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Habitat assessment and utilization by Asian Elephant (Elephas maximus L.) in Palani Hills Northern Slope Reserve Forests of Dindigul Forest Division, Tamil Nadu, Southern India

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Abstract: *Elephants use their traditional habitats in different seasons to obtain their various ecological, physiological and sociological requirements. Sometimes it may happen even after 200 years also. One of the such incident took place in Dindigul Forest Division of Tamil Nadu, Southern India during 2006. This might have happened due to habitat fragmentation, loss or blockage of corridors, indiscriminate growth of any developmental activities, mining and severe biotic threats in its natural habitats. This paper describes the habitat assessment and use pattern of elephants in the foot hills of Palani Hills Northern Slopes Reserved Forests in Dindigul Forest Division after 200 years. This study found elephants effectively used two different trails for their movement through Palani Hills Northern Slopes Reserved Forests either through the foot hill forests or crop fields. The present study revealed that elephant food trees were recorded 65% (3.71 ha.) and elephant preferable shrubs were 15% (0.37 ha.). Among the ground cover variables barren ground was highest (46.8%) followed by grass cover (31.8%) and shrub (8.2%). Other ground cover variables such as herb, rock and weed represented 4.8%, 5.8% and 2.6% respectively. To find out extent of habitat utilization by elephants, a total of 68 elephant dung piles were examined during the study. Of which 57% comprised agriculture crops namely maize, sugarcane, guava, plantain, tamarind and sorghum. The present study concluded the elephants extensively used agricultural crop fields than forests to sustain in this area after 200 years.*

Keywords: *Asian elephant, habitat quality, habitat utilization, elephant trails.*

I. Introduction

Today wild Asian elephants distributed in 13 countries across the South and Southeast Asia with a population estimate is about 45,671 - 49,028 (Sukumar 2018). Indian sub-continent harbours 50% of the world's Asian elephant population, which is estimated to be 27,312 (Synchronized Elephant Population Estimation Report, 2017). Most of these are currently distributed over an area of about 110,000 Sq.km within four regions in India and Tamil Nadu have a population about 2761 elephants (Synchronized Elephant Population Estimation Report 2017). This paper witnessed the habitat assessment and use pattern of elephants in foot hills of Palani Hills Northern Slope Reserved Forests of Dindigul Forest Division, Tamil Nadu, Southern India.

The study site is connecting two major habitats between Anamalai Tiger Reserve and Kodaikanal plateau through the foot hills of Palani Hills Northern Slopes Reserved Forests. Its ecological wealth is important to all downstream animals on this foot hill tract. Although, the foot hills have a natural forest and suitable habitat for

elephants, the elephants were not reported till 2005. Later then elephants are moved into this area since 2006 from Anamalai Tiger Reserve and Chinnar Wildlife Sanctuary. Elephants crossed Palani-Kodaikanal road which is acting as a natural impediment to elephants where the important areas are Thekkanthottam, Annanagar and Varathamanadhi reservoir are located.

Being a mega herbivore, elephant spent 14 to 18 hours in a day to procure food. With increasing numbers, it is expected that the elephants will modify the habitats by their impacts on the vegetation (Laws, 1970). Selection of habitat by elephants varied with the season and other ecological factors (Owen-Smith, 1988; Sukumar, 1989a; Blom *et al* 2005) and is well documented in the African savanna elephant (Laws, 1970; Leuthold 1997; Merz,1986; de Boer *et al* 2000; Ntumi *et al* 2005. Few studies were carried out on elephant habitat in southern India (Sukumar 1989b, Ishwaran 1993), Sri Lanka and Indonesia (McKay 1973, Santiapillai *et al*. 1984 and Hedges *et al.* 2005). Such predictions enable habitat management for endangered species, such as the Asian elephant that have large geographic ranges and undertake extensive annual movements within their home ranges (Desai & Baskaran, 1996). The forage and water required in large quantities for large herds may not always be available at the same location resulting in non-uniform patterns of space use (Sukumar, 1989a). The habitat of Palani Hills Northern Slopes and its adjoining areas are influenced by south-west and north-east monsoon which results various types of forests as well as agricultural crops. Often these vegetations are play a major role for movement of larger mammals especially elephants. Hence it is necessary to determine the wealth of habitat through its availability of food and non-food species, status of ground vegetation and food preference by elephants in this area.

This study exhibits elephants are using this habitat after two centuries hence, it is most important to assess the habitat quality to alleviate a diversity of elephant food plants that would bring a quality of this habitat. The trend of habitat use by elephants in this area would bring out a greater relevance to management of Asian elephant population not only for this area and also adjoining landscape like Anamalai Tiger Reserve and Kodaikanal Wildlife Division. Therefore, this study is viewed as a an unique case to derive management implications for elephant conservation in a long run with the major objectives such as to assess the habitat quality (trees, shrubs, herbs and ground cover) and to find out extent of utilization (examining dung piles) by the elephants in the habitat.

