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ELEPHANT HUMAN CONFLICT IN THE ANAMALAI ELEPHANT LANDSCAPE: A GIS ANALYSIS

N. Baskaran[1], G. Kannan[1] andAnbarasan[1]

[1]Asian Nature Conservation Foundation, Innovation Centre, Indian Institute of Science,

The Anamalai Elephant Landscape (5700 km^2) located in Southern India is part of the "Western Ghats Biodiversity Hotspot". This landscape supports approximately 4000 elephants and it is one area of high potential for the long-term conservation of the Asian elephant. This population is genetically more diverse and distinct from the much larger elephant population further north in the Ghats. This landscape is also known for its rich biodiversity along a rainfall and topographic gradient that supports natural vegetation ranging from tropical montane stunted forest and grassland to lower elevation evergreen, deciduous and thorn forest.

As part of our larger study on evaluation of elephant population and its habitats including mapping of corridors, vegetation and land use patterns of the landscape, we assessed elephant-human conflict through extensive field survey. Data on conflict for the year 2005 was collected by sampling 466 farmers from 176 villages located across 19 forest divisions of the landscape. Additionally, data on compensation paid towards elephant-human conflict were also obtained from all the forest divisions. The land use and vegetation types identified through field surveys and vegetation plots were compared with elephant-human conflict.

Among the 176 villages surveyed across the landscape, nature of conflict recorded includes elephant damage to crop fields (n = 229 cases), destruction of properties (n = 48 cases) and human death (n = 7 cases), together with elephant mortalities/captures (n = 4 cases) due to conflict. Overall in 2005, elephants have affected 38% of villages and farmers sampled. The villages along the eastern side of the landscape experienced significantly higher levels of conflict (61% villages & 54% farmers affected) compared to the western side (23% villages and 28% farmers affected) (M-W U = 8 P<0.05). Similarly, economic loss reported by people and compensation paid by the forest department towards elephant related damage were also higher on the eastern side of the landscape than on the western side. Farmers in the eastern side of the landscape being in rain shadow areas cultivated significantly more annual corps (50%) compared to the western side (12%) (M-W U = 4 P<0.05). The GIS analyses of elephant habitats show that forest divisions in the eastern side of the landscape have more fragmentation as a result of non-forest activities than the western side.

The higher level of conflict observed along the eastern side of the landscape could possibly be due to greater fragmentation by non-forest activities coupled with different crop use patterns and degradation of habitats. Consolidation of elephant habitats and changes in crop use pattern are suggested to reduce conflict level.

Conflicts between elephant and agricultural communities dates back as early as fifth or sixth century BCE (Sukumar 2003). However, the extent of conflicts increased over time across the geographical range of Asian elephants as natural habitats traditionally used by elephants have gradually been converted into agricultural lands and settlements, resulting in a large number of elephants in contact with humans leading to increase in human-elephant conflict (Santiapillai and Jackson 1990, Balasubramanian et al. 1995). In recent years, this has become a serious issue in elephant conservation across Asia. The Anamalai Elephant Landscape or Elephant Range 9 is no exception, as it also experiences increased human-elephant conflicts in some parts of the landscape such as the Valparai plateau of Anamalai Wildlife Sanctuary (Kumar et al. 2005), Theni (Baskaran et al. 2006) and Dindugul Forest Divisions. This landscape supports approximately 4000 elephants (Baskaran et al. 2007) and it is one area of high potential for the long-term conservation of the Asian elephant (Leimgruber et al. 2006). This population is genetically more diverse and distinct from the much larger elephant population further north in the Ghats (Vidya et al. 2003). This landscape is also known for its rich biodiversity along a rainfall and topographic gradient that supports natural vegetation ranging from tropical montane stunted forest and grassland to lower elevation

evergreen, deciduous and thorn forests. Although a study by Kumar et al. (2005) that looked at human-elephant conflict in a small area of the landscape, attributes lack of cover and forage as well as the presence of villages in and around the elephant migratory route as the main cause for such conflicts, no data are available on the conflict scenario or the causes of conflict in the remaining areas of the landscape. Therefore, as part of our larger study on evaluation of elephant population and its habitats including mapping of corridors, vegetation and land use patterns of the landscape, through extensive field survey we assessed elephant-human conflict and its causes, in order to broadly understand variation in conflict levels across the landscape.

Study Area

The Western Ghats is one among the 25 global Biodiversity Hotspots (Myers *et al.* 2000). The Anamalai Elephant Landscape or Elephant Range 9 popularly known as Anamalai - Nelliyampathis and Palani Hill Ranges (Fig. 1) is situated in the southern Western Ghats (76.34° E and 10.44° N to 77.55° E and 10.34° N) to the south of the Palghat Gap, extending over an area of 5700 km^2. The landscape is known for its wide altitudinal gradient ranging from as low as 100m above MSL on either side of the Ghats to as high as 2694m at Anaimudi Peak, the highest elevation in southern India. The remarkable altitudinal gradient results in significant variation in the amount of precipitation across the landscape, with the western face and crest-line of the hills enjoying higher rainfall (mean annual rainfall up to 3500 mm), and the eastern sides in the rain shadow region receiving lower annual rainfall (mean rainfall about 800 mm). Apart from Asian elephant, the landscape is also home for an impressive array of endangered and endemic species of birds and mammals (Stonor 1946, Kannan 1998, Umapathy and Kumar 2000, Shankar Raman 2001).

