# HUMAN ELEPHANT CONFLICT IN HOSUR FOREST DIVISION, TAMILNADU, INDIA

***Interim Report***
***to***

***Hosur Forest Division, Tamil Nadu Forest Department***

***by***

***N. Baskaran and P. Venkatesh***


**ASIAN NATURE CONSERVATION FOUNDATION**
**INNOVATION CENTRE FIRST FLOOR**
**INDIAN INSTITUTE OF SCIENCE**
**BANGALORE - 560 012, INDIA**

**SEPTEMBER 2009**

## ACKNOWLEDGEMENT

We thank the Tamil Nadu Forest Department especially Mr. Sundarajan IFS Chief Wildlife Warden Tamil Nadu, Mr. V. Ganeshan IFS, District Forest Officer, Hosur Forest Division for readily permitting me to carryout this work and extending all supports for this study. I also thank all the Forest Range Officers, Foresters, Forest Guards and Forest Watchers in Hosur Forest Division for their support during my filed work.

We would like to thank Prof. R. Sukumar, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, for having provided a visitor ship to Mr. P. Venkatesh who was part of this study.

Our special thanks are due to Mr. S. Sanjvee Kumar & all others from KANS, who helped in this study directly & indirectly during course of fieldwork.

We wise to thank Mr. Thomas Mathew Executive Director, Asian Nature Conservation Foundation Indian Institute Science, Bangalore, for accepting my request to work under ANCF ongoing research project in Hosur Forest Division and for his encouragement during my project work.

We express my sincere thanks to Mr. K. G. Avinash GIS expert, ANCF for helping me in analyzing the conflict data using GIS and Mr. M. Saravanan, Junior Research Officer, ANCF for supporting me during the filed studies. We acknowledge Mr. Guruprasath CES, IISc., for his valuable effort of entering my field data systematically into the computer that helped me in timely submission of the thesis to my college. We also express my sincere thanks to Mr. Mukti Roy CES, IISc. who extended technical advices and help during the course this study.

Our sincere thanks to Mr. M. Mohan, Field Assistant ANCF for assisting me during the fieldwork and Mr. Mathan, Driver ANCF for taking me to different parts of field.

## 1. INTRODUCTION

Asian elephant (*Elephas maximus*) an 'endangered' species today (IUCN Red List 2008), about 6000 years ago, enjoyed a much wider geographic distribution and higher number than it does today. Its range then extended from Mesopotamia in the west across the Indian subcontinent to Southeast Asia and China, as far north at least as the Yangtze-King (Santiapillai and Sukumar 2006). Today there are about 30000–50000 elephants distributed discontinuously across 13 range states (Hedges 2006). The range counties population varies from perhaps less than 100 in Vietnam to well over 24,500 elephants India (Santipillai and Sukumar 2006). The 2007 elephant population estimate in India shows 27,694 elephant (ranges from 27669 to 27719) with largest populations are regionally seen in southern India (Project elephant 2009).

Asian elephant, a wide-ranging mega herbivore, is highly affected by loss, fragmentation and degradation of habitat, large-scale capture for captivity and poaching for ivory (Daniel 1980, Sukumar 1989). With natural habitats traditionally used by elephants, continuing to drop, fragment and degrade by increasing human population and its pressure, a large number of elephants come in contact with humans leading to increase in human–elephant conflict (Santiapillai and Jackson 1990, Balasubramanian *et al.* 1995, Desai and Baskaran 1995, Baskaran *et al.* 2007). A continental study on the evaluation of Asian elephant habitats (Leimgruber *et al.* 2003) states that only 51% of the geographic range (estimated at < 5,00,000 $km^2$ by Sukumar 2003) of Asian elephants consisted of un-fragmented wild lands in 1990. India, which holds the largest Asian elephant population in the wild, has ongoing developmental activities in all the elephant ranges with the exception of a part of the northeastern region (Leimgruber *et al.* 2003). India experiences approximately 175–200 cases of manslaughters, 10 lakh ha of crops loss and 15,000-house damage annually by elephants. The amount spent on control measures and ex-gratia payment towards human–elephant conflict runs to Rs 15 crores annually (Bist 2002). However, the affected communities feel the ex-gratia payment is negligible given the magnitude of conflict and its adverse impact on their socio-economic status. Therefore, goodwill and tolerance level is decreasing among the affected people over time that could lead to animosity towards the elephant conservation (Madhusudan 2003, Boominathan *et al.* 2008). An average of 41 elephants died annually due to human–elephant conflict with poisoning, taking the major share (25) followed by electrocution (16) (Bist 2002). The intensity increased during 2002–03 as 53 elephants died due to electrocution and poisoning across India (Project Elephant 2009) accounting for 36% of total elephant mortality recorded during that period. Worldwide the conservation programmes and policies affirm that conservation goals cannot make poor people poorer and that poor people cannot be expected to bear disproportionate costs of conservation (Walpole *et al.* 2006). Smallholder subsistence farmers are least able to withstand the risks posed by human–elephant conflict (Nath & Sukumar 1998). Since the human–elephant conflict is posing a major challenge to the conservation of Asian elephant, resolving human–elephant conflict is the major concern among the conservation community (Tchamba 1996, Hedges 2006).

The human–elephant conflict includes crop damage, human casualties, house, and other infrastructure damage by elephants and elephant mortality by human (Barua and Bist 1995, Sukumar 1989, Balasubramanian *et al.* 1993, Zhang and Wang 2003). Crop damage accounts for major type of conflict followed by human deaths in Asia (Lahiri–Chowdhury, 1980; Sumatra (Sukumar 1985, Dey 1991, Balasubramanian *et al.* 1995, Zhang and Wang 2003, Bandara and Tisdell 2003) and Africa (Tchamba 1996, O'Connell-Rodwell *et al.* 2000, Sitati *et al.* 2003, Smith and Kasiki 2000). Depredation of crops by elephants occurs to varying extents throughout their present range in Africa and Asia, wherever cultivation abuts elephant habitat (Sukumar 2003).

The human–elephant conflict is largely attributed to loss, fragmentation and degradation of habitat, which often results in elephants resorting to crop raiding, change in movement pattern

and search for new areas to settle down subsequently leading to elephant–human conflict (Barua and Bist 1993, Balasubramanian *et al.* 1993). The Asian elephant is a wide-ranging, long-living animal with strong fidelity to their home and seasonal ranges and the corridors within, and thus appears to use the same range over several generations (Baskaran *et al*. 1995, Baskaran 1998). Although elephants, especially herds (clans), overlap extensively in space, the hierarchy and resource defense among clans and its resultant spacing mechanisms do not permit those elephant clans that lost their home to developmental activities to move to adjoining undisturbed habitats already inhabited by high density of elephants. Therefore, such clans with significant loss of traditional ranges or cutoff from their corridors by agriculture/settlements will continue to stay in their home or move through their traditional seasonal corridors conflicting with humans (Balasubramanian *et al*. 1995, Baskaran 1998). The elephant population in northern West Bengal in northeastern India is an example where the elephant habitats are highly fragmented, which annually experience 50 manslaughters, and several lakhs worth of crops and properties damaged by about 200 wild elephants (Barua and Bist 1995). Likewise, there are about 60 elephants in about 90 $km^2$ of Dhalma Sanctuary in the state of Jharkhand, central India, that migrate every year into South Bengal and Orissa *enroute* causing severe damage to human life and property (Datye and Bhagwat 1995). Similarly, intensive anthropogenic pressure in terms of cattle grazing and firewood and minor forest produce collections, frequent man-made fires and their resultant weed abundance in elephant habitats reduce and degrade the quality of fodder available to elephants. The elephants ranging in such suboptimal habitats unable to meet their fodder requirements resort to crop raiding by staying on in their traditional ranges or moving into new areas (without or with less elephant occupation) if the new areas are too unable to meet their demands (Baskaran 1998, Daniel *et al*. 2006). In recent years, elephants from northern Karnataka (Belgaum) have strayed into adjoining forest divisions of Maharashtra and Goa states, causing considerable damage to crops and properties. The reason for such straying could be biotic pressure and its impact on their traditional ranges (Koehl 2006). The elephants ranging further south on Karnataka–Tamil Nadu border (Elephant Range 7: The Nilgiri–Eastern Ghats) also follow a similar pattern. There have been incidences of elephant herds straying out, due to degradation and fragmentation of traditional areas, of Hosur Forest Division, Tamil Nadu, bordering Bannerghatta National Park, Karnataka, and colonizing the habitats in neighbouring Andhra Pradesh causing extensive damage both enroute (Daniel *et al.* 1988) and in newly colonized places too. A recent study on these newly colonized elephants (Daniel *et al*. 2006) recommends translocating them as their new habitats are not viable to support them.

The Hosur Forest Division located on the northeastern tip of the Elephant Range 7 is well known to experience severe biotic pressure since the 19$^{th}$ century. Large tract that comprises this division was brought under British rule through treaties with Tippu Sultan in 1792. The tract was well known for sandalwood *(Santalum album)* production and was brought under strict protection during Tippu's regime. Subsequently, when the forest passed on to the East India Company had undergone relentless exploitation for about 180 years. The construction of railways and its demand for sleepers recklessly denuded the forest. In 1859–60 alone 2,45,743 railway sleepers were extracted (Harikrishnan 1970). There have been indiscriminate thefts of timber from these areas by railway contractors in 1865. In 1886, the area was notified as Reserve Forest (Subaiah, 1982). Nevertheless, the forest continues to experience large-scale destruction through exploitation of bamboo (*Babusa arundinacea*), fuel wood (*Canthium dicoccum, Atalantia monophylla, Ixora parviflora* and *Albizzia amara*), selective felling of timber resources (*Hardwickia binata, Tectona grandis* and *Pterocarpus marsupium*), sandalwood, and minor forest produces mostly fruits and nuts from tamarind (*Tamarindus indica*) thanikai (*Terminalia belerica),* soapnut (*Sapindus emarginatus*) and thagaravarai (*Cassia tora*) including honey collection. The forest pastures of the plateau deteriorated by unlimited grazing of cattle and there were not less than 36 cattle pens, with each one of them rearing as many as 1500 cattle, placed right inside the forest. Available statistics shows several thousand cattle (99,772 to 47,059) were licensed to graze inside the forest annually between 1959 and 1969 and incidences of illegal goat browsing, mainly on the northern sides of the division, increased over the years (Harikrishnan

1970). In addition, the plateau is surrounded by large number of villages along with sizable number of enclosures. The major sources of revenue for the people living in and around the plateau are cultivation, livestock grazing, minor forest produce collection and fuel woodcutting. As many as 1200 people were given gun licenses to protect crops. The division, being a territorial forest, all the denuding factors (except selective felling of timber and sandalwood extraction) continue to degrade the plateau resulting in extensive loss of natural resources available to elephants increasing human–elephant conflict. With increasing number of farmers affected over the years (from 43 in 2001–02 to 633 in 2008–09, source: Hosur Forest Division), containing human–elephant conflict has gradually become more challenging for managers in recent years. Although there has been a detailed study that looked at the ecological consequence of human–elephant conflict (Rameshkumar 1994), the data (from 1989–91) used in the study is now almost two decade old. With increasing conflict since 2001, the Tamil Nadu forest department has assigned Asian Nature Conservation Foundation to evaluate the present status of human–elephant conflict and its causes as part of its larger project on Biodiversity in Hosur Forest Division. It is in this context the present study was carried out between June–August 2009 with the following objectives.