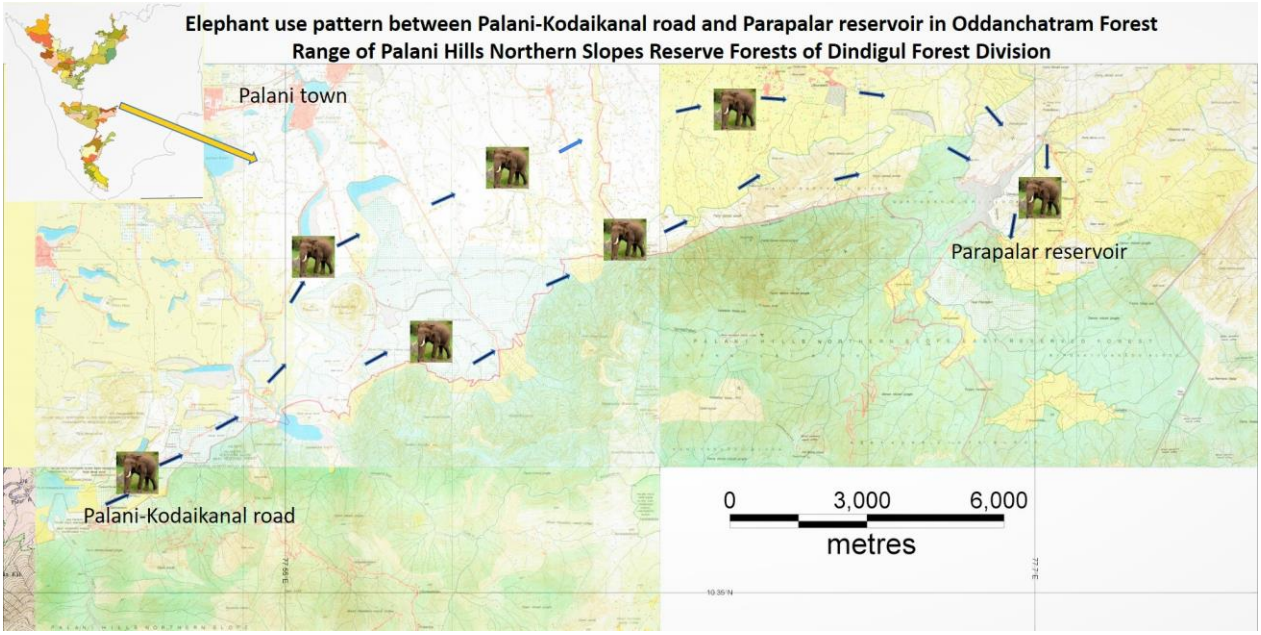
II. Materials and Methods

Vegetation study was carried out to assess the composition of elephant food species by quadrate method. A total of five line transects were laid in five different locations. All these transects were laid from crop fields to foot hill forests and in some places stretched up to hill tops. Length of the transects was varied depending on the topography. Data on trees (>20cm gbh) was classified as mature trees and enumerated as species wise. 100m x 10m quadrates were laid with the interval of 100m on the transects for trees enumeration. Within this quadrat one sub-quadrate of 10m x 10m was laid to assess the shrub species (Vesey-Fitzgerald, 1973; Sivaganesan, 1991, Ramakrishnan, 2007). Totally 96 sub-plots were laid to estimate percent occurrence of grass, herb, weed, barren ground, shrub and rocky surface using ocular estimation in 1m x 1m sub-blots laid either side within the 10m x 10m sub-quadrats (Rameshkumar, 1994) at the beginning and at the end of the sub-quadrate. A total of 68 dung piles were carefully examined for undigested food materials in outside of the forests (n=26) and inside the forests (n=42) to assess extent of use of habitat by elephants. The abundance of agricultural crops remains and other food materials in the dung piles were carefully quantified as suggested by White *et al* (1993). Data on the content of each dung piles were proportionately recorded described by Sivasubramanian and Sivaganesan (1996) and Sivaganesan *et al* (2000). This study was carried out in Palani Hills Northern Slopes Reserved Forests of Dindigul Forest Division from June to November, 2016.

III. Result

The present study revealed that the elephants highly preferred two different trails for their movement in the focused study area either through the foot hill forests or agricultural crop fields. These two trails are crucial to this elephant population in the foot hills of Palani Hills Northern Slopes Reserve Forests in Dindigul Forest Division (Map 1).

