

## Original Research Article

# Seasonal crop raiding of fruit trees by Asian elephants; an insight into Gauging factors that render select trees susceptible to crop raids: An insight into Asian Elephants' seasonal foraging preferences from croplands abutting Bannerghatta National Park, Bengaluru, Karnataka, India

## ABSTRACT

The study was undertaken to evaluate factors which potentially influence crop depredation by Asian elephants during the non-cropping season. The study was conducted in a 2.5 km zone abutting Bannerghatta Wildlife Range of Bannerghatta National Park, Karnataka. Three fruit trees which are commonly raided by elephants, namely, jackfruit *Artocarpus heterophyllus*, mango *Mangifera indica* and tamarind *Tamarindus indica*, which are commonly raided by elephants, were selected for the study. The convenient sampling approach was adopted to map individual trees of belonging to the three species between May and July 2015. Factors such as the phenological stage, the parts of the tree foraged on, the distance from the Park boundary and the crop clustering pattern were recorded. Among 1368 mapped fruit trees, only 4.31% (n = 59) of the trees were found foraged on; among the 1368 trees mapped, however, 79.66% of the damages had occurred in trees that were fruiting. There also seemed to be a preference in fruits foraged; as *A. heterophyllus* had the highest damage (8.84%), followed by *T. indica* (4.20%) and *M. indica* (3.66%). The analysis showed that the spatial foraging pattern was also species dependent with damages in *A. heterophyllus* and *M. indica* recorded at distances more than one km from the park unlike in the case of *T. indica*. Refuge cover availability measured through clustering pattern, was not found to positively increase foraging preference. It was also observed that damages in fruiting *M. indica* were more common in areas which contained both *A. heterophyllus* and *T. indica* within 100 m, than areas which had either none or only one of the species present. Spatial analysis revealed a concentration of foraging in the north-western and south-eastern portions of the National Park regions. Results obtained in the study aided in identifying the indicative an outline of factors which influenced the crop foraging pattern during the non-cropping season. A detailed long-term study on the foraging ecology of elephants in non-~~elephant agricultural land~~ human-dominated regions will help strategize effective human-elephant conflict mitigation measures effectively.

**Keywords:** Asian elephant, Bannerghatta National Park, Elephant-Crop Raiding; Human-elephant conflict; Mango; Jackfruit; Tamarind; Bannerghatta National Park; Non-cropping season; Villages; A Rooha India.

## 1. INTRODUCTION

Evidences suggest that crop raiding is a necessity for elephants in some cases [1] and a foraging strategy in others which offers nutrition which isare either not substantiated or are equivalent to the wild natural fodder [2,3]. Alternatively, crop raiding also occurs due to assumed high palatability [4,5] and other benefits including fewer/lesser parasites [6] compared to non-crop raiders.

Despite the discerned advantages, the behaviour of crop raiding is an acquired practice and may not be adapted by all individuals in a population [1] abutting crop fields. The origin of crop-raiding behaviour

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25 | has been predicted to ~~be~~ either ~~be~~-opportunistic through direct encounters or ~~duringwhile~~ dispersal, or  
26 | obligatory when ~~actively~~ sought ~~after~~ [7]. Crop depredation poses numerous threats to the ~~participatory~~  
27 | ~~concerned~~ individuals [7] and often renders them susceptible to retaliatory killings [8,9]. ~~It may be~~  
28 | ~~considered that Elephants may~~ recognize ~~the~~ potential risks associated with traversing or foraging within  
29 | human-dominated realms [10] and thus, evidences of adaptations has~~ve~~ been ~~recordednoticed~~.

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30 | Some adaptations are temporal where incidences of raiding ~~have~~s occurred predominantly during ~~the~~  
31 | nights [11,12] and some are spatial where crop damages ~~hasve~~ been found to be negatively correlated to  
32 | ~~the~~ distance from forested ~~areasregions~~ [13,14]. ~~FurtherYet some~~ studies ~~have~~ suggested that  
33 | consumption per unit time could be a possible factor in determining the phenological status ~~during at~~  
34 | which crop raids~~s~~ occurs [11].

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35 | ~~Thus, c~~Crop raiding is, ~~thus,~~ dependent on certain factors. Comprehension of ~~the~~ foraging ecology and  
36 | behaviour exhibited during foraging outside natural forested habitats may be one of the key components  
37 | that may aid in ~~developing effective strategizing appropriate~~ mitigation measures ~~effectively~~ [13].

