

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 carried out to gauge factors that potentially influences crop depredation in Asian elephants during 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 namely *Artocarpus heterophyllus*, *Mangifera indica* and *Tamarindus indica* which are commonly raided by elephants were chosen for the study. Convenient sampling approach was adopted to map individual trees belonging to the three species between May and July 2015. Factors such as phenological stage, parts of the tree foraged on, distance from the Park boundary and crop clustering pattern were recorded. 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 spatial foraging pattern was also species dependent with damages in *A. heterophyllus* and *M. indica* recorded at distances more than 1 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 seen that damages in fruiting *M. indica* were more in regions that contain both *A. heterophyllus* and *T. indica* within 100 m, than regions that had none or only either of the species. Spatial analysis revealed a concentration of foraging in the north-western and south-eastern regions. Results obtained in the study aided in obtaining an outline of factors that influenced crop foraging pattern during the non-cropping season. A detailed long-term study of foraging ecology of elephants in non-elephant human-dominated regions will help strategize human-elephant conflict mitigation measures effectively.

Keywords: *Elephant Crop Raiding; Mango; Jackfruit; Tamarind; Bannerghatta National Park; Non-cropping season; Villages; A Rocha 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 are 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 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 has been predicted to either be opportunistic through direct encounter or while dispersal, or obligatory when sought [7]. Crop depredation poses numerous threat to the participatory individuals [7] and often render them susceptible to retaliatory killings [8,9]. It may be considered that elephants recognize potential risks associated with traversing or foraging within human-dominated realms [10] and thus, evidences of adaptations have been noticed.

Some adaptations are temporal where incidences of raiding has occurred predominantly during nights [11,12] and some are spatial where crop damages have been found to be negatively correlated to distance from forested regions [13,14]. Yet some studies have suggested that consumption per unit time could be a possible factor in determining the phenological status at which crop raid occurs [11].

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

In this regard, the current study attempted at gauging certain factors that may influence foraging in select tree species during non-cropping season in regions abutting Bannerghatta National Park.

2. METHODOLOGY

2.1. Study Area:

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

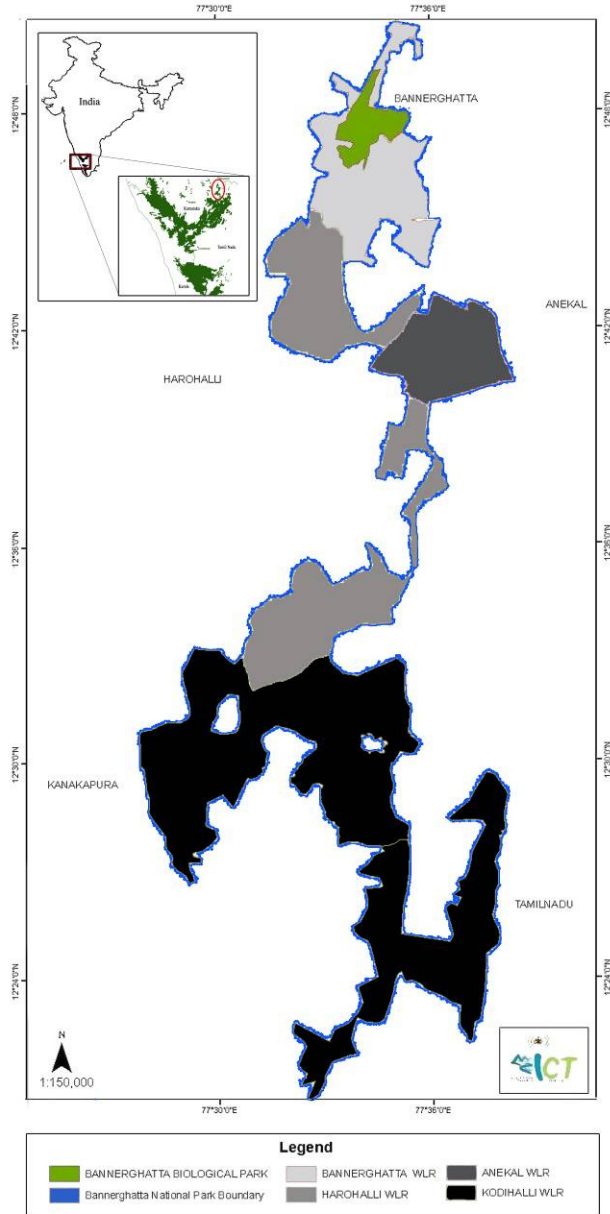
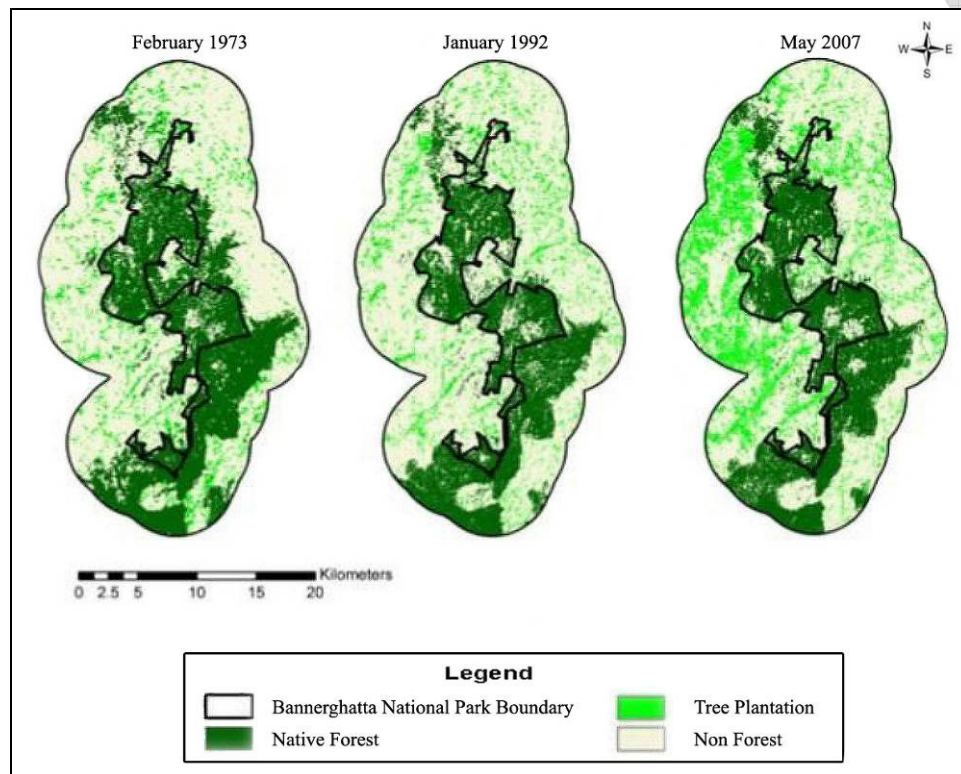