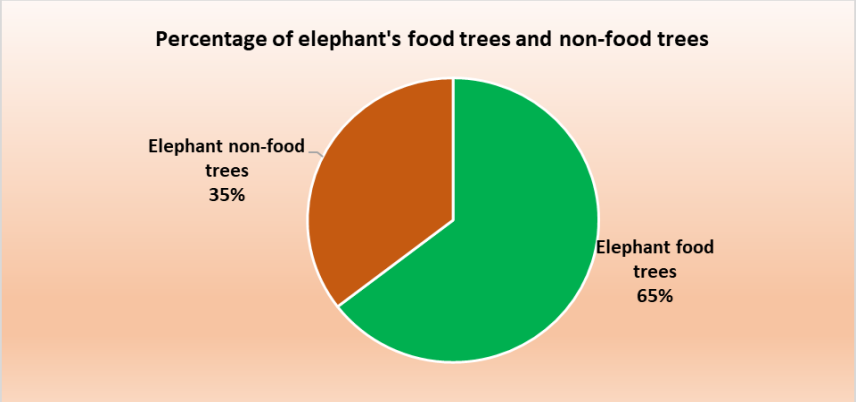
Map 1. Elephant movement pattern in Palani Northern Slopes Reserve Forests in Dindigul Forest Division



Assessment of habitat quality

The elephant food species included both wild plant species and cultivated crops. The proportionate of elephant food trees alone contributed 65% than non-food trees 35% (Fig. 1).

Figure 1. Proportionate of elephant food trees and non-food trees in the sampled area (n=3.71 ha)



Density of elephant food trees and non-food trees

A total of 353 tree individuals comprising 58 tree species was recorded in the sampled plots. Among the 58 tree species, non-food trees of elephants were higher (n=36) than elephant food trees (n=22). Among the elephant food tree species, Silk cotton was recorded highest numbers (13.21/ha) followed by *Albezia amara* (8.89/ha), Mango (8.36/ha), *Anona squamosa* and *Ficus microcorpa* each of them recorded 4.31/ha. Although elephant non-food tree species was higher in number than elephant food tree species namely, *Azadirachta indica* (4.8/ha) followed by *Diospyrus sp* (3.23/ha) and *Limonea allata* (2.43/ha) (Table 1).

Table 1. Density of elephant food trees and non-food trees in the sampled areas of Palani Northern Slopes Reserve Forests of Dindigul Forest Division (Sampled area: 3.71 ha)

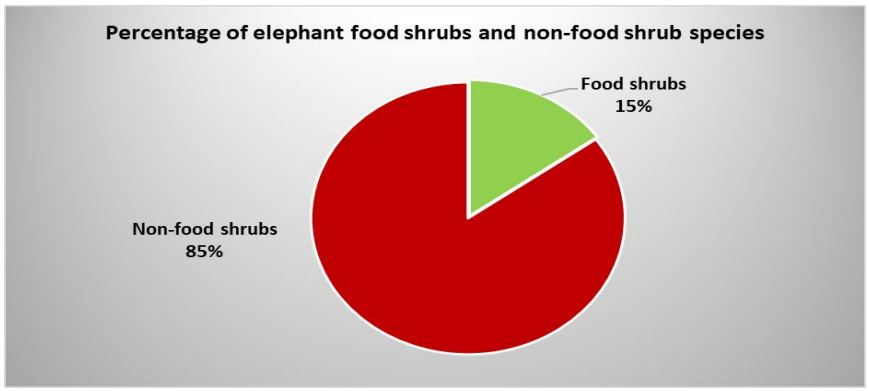
S. No	Name of the tree species	Local name	Total number of trees enumerated	Density/ha	Status of Elephant food species
1	*Acacia intia*	Vella indu	13	3.50	Yes
2	*Acacia leucophloaea*	Vella velan	3	0.81	Yes
3	*Ailanthus exselsa*	Peenarimaram	2	0.54	
4	*Albezia amara*	Usilmaram	33	8.89	Yes
5	*Albezia lebbeck*	Vagaimaram	6	1.62	Yes
6	*Atalantia monophylla*	Kattu elumichai	1	0.27	
7	*Azadirachta indica*	Vembu	17	4.58	
8	*Bauhinea racemosa*	Aathi	2	0.54	Yes
9	*Bombax ceiba*	Kattu elava maram	2	0.54	
10	*Canthium diococcum*	Payira	2	0.54	
11	*Capparis grandis*	Soorimullu	1	0.27	
12	*Holoptelea integrifolia*	Aya maram	2	0.54	
13	*Commiphora berryi*	Mullu kiluva	6	1.62	Yes
14	*Commiphora caudata*	Mala kiluvai	5	1.35	
15	*Anona squamosa*	Seetha maram	16	4.31	Yes
16	*Dalbergia latifolia*	Eetti maram	1	0.27	
17	*Dalbergia sp*	Vella eeti	3	0.81	
18	*Diospyrus montena*	Vakkana	5	1.35	
19	*Diospyrus sp*	Vella thuvarai	12	3.23	
20	*Diospyrus vourdilloni*	Karun thuvarai	8	2.16	
21	*Euphorbis antiquarum*	Kalli	4	1.08	
22	*Ficus bengalensis*	Aala maram	1	0.27	Yes
23	*Ficus microcorpa*	Kal Itchi maram	16	4.31	Yes
24	*Ficus racemosa*	Aththi	5	1.35	Yes
25	*Gardinia commiphora*	Kambimaram	1	0.27	
26	*Gmelina arborea*	Kumulan	3	0.81	Yes
27	*Psidium guajava*	Guava (Koiya)	6	1.62	Yes
28	*Gyrocorpus morsupium*	Danakku maram	7	1.89	
29	*Jatropha sp*	Kattamanaku	1	0.27	
30	*Kalveera maram*	Kalveera maram	4	1.08	
31	*Karumpayira*	Karumpayira	5	1.35	
32	*Leucaena leucophloea*	Leucaena leucophloealu	3	0.81	
33	*Limonea allata*	Kattu elumichai	9	2.43	
34	*Mangifera indica*	Manga	31	8.36	Yes
35	*Millingtonia hortensis*	Mala vembu	2	0.54	

