with used versus available resource unit protocol was used (Manly *et al*., 2002). Forage use was assessed using the feeding trail observation method (English *et al*., 2014; Koirala *et al*., 2016), plant species availability was assessed using the quadrat method (Rawat, 2008) and forage selection was assessed by calculating the ratio of relative forage use and relative plant species availability (English *et al*., 2014).

3.2. LAND USE & LAND COVER CLASSIFICATION

To perform land use and land cover classification, Sentinel 2 imagery of the study area was procured from the United States Geological Survey (https://earthexplorer.usgs.gov/). The images were from the dry season of 2019 with less than 10% cloud cover. Image processing and stitching was done using ERDAS IMAGINE 2014 and image clipping was done using QGIS version 3.6.0. The study area was classified into six land use and land cover types which were forest, semi-open forest, open forest, tea estate, village and river (Fig.2). Forest represented areas with a closed canopy, dense understory and moist floor with thick leaf litter. Semi-open forest represented areas with partially open canopy, where the understory has disappeared and mostly constituted of plantations. Open forest had completely open canopy due to unchecked logging, fire wood collection, forest fire and grazing (Plate 1). Thirty training sites were used for each land use and land cover types to perform ground-truthing. The supervised classification approach (Spectral Angular Mapper) was used to classify the land use and land cover types with Semi-Automatic Classification Plugin (SCP) in QGIS version 3.6.0. Misclassifications occurred between tea estate and open forest.

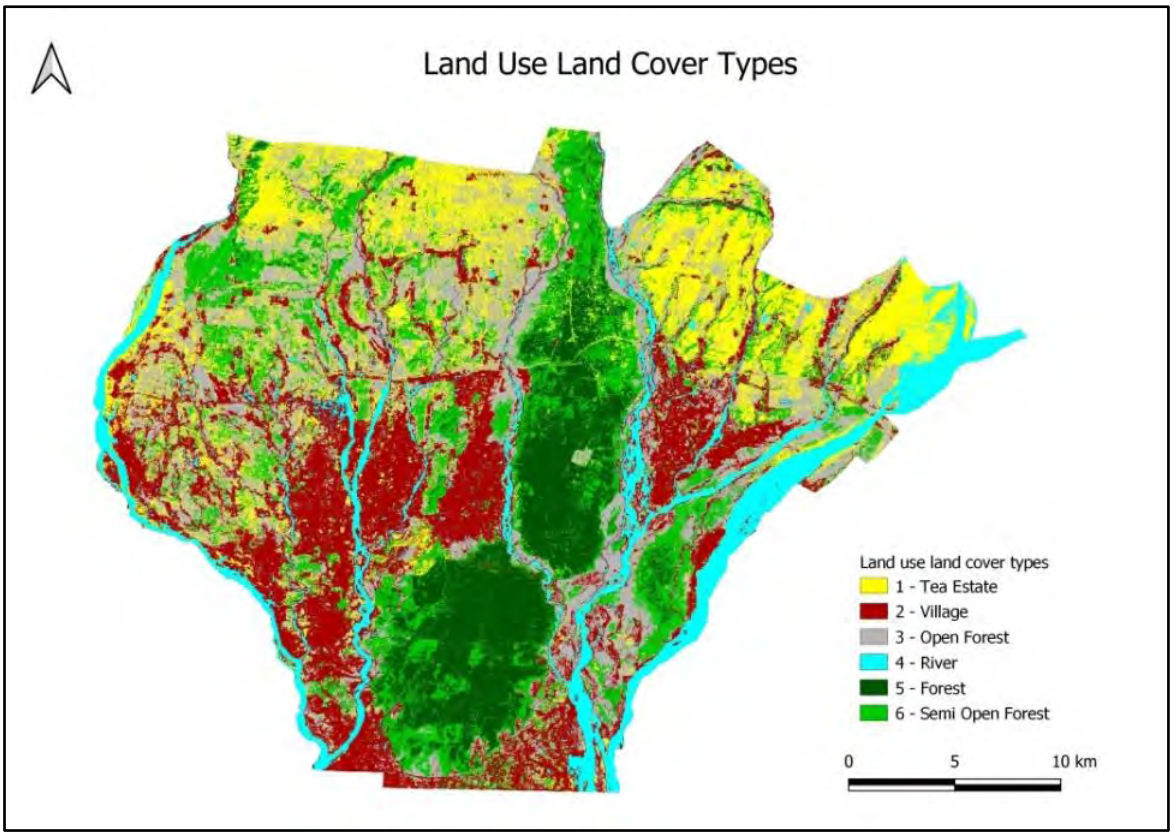

Fig. 2: Classified land use and land cover types of the study area in northern West Bengal

Plate 1: Forest, Semi-open Forest and Open Forest at the study area in northern West Bengal

3.3. ASSESSING FORAGE USE

Feeding trail observation method (English *et al*., 2014; Koirala *et al*., 2016) was used to collect forage use data as direct observation was not possible. Additionally, elephants are known to improve their foraging efficiency by following trails created by repeated movements to and from dependable resources (Blake & Inkamba-Nkulu, 2004). The feeding trails were located based on information about elephant presence received from the information network that was built with Forest Department, tea estate workers and villagers. These trails were visited within three days of use by the elephants, so that the fresh feeding signs could be observed. Indirect signs like foot prints, dung piles, and body rubbing marks on trees were used to follow the feeding trail and the route was recorded using GPS (Garmin eTrex 30x). The trail length sampled varied because of the absence of indirect signs after a certain distance, or presence of elephants on the trail while walking on it or due to forest jurisdiction issues. Belt transect approach was used where all plants showing signs of elephant feeding within 5 m on either side of the trail was recorded. Indirect evidence of plants consumed by elephants (Plate 2) comprised of chewed vegetation, debarked and broken twigs and branches, scratched posts, foot and body marks on soil (White, 1994; Chen *et al*., 2006), uprooted plants, scattered leaves with no stem and branches etc. Individual plants with feeding sign were assigned a score of 1. Along with the plant species consumed, the following things were recorded:

i. Variety of the plant consumed (climber, herb, shrub, tree, bamboo, palm and orchid).
ii. Part of the plant consumed (leaf, stem, branch, bark, root) as elephants are sometimes selective of the plant part consumed (Owen-Smith & Chafota, 2012).
iii. The land use and land cover type of the trail.
iv. Length of the trail using GPS (Garmin eTrex 30x).
v. Information on whether the trail was used by a herd or male. Male includes solitary male elephants or multi male group of elephants henceforth referred as male and herd includes matriarchal group with infants and juveniles of different sexes henceforth referred as herd. The information on whether the trail was used by a male or herd was obtained from the informer and verified on the field. If there were

multiple footprints of different sizes, I assumed feeding trail to be used by a herd and if there was a single footprint, I assumed feeding trail to be used by a male.

Sample size adequacy was determined using the species accumulation curve for the plant species consumed in different land use and land cover types.

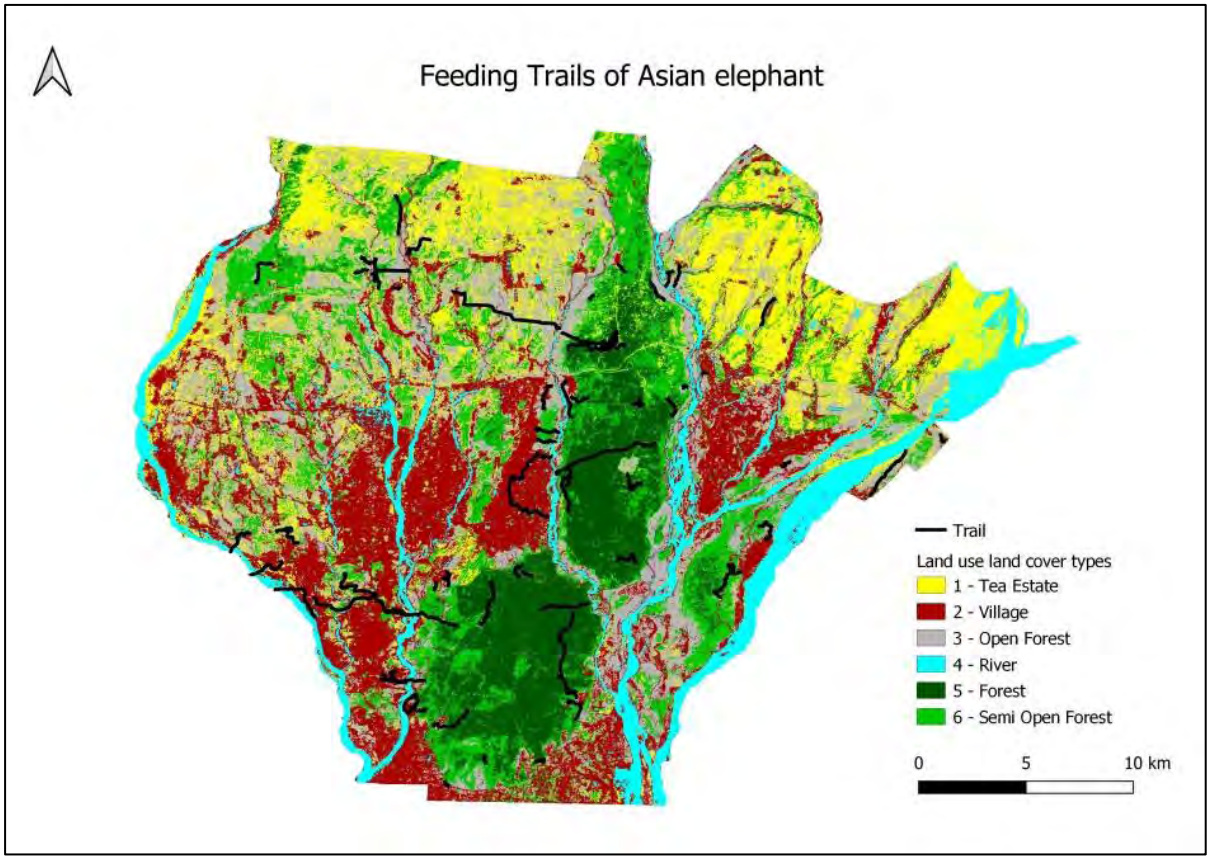

Fig. 3: Feeding trails of Asian elephant sampled for assessing forage use

Plate 2: Feeding signs of Asian elephant

Plate 3: Asian elephant foraging

3.4. ASSESSING PLANT SPECIES AVAILABILITY

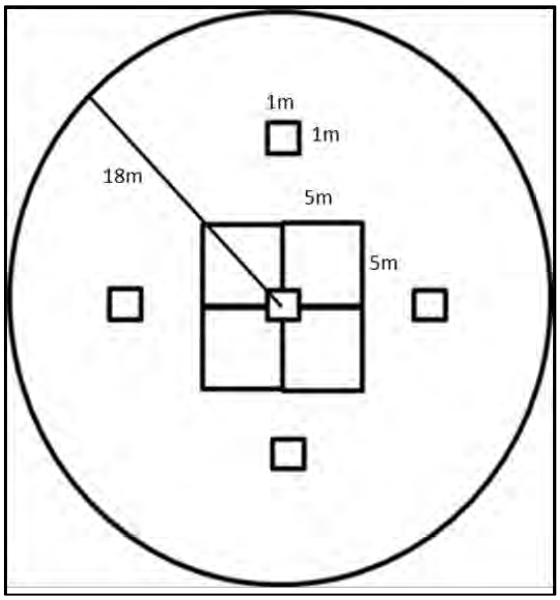

Fig. 4: Sampling protocol for plant species availability

Plant species availability was assessed using the quadrat method (Rawat, 2008). Random points were generated in the classified land use and land cover types (forest, semi-open forest, open forest, tea estate, village) using QGIS version 3.6.0. Treating the random point as centre, a circular plot of 0.1 ha area was made to assess the canopy layer which included trees more than 30 cm girth, bamboos, palms and bananas (in village and tea estate). Within this bigger plot, four 5x5 m sub plots were made to assess the understory which included shrubs, tree saplings (less than 30 cm girth and more than 1 m height) and both soft stemmed and woody climbers; and five 1x1 m sub-plots were made to assess ground flora which included herbs, sapling of less than 1 m height and climbers on the ground (Fig. 4). For the canopy layer species, the height and girth at breast height were recorded. For the understory layer and ground layer, the abundance of all the species present within each plot was recorded. The abundance of understory and ground layer was later extrapolated for the 0.1 ha plot. A total of 123 plots were sampled, of which 31 were in the forest, 24 in the semi-open forest, 26 in the open forest, 22 in the tea estates and 20 in the village (Fig. 5). Sampling adequacy was assessed using the species accumulation curve.