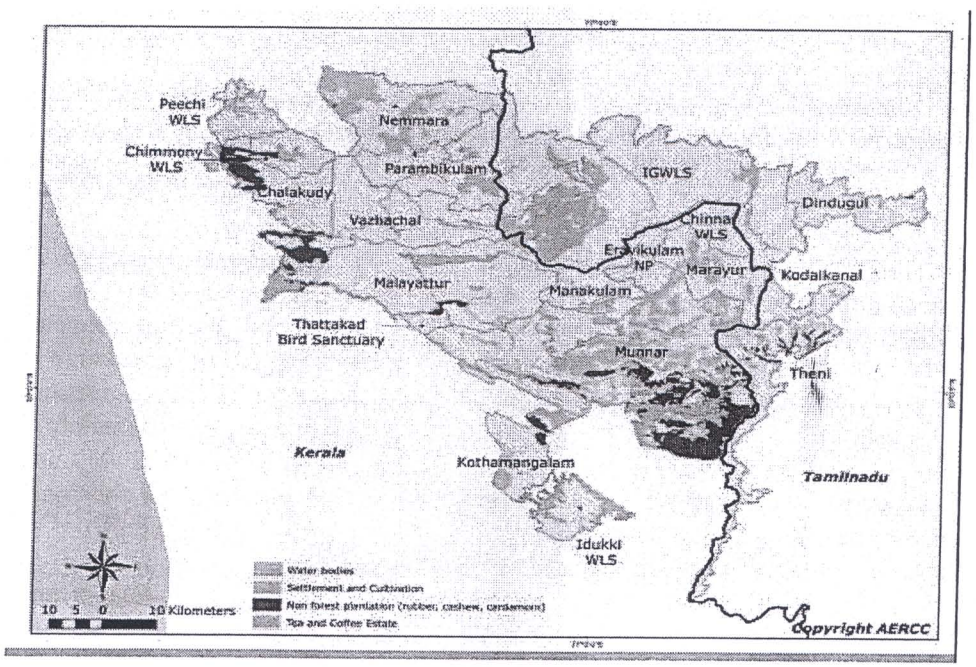

Figure 1. Map showing various forest divisions and non-forest elements within the landscape

Methods

Elephant-human conflict: To assess the intensity of conflicts, a rapid survey was carried out during January 2006 in all the forest divisions of the landscape covering 40-70% of the villages abutting the forest areas. During the rapid survey in each village, farmers were interviewed from the outskirts of the village (bordering the forest areas) towards the interior of the village (up to the extent where elephant intrusions occurred) in order to maximize coverage of the farmers who were affected in a given village keeping in view the constraints of time and manpower. During the interviews, information such as the farmer's name, cultivated area owned, details of various crops cultivated and their extent, elephant damage to each crop and its extent, damage to other properties (house, pipe line, pump sets, etc), economic loss incurred and month of damage were collected from every farmer for the year 2005 using a questionnaire. The geographical locations of crop fields belonging to each farmer interviewed were obtained using Global Positioning System. If a given village was not affected by elephants, only one or two farmers were interviewed. Additionally for each village, details such as Forest Division and Range within the division under which a given village is administered, manslaughter by elephants and elephant mortality/capture due to conflict and their location were also noted down. Also, secondary data pertaining to human-elephant conflict available with all the Forest Divisions in the landscape were collected to supplement the results of rapid assessment. The data were first compiled for each division and then summarized for east and western side of the landscape so as to obtain the percentage of villages, farmers, and crops affected and economic loss due to elephant damage to crops and other properties, etc. Additionally the location data of various farmers surveyed and affected, manslaughter by elephants and elephant mortalities/captures by conflict were superimposed on the map to depict the intensity of conflict across the landscape. The secondary data collected from each forest division were also summarized for eastern and western side of the landscape as supplementary detail to the rapid assessment.

Mapping of vegetation and land use pattern: The vegetation and land use patterns of the elephant habitats were identified through extensive field surveys and vegetation plots of (20 x 20 m^2). These data were incorporated into satellite imageries obtained from Indian Remote

Sensing (spatial resolution 23.5 acquired in Jan-Feb, 2004) using Geographical Information System and produced the vegetation and land use pattern map of the landscape. The vegetation and land use map was compared with degree of elephant-human conflict to understand influence land use on elephant-human conflicts.

Observations And Results

Status of elephant habitats in the landscape: Anamalai Elephant Landscape comprises 19 forest divisions spread over 5657 km^2 (Table 1). However, only 4421 km^2 area falls within the elephant distribution range while the remaining area is not used by elephants due to various reasons. The 4421 km^2 area is broken up into four patches due to developmental activates together with topographical constraints, with the majority (~70%) of the area within a single patch and the rest of the area isolated with a maximum distance of <10km from the other forest patch.