36	*Muringa sp*	Kattu murungai	2	0.54	
37	*Parukka maram*	Parukka maram	1	0.27	
38	*Plnatain*	Vazhai	1	0.27	Yes
39	*Pluctoria sp*	Vella payira	1	0.27	
40	*Premna tomentosa*	Minna	7	1.89	
41	*Prosopis juiflora*	Velikathan / Delli mulu	5	1.35	Yes
42	*Pterolobium hexapetalum*	Seenga mullu	1	0.27	
43	*Pungamia pinnata*	Punga maram	2	0.54	
44	*Pura maram*	Pura maram	1	0.27	
45	*Santalum album*	Santhana maram	2	0.54	
46	*Sapindus emerginatus*	Poocha kai marm	3	0.81	
47	*Silk cotton*	Elavmaram	49	13.21	Yes
48	*Strychnos nyxvomica*	Etti	2	0.54	
49	*Strychnos potatorum*	Thethankottai	2	0.54	
50	*Syzygiuim cumini*	Naval	1	0.27	
51	*Tamarindus indica*	Puliya maram	13	3.50	Yes
52	*Tectona grandis*	Thekku	5	1.35	Yes
53	*Terminalia arjuna*	Neer mathi	1	0.27	
54	*Vazhuka kodi*	Vazhuka kodi	1	0.27	Yes
55	*Writia tinctoria*	Pala maram	3	0.81	Yes
56	*Zizyphus mauritiana*	Elantha maram	4	1.08	Yes
57	*Zizyphus oenoplea*	Soori Elantha	6	1.62	Yes
58	*Zyziphus trinerva*	Karikittan	2	0.54	

Proportionate of elephant food shrubs and non-food shrubs

It is very important and management perspective to note that the availability of elephant non-food shrub species was higher (85%) than elephant preferable shrub species (15%) (Fig. 2).

Figure 2. Proportionate of elephant food shrubs and non-food shrub species recorded in the study area



Density of elephant food shrubs and non-food shrub species

A total of 119 individuals belonging to 36 shrub species were recorded from the sampled area (0.371 ha). Of which, non-food shrub species to elephants was (n=27) recorded higher density than elephant preferable food shrub species (n=9). Among the non-food shrub species of elephants, *Lantana camera* (56.6 ha) was the highest density followed by *Eupotorium sp.* (35.04/ha), *Pteralobium hexapetalum* (29.95/ha) and *Randia dumatorum* (16.17/ha), *Acalypha fruiticosa* and *Fluggea leucopyrus* both of them were equally (13.48/ha) represented in the study area (Table 2). It is important and management point of view to note that poor density of elephant food shrub species such as *Grewia villosa* (18.87/ha) followed by *Acacia intia* (8.09/ha) and *Gmelina arborea* (5.38/ha) found during the study period.

Table 2. Density of elephant food shrub and non-food shrub species recorded in the Palani Northern Slopes Reserve Forests of Dindigul Forest Division (Sampled area 0.371 ha)

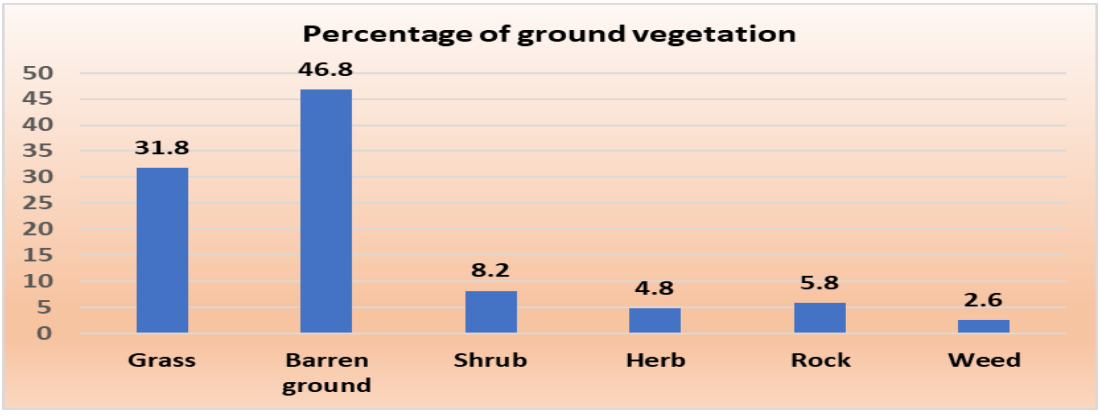
S. No	Name of the shrub species	Local name	Total number of individuals	Density / ha	Elephant food species (Yes / No)
1	*Abutilon indicum*	Thulasi	2	5.39	
2	*Acacia intia*	Vella indu	3	8.09	Yes
3	*Acacia planiferens*	Kodai velan	1	2.70	Yes
4	*Acalypha fruiticosa*	Sinni sedi	5	13.48	
5	*Azadirachta indica*	Vembu	1	2.70	
6	*Capparis grandis*	Soori mullu	1	2.70	
7	*Carissa carandus*	Kila	1	2.70	
8	*Cissus quadrangularis*	Pirandai	2	5.39	
9	*Commiphora berryi*	Mullu kiluvai	1	2.70	Yes
10	*Commiphora caudata*	Mala kiluvai	1	2.70	
11	*Euphorbia antiquarum*	Kalli	4	10.78	
12	*Eupatorium odoratus*	Eupotorium	13	35.04	
13	*Ficus racemosa*	Aththi	1	2.70	Yes
14	*Fluggea leucopyrus*	Veppulan	5	13.48	
15	*Gardinia commiphora*	Kambimaram	1	2.70	
16	*Gmelina arborea*	Kumulan	2	5.39	Yes
17	*Grewia hirsuta*	Sirukadala sedi	1	2.70	Yes
18	*Grewia villosa*	Kadala sedi	7	18.87	Yes
19	*Jasminum angustifolium*	Kodi malli	1	2.70	