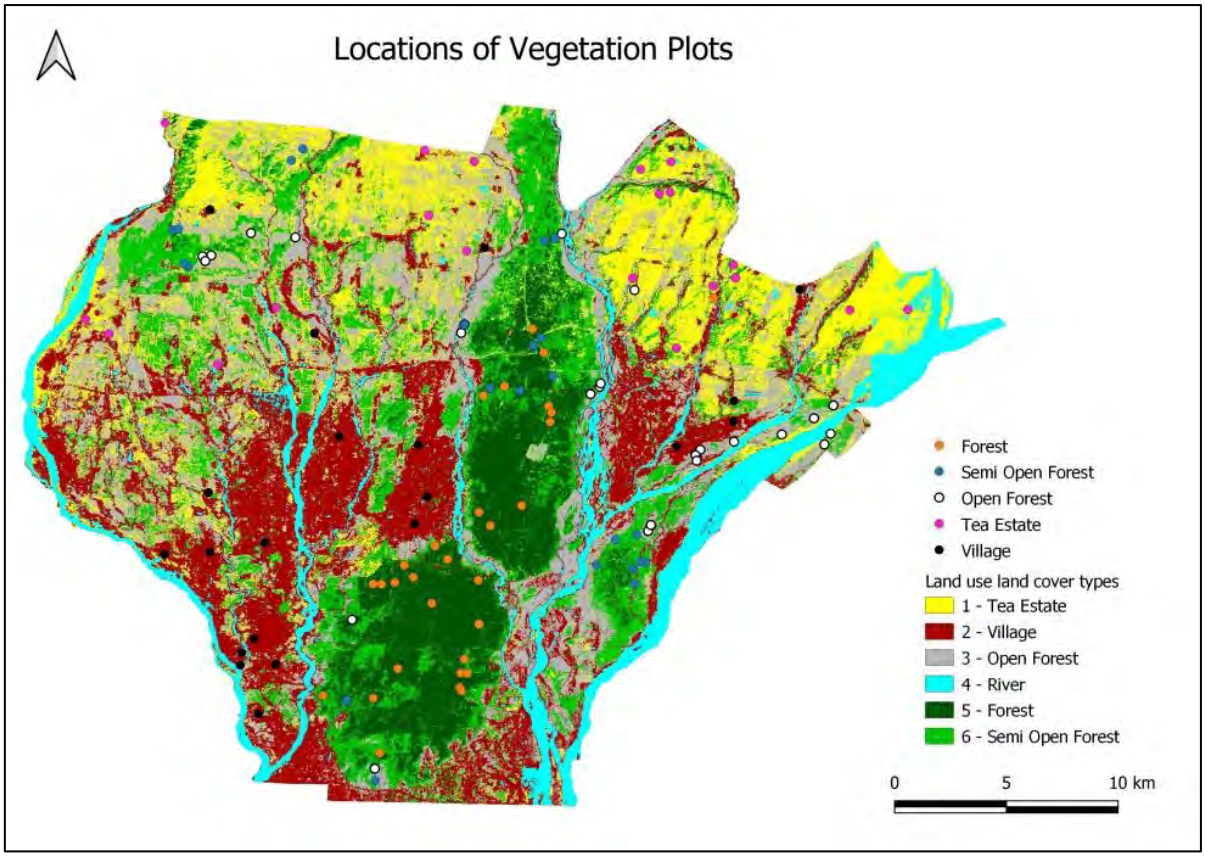

Fig. 5: Locations of vegetation plots for assessing plant species availability

3.5. PLANT IDENTIFICATION

Plant species were identified by their vernacular names (Nepali, Bengali and Sadri) by the field assistant and other Forest Department staff. Scientific names of the plant species were then found with the help of existing literature (Choudhury, 1993; Rawat, 2005; Roy, 2009; Roy & Chowdhury, 2014; West Bengal Zoo Authority, 2016) and online portals like 'Flowers of India' (http://www.flowersofindia.net/) and 'Indian Biodiversity Portal' (https://indiabiodiversity.org/.) In addition, plant species photographs were taken, which were later identified by botanists. The latest accepted scientific names were found using the online portal 'The Plant List' (http://www.theplantlist.org/). All the species of the genus *Musa* was clubbed and has been written as *Musa* sp..

3.6. DATA ANALYSIS

3.6.1. Adequacy of sampling

To assess the adequacy of sampling for forage use in different land use and land cover types, species accumulation curves were plotted with the cumulative number of plant

species that was recorded to be consumed against cumulative effort (in km). To assess the adequacy of sampling for plant species availability, species accumulation curves were plotted with cumulative number of plant species recorded against the cumulative number of plots sampled.

3.6.2. Assessing forage use

A total of 149.95 km trail length was walked of which 44.11 km was in the forest, 27.78 km in the semi-open forest, 13.65 km in the open forest, 36.54 km in the tea estate and 27.93 km in the village (Fig. 3). The total number of trails walked in the forest, semi-open forest, open forest, tea estate and the village were 27, 30, 17, 15 and 29 respectively. The range of trail lengths in the forest was 0.14 to 3.60 km, semi-open forest was 0.06 to 2.74 km, open forest was 0.1 to 2.3 km, tea estate was 0.19 to 6.3 km and the village were 0.04 to 5.5 km. To understand forage use, the total number of feeding signs for individual plant species was summed. The following analyses were done to assess forage use.

Feeding frequency in different land use and land cover types:

The range of the feeding signs recorded in the forest was 4 to 317, semi-open forest was 1 to 65, open forest was 1 to 38, tea estate was 1 to 54 and the village was 1 to 638. The total number feeding signs recorded in each trail was divided by the length of the trail (in km) for all the land use and land cover types and this was termed as feeding frequency. The mean and standard error for the feeding frequency in different land use and land cover types were calculated and plotted. Kolmogorov-Smirnov test (Zar, 1984) was used to check for normality of the data [forest ($p > 0.05$), semi-open forest ($p > 0.05$), open forest ($p < 0.05$), tea estate ($p > 0.05$), village ($p < 0.05$)]. Since the data was not normal in the open forest and village, Kruskal-Wallis test (Zar, 1984) was used to check if the mean feeding frequency in the different land use and land cover types were statistically indistinguishable.

Total number of plant species consumed in different land use and land cover type:

The range of total number of species consumed in each trail in the forest was 1 to 16, semi-open forest was 1 to 11, open forest was 1 to 10, tea estate was 1 to 6 and village was 1 to 6. The total number of plant species consumed by elephant in each trail was divided by the length of the trail (in km) for all land use and land cover types. The mean and standard error

was calculated for the total number of species consumed in each trail of different land use and land cover types and plotted. Kolmogorov-Smirnov test (Zar, 1984) was used to check for normality of the data [forest ($p>0.05$), semi-open forest ($p>0.05$), open forest ($p<0.05$), tea estate ($p>0.05$), and village ($p>0.05$)]. Since the data was not normal in open forest, Kruskal-Wallis test (Zar, 1984) was used to check if the mean number of species consumed across different land use and land cover types was statistically indistinguishable.

Plant variety consumed:

The plants were classified as trees, herbs, climbers, bamboo, palm, orchid and food grain. Plants with woody stem were classified as trees, herb included all soft stemmed plants (including Banana), climbers included both woody and soft stemmed climbers and food grains include any grain stored in human made enclosures for their consumption. The percentage of the total feeding signs for different plant variety consumed was calculated and plotted using a bar graph. Chi-square test for proportions (Zar, 1984) was used to check if the proportion of tree, herb, climber, bamboo and palm was statistically indistinguishable. Orchid and food grain was not included in the analysis as it had very low number of feeding signs of 4 and 8 respectively.

Plant part consumed:

The different plant parts classified were fruit, leaf, branch, bark, stem, root and flower. Grass blade was considered as leaf. The total number of species for which a plant part consumed was calculated and plotted using a bar graph.

Monocot and Dicot consumed:

Since ferns are neither dicots nor monocots, *Diplazium esculentum* was not included while for this analysis. Food grains consumed from the households was not included in the analysis as well because it is not possible to enumerate the number of plants from which a certain quantity of food grain is obtained. The percentage of total feeding signs of monocots (N=1561) and dicots (N=1741) consumed across different land use and land cover types was calculated and plotted using a bar graph. The percentage of monocot and dicot consumed in the forest [monocot (N=1096), dicot (N=444)], semi-open forest [monocot (N=61), dicot (N=304)], open forest [monocot (N=13), dicot (N=50)], tea estate [monocot (N=175), dicot

(N=12)] and village [monocot (N=216), dicot (N=931)] was calculated and plotted using a bar graph. Tea estates and village were clubbed as private land. Forest, semi-open forest and open forest that fall under the jurisdiction of the Forest Department were clubbed as forest land. The total feeding signs of the top five consumed monocots and dicots in private land and forest land were calculated and plotted using a bar graph. Chi-square test for proportions (Zar, 1984) was used to check if the proportion of monocot and dicot consumed in the overall landscape and in different land use and land cover types were statistically indistinguishable.

Browse and herb consumed:

Canopy trees, understory trees, soft stemmed and woody climbers, bamboo, palm and orchid were considered as browse. *Musa sp.* was excluded from the category of herb and considered as browse for this analysis. The feeding signs of food grains consumed from the households were excluded from the analysis. The percentage of total feeding signs of browse (N=2156) and herb (N=1149) consumed across different land use and land cover types were calculated and plotted using a bar graph. The percentage of browse and herb consumed in the forest [browse (N=661), herb (N=882)], semi-open forest [browse (N=332), herb (N=32)], open forest [browse (N=52), herb (N=11)], tea estate [browse (N=137), herb (N=50)] and village [browse (N=974), herb (N=173)] was calculated and plotted using a bar graph. Chi-square test for proportions (Zar, 1984) was used to check if the proportion of browse and herb consumed in the landscape and in different land use and land cover types were statistically indistinguishable.

Forage used by males and herds:

Total effort (in km) of the feeding trails for male and herd in the forest [male (N=22.72), herd (N=21.39)], semi-open forest [male (N=15.34), herd (N=12.38)], open forest [male (N=8.27), herd (N=5.37)], tea estate [male (N=10.99), herd (N=25.54)] and village [male (N=22.45), herd (N=5.49)] were calculated and plotted using a bar graph. Chi-square test for proportions (Zar, 1984) was used to check if the trail length used for males and herds in different land use and land cover types were statistically indistinguishable. The total feeding signs of the top five plant species consumed across different land use and land cover types by male and herd were calculated and plotted using a bar graph.

3.6.3. Assessing plant species availability

The abundance of all the plant species was assessed for the entire sampled area. The total number of plots sampled were 123 (31 in forest, 24 in semi-open forest, 26 in open forest, 22 in tea estate and 20 in village), which encompass an area of 12.3 ha. The abundance of the plant species found in the canopy, understory and ground layer was calculated in the following ways:

Canopy species:

Sum of all the records for a particular species in each plot

Understory species:

Total area sampled for understory species in each plot
= 25 m^2 x 4 = 100 m^2 = 0.01 ha
Total area sampled for understory species in the entire study area
= 123 x 0.01 ha = 1.23 ha
Therefore, Total abundance of the understory species recorded
= ((recorded number of species) x 12.3)/1.23
= recorded number of species x 10

Ground species:

Total area sampled for ground species in each plot
= 1 m^2 x 5 = 5 m^2 = 0.0005 ha
Total area sampled for understory species in the entire study area
= 123 x 0.0005 ha = 0.0615 ha
Therefore, Total abundance of the understory species recorded
= ((recorded number of species) x 12.3)/ 0.0615
= recorded number of species x 200

If a plant species was present in two different layer (example: *Shorea robusta* as a fully grown tree in canopy layer and as a sapling in understory layer), then their total abundance in both the layer were summed up.

Number of plant species available across different land use and land cover types:

The total number of plant species available in different land use and land cover type was calculated and plotted using a bar graph. The mean and standard error was calculated for the total number of species available in each plot in different land use and land cover types and plotted. Kolmogorov-Smirnov test (Zar, 1984) was used to check for normality of the number of species available per plot in different land use and land cover types. Since the data was normal [forest ($p>0.05$), semi-open forest ($p>0.05$), open forest ($p>0.05$), tea estate ($p>0.05$), village ($p>0.05$)], one-way ANOVA (analysis of variance) (Zar, 1984) was used to check if the mean number of species present in different land use and land cover types were statistically indistinguishable.

Availability of monocots and dicots:

Ferns were not included in the analysis since ferns are neither monocots nor dicots. The percentage of the total number of monocots and dicots available in the sampled area of forest [monocot (N=295820), dicot (N=385810)], semi-open forest [monocot (N=109520), dicot (N=354736)], open forest [monocot (N=327940), dicot (N=709512)], tea estate [monocot (N=104820), dicot (N=498585)] and village [monocot (N=253131), dicot (N=823108)] was calculated and plotted using a bar graph.

Availability of browse and herb:

Canopy trees, understory trees, soft stemmed and woody climbers, bamboo, palm and orchid were considered as browse. *Musa* sp. was excluded from the category of herb and was considered as browse for this analysis. The percentage of the total number of browse and herb available in the sampled area of forest [browse (N=321400), herb (N=440380)], semi-open forest [browse (N=225676), herb (N=256910)], open forest [browse (N=188842), herb (N=871750)], tea estate [browse (N=199672), herb (N=424933)] and village [browse (N=436039), herb (N=649000)] were calculated and plotted using a bar graph.

Canopy layer trees and invasive species density in forest, semi-open forest and open forest:

The canopy layer tree density and invasive species density was calculated only in forest, semi open forest and open forest which falls under the jurisdiction of forest department.

Tea estate and village was not included in this analysis because these land use and land cover types are already subjected to intensive human management for maximizing production and there is very less scope for habitat management. The three most dominant invasive species: *Chromolaena odorata, Lantana camara* and *Mikania micrantha* were considered for the analysis. The density of canopy layer trees and invasive species was calculated by dividing the total abundance of canopy trees and invasive species available in each plot by the area of one plot (0.1 ha) for forest, semi-open forest and open forest. The mean and standard error was calculated for the canopy layer trees density and invasive species density in each plot in forest, semi-open forest and village and plotted.

3.6.4. Assessing forage selection

Forage selection was calculated using the relative availability (RA) of each species compared with their relative use (RU) (English *et al*., 2014).

RA = Na/Ta,

RU= Nu/Tu,

Selection ratio = RU/RA

Where, Na is the number of available plants of a given species and Ta is the number of available plants across all species. Nu is the number of times a species was used and Tu is the total number of plants used for feeding across all species. Selection ratio > 1 indicates that the forage was utilised proportionately more than its availability in the environment, and a Selection ratio < 1 indicates that the forage was used proportionately less than its availability in the environment. Selection for food grains consumed from the households was not assessed as they had a very low feeding frequency of eight and assessing availability of food grains is difficult. As the feeding frequency of the orchid consumed was four and orchids require unique quantification method for availability, the selection was not assessed for the orchid species as well. Forage selection was calculated both at a landscape level and separately in the different land use and land cover types (forest, semi-open forest, open forest, tea estate and village).