Fig. 1. Bannerghatta National Park (Inset: Position of Bannerghatta National Park in Nilgiri-Eastern Ghat Landscape)

A land-use mapping of a 7.5 km buffer zone abutting Bannerghatta National Park has shown that 21.3% is occupied by horticultural crops, 11.8% by forested regions and 42.5% by agricultural land [17]. Consequently, 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 conflict occurring between October and January. A collation of compensation claims within villages abutting the BNP has reported that a minimum of 37 crops are being raided by elephants. During some of the non-peak conflict months of May to June, 17 of them, including tree crops, have been reported to be damaged by elephants [17].

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



*Obtained from [19]

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

2.2 Methodology:

Three fruiting trees were chosen, namely *Artocarpus heterophyllus*, *Mangifera indica* and *Tamarindus indica*, to gauge possible factors determining foraging preferences of elephants in non-elephant human-dominated regions during 26th May and 3rd July 2015. The select trees overlaps with fruits naturally consumed in the wild in dry deciduous forest habitats during dry season (January to April) and first wet season (May to August) [20]. The selection aided in eliminating the need to assess nutritional content as a factor for crop raiding. The specified survey period aided in obtaining assumed increased possibility of tree foraging through a. not being a peak cropping season [17] and b. being the peak fruiting seasons for two of them *A. heterophyllus* and *M. indica*. The study period also attempted to comprehend the influence of migration on foraging pattern; the migration of bulls between Savandurga State Forest and BNP 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. Convenience sampling approach was adopted through foot survey to map the select fruiting trees within the 2.5 km non-elephant zone from boundaries of Bannerghatta Wildlife Range. Data on fruiting status of trees was collected to test the

influence of fruiting on foraging, considering that fruits determine the movement of wild elephants [21]. Assuming that clustering in cultivated crops will provide higher gain 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 positioned less than 50 m from each other. Since prior evidence of availability and usage of wild fodder within 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 GPS co-ordinates and distance from the protected area were recorded to check the presence of any probable spatial foraging pattern. Supplementary data collected included parts of tree consumed/damaged, to attempt gauging the economic losses incurred from damages. A feeding ecology report has revealed that 6% of the trees were felled in the wild during consumption [22] and may cause tree mortality apart from 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 Pearson χ^2 Test or Fisher Exact Test with $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Results

A total of 1368 trees belonging to *M. indica* (n = 983), *T. indica* (n = 238) and *A. heterophyllus* (n = 147) were mapped on the Western and Eastern Side of Bannerghatta Wildlife Range within the 2.5 km zone, during the study period (Fig. 3). Among the trees mapped 63.02% (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, high occurrences of non-fruiting trees (78.54%) has been attributed to the unseasonal rainfall that occurred during the first week of March 2015 [23].