38 | In this regard, the current study attempted ~~to identify someat gaugeing key~~certain factors ~~whichthat~~ may  
39 | influence foraging in select tree species during ~~the~~ non-cropping season in ~~agricultural landsregions~~  
40 | abutting Bannerghatta National Park.

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## 42 | 2. METHODOLOGY

### 44 | 2.1. Study Area:

45 | Bannerghatta National Park (BNP) (12° 20'-50'N, 77° 27'-38' E), encompassing an area of 260 sq. km,  
46 | lies ~~aten~~ the ~~most~~ northern ~~most~~-tip of ~~the~~ Eastern Ghats in the State of Karnataka (Fig. 1) and is  
47 | predominantly a tropical dry deciduous forest with patches of mixed deciduous vegetation. It contains a  
48 | minimum diversity of 128 tree species including *Anogeissus latifolia*, *Acacia chundra* and *Cedrela toona*  
49 | [15]. BNP ~~supportsharbours~~ a mean density of ~1.84 elephants/sq. km [16] and elephant habitat usage  
50 | signs have been reported to occur uniformly throughout the year, ~~based upon as per~~ surveys~~s~~ conducted  
51 | between 2005 and 2008 [17].

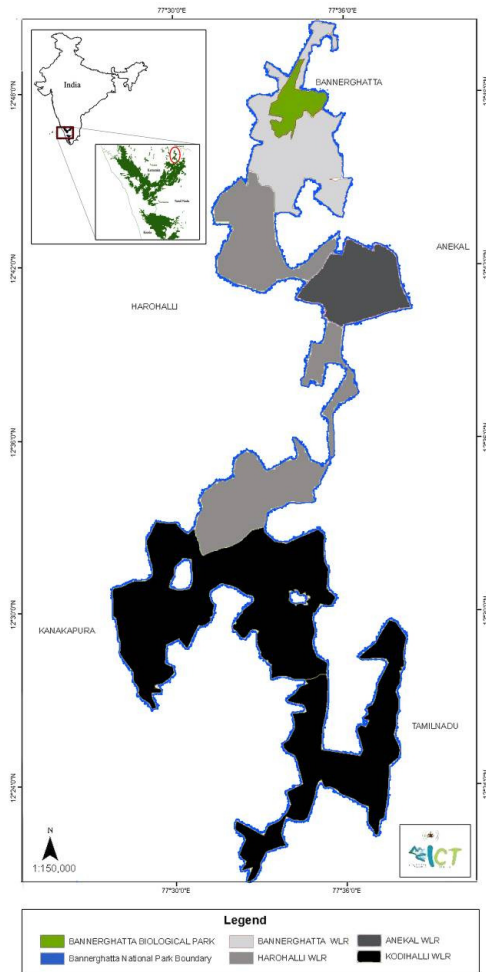


**Fig. 1. Bannerghatta National Park (Inset: Position of Bannerghatta National Park in Nilgiri-Eastern Ghat Landscape)**

A land-use mapping of the 7.5 km buffer zone abutting Bannerghatta National Park has shown that 21.3% is occupied by horticultural crops, 11.8% by forested land regions and 42.5% by agricultural land [17]. As a consequence, there have been many occurrences of human-elephant conflict on the fringes of BNP, especially crop depredation. Crop raiding has been reported to occur throughout the year with peak conflicts occurring between October and January. A collation of compensation claims within the villages abutting the BNP has revealed that a minimum of 37 crops were being raided by elephants. During some of the off-peak conflict months, in of May and to

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63 | June, 17 agricultural and of them, including tree crops, were have been reported to be damaged by  
64 | elephants [17].