All the analyses were performed using Microsoft Excel and IBM SPSS Statistics version 21.

4. RESULTS

The total feeding signs recorded were 3313 and the total number of plant species consumed by Asian elephants in the multi-use landscape with fragments of moist tropical forest was 132. The total number of plant species recorded from the study area was 286. Of the 96 species, for which forage selection was assessed, 19 were consumed less than their availability in the environment and 78 species were consumed more than their availability in the environment.

4.1. ADEQUACY OF SAMPLING

4.1.1. Species Accumulation Curve for forage use in different land use and land cover types

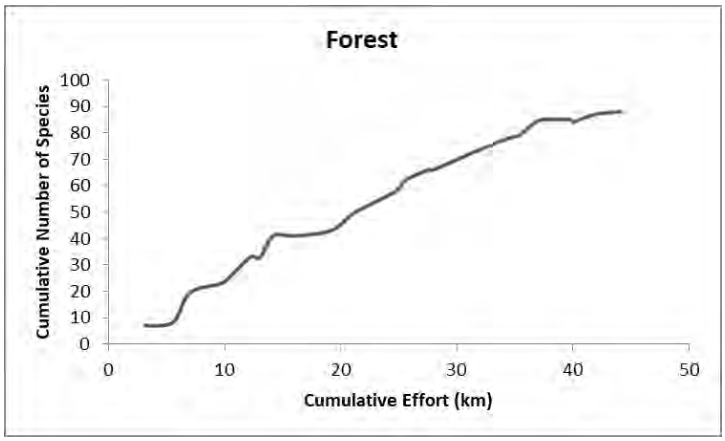

Fig. 6: Species accumulation curve for forage use by Asian elephant in forest

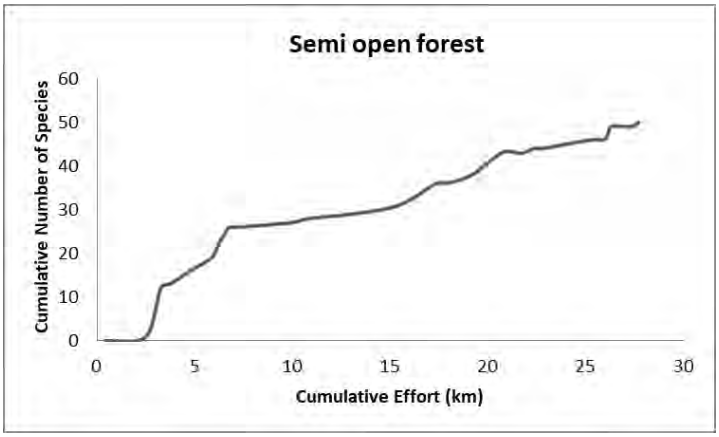

Fig 7: Species accumulation curve for forage use by Asian elephant in semi open forest

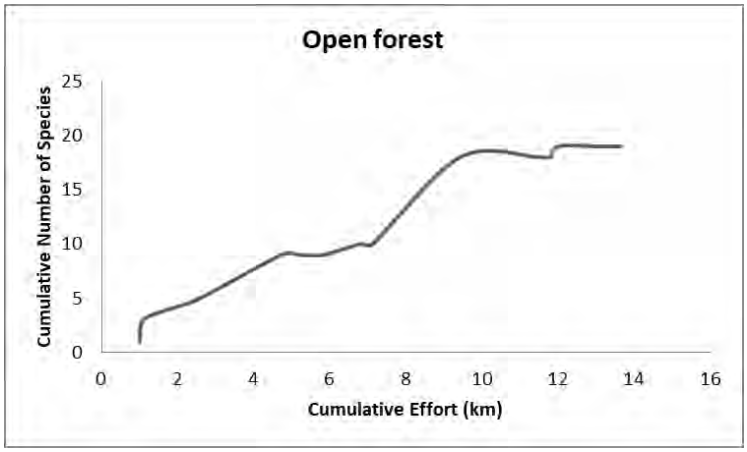

Fig. 8: Species accumulation curve for forage use by Asian elephant in open forest

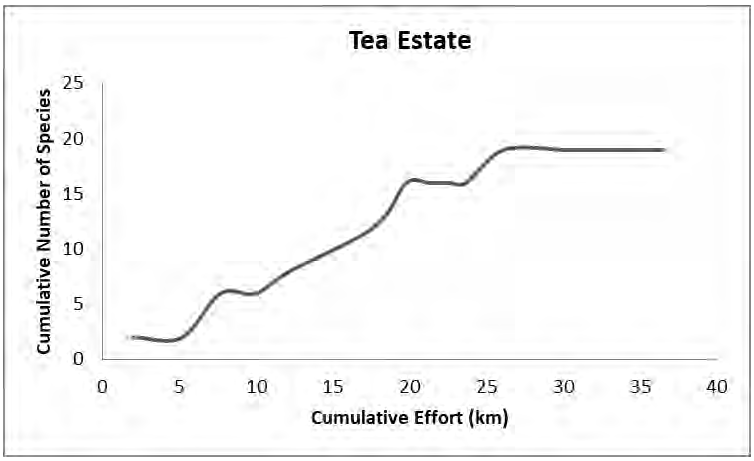

Fig. 9: Species accumulation curve for forage use by Asian elephant in tea estate

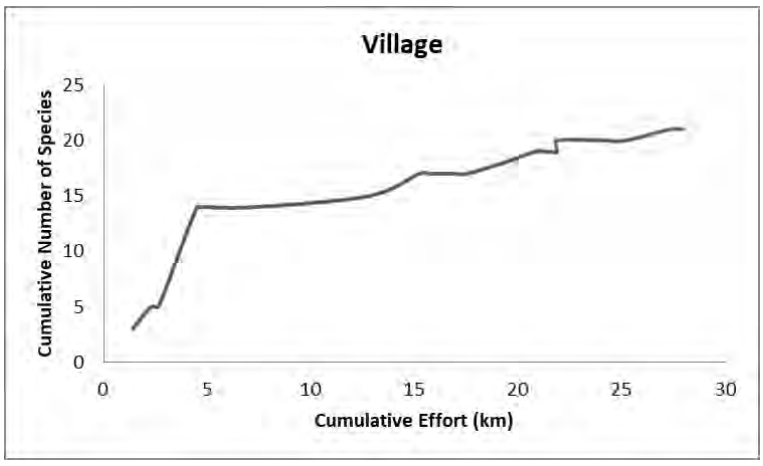

Fig 10: Species accumulation curve for forage use by Asian elephant in village

4.1.2. Species accumulation curve for plant species availability in different land use and land cover types

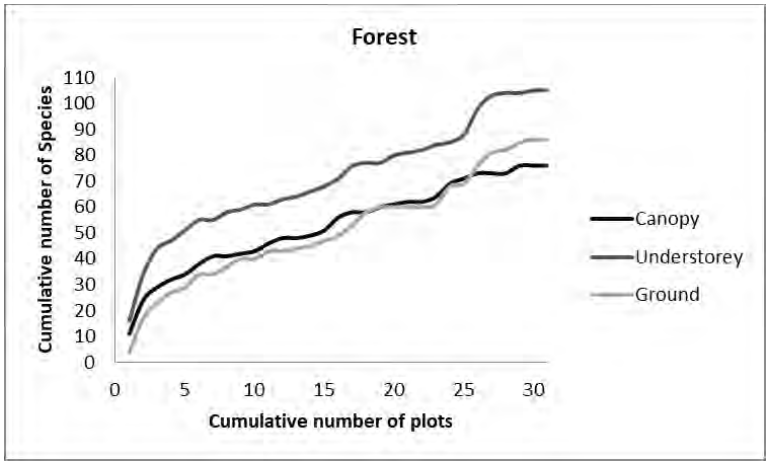

Fig 11: Species accumulation curve for plant species availability in forest

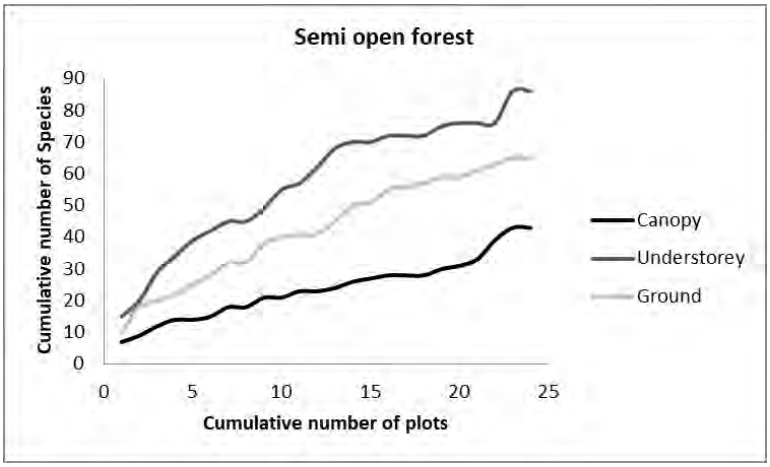

Fig 12: Species accumulation curve for plant species availability in semi open forest

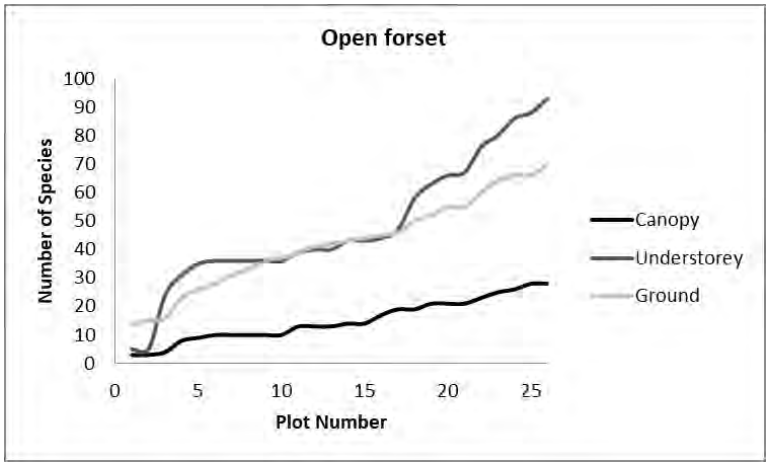

Fig 13: Species accumulation curve for plant species availability in open forest

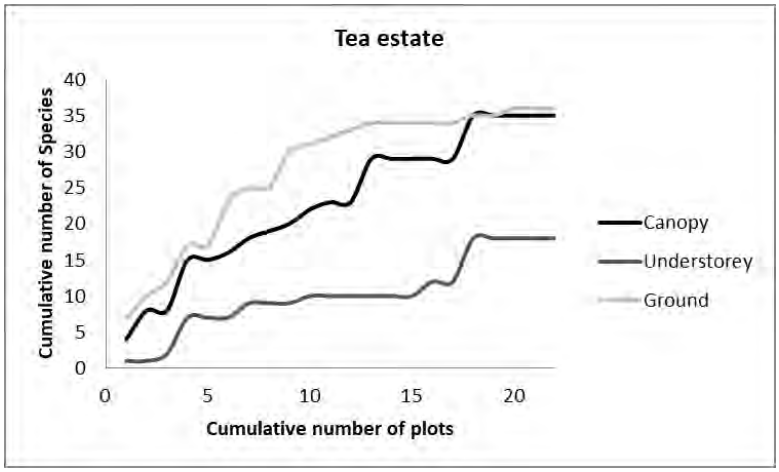

Fig 14: Species accumulation curve for plant species availability in tea estate

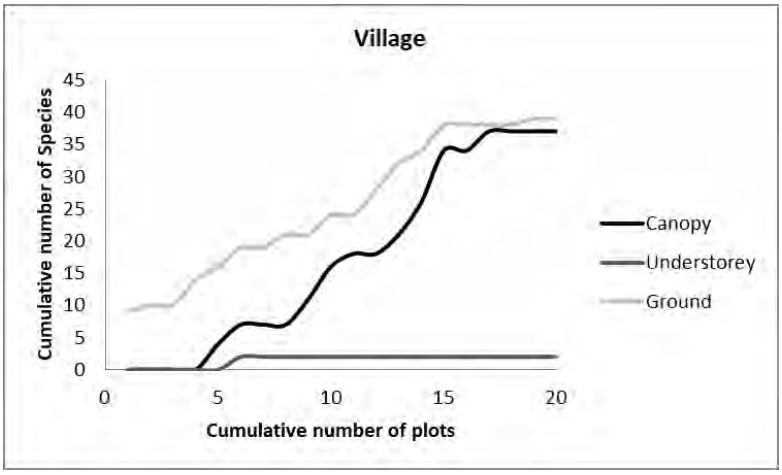

Fig. 15: Species accumulation curve for plant species availability in village

4.2. Forage Use

4.2.1. Feeding frequency in different land use and land cover types

The total feeding signs of Asian elephant recorded were 3313. The total feeding signs recorded in forest, semi-open forest, open forest, tea estate and village were 1543, 365, 63, 187, 1155 respectively. The mean (±SE) feeding frequency in the forest, semi-open forest, open forest, tea estate and village were 40.51 (±9.42), 12.14 (±9.42), 3.31(±1.44), 5.79 (±1.95), 50.15 (±22.85) respectively (Fig.16) which significantly varied from each other ($H=26.99$, $df=4$, $p<0.001$).