Forest division	Extent of Area (km^2)	
	Total	Elephant habitat
Chinnar WLS	94.7	92.9
Dindugul	182.9	172.9
Eravikulam NP	119.8	119.7
IGWLS	958.3	790.1
Kodaikanal	82.3	82.3
Marayur	193.8	159.2
Munnar	1206.5	667.9
Theni[$]	279.2	235.6
Landscape Eastern side	***3117.6***	***2320.6***
Chalakudy	229.9	164.5
Chimmony WLS	95.2	95.2
Idukki WLS	128.0	125.4
Kothamangalam	165.9	33.2
Malayattur	637.4	600.6
Manakulam Wild Life Div	91.3	85.9
Nemmara	373.2	217.1
Parambikulam	288.2	283.9
Peechi WLS	106.6	103.9
Thattakad Bird Sanctuary	29.7	24.6
Vazhachal	393.8	366.2
Landscape Western side	***2539.3***	***2100.5***
Entire Landscape	**5656.9**	**4421.1**

[$] Part of Theni forest Division falls with Elephant Range 9

Table 1. Total forest area and elephant habitat available under various forest divisions in Anamalai Elephant Landscape

Although the elephant habitat is fragmented into many forest patches, only about 5% of the elephant population (found in the Idukki Wildlife Sanctuary and parts of Kothamangalam Forest Division adjoining the Idukki WLS) is isolated from the main landscape (Fig. 1). The settlements coupled with the steep terrain in between the southern part of Munnar Division (Neriyamangalam Range) and the northern part of the Kothamangalam Forest Division (Thodupuzha Range) act as barriers to elephant movement although forest contiguity exists between these two areas. Due to greater fragmentation in the Munnar Forest Division, its contiguity to Theni Forest Division is presently cut-off by the non-forest plantations of tea and cardamom. However, elephants still move through these areas. The eastern part of the landscape has relatively more fragmented forest patches compared to the western part of the landscape.

Vegetation and land use pattern in the landscape: In total, the landscape has about 5680 km^2 of land area within the elephant distribution area (Table 2).

Landscape elements	Landscape region (km^2)		Total landscape area (km^2)
	Eastern side	Western side	
Grassland	286	129	415
Evergreen Forest	462	592	1053
Moist Deciduous Forest	612	922	1533
Dry Deciduous Forest	678	170	848
Dry Thorn Forest	562	128	689
Forest Plantations	201	335	536
Water bodies	8	94	102
Commercial Plantations	409	185	594
Settlements/Cultivations*	10	2	11.4
Total	**3228**	**2557**	**5783**

* Our analysis underestimated the settlements/Cultivations, requires further fine-tuning.

Table 2. Details of various landscape elements identified and their extent within the elephant habitats in Anamalai Elephant Landscape

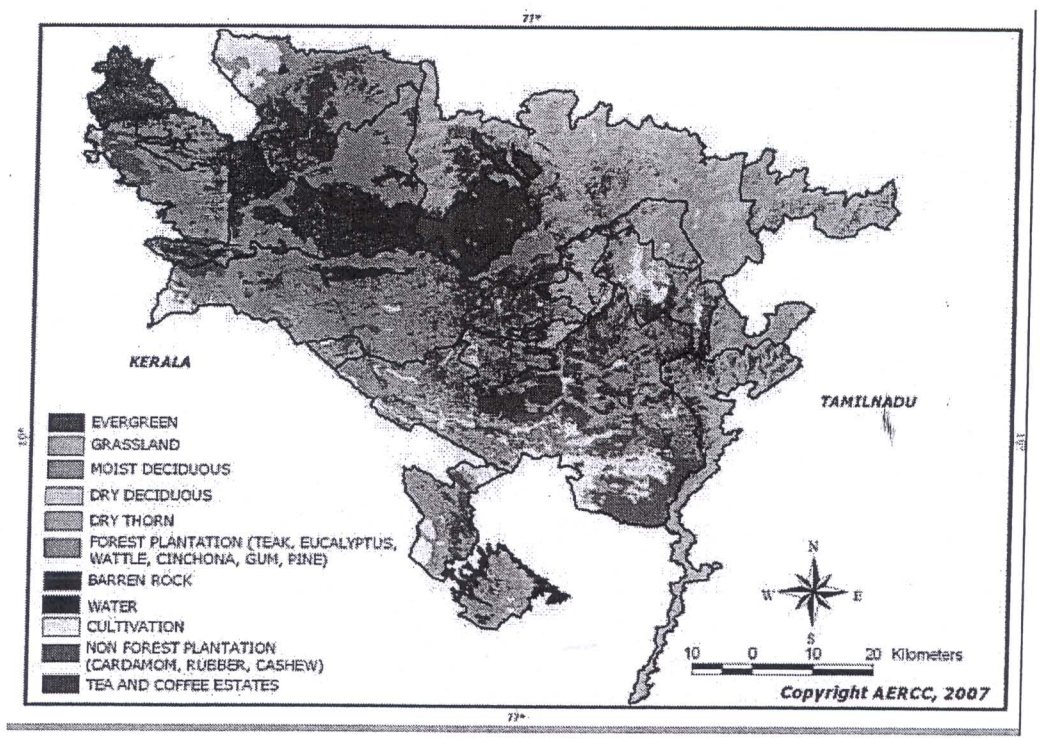

Figure 2. Vegetation and land use map of Anamalai Elephant Landscape

Out of this, 81% (4598 km2) is effective forest cover area and the rest 19% consist of non-forest area predominantly occupied by plantations of tea, coffee, cardamom, and rubber. Although the major part of the effective forest cover area consists of natural forest (87% - 4004 km2), a substantial part is under monoculture forest plantations (13% - 594 km2) of teak, eucalyptus, wattle and pine (Fig. 2). The elephant population in this landscape has access to a wide variety of habitat types ranging from tropical climax grassland habitats to tropical evergreen and semi evergreen forests, tropical moist and dry deciduous forests and tropical dry thorn forest. However, the substantial area under monoculture plantations is used by elephants relatively lesser than the natural habitats in all seasons (Baskaran et al. 2007). Further, it is important to note that large area of non-forest elements such as commercial plantations, and settlements/cultivations that could attract elephant-human conflict are found more on the eastern side (419 km2) as compared to western side of the landscape (187 km2).

