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Non-Woody Crop Loss to Bonnet Macaque and Langur Relative to Fragmentation Amidst Territorial Moist Deciduous Forests, Central Western Ghats, India

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Abstract: A study was conducted on farmers' perception regarding per cent loss of non-woody crops to two species of monkeys - Bonnet Macaque (BM) (*Macaca radiata*) and Langur (*Semnopithecus hypoleucos*) - in the territorial moist deciduous forests of central Western Ghats, India. The losses were compared between farms located deep inside dense moist deciduous forests (DMDF) v/s farms in fragmented moist deciduous forests (FMDF). The hypothesis was that the farms in DMDF should have less crop loss than FMDF as monkeys, especially BM, from elsewhere cannot be brought and released there, more alternate food available to monkeys in such forest, and almost near natural ecosystem around should buffer perturbations, if any. The farms visit were derived from a system of 16 square grids of 5 km^2 each, systematically distributed, with a random start. Using pre-tested semi-structured schedules with open ended questions, 26 farmers were personally interviewed in DMDF, and 28, in FMDF. From the farms in the two forest systems cumulatively, 11 non-woody crop species were listed, of which paddy and banana were the two most frequent. Comparing DMDF: FMDF situations, the per cent loss of paddy, banana, sugarcane, maize, and cotton to BM were 7.1:6.76, 32:24.51, 24.89:6.1, 13.11:8.75, and 12.27:11 respectively. The loss of paddy, banana, sugarcane and cotton to langur were 0.05:0.2, 42.12:40.22, 0.58:0 and 26.29:11.5, respectively. Paddy and sugarcane were lost significantly more to BM; banana and cotton were lost more to Langur. In FMDF, 80.59% of cardamom was lost to BM. Maize and lentils were raided by both the species comparably. Contrary to our hypothesis, there was no significant difference in the crop loss between DMDF and FMDF.

Keywords: Crop loss, Monkey, Macaque, Langur, Western Ghats, Fragmentation

Crop loss to non-human primates has been occurring in different parts of the world, leading to human-primate conflict. Such conflicts have decades of history, and have been reviewed for different parts of the world, say, for Asia and Africa -e.g. Hockings and Humle (2009) reviewed it for great apes, and Priston and McLennan (2013) for macaques. Monkey conflicts with farmers have been occurring in India also for decades. The conflict intensified in the Uttara Kannada District (UKD) over the last two decades with the two most common monkey species - Bonnet Macaque (BM) (*Macaca radiata* E. Geoffroy Saint-Hilaire) and Langur (*Semnopithecus hypoleucos* Blyth 1841) (Menon 2014). Likely very contributive to this intensification, two new issues emerged. One is, monkeys (especially BM), were captured at problem areas (including from the open Deccan Plateau) and translocated to new areas, usually onto well traversed highways in midst of forests in Western Ghats (WG). This has been strongly suspected by local people, supported by anecdotal evidences and media, and noted by primatologists (Kumara et al., 2010, Sinha 2013, Kumara et al., 2016). The second issue is that forest fragmentation can aggravate conflicts further, creating cultivation-forest edges that favor crop raiding by primates, supported by studies across the globe (Tweheyo et al., 2005, Hockings and Humle 2009, Guinness and Taylor 2014, Siljander et al., 2020, Koirala et al., 2021). Bhat and Vijaya Kumara (2024) reported that crop loss from BM was significantly and consistently higher in fragmented semi-evergreen forests (FSEF) than dense semi-evergreen forests (DSEF). The magnitude of conflict also depends on the crop type and the primate species involved in the conflict. Here we present the result of a study aimed to compare the extent of crop loss from BM and Langur in farms located deep inside large expanse of dense moist deciduous forests (DMDF) relative to farms in fragmented moist deciduous forests (FMDF).