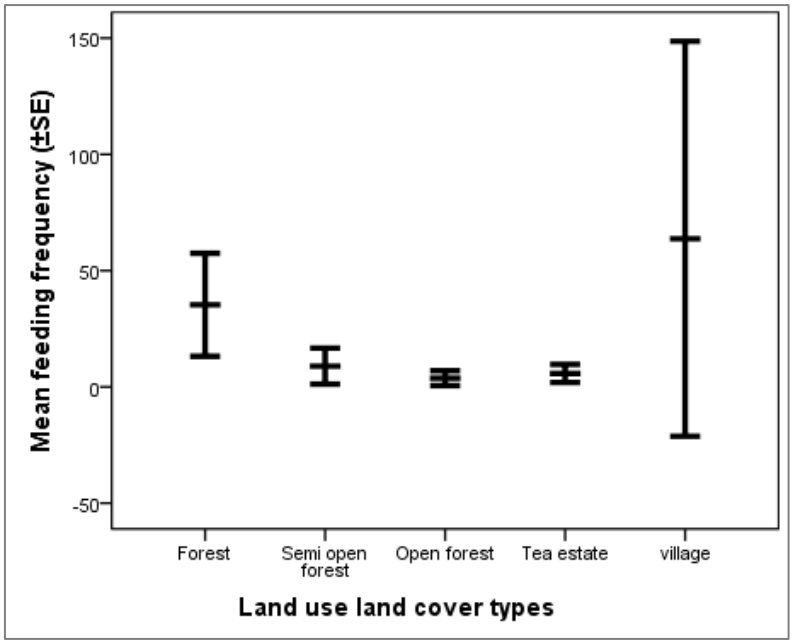

Fig.16: Mean (±SE) feeding frequency of Asian elephant per trail in different land use and land cover types

4.2.2. Total number of plant species consumed in different land use and land cover type

The total number of species recorded to be consumed by Asian elephant across different land use and land cover types was 132 (including 3 varieties of food grain). Of all the plant species recorded, 21 plant species made up 85.3 % of the total feeding signs recorded and 41 plant species was consumed once. The total number of plant species consumed in the forest, semi-open forest, open forest, tea estate and village were 86, 49, 19, 19 and 21 respectively (Fig.17). The mean (±SE) of the plant species consumed by elephant in the forest, semi-open forest, open forest, tea estate and village were 4.79 (±0.89), 3.24 (±1.19), 2.65 (±1.30), 1.13 (±0.34) and 4.48 (±0.93) respectively (Fig.18) that significantly varied from each other ($H=22.26$, $df=4$, $p<0.001$).

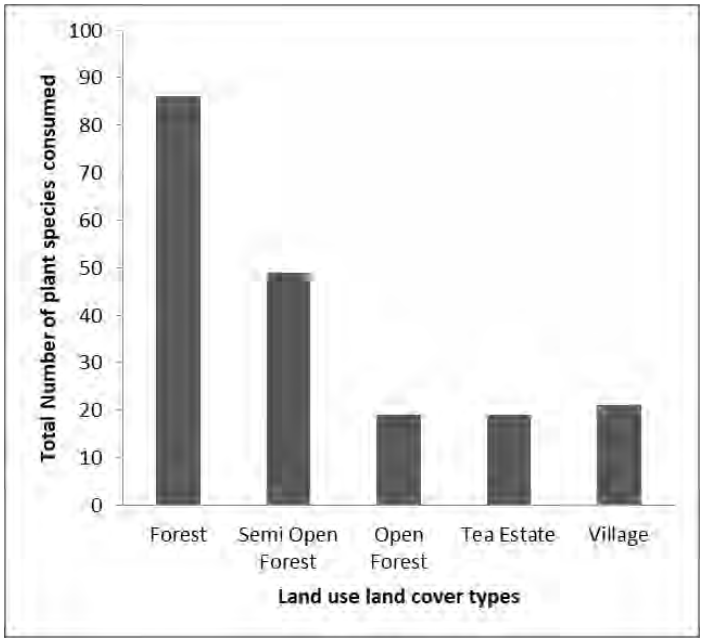

Fig. 17: Total number of plant species consumed in different land use and land cover types by Asian elephant

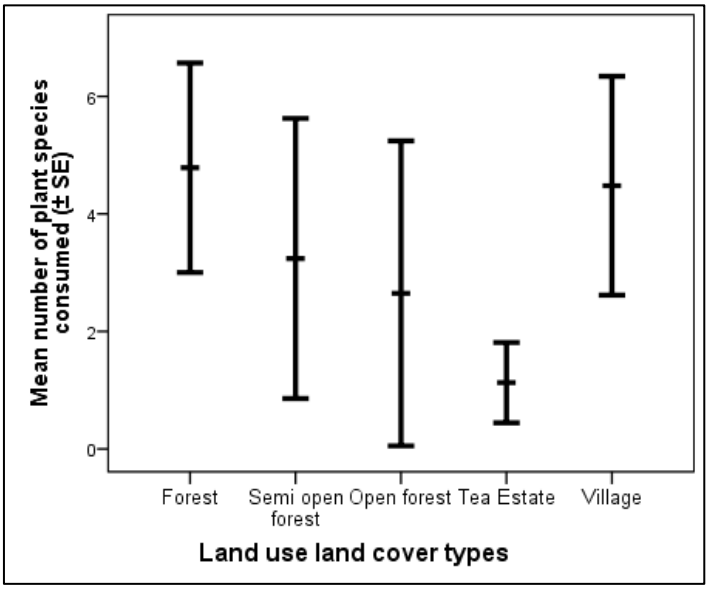

Fig. 18: Mean (±SE) number of plant species consumed per trail by Asian elephant

4.2.3. Plant variety consumed

The percentage of different plants varieties consumed were 39.55%, 44.1%, 7.94%, 2.84%, 5.23%, 0.13%, 0.25% for trees, herbs, climbers, bamboos, palms, orchid and food grain respectively (Fig.19). The proportion of different plant variety (trees, herbs, climbers, bamboos and palms) consumed significantly varied (χ^2=2694.99, df=4, p<0.001).

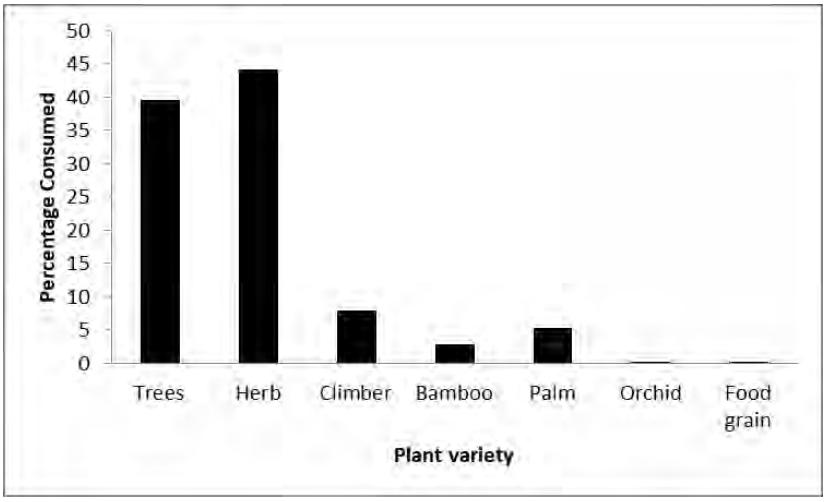

Fig. 19: Percentage of different plant varieties consumed by Asian elephant

4.2.4. Plant part consumed

Asian elephant consumed specific plant parts from specific species. The number of plant species for which fruit, leaf, branch, bark, stem, root and flower was consumed was 6, 87, 51, 22, 13, 30 and 1 respectively (Fig.20).

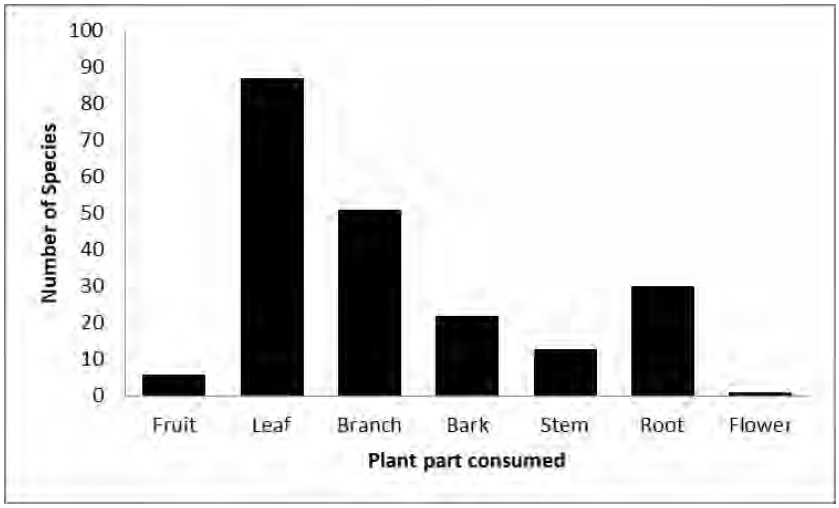

Fig. 20: Number of plant species for different plant parts consumed by Asian elephant

4.2.4. Monocots and dicots consumed

Overall, Asian elephants consumed on 47.27% of monocots and 52.73% of dicots across different land use and land cover (Fig. 21) types which significantly varied (χ^2=9.81, df=1, $p<0.05$). In the forest, semi-open forest, open forest, tea estate and village, the percentage of dicot-monocot consumed were 28.83%-71.17%, 83.28%-16.71%, 79.36%-20.63%, 6.42%-93.58% and 81.17%-18.83% respectively (Fig. 22). There was a significant difference

observed between the proportion of dicots and monocots consumed in forest (χ^2=276.04, df=1, p<0.001), semi-open forest (χ^2=21.73 , df=1, p<0.001), open forest (χ^2=161.78, df=1, p<0.001), tea estate (χ^2=142.08, df=1, p<0.001) and village (χ^2=445.71 , df=1, p<0.001). Asian elephant consumed more monocots in forest and tea estate whereas they consumed dicot more in semi-open forest, open forest and village. Private land includes tea estate and village. The top five dicots consumed in private land were *Acacia catechu*, *Solanum tuberosum*, *Solanum melongena*, *Solanum lycopersicum*, *Tectona grandis* in addition to 14 other plant species (Fig. 23). The top five monocots consumed in private land were *Areca catechu, Musa* sp., *Oplismenus burmanii, Bambusa balcooa,* and *Bambusa nutans* in addition to 9 other plant species (Fig. 24). Forest land includes forest, semi open forest and open forest. The top five consumed dicots in forest land were *Chonemorpha fragrans*, *Albizia lucidior*, *Tectona grandis, Mallotus philippensis*, and *Dillenia indica* in addition to 77 other plant species (Fig. 25). The top five consumed monocots in forest land were *Phrynium pubinerve, Alpinia nigra, Oplismenus burmanii, Isachne* sp. and *Tripsacum laxum* in addition to 24 other plant species (Fig. 26).

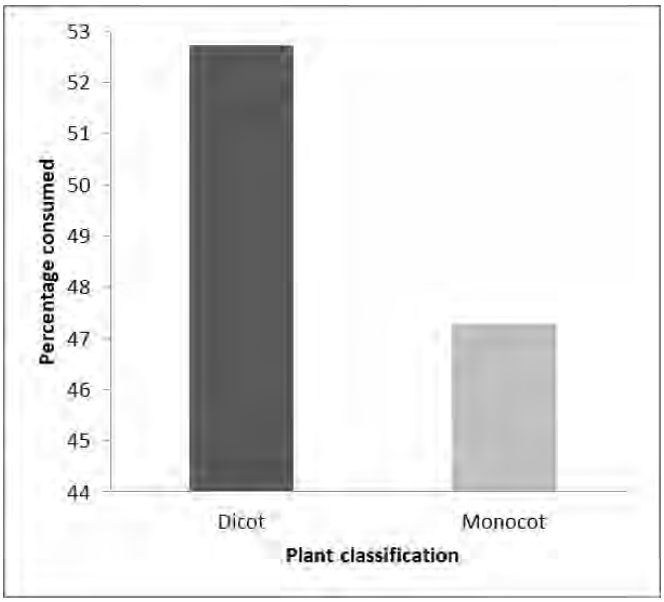

Fig. 21: Overall percentage of monocots and dicots consumed by Asian elephant

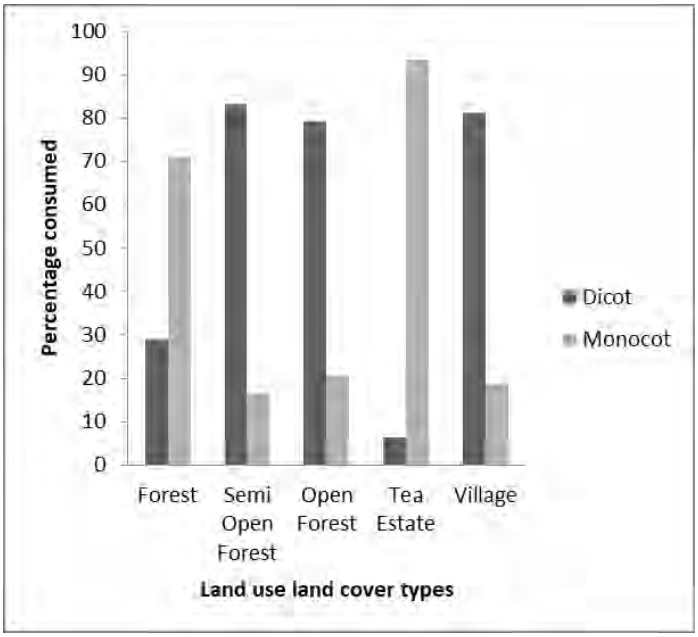

Fig. 22: Percentage of monocots and dicots consumed in different land use and land cover types by Asian elephant