Cropping pattern: The rapid survey carried out in various forest divisions showed that the perennial crops (cultivated and harvested within a year) dominated (64%) cultivated land as compared to annual crops (36%). However, significant variations in cropping patterns were observed between the eastern side and the western side of the landscape (Table 3).

For example, the farmers in the eastern part of the landscape cultivated significantly more annual crops compared to those in the western part of the landscape (M-W U = 4 $P<0.05$). The farmers living in the fringe and enclave areas of forest divisions, especially Dindugul, Theni and Chinnar cultivated more annual than perennial crops. The reason for this variation in cropping pattern across the landscape could be due to the variation in rainfall coupled with local topography. The eastern part being in the rain shadow area, receives significantly lower rainfall (mean annual rainfall 1596 mm) compared to the western side (mean annual rainfall 3344 mm); thus farmers predominantly grow annual crops in the former region.

Degree of elephant – human conflict: Through rapid surveys to assess the degree of human elephant conflict in various divisions, 466 farmers belonging to 176 villages in and around the forest areas of the landscape were sampled. The assessment revealed that the degree of elephant-human conflict varied remarkably across the landscape (Table 4 & Fig. 3).

Landscape region	Percentage of crops cultivated	
	Annual crops	Perennial crops
Eastern side	50.0	50.0
Western side	12.3	87.6
Landscape Total	**36.3**	**63.7**

Table 3. Cropping pattern observed in different parts of Anamalai Elephant Landscape in during 2005

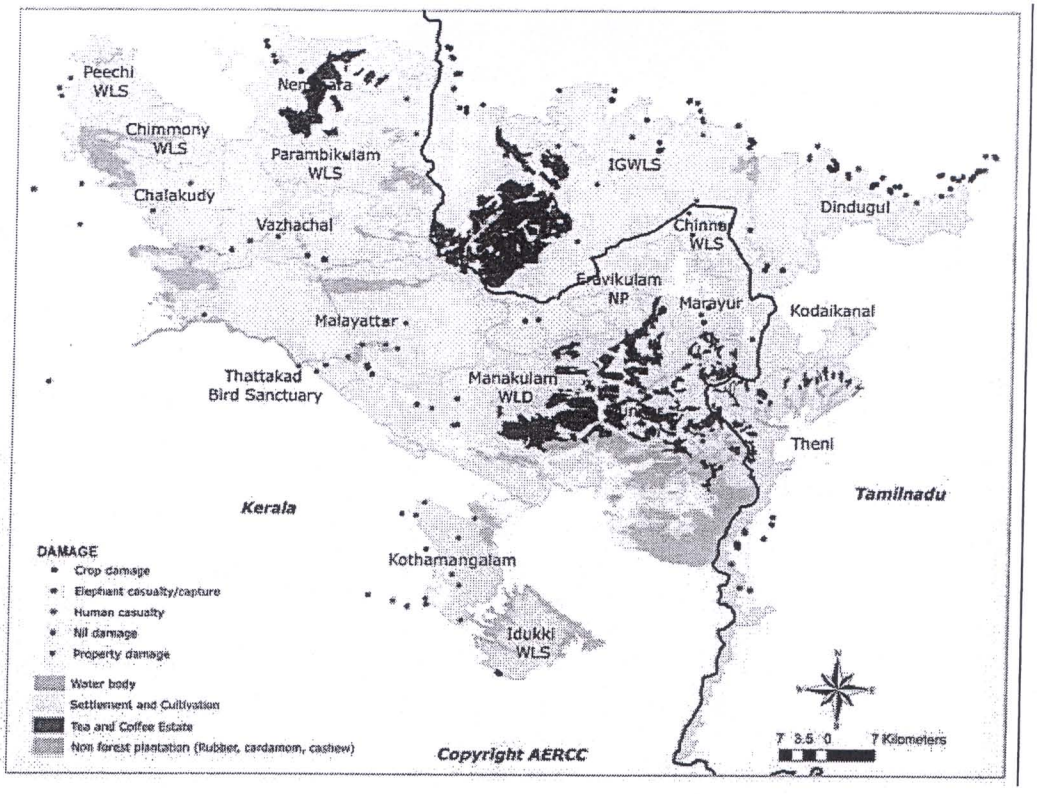

Figure 3. Map showing intensity of elephant-human conflict that took place in 2005 in the surveyed villages of various forest divisions in the landscape.

Landscape region	Villages		Farmers	
	Surveyed	Affected (%)	Surveyed	Affected (%)
Eastern side	122	61.4 (Avg.)	374	54.3 (Avg.)
Western side	54	23.3 (Avg.)	92	28.2 (Avg.)
Landscape total	**176**	**37.6 (Avg.)**	**466**	**38.0 (Avg.)**

Villages along the elephant habitats and within village farmers who cultivated immediately next to the forest area were surveyed and therefore % farmers affected need not necessarily be the actual % of farmers affected in each village. * No villages/ cultivation in the elephant distribution areas.