20	*Jasminum ariculatum*	Kattu malli	1	2.70	
21	*Jatropha curcas*	Kattamanakku	2	5.39	
22	Kurinja	Kurinja	3	8.09	
23	*Lantana camera*	Unni sedi	21	56.60	
24	*Limonea allata*	Kattu elumichai	3	8.09	
25	*Ocimum sp*	Kattu thulasi	3	8.09	
26	*Opentia dilleni*	Sapathi kalli	2	5.39	
27	*Pavetta indica*	Pavatta	4	10.78	
28	*Pluctoria sp*	Vella payira	1	2.70	
29	*Pluctoria titiona*	Payira	1	2.70	
30	*Prosopis juliflora*	Delli mullu	1	2.70	Yes
31	*Pteralobium hexapetalum*	Seengai	10	26.95	
32	*Randia dumatorum*	Kara	6	16.17	
33	*Randia malabarica*	Sinna kara	4	10.78	
34	*Strychnus nuxvomica*	Etti	1	2.70	
35	*Toddalia asiatica*		2	5.39	
36	*Zizyphus eonoplea*	Soori elantha	1	2.70	Yes

Ground cover variables

To assess the ground cover, the percent occurrence of grass, herb, shrub, barren ground, weed and rocky areas were accounted. A total number of 96 plots were laid in the entire study area. Among the ground cover variables, barren ground recorded highest proportionate (46.8%) followed by grass cover (31.8%). Other variables such as shrub (8.2%), rocky terrain (5.8%), herb (4.8%) and weed cover (2.6%) were observed very low proportions in the sampled area (Fig. 4).

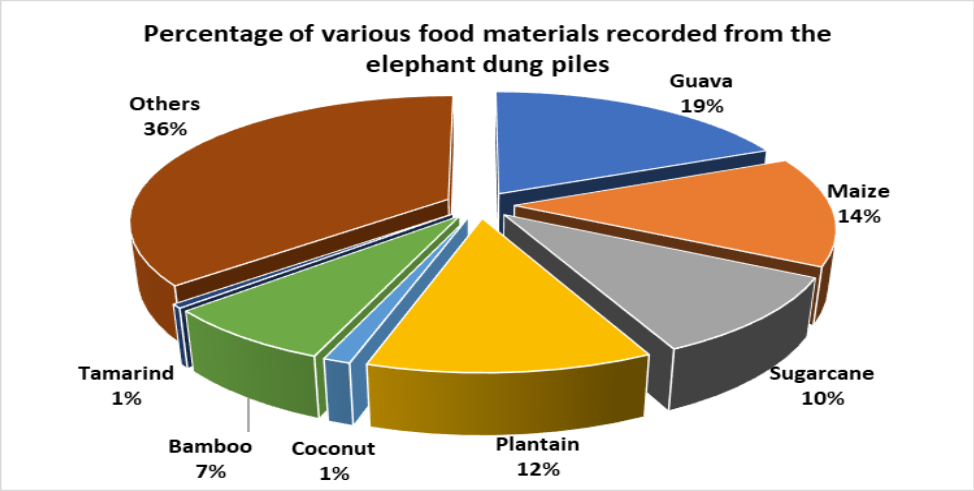
Figure 4. Proportion of ground cover variables in the focused study area



Analyses of elephant dung piles

A total of 68 elephant dung piles were examined in outside (n=26) and inside of the forest areas (n=42). Of which the cultivated crops (57%) attained higher proportionate than wild plants (43%) (Fig. 5). The commonly found crop species in the elephant dung piles were Guava (19%), Maize (14%), Plantain (12%), Sugarcane (10%), Coconut and Tamarind equally as (1%). The major amount of wild plant was bamboo (7%) and other wild plants altogether 36% in the dung piles of elephants. The elephant dung examination result clearly showed that the elephants in this area mostly preferred cultivated crops than wild plants.