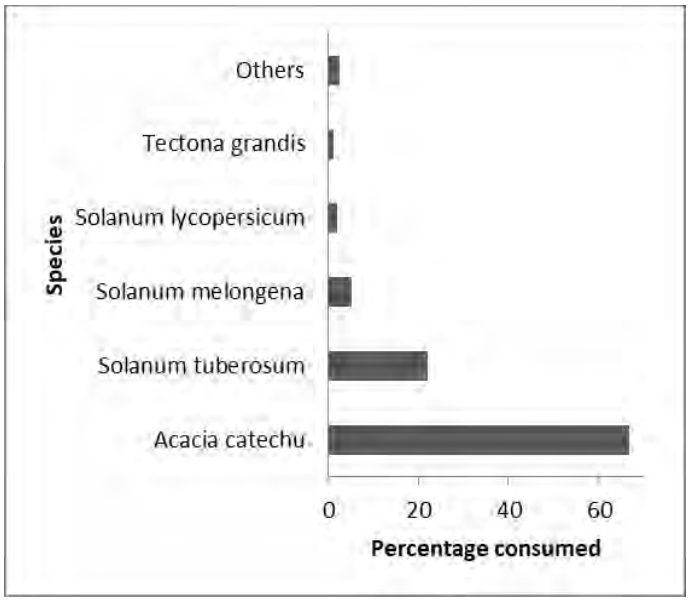

Fig. 23: Percentage of top five dicots and 11 other plants consumed by Asian elephant in private land

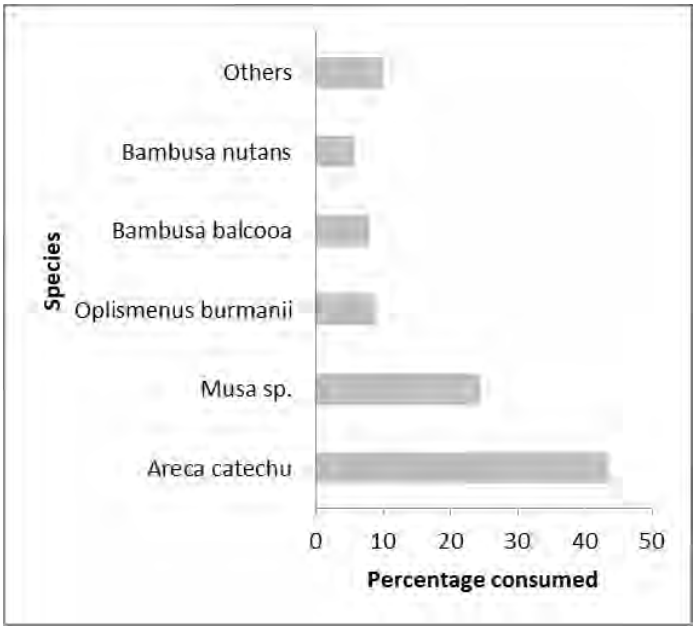

Fig. 24: Top five monocots and 9 other plants consumed by Asian elephant in private land

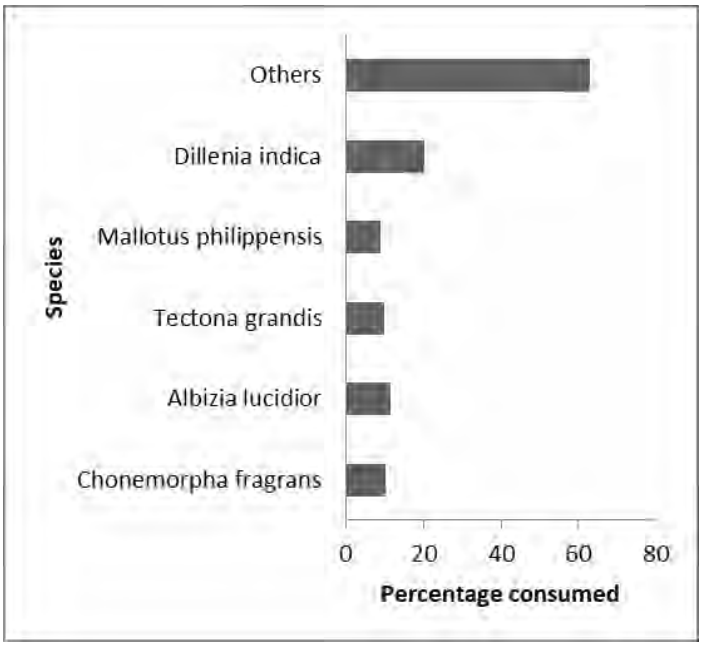

Fig. 25: Top five dicots and 77 other plants consumed by Asian elephant in forest land

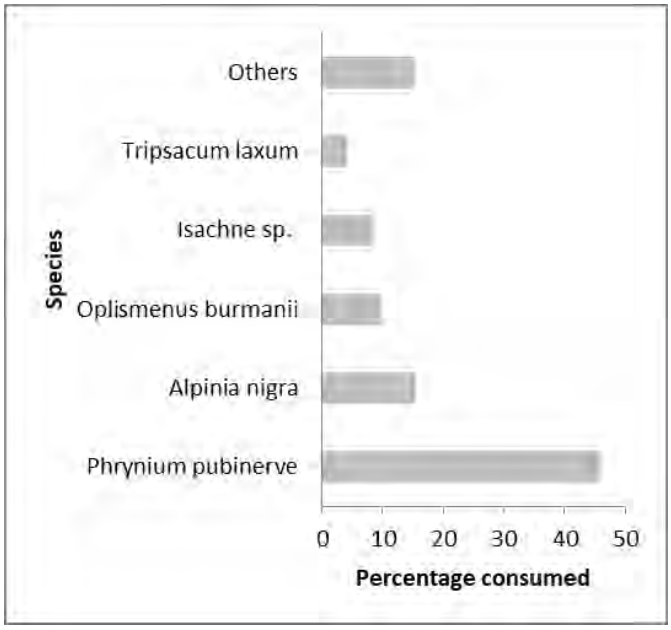

Fig. 26: Top five monocots and 24 other plants consumed by Asian elephant in forest land

4.2.5. Browse and herb consumed

Overall, Asian elephants consumed 65.23 % browse and 34.77 % herb across different land use and land cover types (Fig. 27) which significantly varied (χ^2=306.82, df=1, p<0.001). In the forest, semi-open forest, open forest, tea estate and village, the percentage of browse-herb consumed were 42.84%-57.16%, 90.96%-9.04%, 82.54%-17.46%, 73.26%-26.73% and 84.92%-15.08% respectively (Fig. 28). There was a significant difference observed between browse-herb consumed in forest (χ^2=31.65, df=1, p<0.001), semi-open forest (χ^2=244.93, df=1, p<0.001), open forest (χ^2=26.68, df=1, p<0.001), tea estate (χ^2=40.48, df=1, p<0.001) and village (χ^2=559.37, df=1, p<0.001). In the forest, they consumed more herb species than browse whereas in semi-open forest, open forest, tea estate and village they consumed more browse than herb.

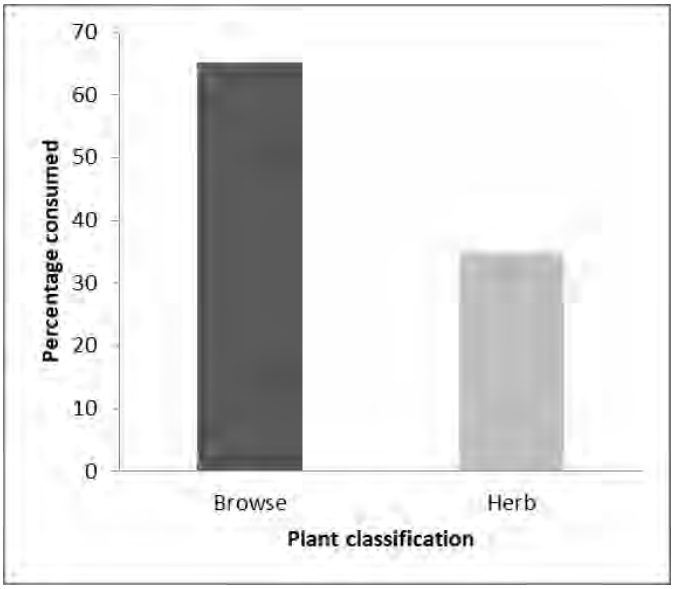

Fig. 27: Overall percentage of browse and herb consumed by Asian elephant

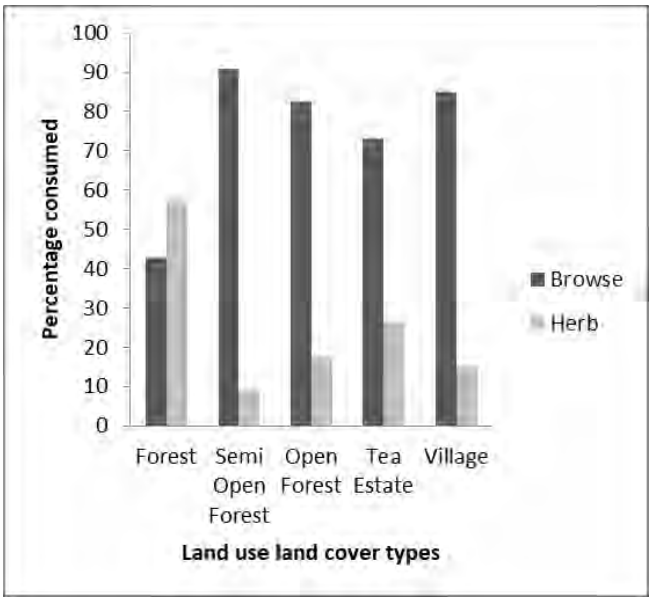

Fig. 28: Percentage of browse and herb consumed in different land use and land cover types by Asian elephant

4.2.7. Forage used by male and herd

The total effort of feeding trail for herd was 70.17 km and for male was 79.77 km. As the effort in different land use and land cover types was on the basis of reporting and not biased towards herd or male, the effort can be a proxy for land use and land cover used by herds and males of Asian elephant population. There was no significant difference observed between use by male and herd in the forest (χ^2=0.09, df=1, p>0.05), semi-open forest (χ^2=0.33, df=1, p>0.05) and open forest (χ^2=0.69, df=1, p>0.05), whereas there was significant difference observed in tea estate (χ^2= 6.08, df=1, p<0.05) and village (χ^2=10.70,

df=1, p<0.05). Herds used tea estates more and males used villages more (Fig.29). The top five plant species consumed by herd were *Phrynium pubinerve, Alpinia nigra*, *Dillenia indica*, *Areca catechu* and *Isachne* sp. (Fig. 30) and the top five plant species consumed by males were *Acacia catechu*, *Phrynium pubinerve, Solanum tuberosum, Oplismenus burmanii,* and *Musa* sp. (Fig. 31).

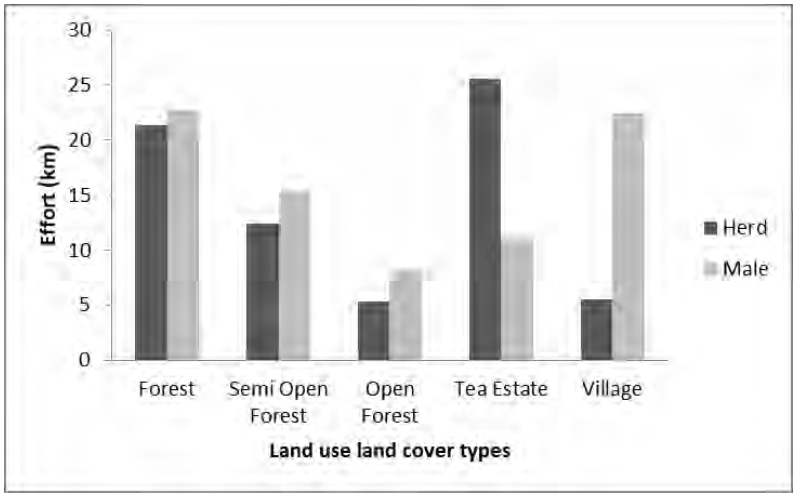

Fig.29: Land use and land cover types used by herds and males of Asian elephant

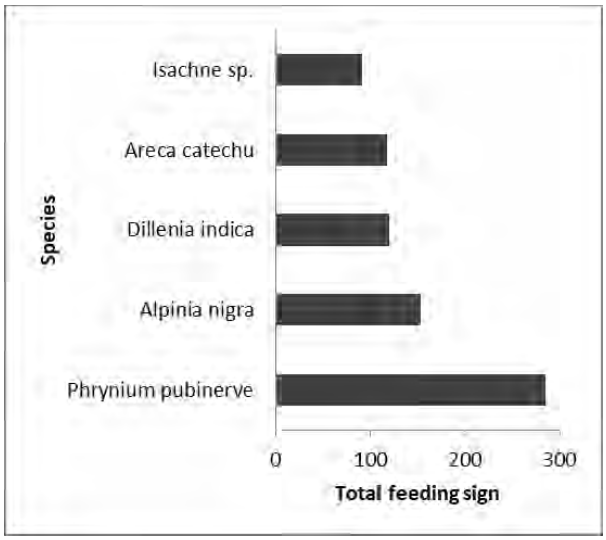

Fig. 30: Top five plant species consumed by herds of Asian elephant

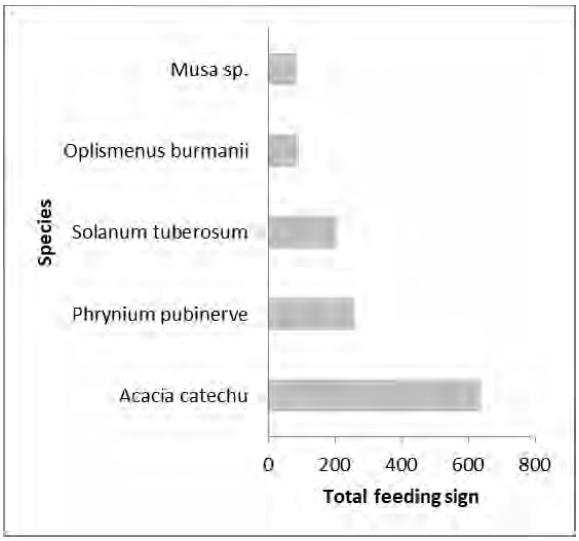

Fig. 31: Top five plant species consumed by males of Asian elephant

4.3. PLANT SPECIES AVAILABILITY

4.3.1. Total number of plant species recorded in different land use and land cover types

A total of 286 plant species was recorded from the sampled area across different land use and land cover types. The total number of plant species recorded in forest, semi-open forest, open forest, tea estate and village were 157, 133, 136, 76, and 80 respectively (Fig.32). The mean (±SE) of the total number of plant species recorded in the forest, semi-open forest, open forest, tea estate and village per plot were 34.96 (± 1.94), 20.83(±1.41), 21.04(±1.54), 11.25(±1.11), 10.70(±1.44) respectively (Fig.33) that significantly varied ($F= 44.13$, $df=4$, $p<0.001$). The average number of plant species present in the forest was the highest, followed by similar numbers plant species found in semi-open forest and open forest and then by similar number of plant species found in tea estate and village.