Table 4. Degree of elephant-human conflict revealed from rapid assessment survey in various parts of Anamalai Elephant Landscape during 2005

Overall at the landscape level, in 2005, elephants affected 38% of the 176 villages and 38% of the 466 farmers sampled indicating lower level of conflicts compared to other parts of the country such as northern West Bengal (Sukumar *et al.* 2003). However, regional variations in conflict indicate that the eight forest divisions in the eastern part of the landscape experienced significantly higher conflict level compared to ten forest divisions in the western side of the landscape (M-W U = 8 $P<0.05$), as >50% of the farmers (cultivating along the fringes and enclaves of forests) and >60% of the villages surveyed were affected by the elephants in the eastern side forest divisions (Table 4).

Nature of conflict: In total, 284 out of the 466 farmers surveyed were affected by elephants during 2005 in Anamalai Elephant Landscape (Table 5). The nature of conflicts includes damage to crops, properties and human casualties by elephants; there were also elephant deaths and captures as a result of conflict. Between the two damage types caused by elephants, damage to crops was more common (83%) as compared to property (17%). There were also 7 human deaths and 4 elephant captures/deaths due to elephant-human conflict during 2005. Conflict is notably higher in the eastern part of the landscape than in the western part of the landscape (Table 5), as five out of seven human deaths and 75% of elephant deaths or capture that took place in the villages surveyed were in the eastern side of landscape.

Economic loss due to elephant-human conflict: The economic loss incurred by individual farmers, due to conflict, was reported by 217 farmers whose crop and property were damaged by elephants (Table 6). The economic loss due to crop damage by elephants reported by 173 farmers has revealed that an average crop worth of Rs. 13,308 (US $ 296) per affected farmer was lost due to elephant damage. Also, 45 properties were damaged, as reported by the affected people; this worked out to an average of Rs. 9119 (US $ 203) per affected person across the landscape. The region-wise analysis showed that the average economic loss due to crop and property per affected farmer or person was far higher in divisions on the eastern side of the landscape compared to divisions on the western side (Table 6).

Landscape region	Number of farmers affected (surveyed)	% Damage to crops & properties by elephants (*n*)		Number of human death	Number of elephant death/capture*
		Crop	Property		
Eastern side	244 (374)	82.4 (197)	17.6 (42)	5	3
Western side	40 (92)	84.0 (32)	15.8 (6)	2	1
Landscape total	**284 (466)**	**83.3 (Avg.)**	**16.7 (Avg.)**	**7**	**4**

*** Number of elephants dead /captured due to conflict.**

Table 5. Nature of elephant–human conflict in Anamalai Elephant Landscape during 2005

Landscape region	Average economic loss / farmer (in Rs.)	
	Crop damage (n)	Property damage (n)
Eastern side (Avg.)	17,112 (165)	12,191 (40)
Western side (Avg.)	5700 (8)	4000 (4)
Landscape (Avg.)	**13,308 (173)**	**9119 (44)**

Table 6. Average economic loss per farmer caused by elephants to crop and property in the villages surveyed on the eastern and western side of Anamalai Elephant Landscape during 2005 (Loss in Indian rupees reported by the farmers – US $ 1 = 45 Indian rupees)

Landscape region	Compensation paid (Indian Rupees)	
	Crop / property damage	Human casualties
Eastern side	4,37,500	2,45,000
Western side	83760	1,20,000
Landscape total	**5,21,260**	**3,65,000**

Table 7. Compensation paid by forest department toward crop damages and human casualties by elephants during 2005 in different parts of landscape (US $ 1 = 45 Indian rupees)

Compensation paid by Forest Department towards conflict: Compensation paid by the forest department towards crop loss, property loss and human death by elephants were collected from all the forest divisions. There has been a difference in the amount paid as compensation for human death by elephants between Tamil Nadu and Kerala. The forest department in Tamil Nadu paid Rs. 1,00,000/human death that took place in non-forest areas, while the forest department in Kerala paid Rs. 20,000/human death. To overcome this difference, the number of human casualties due to elephants was also recorded. The amount paid as crop compensation by the forest department during 2005 in all the divisions was to the tune of Rs. 5,21,260, and towards human casualty Rs. 3,65,000 (Table 7).

The region-wise break-up of compensation amount paid also showed a similar pattern recorded in the rapid assessment that forest divisions on the eastern side paid more compensation (Rs. 6,82,500 - in total for crop, property and human casualties) compared to those on the western side (Rs. 2,03,760). This indicates that the degree of conflict was higher in the eastern side as revealed by our rapid survey results. The economic loss reported by the affected communities and compensation amount paid by the forest department do not tally. For example, based on the affected community perceived value of the economic loss by elephant damage, the rapid survey has estimated an average crop loss worth Rs. 13,308 / farmer and property loss worth Rs. 9119 / affected family in the 176 villages alone during 2005. But the forest department distributed only about Rs. 5,25,000 in total in all the forest divisions across the landscape. Such discrepancies could be due to two reasons. Firstly, the economic loss reported by affected community is always an overestimate and secondly, the compensation paid by the forest department is subject to the availability of funds in the state during that period and thus do not represent the actual economic loss caused by elephants to crops and properties. Even for human death, different states pay different amounts of compensation. Further, the compensation amount paid towards elephant damages in the last six years (Fig. 4.) shows a rapid increase in the elephant-human conflicts in 2005 across the landscape.