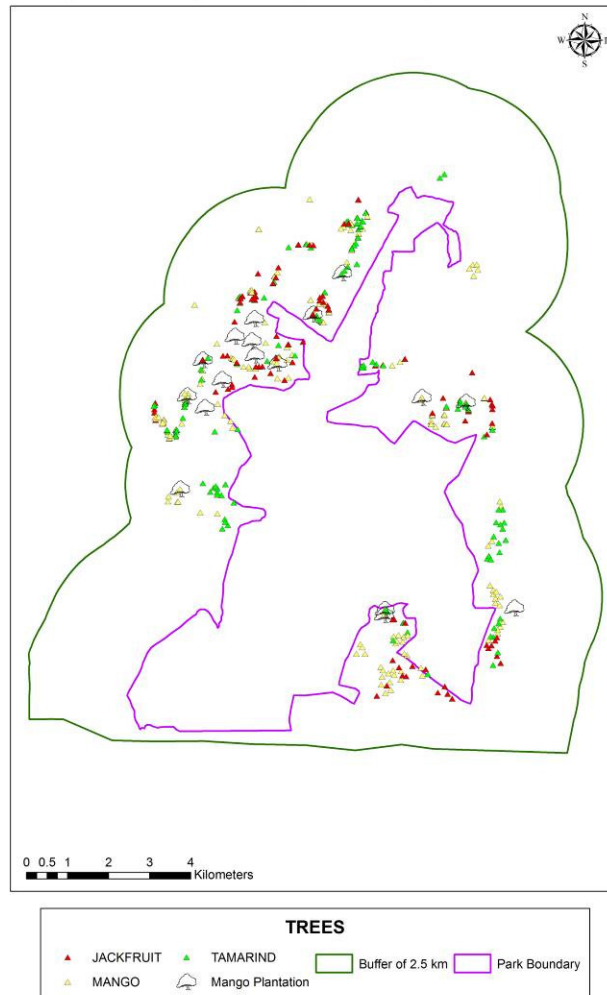


Fig. 3. Spatial Representation of *A. heterophyllum*, *M. indica* and *T. indica* trees mapped during the study period

3.1.1 Foraging preferences within trees

***3.1.1.1 A. heterophyllum* trees**

Out of 13 damages that were noticed, 92.30% ($n = 12$) of 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, 8 trees had been marked as isolated and 4 as scattered; no *A. heterophyllum* plantations were encountered during the study. There is a significant difference in damages between isolated and scattered trees ($P = .01$). *A. heterophyllum* trees in fruiting stages were found to be occurring upto 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 ($n = 36$) 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. heterophyllum* (0.30 km) and *T. indica* (0.01 km) and in regions closer to PB (0.14 km). 94% ($n = 34$) of the damages had occurred in trees that were not isolated. None of the trees in regions classified as plantations were found damaged. There was no significant difference between damages in isolated and non-isolated (scatter and plantation) trees ($P = 1.00$). *M. indica* trees were found distributed from 0 m to 2.5 km from the PB, however, the damage in fruiting trees were found to range from 30 m to 2.5 km and damages in non-fruiting was found to range from 140 m to 1.9 km.

3.1.1.3 *T. indica* trees

10 of the trees mapped were found to have been damaged/foraged by elephants. All the damaged fruiting trees ($n = 8$) were found to be marked as scattered. Damages in the non-fruiting trees were in isolated trees in regions near damaged fruiting *A. heterophyllum* (0.002 km) and near the PB (0.06 km). There is no significant difference between damages in isolated and non-isolated trees ($P = .51$). Though fruiting *T. indica* trees had occurred from 0 to 2 km, damages had occurred within 0.2 km 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 records.

3.1.2 Foraging preferences among trees

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

3.1.3 Foraging preferences between trees

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

3.1.4 Spatial distribution of forages

Three select fruiting trees were found scattered in the 2.5 km buffer zone, however, clustering of damages that had occurred show a concentration in the north-western region and the south-eastern region (Fig. 4).