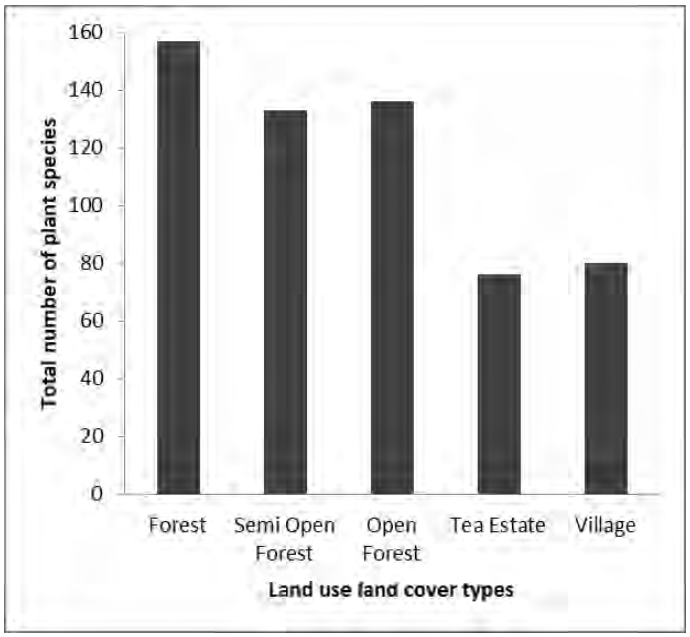

Fig. 32: Total number of plant species recorded in different land use and land cover types

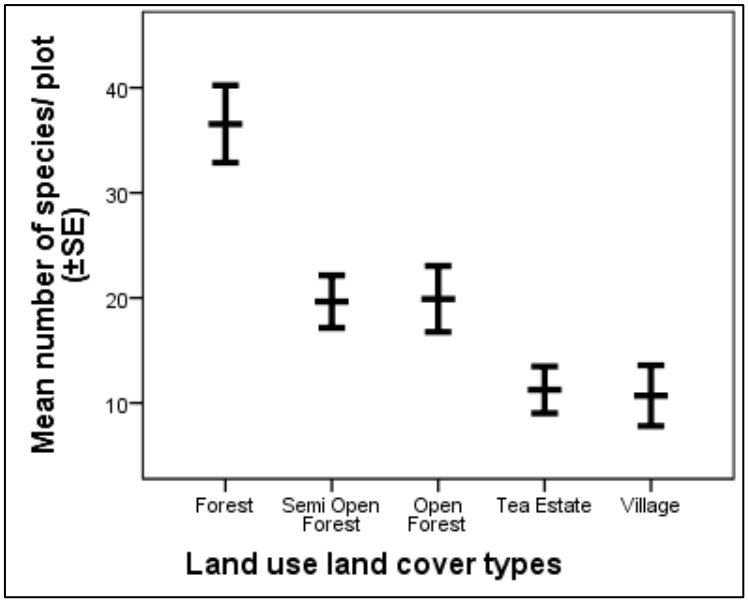

Fig. 33: Mean (±SE) number of plant species/ plot recorded in different land use and land cover types

4.3.2. Availability of monocot and dicot plants

The percentage of available dicots-monocots recorded in the forest, semi-open forest, open forest, tea estate and village were 56.60%-43.39%, 76.41%-23.59%, 68.39%-31.61%, 82.63%-17.37% and 76.48%-23.51% respectively (Fig. 34). In all the land use and land cover types, dicots were present in more number than the monocots.

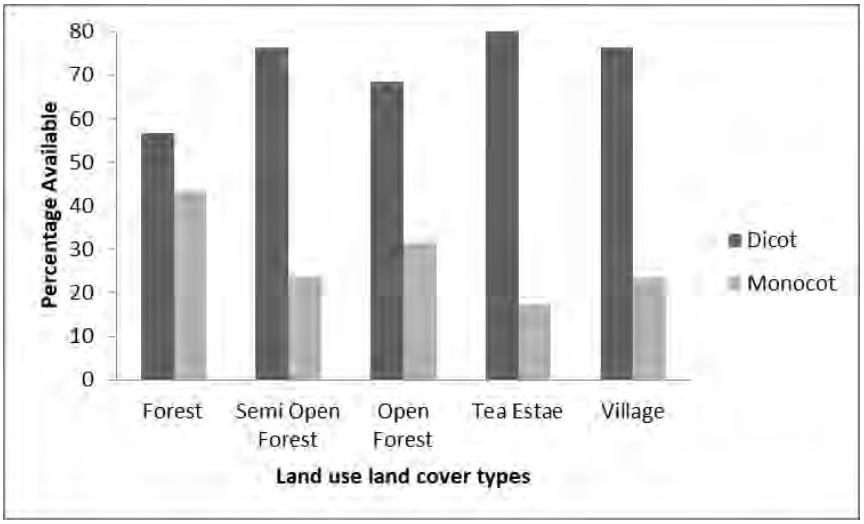

Fig.34: Percentage of monocot and dicot species available in different land use and land cover types

4.3.3. Availability of browse and herb plants

The percentage of available browse-herb recorded in forest, semi-open forest, open forest, tea estate and village were 42.19%-57.89%, 46.76%-53.24%, 17.81%-82.19%, 31.97%-

68.03% and 40.19%-59.81% respectively (Fig. 35). In all the land use and land cover types, herbs were present in more number than browse.

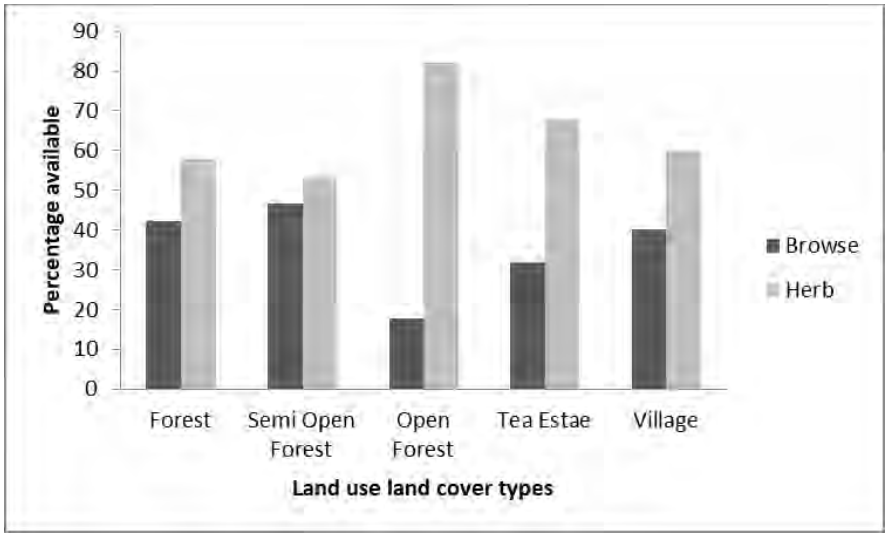

Fig. 35: Percentage of browse and herb species available in different land use and land cover types

4.4.4. Canopy layer tree and invasive species density in forest, semi-open forest and open forest

The mean (±SE) canopy layer tree density in the forest, semi-open forest and open forest per hectare was 552.95 (±29), 290 (±42.1) and 60.83 (±11.75) respectively (Fig. 36). The mean (±SE) of invasive species density in the forest, semi-open forest and open forest per hectare was 1845.83 (±796.64), 6691.66 (±2234.31), 34262.50 (±6721.86) respectively (Fig. 37). Canopy layer tree density was highest in forest followed by semi-open forest and open forest. Invasive species density was highest in open forest followed by semi-open forest and forest.

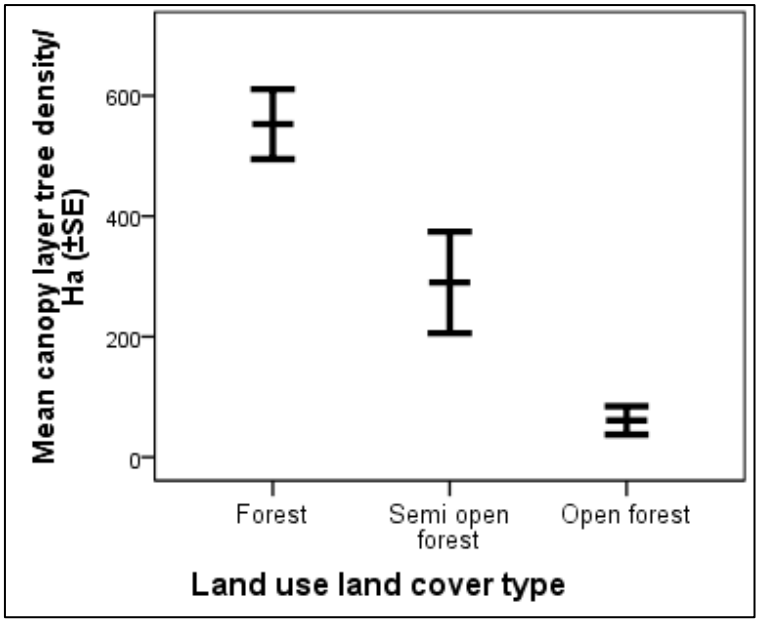

Fig. 36: Mean (±SE) canopy layer tree density in forest, semi-open forest and open forest

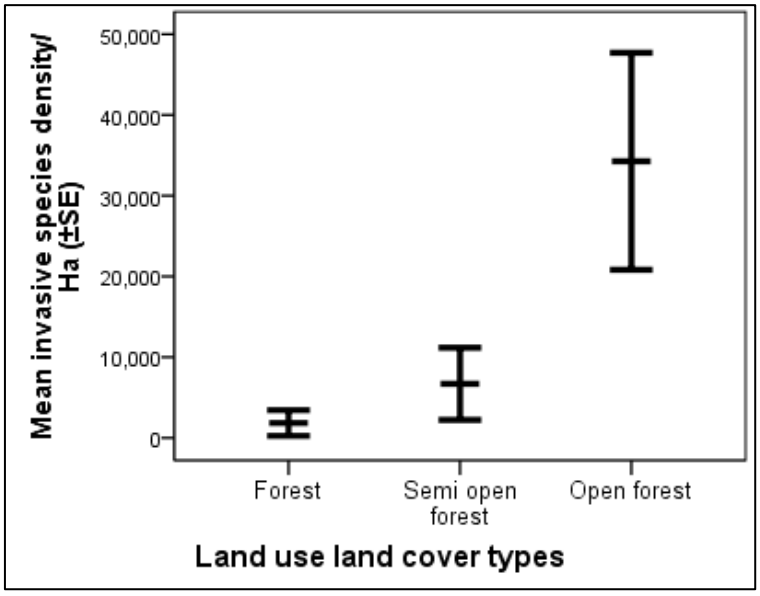

Fig. 37: Mean (±SE) invasive species density in forest, semi-open forest and open forest

4.4. FORAGE SELECTION

4.4.1. Forage selection at the landscape level

Of the 128 plant species consumed by Asian elephants, , selection could be assessed for 96 species, excluding the three varieties of food grain and one orchid species. This is because the rest 32 species were not encountered while assessing plant species availability. Out of 32 species, 16 species had a feeding frequency of one, six species had feeding frequency of

two, four species had feeding frequency of three, one species had feeding frequency of five and the remaining five species had higher feeding frequency [*Solanum tuberosum* : 209, *Tripsacum laxum* : 50, *Coix* sp. : 20, *Manihot esculanta*: 19 and *Brassica sp.* : 15]. *Solanum tuberosum* and *Brassica sp.* are seasonal food crops that are grown in the villages and by the time I started assessing the availability of plant species, it was already harvested. *Tripsacum laxum* is planted in the tea estates as an organic fertiliser, which they cut during the onset of winter, and spread over the soil on which tea saplings are planted. By the times I started assessing the availability of plant species, most of the *Tripsacum laxum* in the landscape were already cut. The selection ratio of these 96 species is presented in Table 1.

Selection ratio ranges for the plant species assessed:

Among the 96 plant species for which selection was assessed, 19 plant species had a selection ratio less than 1 implying that they were used proportionately less than their availability in the environment. 77 plant species had a selection ratio of more than 1 implying that they were used proportionately more than their availability. 48 plant species had selection ratio between 0 and 100, 7 plant species had a selection ratio between 100 and 200, 16 plant species had a selection ratio between 200 and 1000, and 6 plant species had a selection ratio of more than 1000 (Fig. 38).