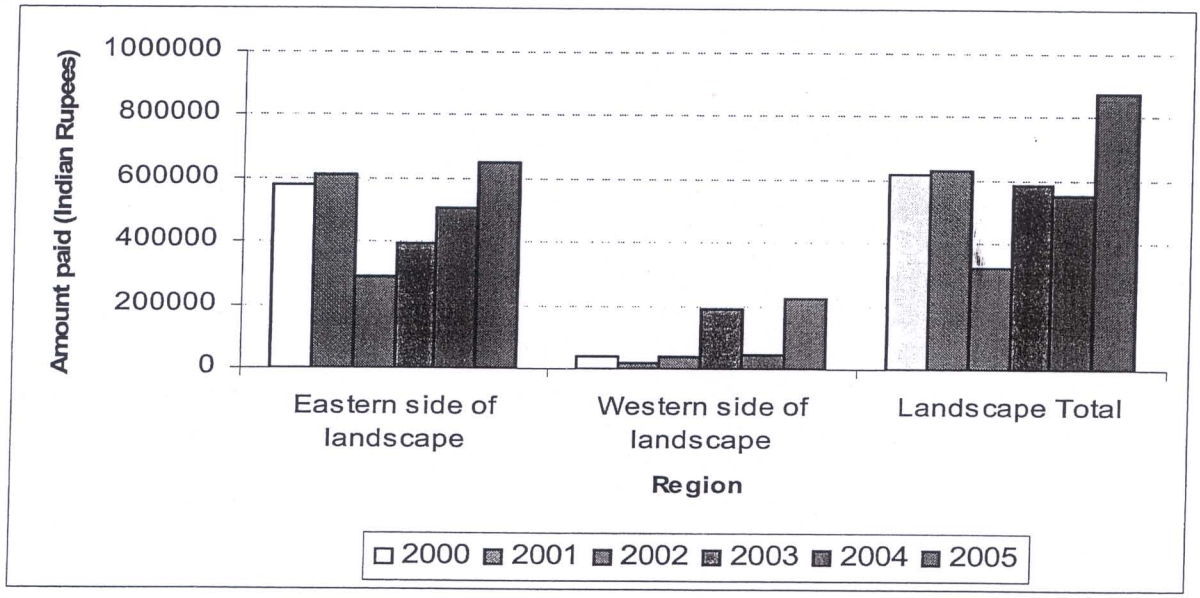

Fig. 4. Compensation paid by various forest divisions towards crop and property damages and human casualties by elephants during 2000-2005 (US$1=45 Indian rupees)

Landscape region	Elephant mortality and capture / Human casualty	
	Elephant	**Human**
Eastern side	3	10
Western side	1	6
Landscape	**4**	**16**

Table 8. Elephant mortality and human casualty due to elephant-human conflict during 2005 in different parts of Anamalai Elephant Landscape

Landscape region	Years												Total	
	2000		2001		2002		2003		2004		2005			
	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc
Eastern side	0	4	1	4	0	4	0	6	0	9	3	10	4	37
Western side	0	1	1	0	1	0	1	2	0	0	1	6	4	9
Landscape	**0**	**5**	**2**	**4**	**1**	**4**	**1**	**8**	**0**	**9**	**4**	**16**	**8**	**46**

Em/c – Elephant mortality and capture due to conflict, Hc – Human casualty by elephant.

Table 9. Elephant mortality and human casualty due to elephant-human conflict from 2000 to 2005 in different parts of Anamalai Elephant Landscape

Conflict related human casualties and elephant mortalities in the landscape: The total number of human casualties by elephants, and elephant mortalities / captures, due to conflict, that took place in various parts of the landscape during 2005 is presented in Table 8. It supports the fact that elephant-human conflict incidents were higher in the forest divisions on the eastern side of the landscape compared to forest divisions on the western side. In the eastern side of the landscape, Munnar a large forest division with large fragmentation and non-forest activities, and the Dindugul and Theni forest divisions with relatively smaller elephant habitats and numbers, have experienced 10 human casualties by elephants in 2005 alone. Further, the long-term data available on human casualties (Table 9) show an overall increase in elephant-human conflict since 2000.

Discussion

The rapid assessment of elephant-human conflict and the secondary data on crop compensation as well as human casualties and elephant mortalities collected from various forest divisions revealed that conflict intensity varied significantly across the landscape. It was remarkably higher in forest divisions (especially IGWLS, Dindugul, Theni, Marayur and Munnar) on the eastern side of the landscape compared to the western side of the landscape. The possible reasons for such variation in conflict across the landscape could be, firstly, the variation in the status of elephant habitats and land use pattern. The results on mapping of elephant habitats show that the forest divisions on the eastern side had large number of non-forest elements such as human settlements/cultivations and commercial plantations. It is likely that these non-forest areas before their conversion had been part of the home ranges of elephant clans and bulls ranging in these areas. Since elephants show strong fidelity to their home, and seasonal ranges and corridors (Baskaran *et al.* 1995, Baskaran 1998), such larger man-made landscape transformations on the eastern side resulted not only in loss and fragmentation of traditional elephant habitats, but also likely to have brought larger number elephants in contact with agriculture/settlements, resulting in higher elephant-human conflict as compared to less fragmented western part of the landscape. The habitat loss and fragmentation has been attributed to human-elephant conflict

elsewhere in India (Balasubramanian *et al.* 1995) and Africa (Hoare 1999). Secondly, the eastern side being in the rain shadow area, degradation by anthropogenic activities is also likely to be high compared to the western side of the landscape resulting in non-availability of sufficient food resources to the elephants ranging in these areas. Such situation may also lead to crop raiding by elephants and increase in human-elephant conflict (Rameshkumar 1994). Thirdly, relatively larger cultivation of annual crops in the eastern side compared to the western side of the landscape coupled with the higher palatability of the annual crops could also be a reason for the higher degree of conflict in the eastern part of the landscape.