Figure 5. Percentage of various food materials recorded from the elephant dung piles in the study area



IV. Discussion

The intensive study was carried about 35 kilometers along the foot hills of Palani Hills Northern Slopes Reserve Forests. It is a clear sign that the elephant herds found new routes through this foot hill forests that they have not been used until 2005. We had seen the elephants use this tract by utilizing crop fields, especially fruit bearing crops and other favorable food crops such as Guava, Mango, Jack, Plantain and Paddy could trigger the elephants to withstand into new areas which is closer to the foot hill forests. It is quite interesting to note that once this area was part of the traditional seasonal home range to elephants which is evidenced after 200 years.

The present study found the elephants mostly use in human dominated areas than forest areas may be due to encroachments and expansion of agriculture. Other reason such as proliferation of exotic weeds and fewer availability of palatable wild food plants force the elephants to use more in agricultural crop areas. Daniel (1980) highlighted the shrinkage of potential habitats due to various land use changes caused for the loss of crucial habitats to Asian elephant populations in India. Availability of water facility in Palar-Puranthalar, Varathamanadhi and Parapalar reservoirs in the study area, retain the elephant population in the agricultural areas. Sukumar (1989a) mentioned elephants are forced to move through human dominated landscapes mainly for water in some areas. Many studies are also suggested that the elephants use microhabitats especially during dry season when deciduous forests become unpalatable (Sukumar, 1989a; Sivaganesan, 1991 and Baskaran, 1998). Thouless *et al* (2008) stated the habitat loss through selective logging or clear felling may not have an immediate effect since the resulting secondary vegetation may provide more food for elephants. The present study findings corroborate with earlier studies as the elephants has come from adjoining areas of Anamalai Tiger Reserve which is dominated by deciduous forests became unpalatable to elephants in dry season could have triggered on elephant conservation and their use in these areas though it is for a shorter duration. But an ecological point of view, this short period dispersal is inevitable to elephants as its own habitat became unpalatable.

This study has revealed that the elephants moved from Thekkanthottam to Parapalar reservoir during the dry spell in search of natural resources like water, food, shade and other ecological requirements which are sparsely

distributed in this area during the onset of north east monsoon. Ishwaran (1981) found that during dry conditions, swampy areas provide grass for elephants in Wilpattu National Park, Sri Lanka. The movement of elephants to large grassy villus during wet season was influenced by the availability of food and dry season movement was influenced by the permanent water source (Eisenberg and Lockhart, 1972). This has been evidenced in the study area due to presence of perennial water sources at Varathamanadhi reservoir and Parapalar reservoir.

Being a wide-ranging species, elephant require large area to forage. Once the habitat is fragmented or reduced in size, elephants become isolated and hemmed in small patches of forest surrounded by vast area of agriculture crops and human habitations. For instance, Anamalai Tiger Reserve and Chinnar Wildlife Sanctuary already have various biological pressure such as fragmentation and large areas became tea garden. This scenario hampered on elephants to extend their range into new areas or resettle into the neighboring habitat to fulfil their ecological requirements. Graham *et al* (2009) indicated elephants' movement and use of habitats are based on a risk-minimization strategy with concomitant diurnal differences in habitat use. Elephants could potentially range outside Protected Areas, survive in reasonable numbers in human-dominated landscapes and get benefit from forest agriculture matrices, despite pressures associated with anthropogenic landscapes (Calabrese et al 2017; Leimgruber *et al* 2003; Madhusudan, 2003). However, space used by elephants is influenced by distribution of resources, vegetation types, changes in land use and presence of human disturbance within their distributional range (Hoare, 1995). In our present study, the proportion of elephant's food trees were constituted more (65%) followed by non-food trees was (35%). Although the ground vegetation showed more proportion of barren ground (46.8%), there was a considerable amount grass cover (31.8%) and shrub (8.2%) may withstand the elephants in the area.

Examination of elephant dung piles revealed a greater proportion of agricultural crops than wild plants. This could be due to availability of agricultural food crops in forest peripheral areas as well as reserved lands. This indicated the pocketed herds are depending on crop fields for their survival than the forests, except for their shelter. Sivasubramanian and Sivaganesan (1996) reported that a few cultivated crops were dispersed in the forest areas which might have become from cultivated crop fields and thus enhance the genetic diversity of the area. Oliver (1978) stated that Asian elephants in rain forest in Malaysia ate fruits rarely. The dispersal of plant seeds by elephants through dung piles was reported by many authors both in Africa and Asia (Buss, 1961; Field, 1971; Williamson, 1975; Olivier, 1978; Short, 1981 & 1983; Barnes, 1982; Sivaganesan, 1991 and White *et al* 1993; Sivasubramanian and Sivaganesan 1996; Ramakrishnan and Saravanamuthu 2010). The extent of seed dispersal by elephants was very high in Africa, Short (1981 & 1983) listed 35 fruit species were eaten by elephants and 9 of them were common in the dung piles. White *et al* (1993) reported at least one species of fruit was found to be 82% of 311 dung piles searched over year period. Our study indicates higher amount of seeds and other materials of agricultural crops in dung piles could be related to more availability of fruit bearing crops. However, more preference in the crop fields by elephants creates negative mindset of people suggested by Sivasubramanian and Sivaganesan (1996). Baskaran *et al* (2011) opined that the increasing dispersal of elephant herds or clans, as well as solitary bulls into newer habitats has brought fresh challenges to management. Hence, this study is not only for the local people and also for the forest managers in terms of conflict management. In addition, Thouless *et al* (2008) stated replacement of forest by farmland will decrease food availability and increase conflict.