**Objectives**

1. To evaluate the status of human–elephant conflict in terms of crop damage, human and elephant mortality due to conflict over the years based on the secondary data available from the forest department,
2. To assess the types of crop cultivated by farmers and their damage by elephants in and around Hosur Forest Division through a rapid survey,
3. To compare the human–elephant conflict with landscape variables such as fragmentation level, extent of settlements/cultivation and perimeter of forest boundary with settlement/cultivation and
4. To assess efficacy of various mitigation measures taken by the Forest Department to prevent crop damage by elephants.

## 2. METHODS

### 2.1. Study area

Hosur Forest Division lies between the latitudes 12° 7' and 12° 44' N and longitudes 77° 30' and 78° 27'E. The study area is bounded on the north and west by Karnataka state except in parts of Rayakotta range that adjoins Krishanagiri range and Andra Pradesh in the northeast (**Figure 1**). River Cauvery that flows between Karnataka and Tamil Nadu states is the southwestern boundary of the study area. The study area is bounded in the south also by Karnataka state lying west of Cauvery and by Dharmapuri Forest Division on the east by Dharmapuri Forest Division and in the northeast by Tirupattur taluk of Vellore district. The study area is spread over 1337 $km^2$ and consists of seven territorial ranges such as Anchetti, Denkanikotta, Hosur, Javalagiri, Krishnagiri, Rayakottai, Urigam and Uttangarai (**Figure 1**). In 1886, the government notified these as Reserve Forests (Subaiah 1982). There are proposals more recently to declare this area as a sanctuary.

The Hosur plateau dominates the study area by both its size and importance. The major part of the study area is lying between the Dharmapuri Forest Division, river Cauvery and Karnataka state. Within the vast block, there are many villages and large cultivated areas, some of which form enclosures in the forests. As a rule, cultivation is within the limits of the flatter portions, where the terrain exhibits sudden changes of elevation, and is generally absorbed in the jungle. Except in the valley of Cauvery, where the ground sinks steeply to about 300 m, the plateau falls within the elevation to the south and the east, leaving exposed in its fall great ribs of hill ranges running roughly north to south. Towards the southeast, the plateau is thrown up into a crowded mass of hills that runs irregularly from northeast to southwest. These hills are known as Melagiris, a peak of 1243 m, and are located on the northern side of the chain. The general altitude of the study area ranges from 400 to 1000 m above MSL. The Melagiris culminate in the impressive peak of Guttirayan Durg with an elevation of 1395 m above sea level. The northwest portion is comparatively plain but is broken by an interminable serious of undulation.

Numerous streams traverse through the forests of the study area. Most of them are small and the flow of water is seasonal. Only one major perennial river is Cauvery. The other rivers, Pennaiyar and Chinnar, are also perennial, which pass through Hosur and Krishnagiri. There are several semi-perennial streams flowing through the forest of the study area, notably on the Hosur plateau. The underlying rock is a gneissic formation of Archean origin traversed by trap dykes. A remarkable five quarts reef exists in the northwestern part of the study area and iron ore is found near Anchetti and along the Cauvery riverbanks. The most common soil is red sandy loam varying in depth and fertility with a general deficiency of lime and supports sandal forests (Harikrishnan 1970). Most of the areas in the former estate forests of the study area are abundant in rocks probably due to indiscriminate felling, unregulated biotic interferences and exposure to sun.

In the northern portions of the Hosur plateau, where the average elevation is about 1000 m or above, the climate is generally salubrious and pleasantly cool for about nine months in a year. During March–June, the weather is reminiscent of the lower plains. During winter (December–January), the temperature is often below 10°C with the maximum generally below 25°C seldom reaching 35°C during the hottest day (Mani 2007). The average rainfall varies between 62 and 360 mm. The annual rainfall on the northern portions of the Hosur plateau (Hosur and Denkanikotta ranges) was high (about 360 mm) while in the southern portions (Anchetti and Urigam) the average is very low and seldom exceeds 260 mm (**Figure 2**). Although both the monsoons (Southwest and Northeast) benefit the study area, the southwest monsoon (May–August) brings more rains. The forests of the area predominantly are dry mixed deciduous type. There are a few small patches of shola forest comprising mainly dry evergreen species in parts of Denkanikotta range. On the Hosur plateau, the dry deciduous forests feature association of considerable number of tree species with undergrowth that is often thorny and luxuriant in blanks. Secondary dry deciduous forests in the study area

are found in portions of Javalagiri, Anchetti, Denkanikotta and Urigam ranges. The dry deciduous scrub forests (**Figure 3**) are located all around the boundary of RFs and along the roadsides. The riverain forests are present along the banks of rivers Cauvery and Chinnar and also along the semi-perennial streams and other large streams all over the Hosur plateau (Harikrishnan 1970) with *Lantana camera* spread in all parts of the study area. The study area has two corridors located on the northwestern side of the division to have contiguity with Bannarghatta National Park, Karnataka. They are Chattiramdoddi and Kempathahalli. Chattiramdoddi is 1.5 km wide, 2 km long with a highly degraded habitat; Kempathahalli has less than a km long connecting Tally RF and Javalagiri RF. The elephants form Bannerghatta NP and Kanakapura forest division are connected through these corridors (AERCC 1997).

The study area richly endowed with the diversity of fauna. The herbivores include Indian elephant (*Elaphas maximus indicus*), gaur *(Bos gaurus*), sambar (*Cervus unicolor*), spotter deer (*Axis axis*) and Indian hare (*Lepus nigricollis*), carnivores such as leopard (*Panthera pardus*), wild dog (C*uon alpinus*), jungle cat (*Felis chaus)*, common mongoose (*Herpestes edwardsi)* and omnivores like sloth bear *(Melursus ursinus*) wild boar (*Sus scrofa*), Indian porcupine (*Hystrix indica)* and jackal (*Canis aureus)* are found in the study area. In addition, Pangolin (*Manis crassicaudata*) and Bonnet macaque (*Macaca radiata)* are distributed in the division (Mani 2007)

Fig. 1. Map of showing various ranges of the study area–Hosur Forest Division–with its adjoining forest divisions

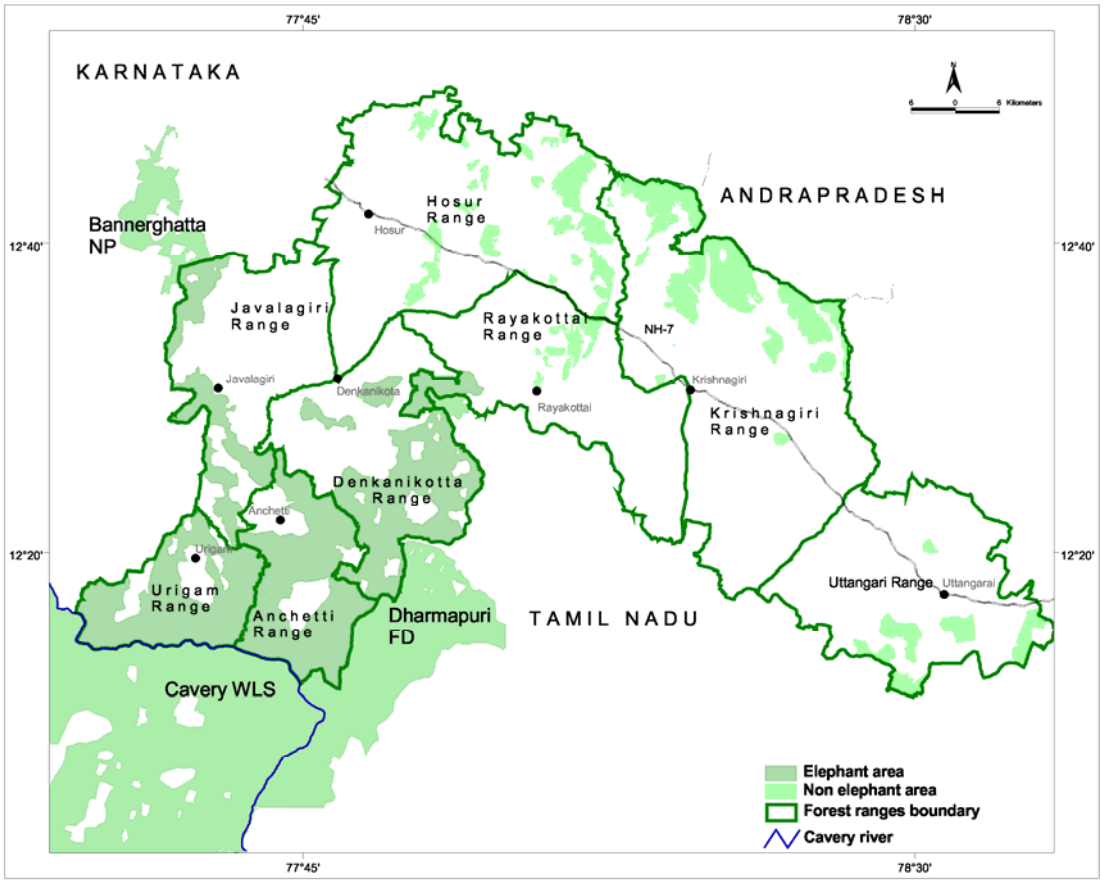



Figure 2. Mean monthly rainfall recorded in various forest ranges of Hosur Forest Division recorded between 1992 and 2007