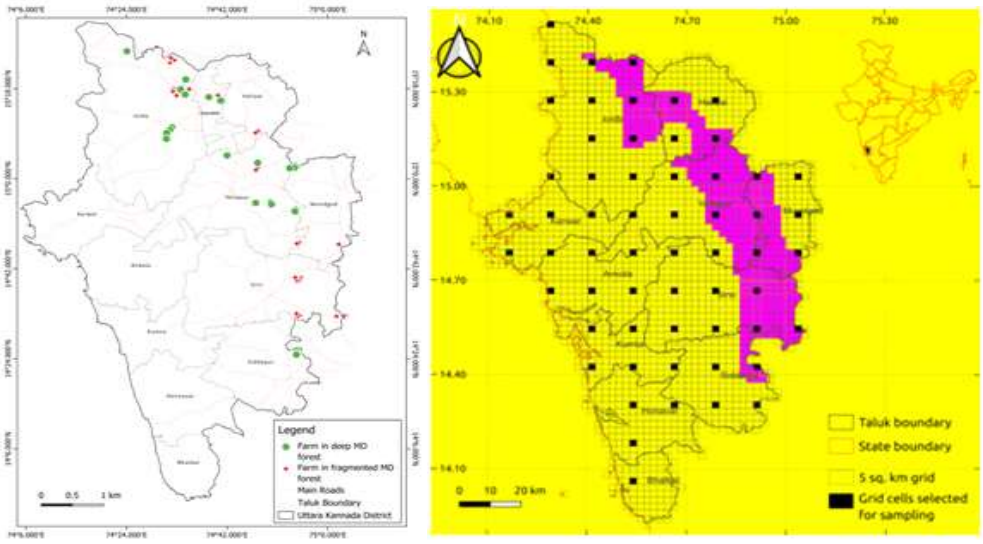
MATERIAL AND METHODS

Study area: The study area was the belt of Moist Deciduous Forest (MDF), in the eastern parts of UKD (Fig. 1). The belt occurs after the crest of the WG and on eastern slopes. It is about 140 km long and 20 km wide, covering roughly 2800 km^2 area lying between 15°29' N:74°21'E and 14°24'N:74°54'E. The terrain is mainly undulating, with rough terrain at one place in the west, tending to a river valley. The altitude is about 620 m MSL. Climate is tropical, with about 2500 mm rainfall in the western side of the belt and about 1500 mm in the eastern side. Maximum temperatures in summer reach about 38°C and the minimum in winter about 10°C.

The farm locations were derived from a system of 16 square grids (each of 5 km^2) distributed systematically. These

grids were part of a larger study, and had a system generated random beginning, overlaid onto Google Earth Pro using QGIS. Grid size 5 km^2 was chosen as that was considered equivalent to the largest known home range sizes of monkey troops and was used by several earlier workers to study monkeys (Sinha 2013, Kumara et al., 2016, Erinjery et al., 2017, Kumar et al., 2018). This grid size is quite compact for intensive study; at the same time, large enough to accommodate the diverse situations that exist in a village, including farm landscapes and surrounding forests, matching the ecology of monkeys.

Locating and deciding a farm or cluster of farms in DMDF or FMDF situation involved three steps: Firstly, by studying in detail the Google Earth Pro live map wherein we located the grids that had already been generated (Fig. 1). The expanse of forest in and around a particular grid, whether it matched DMDF situation or FMDF situation was discerned in this step. The second step was, to strengthen our decisions on farm location, type of forest and whether it was fragmented or not, we simultaneously studied The forest maps of South India (Belgaum-Dharwad-Panaji and Shimoga) by Pascal et al. (1997). Thirdly, with the help of local people or guided by the maps, we reached the intended farm locations in the field and did ground truthing. A farm/cluster of farms located amidst a vast expanse of good forest cover, with very few cultivation/open patches nearby, and away from a well traversed primary road was considered deep located (DMDF). The reverse of it, with broken forest around, and several farms or network of farms or open areas near to a primary road, fragmented (FMDF). Using the dimensions of 5km^2 grid, four parameters were fixed to differentiate DMDF and FMDF (Table 1).



a b

Fig. 1.a. Study area of sampled locations in MDF belt and b) Pink highlighted area indicating moist deciduous territorial belt, Uttara Kannada district, with 16 grids shown in it