V. Acknowledgements

Our sincere thank the District Forest Officer, Dindigul Forest Division for providing the necessary permission to carry out this short-term study. This work would not have been possible without the support of the Forest Range Officer, Foresters, Forest Guards and Forest Watcher of the Oddanchatram Forest Range, we profusely thank them all. We are sincerely thankful to our mentor Dr. N. Sivaganesan for introducing both of us in to elephant studies.

References

[1] Barness, R.F.W. (1982): Elephants feeding behaviour in Ruaha National Park, Tanzania. *African Journal of Ecology*, 20: 123-36.
Baskaran, N. (1998): "An overview of Asian Elephants in the Western Ghats, southern India: implications for the conservation of Western Ghats ecology ", *Journal of Threatened Taxa*, 5, (14): 4854-4870.
[2] Baskaran, N., S. Varma, C.K. Sar & Raman Sukumar (2011): Current status of Asian elephants in India. *Gajah* 35: 47-54.
[3] Blom, A., van Zalinge R., Heitkonig I.M.A. & Prins H.H.T (2005): Factors influencing the distribution of large mammals within a protected central African forest. *Oryx* 39: 381-388.
[4] Buss, I..O. (1961): Some observations on food habits and behaviour of the African elephant. *Journal of Wildlife Management*, 25: 131-148.
Calabrese, A., J. M. Calabrese, M. Songer, M. Wegmann, S. Hedges, R. Rose & P. Leimgruber, (2017): Conservation status of Asian elephants: The influence of habitat and governance. *Biodiversity and Conservation*, 26: 2067-2081.