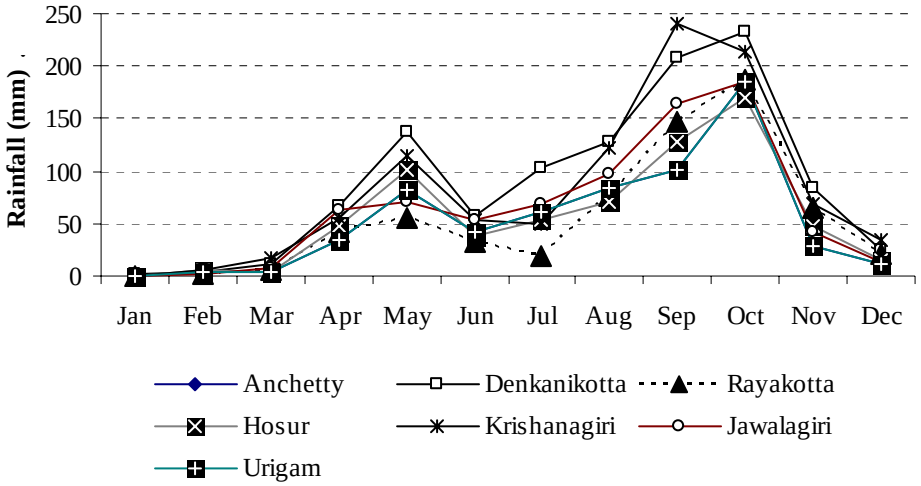



Figure 3. A view of dry thorn forest with an elephant moving downhill towards a stream for afternoon resting

**2.2. Human–elephant conflict**

2.2.1. Evaluation of conflict status: Since the study was short term in nature, available records on crop compensation applications were considered to assess the conflict scenario in the division over the years. The applications received from individual farmers of the villages in different forest ranges were scrutinized and from these records the number of farmers affected between 2001 and 2008 was computed for each village on yearly basis. The data on the number of farmers affected in the villages falling under each forest range were pooled together on yearly basis to assess the trends in conflict over the years in different ranges (regions) of the division.

2.2.2 Assessment on cropping pattern: Through a rapid survey using a questionnaire (Appendix I), 740 farmers in 120 villages located across the division were sampled. The villages sampled were selected through stratification of conflict level to ensure unbiased sampling. Over the last eight years (2001–2008), crop compensation applications were received in total from 281 villages located in and around the forest division by the range offices. Pooling the eight-year data on the total number of farmers affected in each village, the villages were categorized into three conflict categories, viz., low conflict (where the total number of farmers affected ranged 1–10 over eight years), medium conflict (20–30 farmers affected) and high conflict (>30 farmers affected) and worked out the proportion of villages under each of these categories. Proportionate to these three categories, 120 villages were selected for questionnaire survey sampling. During the rapid survey in each village, depending on village size, 7–20 farmers were interviewed uniformly to obtain a realistic situation. During the interviews, information such as the farmer's name, area owned and cultivated, various crops cultivated, elephant damage to each crop and its extent, damage to other properties (house, infrastructure, stored grain, live stock), economic loss incurred and month of damage were collected using the questionnaire. The geographical locations of crop fields belonging to each farmer interviewed were obtained using a Global Positioning System (GPS). Additionally, for each village, details such as Forest Range under which a given village is administered, manslaughter by elephants and elephant mortality due to conflict and their location were also noted down.

2.2.3. Evaluation of human–elephant conflict mitigation measures: The study also collected data on the mitigation measures such as establishment of electric fencing (EF), and elephant-proof trench (EPT), supply of fire crackers to the villagers by forest department to reduce conflict. To evaluate the effectiveness of various measures, the study collected details such as the date, and the cost of establishment and its present status especially in case of EF and EPT, besides mapping them using a Global Positioning System to superimpose on the division map.

Analysis: The data were compiled for each range separately to obtain the percentage of farmers cultivating various crops and crops damaged by elephants and loss to properties, etc. Additionally, the data location of various farmers surveyed and affected, manslaughter by elephants and elephant mortalities due to conflict were superimposed on the map of Hosur Division using Geographical Information System to depict the intensity of conflict across the landscape.

2.2.4. Use of GIS, remote sensing in human–elephant conflict: In recent years, GIS has emerged as an interface that allows digitally mapping and spatially analyzing any data. GIS is defined as a set of programs capable of storing, manipulating, analyzing and displaying geographically referenced data to solve complex spatial problems in an uncomplicated manner. Another system that complements GIS-based research is the Global Positioning System (GPS). This system is commonly used to collect spatial data by recording the geographic positions of entities of interest. Remote sensing is a method of acquiring information about entities on earth without any physical contact. In early times, aerial photos were used for researches concerning spatial elements. Today they have been replaced by satellite imageries of various resolutions. These imageries can be used to extract

comprehensive information on earth resources according to research requirements. Use of GIS in human–elephant conflict analysis enables us to identify key conflict zones at a glance, taking into account the influence of multiple geographical land cover and climatic features. In relation to HEC, researchers in Africa and Asia (Hoare, 1999; Smith and Kasiki 2000, Sitati *et al.* 2003, Baskaran *et al*. 2007) have used GIS and remote sensing to identify and examine the relationship of HEC with determinants and its spatial pattern. In this study, the remote sensing and GIS were used to illustrate the human–elephant conflict in relation to landscape such as variables such as fragmentation level, extent of settlements/cultivation, perimeter of forest with settlement/cultivation and vegetation type.

## 3. OBSERVATIONS AND RESULTS

### 3.1. Status of human–elephant conflict:

#### 3.1.1. Crop damage by elephants

To evaluate the human–elephant conflict status over the past 12-year period, we have scrutinized crop compensation applications received from the farmers by the forest department during 1997–98–2008–09 (**Figures 4**). The data show that the number of farmers affected and the amount paid as compensation have increased over the past 12 years. Further, regression analysis performed confirms (**Figure 4**) that the increasing trend observed on the number of farmers affected is significant ($R^2$ = 0.682, $n$ = 11, $P$ < 0.05). Similarly, the compensation amount paid also increased significantly over the past 12 years ($R^2$ = 0.672, $n$ = 11, $P$ < 0.05). In general, the results show that human–elephant conflicts have increased significantly over the past 12 years in terms of crop damage by elephants.

#### 3.1.2. Human death by elephants

Available data on the number of human casualties in conflicts with elephants were collected from the forest department records for the period from 2000 to August 2009 (**Figure 5**). Unlike crop damage incidents, the number of human beings killed by elephants between 2000 and August 2009 does not show a clear trend. For example, the number of death increased gradually from 3 in 2000 to 7 in 2002 and then decreased gradually to nil in 2005. Similarly, even after 2006 there is no clear patter in the number of human deaths.

Figure 4. The number of crop fields damaged by elephants in Hosur Forest Division and the ex-gratia (compensation) paid between 1997–98 and 2008–09

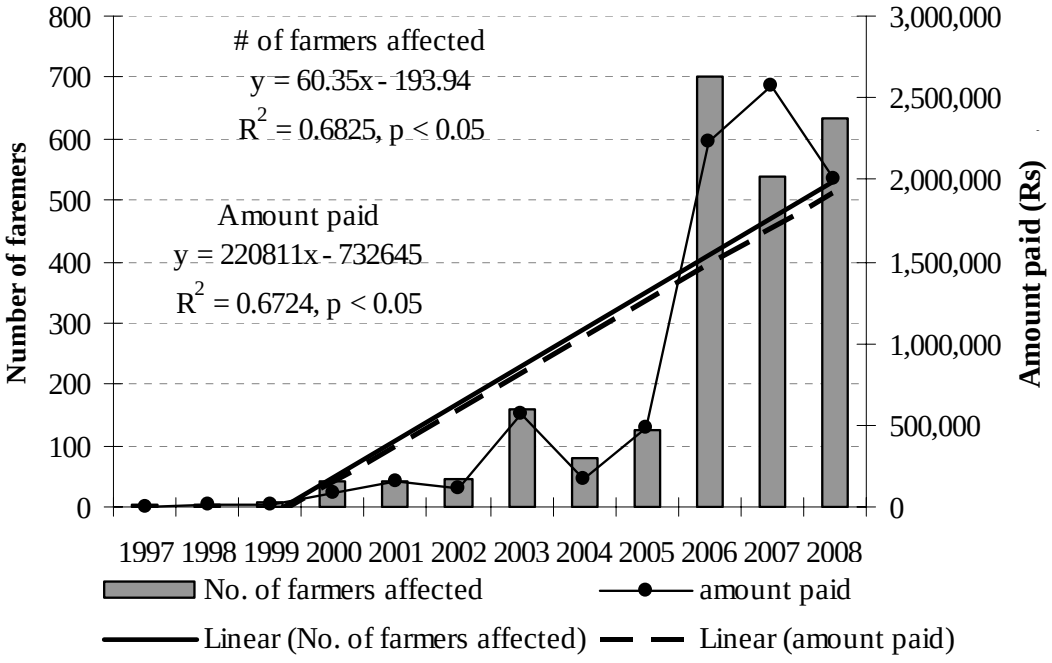
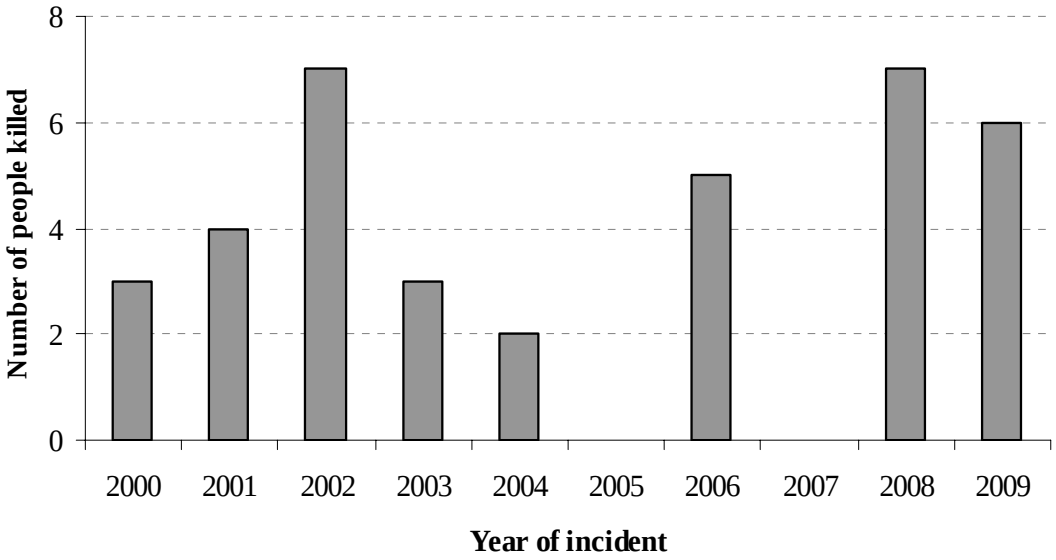