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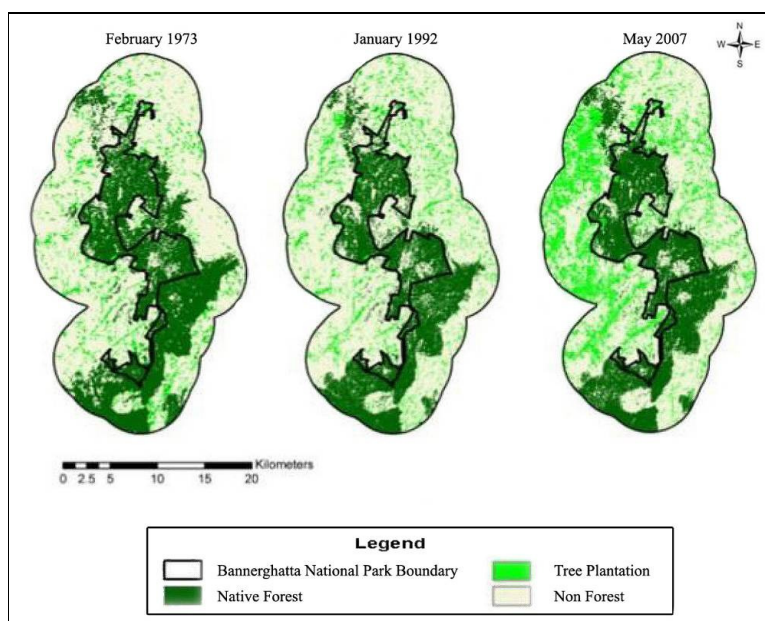
65 | To comprehend factors that influences crop raiding during non-cropping season, the current study was  
66 | conducted in the a designated 2.5 km buffer zone abutting Bannerghatta Wildlife Range, one of  
67 | the four administrative ranges of BNP in order to understand the factors which influences crop raiding  
68 | during the non-cropping season. Bannerghatta Wildlife Range (37.18 sq. km, 14.30% of BNP)  
69 | has had the highest number of elephant feeding signs recorded obtained among the three Ranges  
70 | (Bannerghatta, Anekal and Harohalli) [17] suggesting the limited availability of natural fodder within the  
71 | forested habitatsregions. Being the northern-most Range, there have also been reports suggesting the  
72 | seasonal movement of bulls between BNP and Savandurga State Forest (12° 51' 57' N, 77° 16' 20' E)  
73 | through the northern portionsregions of BNP [18] with presumably high probability chance of crop  
74 | encounters with crops. The Besides, vegetation cover map reveals the presence of forest patches  
75 | extending in both the north-west direction and a south-east direction (Fig. 2) [19].

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\*Obtained from [19]

Fig. 2. Periodic Vegetation Cover Map of Bannerghatta National Park

## 2.2 Methodology:

81 | Three fruiting trees were chosen, namely jackfruit *Artocarpus heterophyllus*, mango *Mangifera indica* and  
82 | tamarind *Tamarindus indica*, to identify gauge the possible factors determining the foraging preferences of  
83 | elephants in non-elephant human-dominated regions during the period 26<sup>th</sup> May and 3<sup>rd</sup> July 2015. The  
84 | selected trees overlaps with the fruits naturally consumed in the wild in dry deciduous forest habitats  
85 | during the dry season (January to April) and the first wet season (May to August) [20]. The selection  
86 | aided in eliminating the need to assess the nutritional content as a factor for crop raiding. The specified  
87 | survey period aided in obtaining assumed increased possibility of tree foraging through (i) a: not being a  
88 | peak cropping season [17] and (ii) b: being the peak fruiting seasons for two of them *A. heterophyllus* and  
89 | *M. indica*. The study period also attempted to clarifycomprehend the influence of migration on the

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foraging pattern; the migration of bulls between Savandurga State Forest and BNP were observed have been noticed to occur predominantly in the second wet season (September to December), often during *musth* (Avinash Krishnan, A Rocha India, Bengaluru, personal communication, 2015), suggesting the study period (May to July) to be possibly non-migratory months.

A convenience sampling approach was adopted through foot survey to map the selected fruiting trees within the 2.5 km non-elephant zone from the boundaries of Bannerghatta Wildlife Range. Data on the fruiting status of trees was collected to assess the influence of fruiting on foraging, considering that fruits determine the movement of wild elephants [21]. The mapped trees were classified into isolated trees, scattered trees and plantations to identify the relationship dependency of clustering on the intensity of damage, on the assumption Assuming that clustering in cultivated crops will provide higher gains and better refuge cover for elephants, the mapped trees were classified into isolated trees, scattered trees and plantation to test the dependency of clustering on intensity of damage. Trees were considered to be scattered, if 2-10 trees were located less than 50 m apart from each other. Since prior data exist evidence on the availability and usage of wild fodder within the adjoining wildlife range throughout the year exists, obligatory foraging as a reason for crop depredation was assumed to be less probable in this study. In that regard, parameters such as the GPS co-ordinates and the distance from the protected area were recorded to evaluate the presence of any probable spatial foraging pattern. Supplementary data collected included the parts of tree consumed/damaged, to attempt gauging the economic losses incurred from the damage inflicted on the fruit trees. A feeding ecology report has revealed that six per cent 6% of the trees were felled in the wild during consumption [22] and may cause tree mortality apart from the temporary loss in the crop yield to the cultivator. Adjoining village names were noted to enable easy referencing. Analyses were performed using Excel. Significance was tested using the Pearson  $\chi^2$  Test or the Fisher Exact Test with  $P < 0.05$ .