[5] Daniel, J.C. (1980): The Status of Asian Elephants in the Indian Sub-continent. lUCN/SSC Report. Bombay Natural History Society, Bombay.
[6] de Boer, W.F., Ntumi C.P., Correia A.U. & Mafuca J.M. (2000): Diet and distribution of elephant in the Maputo Elephant Reserve, Mozambique. *African Journal of Ecology* 38: 188-201.
[7] Desai, A.A & Baskaran, N. (1996): Impact of human activities on the ranging behaviour of elephants in the Nilgiri Biosphere Reserve, Southern India. *J. Bombay Nat. Hist. Soc*. 93: 559-569.
[8] Eisenberg, J.F. & M. Lockhart (1972): An ecological reconnaissance of Wilpattu National Park, Ceylon. *Smithsonian Contribution to Zoology, 10*. Smithsonian Institution, Washington DC, USA.
[9] Field, C.R. (1971): Elephant ecology in the Queen Elizabeth National Park, *East African Wildlife Journal*, 9: 99-123.
[10] Graham, M. D., L. Douglas-Hamilton, W.M. Adams & P.C. Lee (2009): The movement of African elephants in a human-dominated land-use mosaic. *Animal Conservation* 12: 445-455.
[11] Hedges.S., Tyson, M.J., Sitompul, A.F., Kinnarid, M.F., Gunaryadi,D & Aslan (2005): Distribution, status and conservation needs of Asian elephants (Elephas maximus) in Lampung Province, Sumatra, Indonesia. *Biological Conservation* 124: 35-48.
[12] Hoare, R. (1995): Options for the control of elephants in conflict with people. *Pachyderm* 19: 54-63.
[13] Ishwaran, N. (1981): Comparative study of Asiatic elephant (*Elephas max*imus) populations in Gal Oya, Sri Lanka. *Biological Conservation* 21: 303-313.
[14] Ishwaran, N. (1993): Ecology of the Asian elephant in lowland dry zone habitats of the Mahaweli River Basin, Sri Lanka. *Journal of Tropical Ecology* 9: 169-182.
[15] Laws R.M. (1970): Elephants as agents of habitat and landscape change in Est-Africa. *Oikos* 21: 1-15.
[16] Leimgruber, P., J.B. Gagnon, C. Wemmer, D.S. Kelly, M.A. Songer & E.R. Selig (2003): Fragmentation of Asia's remaining wild lands: implications for Asian elephant conservation. *Animal Conservation*, 6: 347-359.
[17] Leuthold, W. (1977): Spatial organization and strategy of habitat utilization of elephants in Tsavo National Park, Kenya. Zeitschrift fur Saugetierkunde 42: 358-379
[18] Madhusudan, M. (2003): Living amidst large wildlife: Livestock and crop depredation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. *Environmental Management*, 31: 466-475.
[19] MecKay, G.M. (1973): The ecology and behaviour of the Asiatic elephant in South eastern Ceylon. Smithsonian Contributions to Zoology 125: 1-113.
[20] Merz, G. (1986): Movement pattern and group size of the African forest elephant (*Loxodonta Africana*) in Tai National Park, Ivory Coast. *African Journal of Ecology* 24: 133-136.
[21] Ntumi C.P., van Aarde R.J., Fairall N. & de Boer W.F. (2005): Use of space and habitat by elephants (Loxodonta Africana) in the Maputo Elephant Reserve, Mozambique. *S. African Journal of Wildlife Research* 35: 139-146.
[22] Oliver, R.C.D. (1978): On the ecology of the Asian elephant. Ph.D. Thesis, University of Cambridge, England.
[23] Owen-Smith R.N. (1988): Megaherbivores: the influence of very large body size in ecology. Cambridge University Press, Cambridge: 1-369.
[24] Ramakrishnar, B. (2007): Significance of corridors to Asian elephant (*Elephas maximus* Linnaeus) and strategies for conservation and management in the Nilgiri Biosphere Reserve, Tamil Nadu, India. Ph.D Thesis submitted to Bharathidasan University, Tamil Nadu.
[25] Ramakrishnan, B & R. Saravanamuthu. (2010): Elephant – The Keystone Species. Published by Tamil Nadu State Council for Science and Technology, Chennai and Indo-American Wildlife Society, Chennai, Tamil Nadu, India.
[26] Rameshkumar, S. (1994): Ecology of Asian elephants (*Elephas maximus*), their habitats and interactions with people in Hosur and Dharmapuri Forest Divisions, Dharmapuri District, Tamil Nadu. Unpublished Ph.D thesis submitted to Bharathiar University, Tamil Nadu, South India.
[27] Santiapillai, C., M.R. Chambers & Ishwaran (1984): Aspects of the ecology of the Asian elephants *Elephas maximus* in the Ruhuna National Park, Sri Lanka. *Bio. Conserv*. 29: 47-61
[28] Short, J.C. (1981): Diet and feeding behaviour of the forest elephant, Mammalia., 45: 177-185.
[29] Short, J.C. (1983): Density and seasonal movements of the forest elephant (*Loxodonta Africana cyclotis*) in Bia National Par, Ghana. *African Journal of Ecology*, 21: 175-184.
[30] Sivaganesan, N. (1991): Ecology and Conservation of Asian Elephants (*Elephas maximus*) with Special Reference to Habitat Utilization Pattern in Mudumalai Wildlife Sanctuary, Tamil Nadu, South India. Ph.D. Thesis, Bharathidasan University, Trichy, Tamil Nadu, India.
[31] Sivaganesan, N., Ajithkumar. & B. Ramakrishnan. (2000): Status of the corridors and their use by mammals with special reference to selected endangered mammals in the Nilgiri Biosphere Reserve, Southern India, Technical Report, Salim Ali Centre for Ornithology and Natural History, Coimbatore.
[32]Sivasubramanian, G. & N. Sivaganesan. (1996): Role of elephants in Sujalkuttai-Bannari corridor in Sathyamangalam forest division, Tamil Nadu, Southern India. *Gajah* 15: 9-27.
[33] Sukumar, R. (1989a): Ecology of the Asian elephant in Southern India. I Movement and habitat utilization patterns. *J. Tropical Ecology*, 5: 1-18.
[34] Sukumar, R (1989b): The Asian elephants ecology and management, Cambridge University Press, Great Britain, Pp 251.
[35] Sukumar, R. (2018): Elephant minimum and maximum number of Asian elephants in the wild and captivity in Asia. In: National Elephant Survey report, Updates by IUCN SSC Asian Elephant Specialist Group in 2016 and 2018.
[36] Synchronized Elephant Population Estimation in India. (2017): Report of the Project Elephant Division, Ministry of Environment, Forests and Climate Change, Government of India, New Delhi.
[37] Thouless, C., J. King, P. Omondi, P. Kahumbu & I. Douglas-Hamilton. (2008): The status of Kenya's elephants 1990-2000. In collaboration of the Kenya Wildlife Service and Save the Elephants, Nairobi, Kenya. *Eds by*: Helen van Houten and Dali Mwagore.
[38] Vessey-Fitzgerald, D. (1973): Browse production and utilization in Taranzine National Park. *J.E.Afr. Wildl*., 11: 291-305
[39] White, L.J.T., C.E.G. Tutin & M. Fernandez. (1993): Group composition and diet of forest elephants, (*Loxodonta Africana cyclotis)* in the Lope Reserve, Gobon. *African Journal of Ecology*. 31: 181-199.
[40] Williamson, B.R. (1975): The condition and nutrition of elephant in Wankie national Park, *Arnoldia*, 7: 1-20.