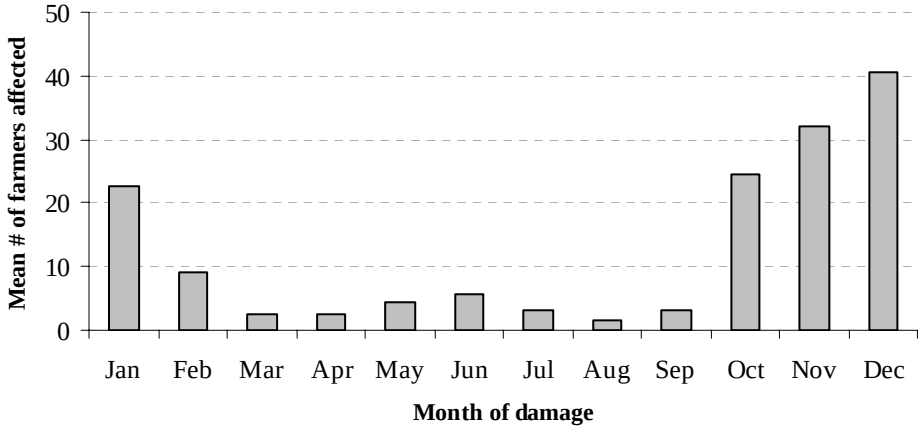
Figure 5. The number of human deaths caused by elephants in Hosur Forest Division between 2000 and August 2009.




### 3.1.3. Crop damage in relation to month

The damage to crop fields caused by elephants in different months was obtained on scrutiny of individual farmer crop compensation applications (mean from 2001–02 to 2008–09). It is plotted in **Figure 6**. The figure shows that crop damage caused by elephants is year-round phenomenon. However, the number of farmers affected increases gradually from October every year with the onset of northeast monsoon and continues considerably until the early dry season (February) in the subsequent calendar year with a peak during December. During March– September, the total number of farmers affected was very less indicating that elephant damage to crop filed is less during this period.

Figure 6. Data on crop damage caused by elephants from the mean number of farmers affected in different months during 2001–02 and 2008–09




### 3.1.4. Other damages caused by elephants

The damage caused by elephants in Hosur Forest Division is similar to patterns elsewhere. The elephants here also damage other properties such as houses while trying to access stored

grain and borewell accessories while attempting to quench thirst. However, these incidences are rather scarce and cause limited damage. Therefore, people do not apply for compensation for property loss in this division and as such, no record is available with the forest department.

### 3.1.5. Spatial variation in crop damage

The number of farmers affected over the past 12 years has shown an increasing trend. To understand if these incidences are spread uniformly all over the forest division or patchily distributed in certain areas, the average number of farmers affected by elephants/village/year was arrived from the records. The data on average number of farmers affected/year/village was divided into three different conflict zones/villages, viz. low conflict villages—those that had < 2 farmers affected by elephants/year, medium conflict villages—those that had 2–5 farmers affected/year and high conflict villages—those that had >5 farmers affected/year. Using GIS, the conflict data are plotted into the study area map assigning a symbol of small, medium and large solid circles, respectively, for the three categories of villages to visualize the intensity of conflict across the forest division (**Figure 7**). In addition, other human–elephant conflict-related incidences such as deaths of humans and elephants (due to electrocution, shooting to protect crop field, and ivory, poisoning) that took place in the study area from 2001–02 to August 2009 were also plotted in the same study area map (**Figure 7**).

It is obvious from the **figure 7** that the distribution of (1) villages affected by elephants including higher conflict villages, (2) number of human deaths and (3) elephant mortality due to conflict are patchily distributed, mostly in and around Denkanikotta range followed by Javalagiri range jurisdiction. The other two ranges, Anchetti and Urigam, on the southern side have more contiguous forest and have reported lesser number of conflict incidences.

Further, available records on the number of farmers affected during 2001–02–2008–09 were segregated into five different forest ranges, under which elephant distribution was reported in the division. The segregated range-wise data, plotted in **Figure 8**, show that the increase in the crop damage incidences by elephants is largely gradual in all the forest ranges except Royakottai range. For example, over the past 8 years, the total number of farmers affected by elephants is more in forest ranges in central (Denkanikotta) and northern (Javalagiri) areas of the division as compared to those in southern areas (Anchetti and Urigam ranges) (**Figures 8**). Further, the number of farmers affected was found to increase considerably over the past eight years in Denkanikotta and Javalagiri ranges. On the other hand, Roaykottai range, which is on the eastern side of the division, which reported fewer incidents in the past, experienced a considerable increase in the number of crop damages during 2007–08.

However, other conflict-related incidences such as death of humans at the hands of elephants and those of elephants by humans due to electrocution, gunshots to prevent crop damage, ivory poaching and train accidents while moving in the village areas did not exhibit any pattern over the years (**Table 1**). They were found to take place in all forest ranges unlike incidences of crop damage.

Figure 7. Distribution of human–elephant conflict intensity in different forest ranges of Hosur Forest Division (average number of farmers affected/year/village arrived using data from 2001–02–2008–09, human deaths (from 2001–02 to August 2009) and elephant mortality (from 1986–07 to August 2009) due to conflict

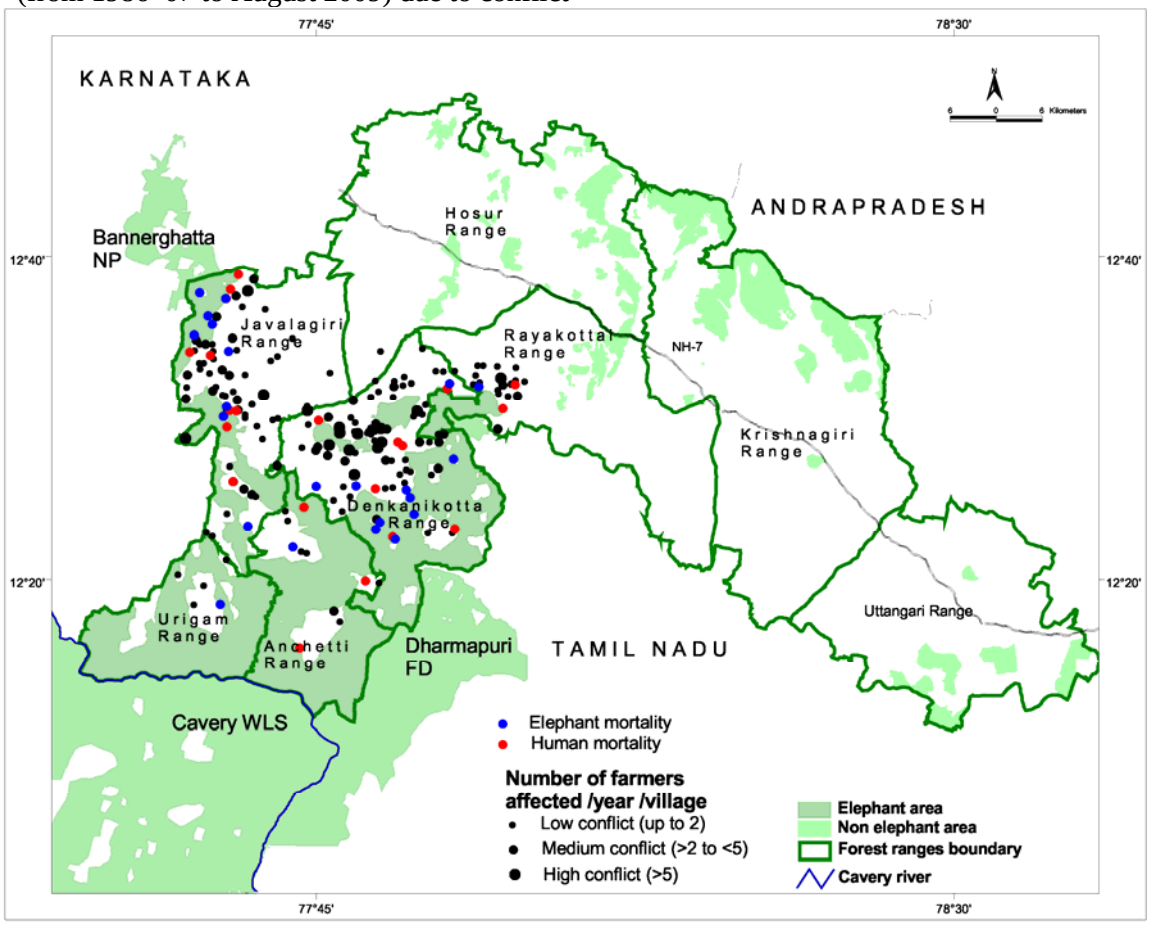



Figure 8. Status of crop damage by elephants in relation to Forest Range over years (Number of farmers affected, (human casualty and elephant mortality) due to conflict.