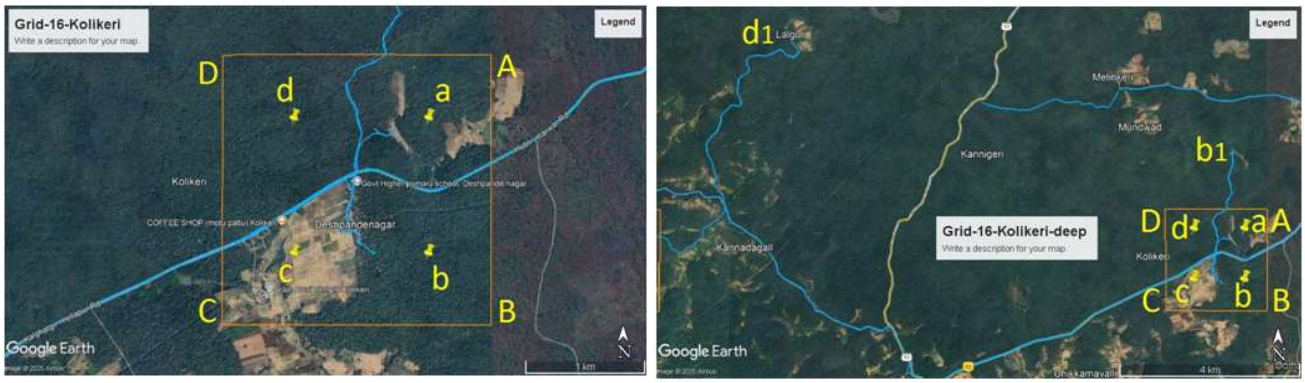


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Fig. 2. Grid, sub-grids, centroids, selection of farms, fragmented and deep situations, a) Showing a grid ABCD of 5 km^2, with centroids a,b,c,d in respective sub-grids. a and c have farms, and that is FMDF situation and b) Sub-grids b and d do not have farms in them. So, b1 and d1 have been taken from DMDF as replacements for b and d

The 5 km^2 grid was divided into four sub-grids of 1.25 km^2 each as spatial replicates, with one centroid at the centre of each sub grid (Fig. 2). If a particular sub-grid had farms in it, the farmer nearest to the centroid was considered for the interview (Fig. 2a), provided he/she consented (Hill 1997). If no consent, another farmer nearest to the first was considered, and so on, and interviewed. If a sub-grid did not have farms in it, the occasion was utilized as a chance to look for a farm located deep inside forest, DMDF, somewhere in the MDF belt (Fig. 2b).

The study was carried out between July 2021 and June 2024. Farmers were interviewed using pre-tested semi-structured schedules with open ended questions, asking about crops grown and perceived losses (worked out in terms of percentage) to the two species of monkeys – BM and Langur (Fig. 3). Our movements in the field were tracked with GPS GARMIN 78s, and the tracks overlaid onto Google Earth Pro for any clarifications for the site.

Statistical analysis: The data were analyzed using Excel software for descriptive statistics, and SPSS software for non-parametric test of significance and Mann Whitney U Test also see Table 2.

RESULTS AND DISCUSSION

Twenty six farmers were interviewed in DMDF, and 28, in FMDF. Eleven non-woody crop species were encountered - paddy (*Oryza sativa* L.), banana (*Musa paradisica* L.), sugarcane (*Saccharum officinaru*m L.), maize (*Zea mays* L.), black-pepper vine (*Piper nigrum* L.), cotton (*Gossypium hisrsutum* L.), cardamom (*Elettaria cardamomum* L. Maton.), lentils, ginger (*Zingiber officinale* Rosc.), papaya (*Carica papaya* L.) and patchouli (*Pogostemon cablin* Benth.).