Conclusions And Recommendations

- The rapid survey of elephant-human conflict in a sample of 466 farmers belonging to 176 villages in various Forest Divisions across the landscape has revealed that Forest Divisions in the eastern part of the landscape experienced significantly higher level of conflict than the Forest Divisions on the western side. The secondary data on human casualties, elephant mortality and capture due to conflict, and compensation amount paid towards elephant-human conflict also showed a similar trend.
- The higher degree of landscape transformations by human activities such as settlements, agriculture and hydro-electric projects resulting in loss and fragmentation of elephant habitats along with higher level of biotic pressure and highly palatable annual crops cultivated in Forest Divisions on the eastern side of the landscape, seemed to be the possible reasons for the high degree of elephant - human conflict in eastern areas compared to the western part of the landscape.
- Therefore, there is a need for consolidating the fragmented forest patches and change in cropping pattern to reduce the elephant-human conflict.

Acknowledgements

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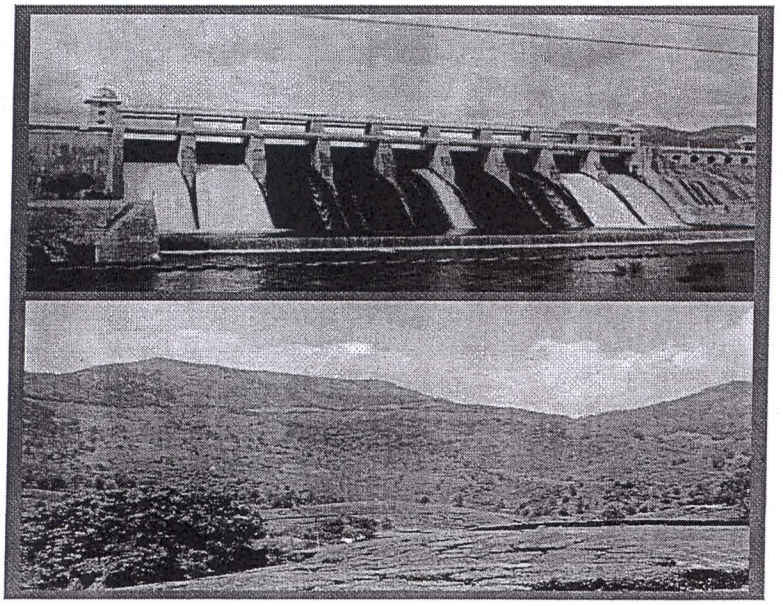


Plate 1. Developmental activities like hydroelectric power project [top] and commercial tea plantation [bottom] within the Anamalai Elephant Landscape

Plate 2. Types of natural vegetation and teak (*Tectona grandis*) plantation present in the Anamalai Elephant Landscape