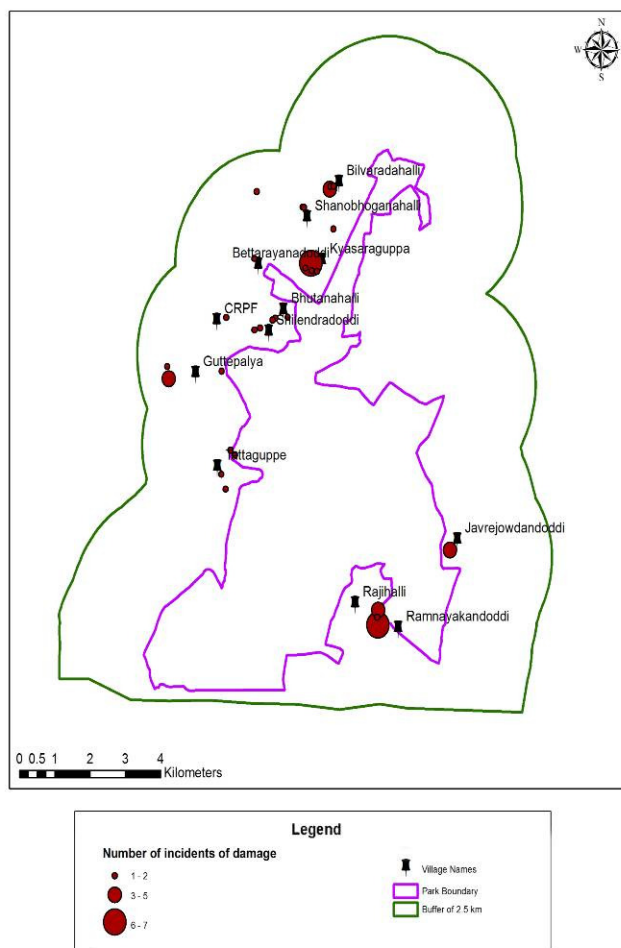


Fig. 4. Map showing cluster analysis of damages recorded during the study period

3.1.5 Economic loss incurred from damages

In 81.35% of the damages that had occurred were in fruits, 72.88% in branches and 37.28% in leaves. 4 fruiting *M. indica* trees that were not isolated were found felled during the survey period. Estimated economic loss was found to be highest in *A. heterophyllus* compared to *M. indica* and *T. indica* (Table 1).

Table 1. Estimated economic losses caused by the damages recorded

S.No.	Name 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) against non-fruiting trees (20.34%, n = 12). Consumption in the non-fruiting trees were encountered predominantly in regions adjoining damaged trees or in regions closer to PB. This may suggest that fruits are the primary attractants for elephants foraging in non-forested regions during this season. It was also evident that damages in *T. indica* were confined to regions closer to the park but foraging has occurred in *A. heterophyllus* and *M. indica* at distances more than 1 km from the park. However, analysis has shown a significant preference of *A. heterophyllus* over *M. indica*. These evidences may suggest that human elephant conflict during non-cropping season might be species dependent similar to cropping season [11,17]. Foraging pattern was found to be independent of clustering or refuge cover availability except in *A. heterophyllus* trees, where isolated trees had significant number of damages. None of the plantations encountered had foraging signs, probably due to effective elephant mitigation measures being practiced. It was also seen that damages in fruiting *M. indica* was recorded more in regions that contain both *A. heterophyllus* and *T. indica* within 100 m, than regions that had none or only either of the species. Thus, fruiting of these two trees may be a potential attractant and hence creating a 100 m zone of no *A. heterophyllus* and *T. indica* trees around mango cultivations, may help in decreasing crop depredation in those regions.

Besides, spatial distribution of foraging noticed during this study shows a concentration of damages in areas where forested regions have occurred in early 1973s (Map 2). This suggests that these encounters with potential forages, may have 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 occurring during non-migratory months revealing that elephants may have acquired the practice of foraging for the fruits and it may be an annually recurring phenomenon. Identification of individual elephants foraging in these non-forested regions was beyond the scope of this study. Hence, a detailed systematic long-term mapping of foraging patterns may aid in comprehending the foraging behaviour and mitigate conflict, accordingly.

4. CONCLUSION

From the study carried out, it was found that distances at which foraging signs were encountered, from the park boundary, was dependent on the species of fruit and the phenological stage of the trees. Refuge cover availability was not found to increase susceptibility of foraging, however, presence of two or more

species of fruit trees in close proximity showed an increase foraging on one another. On a spatial scale, though it revealed a significant concentration of foraging signs on north-western and south-eastern regions, the obtained results are constrained by the short sampling period. A long-term study in this regard may aid in assessing probable presence of annually recurring foraging pattern and the individuals contributing to human-elephant conflict in this region. Thus, a detailed comprehension of foraging ecology may help in extending the possibility of mitigating human-elephant conflict effectively.

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ACRONYMS

1. WLR: Wildlife Range