Papaya was damaged in one farm due to macaque and surprisingly, in not due to langur. Ginger and pachouli were grown only by one farmer each in DMDF; both not damaged by either of the monkey species. Paddy and banana were the most frequently grown crops. Loss of paddy to BM was considerable and consistent, and to Langur, negligible; the differences between them highly significant in both DMDF as well as FMDF. Sugarcane also, in both systems, loss significantly more to BM than to langur. Loss of cardamom too, significantly more to BM than to langur in FMDF. Langur raided cotton significantly more than BM in DMDF and banana in FMDF. Loss of sugarcane to macaque significantly higher in DMDF than FMDF. The series of percent losses from entire list of crops in DMDF for BM when tested against that in FMDF, did not differ significantly; same with langur (Table 3, Fig. 4). BM raided paddy, sugarcane, and cardamom more; Langur raided banana and cotton more. Maize and lentil were raided by both the species comparably. In earlier reports in DSEF v/s FSEF in the upper parts of WG, percent damages by BM were 2.95 v/s 10.26 in paddy and 1.38 v/s 13.36 for banana (Bhat and Vijaya Kumara 2024). In the Kali Tiger Reserve (KTR) ratio of percent losses to BM: langur were 3.32:0.17 in paddy, 10.82:19.66 in banana. In the same KTR MDF BM: langur scores were 7.66:0.37and 14.05:64.06 in paddy and banana respectively (Bhat and Vijaya Kumara 2024a). BM feeding more on paddy, sugarcane, and cardamom than langur may be explained by their biology and ecology. Macaque are general feeders, and feed more on fruits, while langur are mainly leaf eaters (Singh et al., 2000, Singh et al., 2011, Menon 2014). Rhesus macaque (RM) (*Macaca mulatta* Zimmerman) showed strong preference to raid maize over rice in Nepal (Koirala et

Table 1. The overall parameters to decide a farm location as in DMDF v/s FMDF, for studies on crop loss to monkeys, Uttara Kannada District

General parameters	Farm(s) in DMDF	Farm(s) in FMDF
Percent forest cover in a grid of 5 km^2 subtended around the farm/cluster of farms	More than 85%*	Less than 85%
Straight distance (derived from Google Earth Pro) from well traversed all season primary roads, with forests in between#	Not less than 1.1 km (1.12 km is half the length/breadth of 5 km^2 grid)	Less than 1.1 km
The interviewed farm or cluster of farms should be surrounded by good expanse of forests; should not be connected to another farms/cluster of farms/open area that touches a well traversed all season primary road#.	Forest all around the interviewed farm/cluster of farms; the ring of forest around not less than 600m horizontally (half the length/ breadth of a sub-grid of 1.2 km (details ahead)	No intervening forest; or connected directly to road/ network of cultivated/open areas; less than 600 m of intervening forest ring
Length of Forest: Cultivation edge/interface (measure of forest fragmentation) inside the grid, relative to perimeter of grid (modified from Rivas et al., 2022)	Less than 8.8 km (i.e., the perimeter of 5 km^2 grid)	More than 8.8 km

* In one case the grid had only 80% forest cover, but still considered DMDF because other vegetation-scape criteria met the conditions; # These two forest features more relevant to deter BM that might have been brought from open areas of Deccan Plateau and released onto roads in forested areas; such macaques are used to open areas but may not be able to penetrate dense forests immediately and reach the farms inside

Table 2. Socio-economic status of farmers/respondents

Particulars	DMDF situation	FMDF situation	Remark
Age of farmers/respondents:			
Average age	58	48	
Maximum age	84	78	
Minimum age	35	27	
Gender of farmers/respondents:	24 M, 1 F	27M, 1F	
No. of interviews in which ladies/girls of the family also participated with male members	6	11	Tells participation of female members in the interview
Land holding:			
Average	5.45acres	4.1 acres	
Largest	22 acres	18 acres	
Smallest	1.5 acres	1 acre	
Formal education of farmers/respondents themselves			
No. with no formal schooling	6	5	
No. with up to primary education	12	13	
No. with up to high school	5	8	
No. with up to Pre-University	1	1	
No. of graduates	1	1	
No. of interviews during which younger generation of the family, with formal schooling, also participated along with senior members	14	3	Improves the quality and quantitative assessment during the interview
Highest level of education in family, in younger generation:			Improves general and quantitative awareness of elders
Graduate/post graduate	13	8	
High School and above	12	18	
Primary	-	2	
Dependency on farming:			
No. farmers dependent only on farming and allied	22	25	
No. farmers with other occupations in addition to farming	3	3	