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

During the study period, a total of 1368 fruit trees comprising belonging to mango *M. indica* (n = 983), tamarind *T. indica* (n = 238) and jackfruit *A. heterophyllus* (n = 147) were mapped on the western and eastern borders of Bannerghatta Wildlife Range within the 2.5 km zone, during the study period (Fig. 3). Among the mapped trees, mapped *T. indica* (63.02% where (n = 150), 50.34% (n = 74) and 21.46% (n = 211) trees of T. indica, *A. heterophyllus* and *M. indica*, were in the fruiting stages, respectively. Despite the fruiting season for *M. indica* being April - July, the high occurrences of non-fruiting trees (78.54%) was has been attributed to the unseasonal rainfall rainfall which that occurred during the first week of March 2015 [23].

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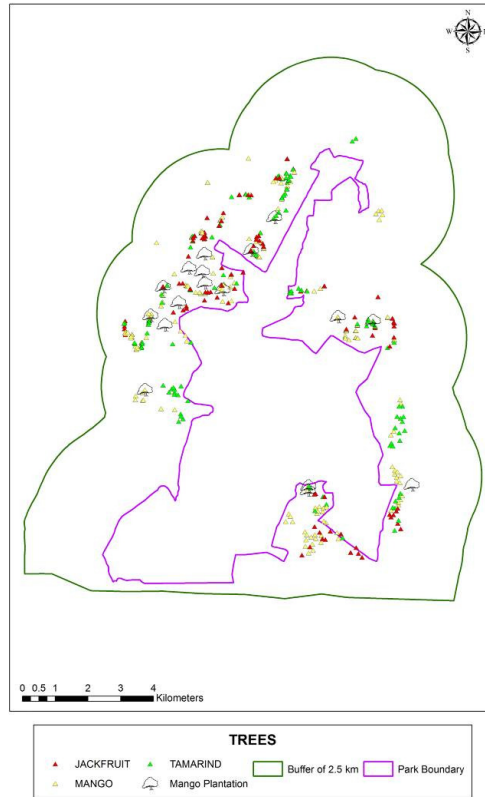


**Fig. 3. The Spatial Distribution Representation of the fruit trees *A. heterophyllus*, *M. indica* and *T. indica* trees mapped during the study period**

### 3.1.1 Foraging damage preferences of the different fruit tree species within trees

#### 3.1.1.1 *A. heterophyllus* trees

A total of Out of 13 damaged trees that were recorded noticed, of which 92.30% (n = 12) of the damages/foraging had occurred in fruiting trees. The damaged non-fruiting tree lies at a distance of 0.04 km from scattered fruiting *M. indica* trees that was also noticed foraged. Among the damaged fruiting trees, eight trees were had been marked as isolated and four as scattered; no *A. heterophyllus* plantations were encountered during the study. There was a significant difference in damages between isolated and scattered trees ( $P = .01$ ). *A. heterophyllus* trees in fruiting stages were found to be present occurring up to two 2 km (min = 0 km) from the park boundary (PB) and damages had occurred in trees at a maximum distance of 2 km (min = 0.08 km).

#### 3.1.1.2 *M. indica* trees

Among the damages (n = 36) which that had occurred, 75% (n = 27) of them were in fruiting trees. Damages in non-fruiting trees had occurred in regions close to foraged *A. heterophyllus* (0.30 km) and *T.*

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149 | *indica* (0.01 km) and in regions closer to PB (0.14 km). 94% (n = 34) of the damages had occurred in  
 150 | trees which that were not isolated. None of the trees in regions classified as plantations were found  
 151 | damaged. There was no significant difference between the damages in isolated and non-isolated  
 152 | (scattered trees and plantation) trees ( $P = 1.00$ ). *M. indica* trees were found distributed from 0 m to 2.5  
 153 | km from the PB. However, the damage in fruiting trees was found to range from 30 m to 2.5 km and  
 154 | the damages in non-fruiting trees was found to range from 140 m to 1.9 km.