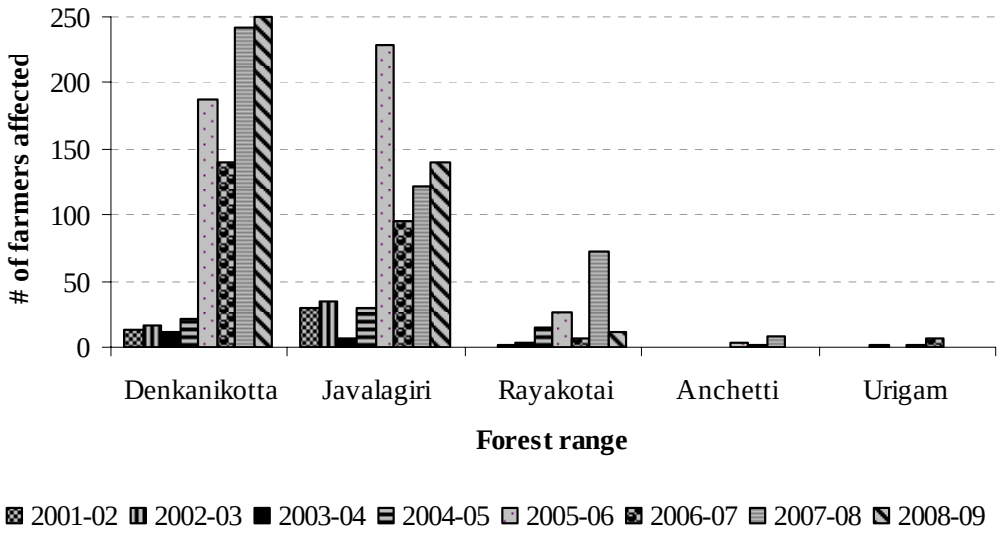


Table 1. Number of human deaths and elephant mortality due to human–elephant conflict in different forest ranges recorded between 2001 and August 2009

| Year | Javalagiri Range | | Denkanikotta Range | | Anchetti Range | | Urigam Range | | Rayakottai Range | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Human death | Elephant death | Human death | Elephant death | Human death | Elephant death | Human death | Elephant death | Human death | Elephant death |
| 2001 | 4 | - | - | 3 | - | 1 | - | - | - | - |
| 2002 | 5 | - | 1 | 3 | 1 | - | - | 2 | - | 2 |
| 2003 | 2 | - | - | - | - | 2 | - | 1 | 1 | 5 |
| 2004 | - | - | 1 | - | 1 | - | - | - | - | - |
| 2005 | - | - | - | - | - | - | - | - | - | - |
| 2006 | 3 | - | 1 | - | 1 | - | - | - | - | - |
| 2007 | - | - | - | - | - | - | - | - | - | - |
| 2008 | 1 | - | - | - | 3 | - | - | - | 3 | - |
| 2009 | 2 | 1 | 2 | - | - | - | - | - | 1 | - |
| **Total** | **17** | **1** | **5** | **6** | **6** | **3** | **0** | **3** | **5** | **7** |

### 3.2 Causes of human–elephant conflict

#### 3.2.1. Cropping pattern and its influence

To assess the cropping pattern and its influence on crop damage by elephants, 120 villages spread across five forest ranges were sampled using rapid questionnaire survey (**Figure 9**). In general, the study area grows both annual and perennial crops, cultivated using borewell irrigation and rainwater. The annual crops include ragi (*Eleusine coracana*) paddy (*Oryza sativa*), vegetables like tomato (*Solanum lycopersicum*), cabbage (*Drassica oleracea*) and maize (*Zea mays*) and perennial crops, mostly mango (*Mangifera indica*). These crops are sown and harvested in different times of the year (**Table 2**). The villagers in the northern parts of the division, such as Javalagiri and Denkanikotta ranges, have started cultivating vegetables and fruits intensively as both the returns and demand are higher owing to their proximity to Bangalore city.

Among the crops grown in the study area, ragi (finger millet) is the most common and widely cultivated ones (**Figure 10**) occupying over half (58%) of the total cultivated area. The other major crops include vegetables, paddy and fruits species like mango and coconut. Of these crops, elephants prefer ragi (**Figure 10**) and most of the damage to this crop takes place during the reproductive phase (**Figure 11**). Elephants also cause considerable damage to vegetables such as cabbage and tomato with eating the former and trampling the latter. The area under paddy cultivation is less in this area, probably due to insufficient rainfall or absence of canal irrigation. The paddy mostly trampled by elephants during early vegetative phase (**Figure 12**). From coconut tree elephants prefer to feed mainly the terminal shoot (**Figure 12**), while in the case of banana they feed on inner stem (**Figure 12**).

Figure 9. Map showing the villages affected and unaffected by elephants assessed through rapid questionnaire survey among 120 villages in Hosur Forest Division

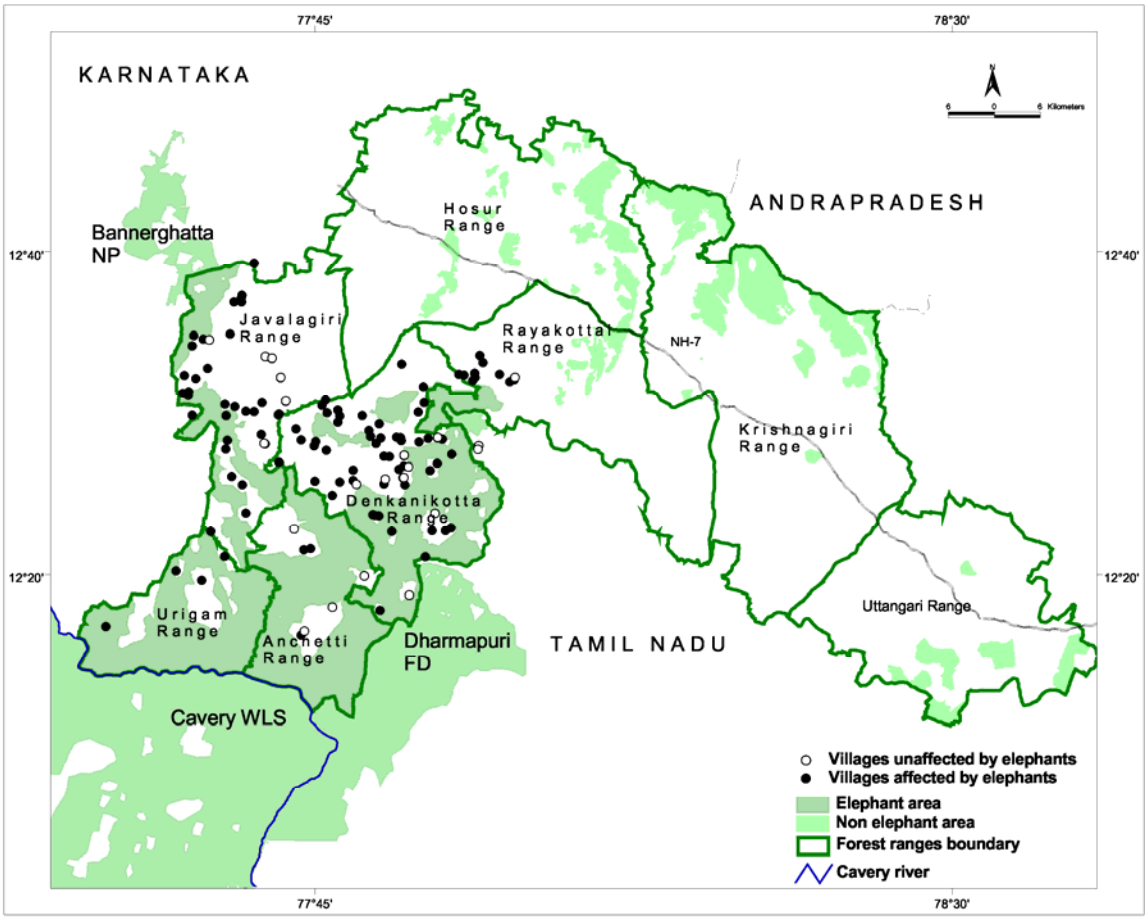



Table 2. Details of crops cultivated among the 120 villages surveyed through questionnaire survey

| Crop type | Crop name | Botanical Name | Month of sowing | Month of harvest | Nature of elephant damage |
|---|---|---|---|---|---|
| Annual | Tomato | *Solanum lycopersicum* | May–June | Aug–Sept | Trampling |
| Annual | Cabbage | *Drassica oleracea* | May–June | Aug–Sept | Eaten |
| Annual | Ragi | *Eleucine coracana* | Oct–Nov | Jan–Feb | Eaten |
| Annual | Paddy | *Oryza sativa* | Oct-–Nov | Jan–Feb | Eaten |
| Annual | Maize | *Zea mays* | Oct–Nov | Jan–Feb | Eaten |
| Annual | Banana | *Musa paradisiaca* | June–July | Feb–Mar | Eaten |
| Perennial | Mango | *Mangifera indica* | Oct–Nov | June–July | Eaten |

Figures 10. The extent of crops cultivated and damage caused to them by elephants in the study area. (bar = mean extent of crop cultivation and damage from different ranges, and error bar = SD)

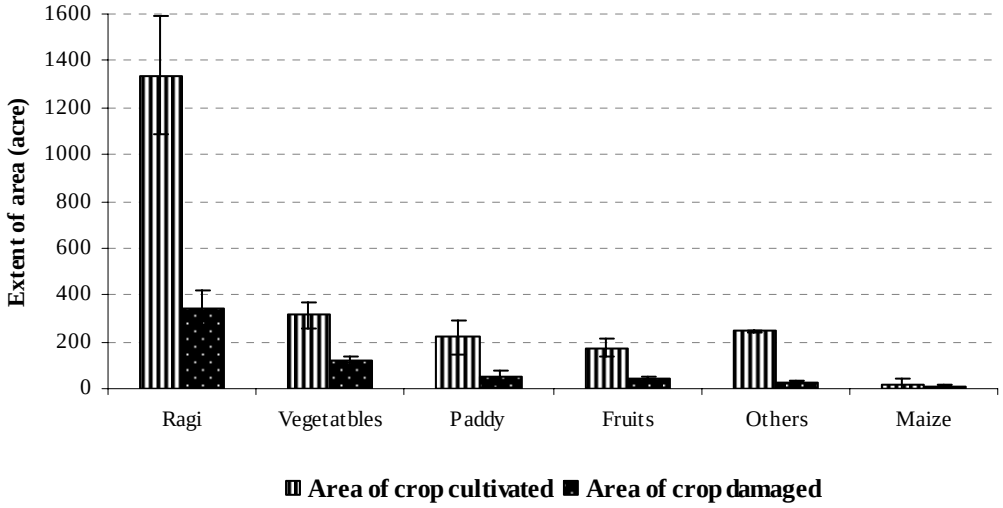


Figure 11. An enclave village with ragi (*Eleucine coracana*) in early reproductive phase (top) and harvested ragi crop damaged by elephants in the study area (bottom).