Table 3. Per cent mean loss, in non-woody crops due to monkeys in two systems of moist deciduous forests (DMDF and FMDF), Central Western Ghats, Karnataka, India

Farm location	From 26 farms amidst DMDF			From 28 farms amidst FMDF		
Non-woody Crop species	No. of farmers reported percent loss (n)	Crop loss due to macaque. (%)	Crop loss due to langur (%)	No. of farmers reported percent loss (n)	Crop loss due to macaque. (%)	Crop loss due to langur. (%)
Paddy	22[#]	7.1 [0-15.56]	0.05 [0-1.25]	22	6.76 [0-25.5]	0.2 [0-1.8]
Banana	17	32 [0-79.69]	42.12 [0-90]	20	24.51 [0-90]	40.22 [0-90]
Sugarcane	5	24.89 [3.5-75]	0.58 [0-2.92]	5	6.1 [0-16.5]	0.0
Maize	3[*]	13.11 [6.82-22.5]		4	8.75 [4.5-12.86]	6.79 [5.82-8.57]
Pepper vine	2	0.00	0.00	5	18.26 [0-78]	2.0 [0-10]
Cotton	4	12.27 [3.95-26.25]	26.29 [11.05-37.5]	2	11	11.5 [8-15]
Cardamom	1	0.00	0.00	4	80.59 [36.67-100]	0.0
Lentils	-	-	-	2	10.75 [5-16.5]	10.75 [5-16.5]