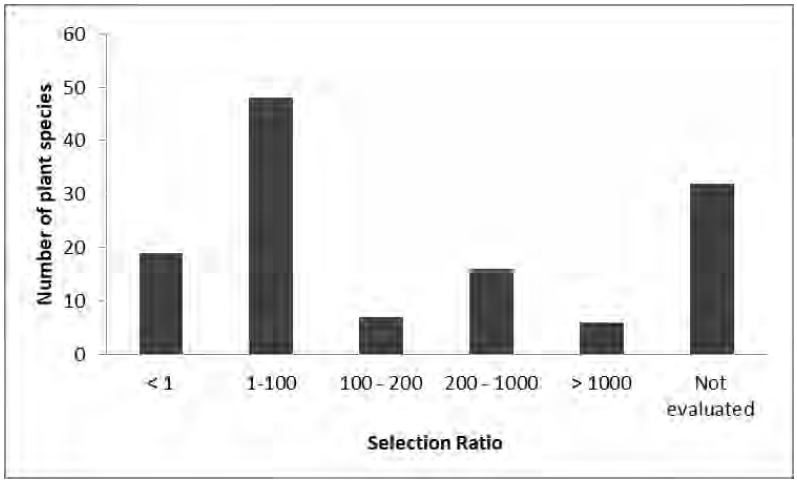

Fig.38: Number of plant species in different selection ratio range

Availability of plant species with selection ratio >100:

Tea estate and village was considered as private land and forest, semi-open forest and open forest was considered as forest land. Out of the 29 plant species that had a selection ratio

more than 100, 15 plant species were available only in forest land and 9 plant species were available only in private land and 5 plant species were available in both forest land and private land. *Terminalia alata,* 'Chiuri' (vernacular name)*, Bambusa bambos, Ardisia solanacea*, *Phrynium pubinerve, Ficus elastica, Oroxylum indicum, Acacia pennata, Macaranga denticulate, Bauhinia* sp., *Chonemorpha fragrans*, *Dillenia indica, Smilax perfoliata, Walsura tabularis* and *Dendrocalamus* sp. were available only in forest land whereas *Bambusa balcooa*, *Melocanna baccifera*, *Bambusa nutans, Pandanus furcatus, Musa* sp.*, Areca catechu, Artocarpus heterophyllus, Solanum lycopersicum, Solanum melongena* were available only in private land. *Ficus virens, Tectona grandis, Mangifera indica, Acacia catechu* and *Emblica officinalis* were available in both private land and forest land (Fig. 39).

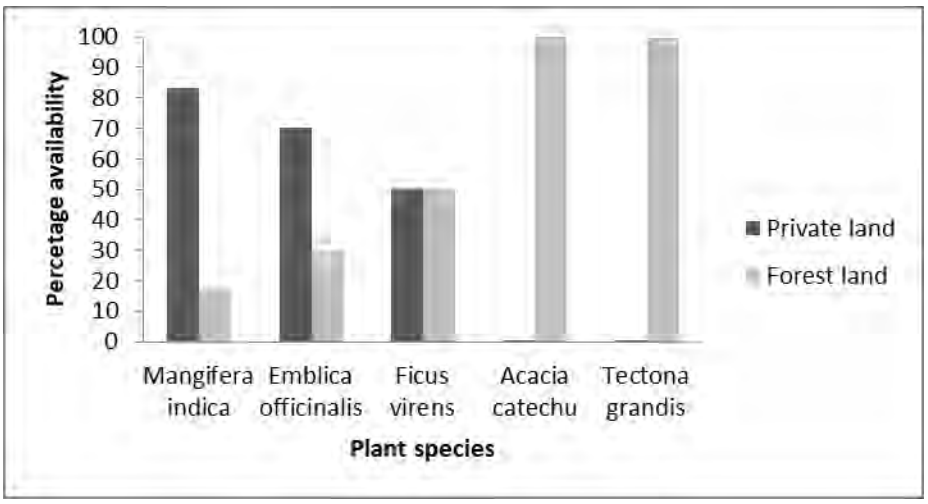

Fig 39: Percentage availability of the seven plant species present both in forest land and private land

4.4.2. Forage selection in different land use and land cover types

Forest:

Out of the 86 plant species consumed by Asian elephants in forest, forage selection could be assessed for 54 plant species. 14 of these plant species had a selection ratio of less than one implying that they were used proportionately less than their availability in the environment, and 40 plant species had a selection ratio of more than one implying that they were used proportionately more than their availability in the environment. The plant species with the highest selection ratios include *Chonemorpha fragrans*, *Alstonia scholaris*, *Mangifera indica*, *Ficus virens* and *Phrynium pubinerve*.

Semi open Forest:

Out of the 49 plant species consumed by Asian elephants in semi open forest, forage selection could be assessed for 30 plant species. Four of these plant species had a selection ratio of less than one, implying that they were used proportionately less than their availability in the environment and 26 plant species had a selection ratio of more than one, implying that they were used proportionately more than their availability in the environment. The plant species with the highest selection ratios include 'Chiuri' (vernacular name), *Bauhinia* sp., *Sterculia villosa*, *Tectona grandis* and *Chonemorpha fragrans*.

Open Forest:

Out of the 19 plant species consumed by Asian elephants in open forest, forage selection could be assessed for 12 plant species. All these 12 plant species had a selection ratio of more than one, implying that they were used proportionately more than their availability in the environment. The plant species with the highest selection ratio include *Bambusa bambos*, *Ailanthus integrifolia*, *Callicarpa arborea*, *Shorea robusta* and *Lagerstroemia parviflora*.

Tea Estate:

Out of the 19 plant species consumed by Asian elephants in tea estate, the three food grains (rice, wheat flour and dal) were excluded from the analysis. From the remaining 16 species, forage selection could be assessed for ten species. All these ten species had a selection ratio of more than one, implying that they were used proportionately more than their availability in the environment. The plant species with the highest selection ratios were *Musa* sp., *Bambusa nutans*, *Melocanna baccifera*, *Pandanus furcatus* and *Albizia procera*.

Village:

Out of the 21 plant species consumed by Asian elephant in village, the one food grain (rice) was excluded from the analysis. From the remaining 20 species, forage selection could be assessed for ten species. All these ten species had a selection ratio of more than one implying that they were used proportionately more than their availability in the

environment. The plant species with the highest selection ratios include *Bambusa balcooa*, *Tectona grandis*, *Melocanna baccifera*, *Bambusa nutans* and *Areca catechu.*

5. DISCUSSION

5.1. FORAGE USED, AVAILABLE AND SELECTED

The present study recorded 132 plant species (including three species of food grains) consumed by Asian elephants in the dry season in a multi-use landscape with fragments of moist tropical forest in northern West Bengal. In earlier studies, a varying number of plant species were recorded to be consumed by Asian elephant: 57 in Nepal (Koirala *et al*., 2016), 112 in south India (Sukumar, 1990), 106 in China (Chen *et al*., 2006), 182 in Borneo (English *et al*. 2014), 26 in Vietnam (Varma *et al*., 2008), 71 in central India (Mohapatra *et al*., 2012) among others. In northern West Bengal, 91 species were recorded in the dry season and 150 species across all seasons (Roy, 2009). As elephants are monogastric hindgut fermenters, they are poor at dealing with defensive toxins produced by plants - a problem they can addressed by increasing food diversity, thus reducing the intake of particular toxins (Clauss *et al*., 2003). Though all studies found the elephant diet to be highly diverse, the difference in the number of species is reflective of the diversity and composition (nutrients and secondary compounds) of the plants available in the particular landscape they inhabit (Campos-Arceiz & Blake, 2011) and also due to the differences in the method used to study (Koirala *et al*., 2016).

Twenty-one plant species contributed 85.3% of the total feeding signs recorded while 41 plant species were recorded to be consumed by elephants just once. Elephants are known to feed on the plants most familiar to them while continuously sample other plants (Sukumar, 2003). In particular, the Asian elephant is known to consume more than 100 plant species but only few species constitutes the majority of their dietary intake (Bi *et al*., 2016). For example, 85% of their diet composed of 25 species in south India (Sukumar, 1990) and 15 species in northern West Bengal (Roy, 2009).

I found that 39.55% of the dry season diet in my study area constituted of trees, while the rest composed of bamboos, palms, herbs, orchid and food grains. Previous studies showed a variation in diet composition across its range. 66% of their intake constituted of trees in central India (Mohapatra *et al*., 2012) while in China (Chen *et al*., 2006), Myanmar (Campos-Arceiz *et al*., 2008) and Borneo (English *et al*., 2014; Suba *et al*., 2018) non-tree species were found to dominate the forage intake. If the forest types are considered, the pattern could be

explained: tree species dominated the forage intake in dry tropical forest and non-tree species dominated the diet in moist tropical forests. My observation of non-tree species dominating the forage intake could be because of two reasons: i). the forest fragments are of moist tropical type, and ii). the previous studies recorded forage use only in forest land but I recorded in a heterogeneous landscape. In private land, non-tree species like *Musa* sp., *Areca catechu* and different species of bamboo dominated the diet. The proportion of feeding signs of food grains consumed from the households was 0.25% which is almost negligible and indicates that elephants rarely break into houses to access food.

Asian elephants are sometimes selective of the plant part they consume (Owen-Smith & Chafota, 2012), with less nutritious diets that are rich in indigestible fiber during the dry season (Pradhan *et al*., 2008). Elephants are known to feed on fresh foliage more while browsing and consume dry branches and twigs when the need arises in the dry season (Sukumar, 2003). This is consistent with my findings, where I recorded elephants to feed on the leaves for most of the plant species followed by branch, root, bark and stem. *Mimosa pudica* was the only species whose flower was consumed similar to previous studies (Sukumar, 1990). Out of six species whose fruits were consumed on, four were food crop and two grew in forest land of which *Dillenia indica* had a very high total feeding sign of 131. In Buxa Tiger Reserve, elephants were observed to remove 63.3% of *Dillenia indica* camera trap-monitored fruits (Sekar & Sukumar, 2013). The lack of fruits in the diet could be because of the unavailability of fruiting trees. Moreover, Asian elephants are known to be less frugivorous in contrast to the African elephant, with evidence from moist tropical forests of Thailand where only 21% of dung piles contained seeds, in contrast to African forest and savannah elephants where 65% of dung piles contained seeds (Kitamura *et al*., 2007).

The sexes in Asian elephants have been long predicted to have different nutritional requirements and habitat use pattern which, could be due to greater need of females and young to avoid predators and anthropogenic disturbances and high nutritional requirement of lactating females (Sukumar, 2003). I found males used villages significantly more, whereas herds used tea-estates significantly more. Males came to villages particularly for foraging, while herds foraged opportunistically in tea estates while moving between adjacent forest fragments. As a result, four of the five most commonly consumed plant

species differed between males and herds. In a fragmented landscape, herds have been found to occur significantly higher in medium-forage, medium-disturbance areas (Srinivasaiah *et al*., 2012) and male elephants are known to adopt a high-risk, high-gain foraging strategy (Sukumar & Gadgil, 1988; Chiyo *et al*., 2011; Pokharel *et al*., 2018).

Overall, elephants diet was found to be composed of 47.27% monocots and 52.73% dicots. However, since previous studies were done in forest land alone, it is ideal to compare the results with the same. This study found in the forest, elephants consumed on more monocots whereas in semi-open forest and open forest, they consumed on more dicots. The availability of monocots was lesser than dicots in all these land use and land cover types. The difference could probably be because of the lesser abundance of the palatable monocots in semi-open forest and open forest. Monocots are suggested to be one of the driving factors of dietary preference by elephants due to their relatively high carbohydrate content (Van Soest, 1994) and in moist tropical forest Asian elephants have been found to have a strong impact on monocots diversity (English *et al*., 2014; Terborgh *et al*., 2017; Suba *et al*., 2018).

During the present study, 65.23% browse and 34.77% herb constituted the overall forage intake by Asian elephant. The intake of browse was more in all land use and land cover types except forest. Although the proportion of herb was more in terms of availability in all land use and land cover types, it was probably not consumed as the species were not palatable. My finding is in contrast with the findings from Buxa Tiger Reserve where they 93% of the dry season intake was found to be browse. The dominance of browse in the diet in the dry season has been established by several others (Sukumar, 1990; Pradhan *et al*., 2008), where within a particular habitat type, the choice was influenced by the availability of these plant types (Sukumar, 2003).

The logistical problem in quantifying the distribution and availability of various plant species has long prevented the quantification of forage selection (Sukumar, 2003) and this is one of the few studies to examine forage selection in the Asian elephant. Out of the 29 species that had a selection ratio of more than 100, 51.72% were available only in forest land, 31.03% was available only in private land and the rest available in both. Thus, in terms of forage availability, non-forested areas play only a subsidiary role in supporting foraging of

elephants and are not substitutes for forest land. On the other hand, the presence of 31.03% of the forage species in private land alone demands development of measures and strategies to guard them or ensure the cultivation of these species at a distance from houses so that accidental encounters could be avoided when elephants venture close to settlements to access these. Elephants like other large generalist herbivores were thought to feed on plants that are usually available in abundance (Sukumar, 2003) but the present study shows that among the plants for which selection was analysed, 80.21% species were consumed more than their availability in the environment. The results indicate significant selectivity in the diet of the Asian elephants in the landscape.

5.2. DIFFERENCES ACROSS DIFFERENT LAND USE AND LAND COVER TYPES

This was the first study that assessed relative forage use and selection in a heterogeneous landscape. On an average, elephants consumed on plant species more frequently in villages followed by forests, semi-open forests, tea estates and open forests. However, the average feeding frequency in the village had a high variance which could be because sometime elephants used villages just as passage and sometimes came for foraging. The average number of plant species consumed was highest in the forest followed by the village, semi-open forest, open forest and tea estate. Although the average number of species consumed in the forest [4.79 (±SE 0.89)] and village [4.48 (±SE 0.93)] was similar, the total number of species consumed in the forest (86) was much higher than that in the village (21). In terms of availability, forest supported most number of plant species followed by semi-open forest, open forest, village and then tea estate. The canopy layer tree density reduces from forest to semi-open forest and open forest, while the invasive species density increases from forest to semi-open forest and open forest. Invasive species are known to cause habitat modification and native plant species loss (Didham *et al*., 2005) and the findings of this study indicate towards a similar mechanism occurring in semi-open forest and open forest. As a high diversity of food plants is necessary to ensure access of different nutrients for elephants (Sukumar, 2003), it important to adopt appropriate habitat management measures in semi-open forest and open forest to curb growth in invasive species density and restore them to ensure forage availability for elephants in these land use and land cover types.