Figure 12. Fresh damage by elephants to a Paddy (*Oryza sativa*) field (top), Coconut trees (*Cocos nucifera*) (middle) and a banana (*Musa paradisiaca*) field (bottom) in the study area

### 3.2.2. Landscape attributes

The five forest ranges of the Hosur Division that have elephant distribution have different levels of landscape attributes such as extent of forest versus non-forest (settlements/cultivation) areas, fragmentation effect (number forest fragments) and perimeter of forest boundary abutting non-forest areas (settlement/cultivation) (**Table 3**). It is interesting to note that ranges such as Denkanikotta and Javalagiri that have experienced higher human–elephant conflict incidences also have higher number of forest fragments and perimeter of forest boundary with non-forest areas as compared to other three ranges (**Table 3**). Factors such as higher-level of fragmentation and perimeter of forest boundary with non-forest areas would increase the contact for elephants with human settlements/cultivation and therefore influence the human–elephant conflict positively.

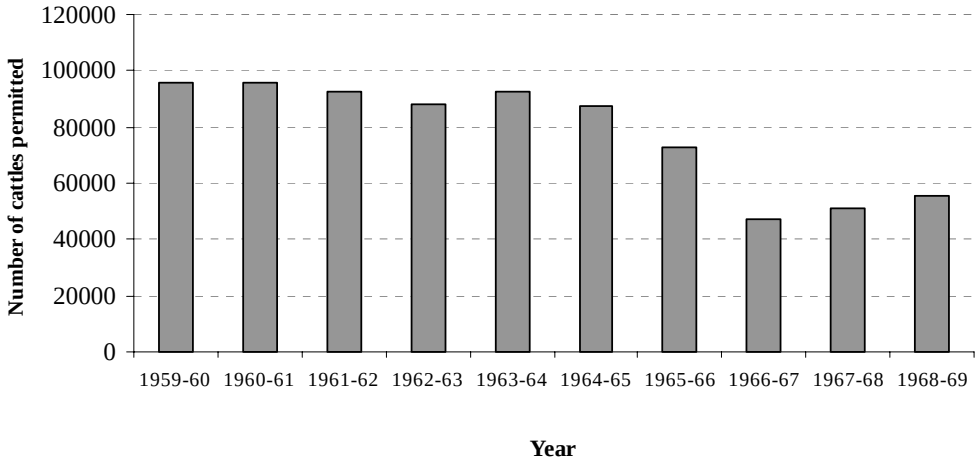
### 3.2.3. Cattle grazing and its impact

The Hosur Forest Division, being a territorial division, accommodates a large number of cattle pens inside the forest areas. Cattle are legally permitted to graze inside the forest at nominal fees. Available data (from the Hosur Forest Division Working Plan) (**Figure 13**) shows that annually about 78,000 cattle were permitted to graze inside the forest areas between 1959–60 and 1968–70. The latest working plan (Mani 2007: 2007–2017) also shows that until 2001–02, a sum of Rs 60,746 was raised through cattle grazing permits. Although cattle grazing has been stopped presently (Mani 2007: Working Plan 2007–2017), a large number of cattle including goats graze illegally inside the reserve forest areas of Hosur Division. Overgrazing by cattle adversely affects the fodder resource available to elephants in the division.

Table 3. Details of landscape attributes of the elephant bearing forest ranges of Hosur Forest Division

| Range | Extent of forest area ($km^2$) | Number of fragments | Number of enclaves/ settlements | Extent of settlements/ cultivation ($km^2$) | Perimeter with non-forest area (km) |
|---|---|---|---|---|---|
| Denkanikotta | 292.05 | 3 | 13 | 4.7 | 73.0 |
| Javalagiri | 135.61 | 3 | 2 | 0.2 | 38.9 |
| Urigam | 246.2 | 1 | 4 | 5.1 | 30.7 |
| Anchetti | 318.4 | 1 | 2 | 5.5 | 27.2 |
| Rayakottai | 33.16 | 1 | 0 | 0 | 11.9 |

Figure 13. Number of cattle grazing permits issued by Hosur Forest Division between 1959–60 and 1968–70 (source: Hosur Forest Division Working Plan 1972–1982)



### 3.3. Measures of conflict mitigation and their efficacy

Towards human–elephant conflict, forest department pays ex-gratia for the (1) crop damaged and (2) humans killed/injured by elephants to the affected family mainly to keep up the social tolerance to wild elephants or prevent the animosity of people against elephant damage. However, affected people feel that ex-gratia amount paid is negligible compared to the cost of elephant damage to crops and human life. In addition to ex-gratia payment, the forest department also spends towards crop protection measures such as erection of Solar Powered Electric Fence (SPEF), establishment of elephant proof trench (EPT) and also supply of crackers to the farmers to scare away crop raiding elephants (**Table 4**). In total the forest department established 92.5 km of SPEF and 12 km of EPT between 2003–04 and 2008–09. Nevertheless, an assessment carried out to evaluate the efficacy of SPEF & EPT (**Table 5**) reveals that almost all such measures were only effective for a short span of time (average effective period of SPEF was 0.75 years and EPT was 1.5 years as on August 2009), but not for the long-run, as in the case of SPEF erected & managed by individual private owners. Amount spent towards compensation and crop protection measures significantly increased over the years (**Table 4**), and there are now increasingly large provisions for the same in FD plans (**Table 6**). The human–elephant conflict continues to increase over the years and does not show any sign of declining or stabilizing trends.

Table 4. Total amount spent towards human–elephant conflict mitigation measures from 1997–98 to 2008–09. (EPT = Elephant–proof trench, other conflict mitigation measures includes supply of fire crackers and purchase of charger lights for chasing crop raiding elephants)

| Year | Compensation paid for crop damage (Rs.) | Amount spent for Solar Fence & EPT (Lakhs) | Amount spent for other conflict mitigation measure (Lakhs) | Total amount spent / year (Lakhs) |
|---|---|---|---|---|
| 1997-98 | 0.06 | NA | NA | 0.06 |
| 1998-99 | 0.09 | NA | NA | 0.09 |
| 1999-00 | 0.13 | NA | NA | 0.13 |
| 2000-01 | 0.83 | NA | NA | 0.83 |
| 2001-02 | 1.63 | NA | NA | 1.63 |
| 2002-03 | 1.20 | NA | NA | 1.20 |
| 2003-04 | 5.69 | 1.2 | NA | 6.89 |
| 2004-05 | 1.66 | NA | NA | 1.66 |
| 2005-06 | 4.86 | 27.4 | NA | 32.26 |
| 2006-07 | 22.37 | 33.62 | 2.6 | 58.59 |
| 2007-08 | 25.74 | 33.6 | 2.45 | 61.79 |
| 2008-09 | 20.08 | 44 | 0.9 | 64.98 |

Table 5. Details of solar powered electric fence (SPEF) and elephant–proof trenches (EPT) established by forest department between 2003–04 and 2008–09 to prevent crop depredation by elephants in Hosur Forest Division and their present status

| Type | Year of establishment | Range | Distance | Amount spent (lakhs) | Duration of functioning since establishment (Year) | Present status (Reason for non-functioning) |
|---|---|---|---|---|---|---|
| Solar electric fence | 2003-04 | Denkanikotta | 2.0 | 0.60 | 1.5 | Not working (battery repair) |
| | | Javalagiri | 2.0 | 0.60 | 1 | Not working (covered by plants) |
| Solar electric fence | 2005-06 | Denkanikotta | 3.5 | 5.6 | 2 | Not working (fence wire is highly damaged by people & elephants ) |
| | | Javalagiri | 12.0 | 19.60 | 0.25 | Not working (fence wire is highly damaged by people & elephants ) |
| Solar electric fence | 2006-07 | Javalagiri | 26.0 | 42.02 | 1 | Not working (fence wire is highly damaged by people & elephants ) |
| Solar electric fence | 2007-08 | Denkanikotta | 6.0 | 9.60 | 0.5 | Not working, (battery stolen by local people) |
| | | Denkanikotta | 10.0 | 16.00 | 0.25 | Not working (post & wires damaged by elephants) |
| | | Javalagiri | 5.0 | 8.00 | 0.25 | Not working (battery repair) |
| Solar electric fence | 2008-09 | Rayakottai | 15.0 | 20.00 | 0.25 | Not working (covered by plants) |
| | | Anchetti | 11.0 | 17.00 | 0.25 | Not working (covered by plants |
| **Solar fence erected during 2003-04–2008-09** | | | **92.5** | **139.02** | **Average = 0.75** | |
| EPT | 2003-04 | Javalagiri | 10.0 | 15.50 | 2 | Not working (closed due to erosion) |
| EPT | 2008-09 | Anchetti | 2.0 | 2.40 | working | Working (some parts covered by plants) |
| **EPT erected between 2003-04 and 2008-09** | | | **12.00** | **17.90** | | |

Table 6. Provisions for conflict mitigation for 10 years from 2007–08 to 2016–17 (source: Mani 2007: Working Plan Hosur Forest Division 2007–08 to 2016–17)

| Financial year | Compensation for crop damage (amount in lakhs) | Compensation for death (amount in lakhs) | Numbers of human death | Compensation for injuries (amount in lakhs) | Numbers human injury | Erection of solar fence (amount in lakhs) | Distance (km) |
|---|---|---|---|---|---|---|---|
| 2007-08 | 10.00 | 5.00 | 5 | 2.00 | 20 | 135.00 | 75.0 |
| 2008-09 | 11.00 | 5.50 | 5 | 2.20 | 20 | 148.50 | 75.0 |
| 2009-10 | 12.10 | 6.05 | 5 | 2.42 | 20 | 163.35 | 75.0 |
| 2010-11 | 13.31 | 6.66 | 5 | 2.66 | 20 | 179.69 | 75.0 |
| 2011-12 | 14.64 | 7.32 | 5 | 2.93 | 20 | 197.65 | 75.0 |
| 2012-13 | 16.10 | 8.05 | 5 | 3.22 | 20 | 217.42 | 75.0 |
| 2013-14 | 17.72 | 8.86 | 5 | 3.54 | 20 | 239.16 | 75.0 |
| 2014-15 | 19.49 | 9.74 | 5 | 3.90 | 20 | 263.80 | 75.0 |
| 2015-16 | 21.44 | 10.72 | 5 | 4.29 | 20 | 289.38 | 75.0 |
| 2016-17 | 23.58 | 11.79 | 5 | 4.72 | 20 | 318.32 | 75.0 |

## 4. DISCUSSION

Depredation of cultivated crops by elephants is widespread in both Africa and Asia. Elephants have damaged crops ever since the advent of agriculture and elephant–human conflict occurs throughout the elephant's range in India that goes back to the fifth or sixth century BC (Sukumar 2003). Human–elephant conflict that has been documented to occur to varying extents from very negligible levels as in the optimal habitats with high density of elephants in Nilgiri Biosphere Reserve, southern India (Balasubramanian *et al.* 1995) to high levels in highly fragmented landscapes with small populations in northern West Bengal (Sukumar *et al*. 2003). However, the extent of conflicts increased over time across the geographical range of Asian elephants as natural habitats traditionally used by elephants were gradually converted into agricultural lands and settlements. This resulted in a large number of elephants remaining in contact with humans leading to increased levels of human-elephant conflict (Santiapillai and Jackson 1990, Balasubramanian *et al*. 1995). The present scenario of increasing conflict is largely due to unplanned developmental activities established within elephant ranges in the past (Baskaran *et al.* 2007).