Figures in parentheses indicate the range

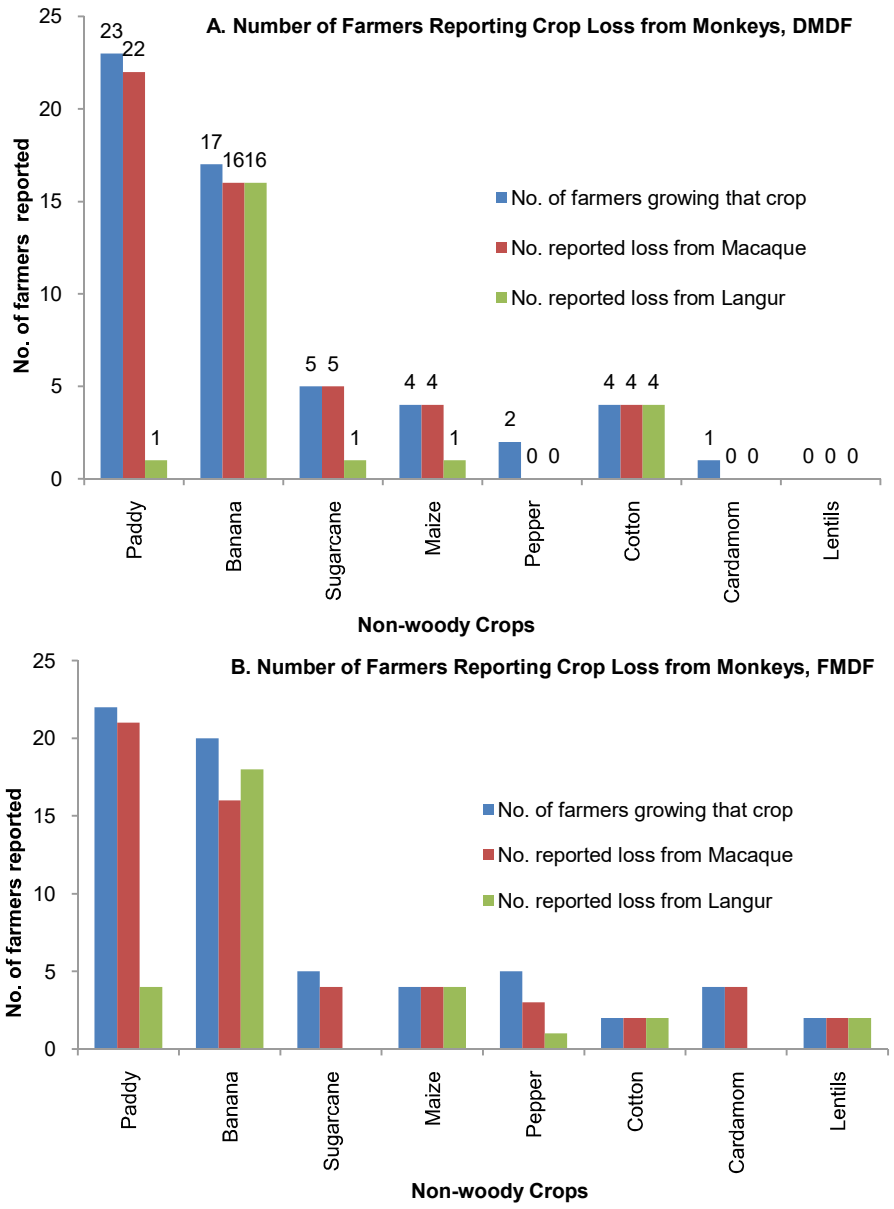

Fig. 3. Number of farmers growing the respective non-woody crops, and loss from monkeys amidst dense v/s fragmented moist deciduous forest system

Table 4. Nature of loss to non-woody crops from the two monkey species

Crop species	Bon. Mac.	Langur
Paddy	Panicle eaten in crop season; of standing crop as well as harvested and spread in field for drying.	Grain eaten in crop season; of standing crop.
Banana	Succulent shoots eaten; green fruit eaten	Green fruit eaten
Sugarcane	Stem eaten	Stem eaten
Maize	Cob eaten in crop season	Cob eaten in crop season
Cotton	Succulent boll, shoots, leaves eaten	Succulent boll, shoots, leaves eaten
Pepper vine	Mainly physical damage; feed on berries, but less	Mainly physical damage; feed on berries, but less
Cardamom	Shoots eaten, whole plants split	-
Lentil	Whole plant, inflorescence, beans eaten	Whole plant, inflorescence, beans eaten
Papaya	Young leafy shoots and grown fruits eaten	-

a b

Fig. 4. a) Sugarcane damaged by macaque, b) Banana bunch damage by langur

al., 2021). Maize was raided highest (58.43%), followed by rice and lentil by Assamese macaque (*Macaca assamensis* McClelland) in Nepal (Ghimire S and Chalise M 2018). In Chamba region (Himachal Pradesh), out of the total loss of maize, RM contributed 31 and 38% respectively in 2014-15 and 2015-16. Himalayan (Chamba) Langur (*Semnopithecus ajax* Pocock) contributed 20% and 14% in the same two years (Ahuja 2017). In Himachal Pradesh, RM raided maize and caused about 26% loss to all non-woody crops put together (Saraswat et al., 2015). In China, sugarcane loss was 7.69% of the crop (Li and Essen 2021).

CONCLUSION

Eleven non-woody crops were reported by farmers in the MDF territorial belt of UKD, Central Western Ghats. Of these, paddy and banana are the two most frequent crops, followed by sugarcane, maize, pepper vine, cotton, cardamom and lentils. Paddy and sugarcane were impacted by macaque quite frequently in both DMDF and FMDF, cardamom in FMDF, while langur interaction with these crops was almost negligible in frequency and extent of damage. Langur raided banana more and to some extent cotton, than BM. Maize and lentil loss were almost comparable between both the monkey species. Contrary to our hypothesis, FMDF and DMDF did not differ much with respect to the extent of crop loss. But this should not be taken as a nod for further forest fragmentation.. This study can serve as a bench mark to compare such crop and monkey interactions for future times in space as well as time.

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