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### 155 | 3.1.1.3 *T. indica* trees

158 | Ten of the trees mapped were found to have been damaged/foraged by elephants. All the damaged  
 159 | fruiting trees (n = 8) were found to be marked as scattered. Damages to the —non-fruiting trees were  
 160 | in isolated trees in regions near damaged fruiting *A. heterophyllum* (0.002 km) and near the PB (0.06 km).  
 161 | There is no significant difference between the damages in isolated and non-isolated trees ( $P = .51$ ).  
 162 | Though fruiting *T. indica* trees had occurred from 0 to 2 km, the damages had occurred within 0.2 km  
 163 | from PB (min = 0.02 km) in 80% (n = 8) of the damages and at 0.57 km and 1 km in the other two  
 164 | records.

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### 166 | 3.1.2 Foraging preferences between among the fruit trees

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168 | During the study period, damages had occurred in 4.31% (n = 59) of the total trees mapped. Among the  
 169 | three selected trees, *A. heterophyllum* had the highest damage (8.84%, n = 13), followed by *T. indica*  
 170 | (4.20%, n = 10) and *M. indica* (3.66%, n = 36). Within the three selected trees, there was a significant  
 171 | difference in the damages/consumption between *A. heterophyllum* and *M. indica* ( $P = .004$ ) but not  
 172 | between *A. heterophyllum* and *T. indica* ( $P = .06$ ), and *T. indica* and *M. indica* ( $P = .69$ ).

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### 174 | 3.1.3 Foraging preferences related to fruit between tree spatial patterns

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176 | Among the trees mapped, 12.32% (n = 26) of fruiting *M. indica* were found in close proximity (distance  
 177 | between two species  $\leq 100$  m) to fruiting *A. heterophyllum*, 30.33% (n = 64) to fruiting *T. indica*, 16.12%  
 178 | (n = 34) to both and 41.23% (n = 87) to none. However, damages were recorded more in  
 179 | fruiting *M. indica* trees which were in close proximity to both trees (51.85%), compared to only *A.*  
 180 | *heterophyllum* (11.11%), only *T. indica* (14.81%) and to none (22.23%).

### 182 | 3.1.4 Spatial distribution of foraging in the buffer zones

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184 | The three selected fruiting trees were found scattered in the 2.5 km buffer zone. However, clustering of  
 185 | the damages which that had occurred showed a concentration in the north-western region and the south-  
 186 | eastern region (Fig. 4).

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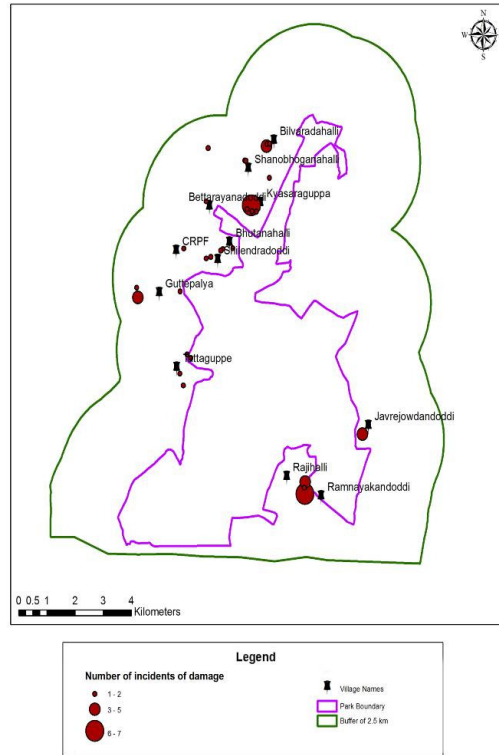


**Fig. 4. Map showing cluster analysis of damages recorded during the study period**

### **3.1.5 Economic loss incurred from damages**

Damage was inflicted on different parts to the fruit trees. Damage occurred in the fruits (In 81.35%), the branches of the damages that had occurred were in fruits, (72.88%) in branches and the leaves (37.28%) in leaves. Four4 fruiting *M. indica* trees that were not isolated were found felled during the survey period, all of which were not isolated trees. The eEstimated economic loss was found to be highest in *A. heterophyllum* compared to *M. indica* and *T. indica* (Table 1).