Lying within the Nilgiri–Eastern Ghats area, the Hosur Forest Division is known to experience a high level of human–elephant conflict and straying incidences of elephant herds from more than two decades back (Daniel *et al*. 1987 and Rameshkumar 1994). The present study, with secondary data on number of farmers affected between 1997–98 and 2008–09 has further shown that crop damage incidences have increased significantly over the last 12 years. The study has used a GIS framework to integrate the cases of human elephant conflicts (such as crop depredation by elephants, human death and elephant death due to human–elephant conflict), that took place over the past 8 years, into the landscape of the study area (**Figure 7**). This detailed GIS based analysis has revealed that conflict cases were patchily distributed along the central (Denkanikotta range) and northern (Javalagiri range) parts of the division, that have more fragmented forest patches and longer perimeter of forest boundary with non-forest areas than the ranges in the southern parts of the division (Anchetti and Urigam). It is likely that habitat contiguity existed in the form of revenue/private forest between fragmented Reserve Forests in Denkanikotta and Javalagiri ranges that have been lost during recent decades in the course of development or due to increasing human encroachment. Since Asian elephants show strong fidelity to their home and seasonal ranges and the corridors within them (Baskaran *et al*. 1995, Baskaran 1998), it is possible that the elephant herds/bulls ranging across the forest division through the fragmented patches of Denkanikotta and Javalagiri ranges have lost significant parts of their home ranges to agriculture/settlements. Being unable to find better habitat without elephants or with less elephants, the herds and

bulls continue to stay in the same home by partly sustaining themselves from cultivated crops (Balasubramanian *et al*. 1995, Baskaran 1998). Furthermore, the elephant herds and bulls from Hosur Forest Division also range into Bannerghatta National Park, which is further north from Javalagiri range. Since the southern parts of Javalagiri range do not have direct contiguity with its northern part forest patch (Talli RF) although there is contiguity through Kanakapura RF of Karnataka state forest, elephants may tend move across settlement/cultivation exist between the southern and northern forest patches of Javalagiri range to range into Bannerghatta, resulting in intense human–elephant conflict in this region.

The findings of the present study show that elephant damage to crop fields occur round the year in this division, though the peak was observed from the month of October to the month of January of the subsequent year. As shown in **Figures 2,** Hosur Division receives a maximum rainfall during the northeast monsoon that peaks during October–November. In general, rainfall influences the wet season movements of elephants by providing many temporary water sources and by favouring a luxurious growth of grass, the main food source for the elephants. This has been documented both in Asia (Baskaran 1998) and Africa (Leuthold and Sale (1973). Similarly, several studies have documented a higher elephant density in dry thorn forest during the northeast monsoon time (Sukumar 1985, Sivaganesan 1991, Baskaran *et al*. 1995, 1998) due to the availability of young grass in soft texture (Sivaganesan 1991). The elephant habitats in Javalagiri range and further north in Bannerghatta National Park is known to have more dry thorn forest (Rameshkumar 1994), whereby higher elephant movement take place during northeast monsoon time and this period coincides with the extensive cultivation of ragi, a rain-fed crop. As forest areas are more fragmented in the northern (Denkanikotta and Javalagiri ranges) part of Hosur division, the higher elephant movements among fragmented forest patches could result in higher damage to crop field in this region. Therefore, the higher damage to crop fields during Oct–Jan in Hosur division could be related to the influence of northeast monsoon coupled with fragmentation of habitats on the elephant movement pattern.

The type of crop cultivated could also influence the extent of crop damage by elephants (Sukumar 2003). The study further show that ragi was the major crop cultivated extensively in all the villages, constituting nearly 60% of the total cultivation area. Although the people are aware that ragi is one of the most palatable crop species for elephants, the fact that it is a staple food of the rural community in this region, farmers are unwilling to replace ragi with some other crops. Therefore, there is a need for an integrated approach to solving such basic problems. A scheme to supply food grain needed for rural people in exchange for food grains of crops that are unpalatable to elephants would encourage the farmers to shift their cropping pattern. Secondly, though there has been an increase in the extent of vegetable and fruit cultivation in areas around the northern part of the division due to growing demands from nearby Bangalore city, people are still into the intensive farming of these crops that yield more economic profit than old traditional crops like ragi and maize. Nevertheless, with such intensive farming tolerance level among farmers to crop damage by elephants is decreasing over years, which could also result in significant increase in compensation payment towards crop damage in the recent years.

The Hosur Forest Division, being a territorial division, accommodated in the past a large number of cattle pens inside the forest areas. With cattle grazing continue to exert further stress on the habitat resulting in a reduction of grazing areas for elephants due to human disturbance during the day hours and also by depleting fodder resources available to elephants. Given that the forest area in this division falls under a low rainfall gradient, the long grazing pressure exerted is very severe. Additionally, the large human population lives in and around in this area is also depending on the forests for fuel wood, which adds to the existing biotic pressure. The degradation of habitats brought about by grazing and fuel wood cutting opens up spaces that facilitate the proliferation of weeds like Lantana and Eupatorium. These weeds suppress the growth of grass and other natural vegetation, which in turn results

in reduced food resources for elephants. Therefore, there is urgent need to reduce the biotic pressure in this division.

Although, the amount spent in crop protection measures such as solar powered electric fence and elephant proof trench have increased over the years, almost all such measures were only effective in the short term. They were not effective in the long term as in the cases of SPEF erected & managed by individual private owners. One reason for the failure of government established elephant proof barriers is the lack of maintenance. Since the government policy is to sanction funds only for new assets, and no funds are allotted for the maintenance of existing assets, measures taken by forest departments/ government agencies are not successful. There is a need for community participation in maintaining barriers, which needs to be clearly explained to the community concerned before the establishing a barrier in any village. The amount spent for compensation and crop protection measures significantly increased over the years (**Table 4**), as did the amounts proposed to be spent (**Table 6**) in the future, while the human–elephant conflict continues to increase over the years and does not show declining or stabilizing trends. The reason for such a situation is that compensation payment for crop damage or human death (or even for elephant proof barriers to some extent) are only temporary measures. Since elephants are wide ranging species with strong fidelity to their home range and corridors, an equal or more importance needs to be given to permanent solutions such as consolidating the elephant habitats. Reestablishing elephant corridors cutoff in the recent past, and relocation of enclave villages into the isolated forest patches without elephants, with better welfare packages, would not only reduce the human–elephant conflict but also enhance peoples' living standards.

## 5. SUMMARY

- The present study was carried out to assess the status of human–elephant conflict in Hosur Forest Division located in the Nilgiri–Eastern Ghats Elephant Range in southern India between June and August 2009.
- The status of human elephant conflict that prevailed over the past 12 years from 1997–98 to 2008–09 was assessed through study of the records of crop compensation applications, incidences of human casualties by elephants and elephant mortality by humans, that were available with the forest department. The analysis of the data on number of farmers affected showed that crop damage by elephants increased significantly over the past twelve years. Similarly, compensation amount paid towards crop damage by elephants has also increased significantly over the years. However, the incidences of human casualties by elephants, and elephant mortality by humans, did not show any trend.
- Data on spatial variation of crop damage by elephants reveals that of the five forest ranges, which have elephants distribution, two were affected more intensively and their damage increased over the past eight years (from 2001–02 to 2008–09). Further, incorporation of village-wise crop damage, human death and elephant mortality onto land use maps using a GIS framework shows that distribution of human–elephant conflict was more common among the ranges with fragmented forests than with those having contiguous forests, indicating influence of habitat fragmentation on human–elephant conflict.
- Types of crops cultivated by farmers and their damage by elephants were evaluated through a rapid questionnaire survey covering 740 farmers across 120 villages located in and around Hosur Forest Division. The results show that farmers cultivate both annual and perennial crops and the important crops are ragi (*Eleusine coracana*), paddy (*Oryza sativa*), maize (*Zea mays*), and vegetables like tomato (*Solanum lycopersicum*), cabbage (*Drassica oleracea*), and fruits like mango (*Mangifera indica*) and banana (*Musa paradisiacal)*. However, ragi was a major crop cultivated by the farmers in this region that constitute nearly 60% of the total cultivation followed by vegetables. Most of the important crops cultivated were eaten by elephants, though not tomato, with ragi being most preferred.
- Range-wise comparison of human–elephant conflict with their landscape variables such as fragmentation level, number and extent of settlements/cultivation and perimeter of forest boundary with settlement/cultivation reveals that ranges with more forest fragmentation and perimeter of forest boundary with settlement/cultivation experienced greater human–elephant conflict. While the forest range with more contiguous forest and less perimeter of forest with settlement/cultivation experienced less human–elephant conflict.
- Overall, the results show that forest fragmentation appears to be the major cause of human–elephant conflict with biotic pressure acting as a contributing factor. The points to the need to consolidate elephant habitats and to reduce biotic pressure to minimize the human–elephant conflict.