5.3. CONSTRAINTS

I could not find the scientific names of all the plant species because I could not visit the three institutes in West Bengal (Botanical Survey of India, North Bengal University and Uttar Banga Krishi Vishwavidyalaya) which I was supposed to visit for help due to the pandemic. Moreover, the botanists I had contacted found it difficult to identify the plant species, especially from the family Poaceae because I had photographs of only the vegetative parts. The study was conducted in the dry season when most plant species in the study area do not flower or fruit. Nevertheless, this caveat should not affect conservation initiatives in the study area because I have documented the local names which people are familiar with. Although the species accumulation curve for understory and ground flora in open forest did not reach an asymptote, sampling was stopped because this land cover type has been created as a result of degradation of forest due to logging, fire wood collection and grazing. Hence, plant species available in the open forest type is a subset of the species available in the forest. The phenology of the plants available could not be assessed as field work for plant species availability in forest land had to be postponed to the monsoon due the emergence of COVID 19 pandemic. This would have helped in assessing selection for plant part consumed as well. Accuracy assessment of the land use and land cover classification was not possible as it requires heavy computational processing and I did not have a suitable device at my disposal and it could not been outsourced as it requires familiarity with the landscape. Originally, it was supposed to be done at the GIS laboratory in SACON but did not materialise due to the pandemic. The reclassification of the misclassified cell was not possible, so I could not calculate the area of different land use and land cover types. While recording the geo-coordinates of the training sites for the forest, semi-open forest, and open forest, the canopy cover was not recorded. This would have been helpful in providing empirical evidence for the classification.

5.4. CONCLUSION

This was the first study that assessed forage selection by Asian elephants in a heterogeneous landscape. Asian elephants showed high selectivity for forage species in this landscape. Non-forested areas play only a subsidiary role and not a substitute for forest land in terms of supporting the availability of the selected forage species by Asian elephants.

However, as quite a few selected forage species by Asian elephants were available only in the private land, it demands the development of strategies to prevent negative interactions in terms of economic loss or accidental attacks when elephants come to forage on these species. In forest land, appropriate habitat management measures are required in semi-open forest and open forest to ensure forage availability for elephants. Future research on Asian elephant in the heterogeneous landscape of northern West Bengal must be focussed on the following: i). assessment of forage selection in the wet season as the scope of this study was limited to the dry season, ii). role in seed dispersal and forest regeneration and iii). nutritional composition of the foraged species to understand if the elephant population is undergoing nutritional stress. These information would not just expand our knowledge about the ecosystem services provided by Asian elephants which is limited (Sekar & Sukumar, 2013) but help in developing better conservation strategies for the species as well.

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APPENDIX

Table 1: Plants species consumed by Asian Elephant along with plant parts consumed, feeding frequency in different land use and land cover types (F- Forest, SOF – Semi-open Forest, OF – Open Forest, TE – TE, V- Village), total feeding frequency (Total FF) and selection ratio.

SL No	Local Name	Scientific Name	Plant part consumed	F	OF	SOF	TE	V	Total FF	Selection Ratio
1	Paka Sash	*Terminalia alata*	Leaf, Root	1		1			2	4070150
2	Tel baas	*Bambusa balcooa*	Leaf	1			14	17	32	39408.42
3	Chiuri		Blade			4			4	4926.06
4	Filling baas	*Melocanna baccifera*	Leaf	6			1	5	12	4926.06
5	Kata baas	*Bambusa bambos*	Leaf	1	2	20		1	24	2955.64
6	Makla baas	*Bambusa nutans*	Leaf				12	10	22	1354.67
7		*Pandanus furcatus*					3		3	923.64
8	Haringudi	*Ardisia solanacea*	Branch, Leaf, Root	7					7	862.06
9	Banana	*Musa* sp.	Fruit, Leaf, Stem				31	64	95	801.33
10	Mechia Pata	*Phrynium pubinerve*	Leaf, Stem	541					541	774.71
11	Supari	*Areca catechu*	Leaf, Stem				52	117	169	754.08
12	Kabra	*Ficus virens*	Bark, Leaf	1					1	615.76
13	Labar	*Ficus elastica*	Branch	1					1	615.76
14	Totola	*Oroxylum*	Leaf			2			2	615.76

		indicum								
15	Arare Kara	*Acacia pennata*	Bark, Branch, Leaf, Root	4	3	12			19	467.98
16	Teak	*Tectona grandis*	Bark, Branch, Leaf, Root, Stem	2	1	61		11	75	441.94
17	Moleto	*Macaranga denticulata*	Bark, Branch, Leaf, Root, Stem	33		11			44	320.64
18	Taki	*Bauhinia sp.*	Branch, Leaf	6		2			8	289.77
19	Kathal	*Artocarpus heterophyllus*	Leaf					1	1	246.31
20	Dudhe Lahara	*Chonemorpha fragrans*	Branch, Leaf	64		2			66	239.06
21	Aam	*Mangifera indica*	Branch, Leaf	1					1	205.26
22	Chalta	*Dillenia indica*	Fruit, Leaf	113	15	3			131	201.16
23	Khair	*Acacia catechu*	Root			4		630	634	161.39
24	Amra/ Amloki	*Emblica officinalis*	Branch, Leaf	1					1	123.16
25	Baghe kata	*Smilax perfoliata*	Leaves	1					1	123.16
26	Tomato	*Solanum lycopersicum*	Fruit					20	20	123.16
27	Falame	*Walsura tabularis*	Branch, Leaf	1					1	123.16
28	Jongli baas	*Dendrocalamus*	Leaf	1					1	123.16

		sp.								
29	Brinjal	*Solanum melongena*	Fruit					49	49	100.58
30	Chatim	*Alstonia scholaris*	Leaf	3					3	80.32
31	Gualo	*Callicarpa arborea*	Branch, Leaf		1	2			3	78.61
32	Simul	*Bombax ceiba*	Bark, Leaf	1		1		1	3	76.97
33	Sindure	*Mallotus philippensis*	Bark, Branch, Leaf, Root, Stem	19	2	36			57	76.14
34	Gomari	*Gmelina arborea*	Bark, Branch			1			1	68.42
35	Purundi	*Alpinia nigra*	Leaf, Stem	180		3			183	66.09
36	Bon Kathal/ Barhar	*Artocarpus lakoocha*	Leaf, Branch					1	1	61.58
37	Ful jharu/ kucho	*Thysanolaena latifolia*	Blade		1				1	41.06
38	Patpate Sirish	*Albizia lucidior*	Branch, Leaf	1		72	1		74	36.43
39	Goleni/ Hatubhanga	*Leea indica*	Bark, Branch, Leaf, Root	42		14			56	34.84
40	Chana ghas/ Kasai		Branch, Leaf	1	11	1			13	34.36
41	Ful ghas	*Holmskioldia sanguinea*	Leaf	1		1			2	30.79
42	Ghora ghas		Blade	10					10	30.79
43	Jongli anaros		Leaf	5		4			9	27.71
44	Charpate	*Carex* sp.	Blade	32					32	24.48

45	Bakshi Kata	*Caesalpinia cucullata*	Bark, Branch	1		3			4	23.46
46	Ram Suntala	*Chisocheton cumingianus*	Root	1					1	22.4
47	Jarul	*Lagerstroemia speciosa*	Bark, Branch, Leaf, Root	8	3	27	1		39	19.53
48	Gokul	*Ailanthus integrifolia*	Stem		1				1	19.25
49	Bash pate ghas	*Molineria capitulata*	Blade	3					3	16.8
50	Tatari	*Dillenia pentagyna*	Bark, Branch, Root	4					4	16.1
51	Thali	*Turpinia pomifera*	Leaf	1					1	15.4
52	Haldikath	*Morinda augustifolia*	Bark, Branch, Leaf	13		1			14	14.74
53	Sida/ Burdamero	*Lagerstroemia parviflora*	Branch		2				2	14.24
54	Kotush/ Musure	*Castanopsis hystrix*	Bark, Branch, Leaf, Root	4		1			5	12.39
55	Maidulu Kara/Myna Kara	*Meyna spinosa*	Branch, Leaf, Root	1	2	1			4	11.2
56	Jhingeni	*Eurya acuminata*	Branch	1					1	10.18
57	Sada Sirish	*Albizia procera*	Bark, Leaf, Root		1		2		3	8.31

58	Sal	*Shorea robusta*	Bark, Branch, Root	14	1	24			39	7.66
59	Kalo Sirish	*Albizia lebbeck*	Leaf				1		1	6.13
60	Kumbi	*Careya arborea*	Branch			1			1	4.14
61	Hare Khirra	*Holarrhena pubescens*	Leaf			1			1	3.93
62	Gayo	*Bridelia retusa*	Bark, Branch, Leaf	5	2	3			10	3.57
63	Jamun	*Syzygium cumini*	Branch, Leaf, Root	5		1			6	3.39
64	Kaulo	*Persea gamblei*	Branch, Leaf	3					3	2.93
65	Khakar	*Albizia odoratissima*	Leaf				1		1	2.89
66	Thakouli		Leaf, Branch	3		1			4	2.8
67	Lali	*Aglaia spectabilis*	Branch, Leaf		1				1	2.72
68	Odal	*Sterculia villosa*	Bark, Branch	1	1	1			3	2.71
69	Birali Lahara		Leaf			1			1	2.57
70	Bashe Bonsho	*Isachne* sp.	Leaf, Stem	96		4			100	2.53
71	Kaphol	*Myrica* sp.	Fruit	1					1	2.52
72	Choulane	*Litsea lancifolia*	Branch, Root	14		1			15	2.39
73	Amkoili	*Cryptocarya* sp.	Branch, Leaf, Root, Stem	2					2	2.34
74	Archal/ Bandar	*Antidesma*	Root	1					1	2.24

	khaja	*acidum*								
75	Mikania/Asamilata	*Mikania micrantha*	Leaf, Stem	17					17	2.22
76	Tite Lahara		Leaf, Branch	1		1			2	2.06
77	Jongli lichi		Branch, Leaf, Root	7					7	1.7
78	Jhakri kath	*Ocotea lancifolia*	Root			1			1	1.49
79	Pani Lahara	*Cissus repanda*	Branch, Leaf	3					3	0.96
80	Kutmero	*Litsea monopetala*	Branch, Leaf, Root		2				2	0.93
81	Lapche	*Polyalthia simiarum*	Bark			1			1	0.86
82	Kali Lahara		Branch, Leaf	6	3				9	0.81
83	Bonsho ghas	*Oplismenus burmanii*	Blade	116			35		151	0.75
84	Dhotisuro	*Setaria palmifolia*	Blade	1					1	0.69
85	Lata Sirish	*Dalbergia stipulacea*	Branch, Leaf	3					3	0.45
86	Shiru ghas		Root			10			10	0.38
87	Charchare Lahara	*Tetrastigma serrulatum*	Branch, Leaf	4		1			5	0.32
88	Kane ghas		Leaf, Stem	4	10				14	0.22
89	Jongli Bhatne	*Clerodendrum bracteatum*	Root	3					3	0.16
90	Ghatu pata	*Clerodendrum*	Root	7					7	0.15

		infortunatum								
91	Gaujo	*Millettia extensa*				1			1	0.11
92	Akle ghas		Blade			3			3	0.08
93	Dheki Shak	*Diplazium esculentum*	Root, Stem	3					3	0.06
94	Jongli Pan	*Piper beteloides*	Leaf	4					4	0.05
95	Chepti Ghas	*Axonopus compressus*	Blade			12			12	0.04
96	Lajjabati	*Mimosa pudica*		1					1	0.04
97	Kuro ghas	*Urena lobata*	Blade	1					1	0.02
98	Aran/ Thesh		Branch	1					1	-
99	Basak Pata		Leaf	1					1	-
100	Burjo Lahara		Branch	1					1	-
101	Cabbage	*Brassica oleracea*	Fruit					3	3	-
102	Coconut	*Cocos nucifera*	Branch					1	1	-
103	Dal (masoor)	*Lens culinaris*								-
104	Deu Purundi	*Alpinia malaccensis*	Leaf	1		1			2	-
105	Dhakia Lorong			1					1	-
106	Flour (ata)	*Triticum aestivum*					1		1	-
107	Guatemalan	*Tripsacum laxum*		50					50	-
108	Harkata		Leaf	3					3	-
109	Huku Lali		Branch	1					1	-
110	Jhirpitia		Leaf	2					2	-
111	Jiga		Bark, Root	1					1	-
112	Jongli bokshu		Leaf	1					1	-
113	Jongli Cha Pata		Branch	1					1	-

114	Jongli Dhan	*Coix* sp.		20					20	-
115	Jongli Sirish		Leaf, Root	3					3	-
116	Kata sule		Leaf	1					1	-
117	Kukur diane	*Smilax macrophyla*	Leaf, Branch			1			1	-
118	Mondola		Leaf	1					1	-
119	Nebara		Fruit					1	1	-
120	Nima Bash	*Bambusa* sp.	Leaf					1	1	-
121	Unidentified Orchid		Leaf	4					4	-
122	Peepal	*Ficus religiosa*	Bark, Branch					2	2	-
123	Pitwai		Branch	2					2	-
124	Potato	*Solanum tuberosum*	Root				6	203	209	-
125	Rai shak	*Brassica* sp.	Leaf				15		15	-
126	Rice	*Oryza sativa*					2	4	6	-
127	Shit Lata		Leaf, Branch			1			1	-
128	Simul kandha	*Manihot esculanta*	Leaf, Root				10	9	19	-
129		*Asplenium* sp.	Leaf			2			2	-
130	Unidentified Bamboo						2		2	-
131		*Pericampylus glaucus*	Leaf	3					3	-
132	Unidentified climber		Leaf	1					1	-