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198 Table 1. **Estimated economic losses to fruit trees caused by the elephant-inflicted damages**  
 199 **recorded**

| S.No. | Species of fruit treeName-of the Tree | Average Yield/Tree (kg)* | Market Price (INR/kg)** | Total Trees Damaged (No.) | Loss of Yield due to Damage (kg) | Loss of Income due to Damage (INR) |
|-------|---------------------------------------|--------------------------|-------------------------|---------------------------|----------------------------------|------------------------------------|
| 1     | <i>Artocarpus heterophyllus</i>       | 500                      | 37                      | 13                        | 6500                             | 2,40,500                           |
| 2     | <i>Mangifera indica</i>               | 30                       | 30                      | 36                        | 1080                             | 32,400                             |
| 3     | <i>Tamarindus indica</i>              | 17.5                     | 51                      | 10                        | 175                              | 8,925                              |

\*Values obtained from [17]

\*\*Values obtained from [23]

### 3.2 Discussion

From the results obtained, it can be projected that damages had occurred predominantly in fruiting trees (79.66%, n = 47), as opposed to in-against non-fruiting trees (20.34%, n = 12). Consumption of the non-fruiting trees were encountered predominantly in arearegions lying in close proximity to adjoining damaged fruit trees or in arearegions closer to PB. This may suggests that fruit trees, and their fruits, are the primary attractionants for elephants foraging in agricultural lands non-forested regions during this season. It was also evident that the damages in *T. indica* wasere confined to arearegions closer to the park but foraging has occurred in *A. heterophyllus* and *M. indica* at distances more than one1 km from the park. However, analysis reveals has shown a significant preference of *A. heterophyllus* over *M. indica*. Thisese evidences may suggests that human elephant conflict during the non-cropping season might be species-dependent similar to the cropping season [11,17]. The fForaging pattern was found to be independent of clustering or refuge cover availability except in *A. heterophyllus* trees, where isolated trees had a significant amount number of damages. None of the plantations encountered had foraging signs, probably due to effective elephant mitigation measures being practiced. It was also observedseen that damages in fruiting *M. indica* was recorded more in arearegions that contain both *A. heterophyllus* and *T. indica* within 100 m, than arearegions that had none or only either of the species. Thus, the fruiting of these two tree species may be a potential attractionant to wild elephants. The creation and hence preating of a 100 m wide belt devoidzone of the two fruit tree species no *A. heterophyllus* and *T. indica* trees around mango cultivations, may assist help to in-decreaseing crop depredation in those croplandsregions.

TheBesides, spatial distribution of foraging recorded noticed during this study shows a concentration of damages in localitiesareas where the areas forested regions were formerly forested present have occurred in the early 1973's (Map 2). This suggests that these elephant encounters with potential forages, may behave been opportunistic during migration or dispersal, as one of the possibilities suggested by [7]. Opinions from villagers also proposed higher participation of bulls in crop raiding than cows [24 (Unpublished data)], which suggests that bull elephants may have encountered these fruit crops during migration. However, as seen during the study period, damages are which occurred during the non-migratory months, suggests revealing that elephants may have acquired the practice of foraging for the fruits of fruit trees and that it may be becoming an annually recurring phenomenon. Identification of individual elephants foraging in these agricultural lands non-forested regions was beyond the scope of this study. Hence, a detailed systematic long-term mapping of the foraging patterns of individual elephants may further aid in our understanding of elephant comprehending the foraging behaviour and mitigate the human-elephant econflict, accordingly.

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#### 239 | 4. CONCLUSIONS

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241 The study revealed From the study carried out, it was found that the distances at which foraging signs  
242 were encountered in relation to ,from the national park boundary, whereas dependent on the species of  
243 fruit and the phenological stage of the fruit trees. Refuge cover availability was not found to increase  
244 susceptibility of foraging., However, the presence of two or more species of fruit trees in close proximity  
245 showed an increase in being foraged with regards to on one another. On the spatial aspects scale,  
246 though the study revealed a significant concentration of foraging signs in the north-western and south-  
247 eastern areas of the national park regions; however, the results obtained were results are constrained by the  
248 short sampling period. A long-term study in this regard may aid in assessing the probable presence of  
249 annually recurring foraging patterns and the individuals contributing to human-elephant conflict in this  
250 landscape region. Thus, a detailed research comprehension of the foraging ecology of the Asian elephant  
251 may increase help in extending the possibility of effectively mitigating the human-elephant conflict  
252 effectively.

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## 341 ACRONYMS

- 342  
 343 1. WLR: Wildlife Range