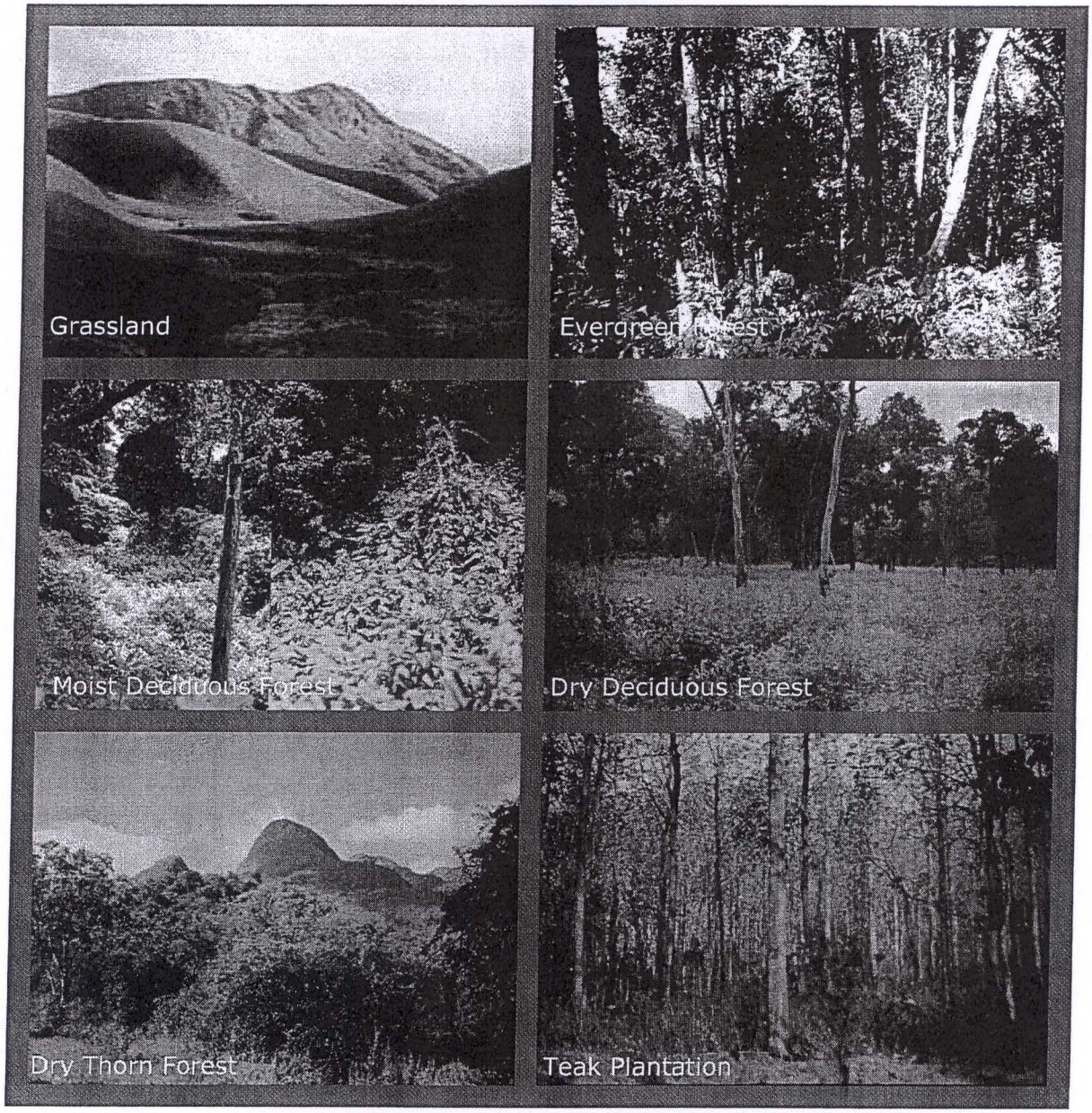
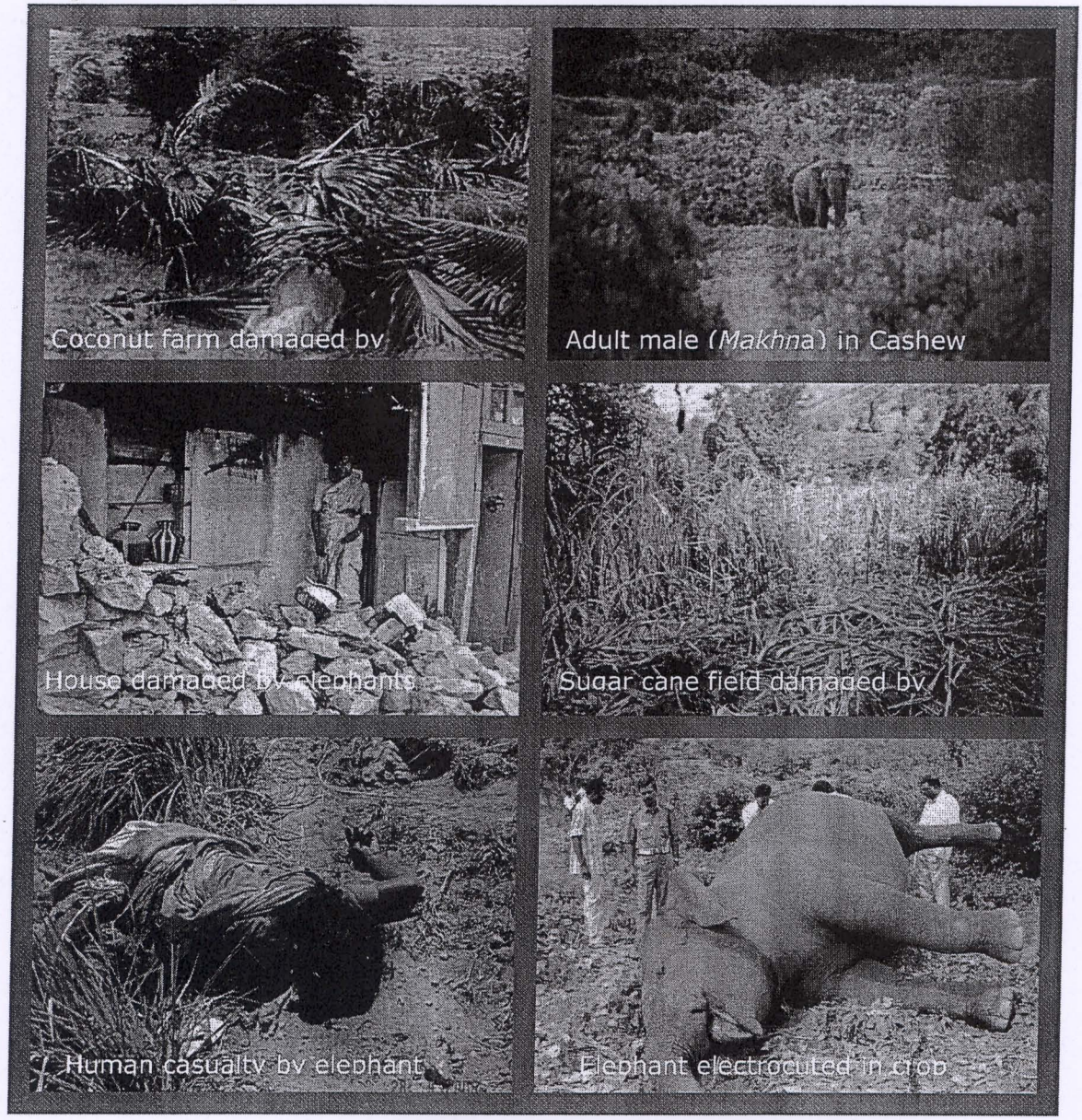


Plate 3. Indications of elephant-human conflict recorded in various parts of Anamalai Elephant Landscape



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