## REFENCES


AERCC, (1998). Asian Elephant Research and Conservation Centre. The Asian elephant in Southern India: A GIS database for conservation of Project Elephant Reserves. Centre for Ecological Sciences, Indian Institute of Science Bangalore.

Athreya, V.R., Thakur, S.S., Chaudhuri, S., & A.V. Belsare. (2004): A study of the man-leopardconflict in the Junnar Forest Division, Pune District, Maharashtra. Submitted to the Office of theChief Wildlife Warden, Nagpur. Maharashtra Forest Department and the Wildlife ProtectionSociety of India, New Delhi.

Balasubramanian, M., N. Baskaran, S. Swaminathan & A.A. Desai. 1995. Crop raiding by Asian elephant (Elephas maximus) in the Nilgiri Biosphere Reserve, South India." In *A Week with Elephants*, by J.C.Daniel & H.S.Datye (eds.), 350-367. Bombay: Bombay Natural History Society/Oxford University Press.

Bandara, R., and Tisdell, C., 2003. Comparison of rural and urban attitudes to the conservation of Asian elephants in Sri Lanka. Biological Conservation 110, 327–342.

Barua, P. & S.S. Bist. 1995. "Changing patterns in the distribution and movement of wild elephants in north Bengal." In *A Week with Elephants*, by J.C. Daniel & H.S. Datye (eds.), 66-84. Bombay: Bombay Natural History Society/Oxford University Press, 1995.

Baskaran, N. 1998. Ranging and resource utilization of by Asian elephants *(Elephas maximus Lin.)* in Nilgiri Biosphere Reserve, South India. Ph.D. Thesis, Bharathidasan University, Thiruchirapally.

Baskaran, N.. Kannan, G., and Anbarasan, U., .2007. Conservation of the Elephant population in the Anamalais-Nelliyampathis and Palani hills (Project Elephant Range 9), Southern India.

Bist, S.S. 2002. An Overview of Elephant Conservation in India. Indian Forester 128(2): 121–136.

Boominathan, D., N. Mohanraj, T. Aziz & A. Desai. Management of the Asian elephant in the Nilgris and Eastern Ghats: human-elephant conflict in Somwarpet Subdivision (Madikeri Forest Division). WWF AREAS, 2008.

Chandra,J.(1997). Crop damage caused by blackbucks ( Antilope cervicapra) at Karera Great Indian Bustard Sanctuary, and possible remedial solution. Tiger paper, 24(3):26-32.

Chauhan, N.P.S.and Ramveer Singh(1990), Crop damage by over abundant population of Nilgai and Blackbuck in Haryana(India) and its management.Proc. 14th Vertebrate Pest Conference, University of California, Davis, pp.218-220.

Chhangani,A.K. and Mohnot,S.M 2004 Crop raided by Hanuman Langur *Semnopithecus entellus* in and around Aravallis (India). Primate report.

Daniel, J. C., Desai, A. A., Sivaganesan N., and Rameshkumar, S. 1987. The study of the some endangered species of wildlife and their habitats-The Asian elephant. Report October 1985 to September 1987. Bombay Natural History Society, Bombay.

Daniel, J. C., Manakadan, R. and Swaminathan, S. 2006. An assessment of the population, distribution, habitat use and problems of Asian elephant (*Elephas maximus*) in Koundinya Wildlife Sanctuary, Andhra pradesh, India. Final report to U.S. Fish and Wildlife service. Bombay Natural History Society, Bombay.

Daniel, J.C. (.Ed.) 1980. The Asian elephant in the Indian Sub- continent. IUCN/SSC Asian Elephant Specialist Group.

Daniel, J.C., A. Desai, A. Kumar & C. Sakthivel. Evaluating population enumeration methods and human elephant conflict mitigation methods in Mudumalai Tiger Reserve, Tamil Nadu, India. Unpubd., Mumbai: Bombay Natural History Society, 2008.

Datye, H.S. & Bhagwat, A.M. 1995. Home range of elephants in fragmented habitats of

Desai, A.A. & N. Baskaran. "Impact of human activities on the ranging behaviour of elephants in the Nilgiri Biosphere Reserve, South India." *Journal of Bombay Natural History 93*, 1996: 559-569.

Dey, S.C. 1991. Depredation by wildlife in fringe areas in North Bengal with special to elephant damage, *Indian Forester*, 117(10): 901-908.

Harikrishnan, M. The Forest working plan for Hosur Forest Division between1972-1982

Hedges, S.2006. Asian Elephants: Status and Threats. Elephant Range States Meeting, Kuala Lumbur, Malaysia.

Hoare, R., 1999. Determinants of human–elephant conflict in a land-usemosaic. Journal of Applied Ecology 36 (5), 689–700.

IUCN Red List 2008 The IUCN Red List of Threatened Species. http://www.iucnredlist.org/details/7140: Date of Access October 16, 2008.

Koehl, D. 2006. Elephant News. http://www.elephant-news.com/index.php?type conflict.(Accessed in January 2007).

Lahiri Choudhury, D. (1980) An interim report on the status and distribution if elephants in north-east India. In The status of the Asian elephant in the Indian sub-continent (ed. J. India. Tiger Paper 30, 3-6.

Leimgruber, P., J.B. Gagnon, C. Wemmer, D.S. Kelly, M.A. Songer & E.R. Selig."Fragmentation of Asia's remaining wildlands: implications for Asian elephant conservation." *Animal Conservation 6*, 2003: 347-359.

Leuthold, W. and J. B. Sale. 1973. Movements and patterns of habitat utilization of elephants in Tsavo National Park, Kenya. *E. Afr. Wildl. J.* **11**: 369-384.

Madhusudan,M.D. (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(4): 466-475

Mani, P.A.2007 The Forest working plan for Hosur Forest Division between 2007-2017.

Mukherjee, S. 2003. Tiger human conflicts in Sundarban tiger reserve, West Bengal, India. Tiger Paper 30, 3-6.

Nath, C. and Sukumar, R. 1998. Elephant-human conflict in Kodagu, southern India: distribution patterns, people's perceptions and mitigation methods. Un published report, Asian Elephant Conservation Centre, Bangalore.

O_Connell-Rodwell, C.E., Rodwell, T., Rice, M., Hart, L.A., 2000. Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. Biological Conservation 93, 381–391.

Pirta. R.S., Gadgil, M. and Kharshikar,A.V. 1977. Management of the rhesus monkey, *Macaca mulatta* and Hanuman langur *Presbytis entellus* in Himachal Pradesh. India. Biol. Conserv. 70: 97-106.

Rajpurohit, K. S. and P. R. Krausman. 2000. Human-sloth-bear conflicts in Madya Pradesh, India. Wildlife Society Bulletin 28, 393-399.

Rajpurohit, L. S. (1993). Bluebull (*Boselaphus tragocamelus*) depredation on crop field andother mammalian pests around Jodhpur. Proceedings of the National Symposium on UnconventionalPests: *Control vs conservation*. Bangalore: University of Agriculture Science Bangalore.

Ramesh Kumar, S. 1994 Ecology of Asian Elephants(*Elephas maximus*), their habitats and interactions with people in Hosur and Dharamapuri Forest Divisions, Tamil Nadu South India. Ph.D. Thesis Submitted to Bharathidasan university, Thiruchirappali.

Saberwal, V. K., Gibbs, J. P., Chellam, R. & Johnsingh, A. J. T. (1994) Lion-Human Conflict in the Gir Forest, India. *Conservation Biology*, **8,** 501-507.

Saberwal, V. K., J. P. Gibbs, R. Chellam, and A. J. T. Johnsingh. 1994. Lion-human conflict in the Gir Forest, India. Conservation Biology 8, 501-507.

Santiapillai, C. and Sukumar R. 2006. An overview of the status of the Asian elephant's. *Gajah.* 25: 3-8.

Santiapillai, C., Jackson, P., 1990. The Asian Elephant: An ActionPlan for Its Conservation. IUCN/SSC Asian Elephant SpecialistGroup, Gland, Switzerland.

Shahi, S. P. (1982). Report of Grey wolf (*Canis lupus pallipes sykes*) in India—a preliminary survey. Journal of Bombay Natural History Society, 79, 493–502.

Singh, M., and Raval, P P. (2000). Crop damage by Wild ungulates around Gir protected area—A report. Gir National Park and Sanctuary. Forest department. Gujarat State.

Sinha, S.P. (2000). Man-animal conflicts in and around the Gir protected area—A report, Gir National Park and Sanctuary, Forest Department, Gujarat State

Sitati, N.W., Walpole, M.J., Smith, R.J. & Leader-Williams, N.(2003) Predicting spatial aspects of human-elephant conflict. *Journal of Applied Ecology*, 40, 667–677.

Sivaganesan, N. 1991. The ecology of the Asian elephant in Mudumalai Wildlife Sanctuary, with special reference to habitat utilization. *Unpublished Ph. D. Thesis.* Bharathidasan University, Tiruchirapalli.

Smith, R.J. & S.M. Kasiki. *A spatial analysis of human-elephant conflict in the Tsavo ecosystem, Kenya.* January 2000

Srivastav, A., Meena, R. L., Kamboj, R. D., Singh, M., Raval, P. P., and Parmar, M. (1998). Lion Meta population of Gir—A report on transect survey. *The Indian Forester,124(10),*771–782.

Subbiah, V.1982. The Forest working plan for Hosur Forest Division between 1982-92. The forest working plan division, Madras. Pp.420

Sukumar, R. 1985. Ecology of the Asian elephant *(Elephas maximus)* and its interaction with man in south India, Ph. D., Thesis, Indian Institute of Science, Bangalore. India.

Sukumar, R. 1989. The Asian Elephant: Ecology and Management. Cambridge Univ. press, Great Briton.

Sukumar, R. 2003 The Living Elephants: Evolutionary Ecology, Behavior and Conservation. Oxford University Press, New York.

Tchamba, M.N. (1996) History and present status of thehuman/elephant conflict in the Waza-Logone region, Cameroon, West Africa. Biological Conservation, 75, 35–41.

Veeramani, A 1999. An assessment of crop damage by wild animals and effectiveness of control measures, Ph.D., Thesis submitted to Forest Research Institute, (deemed university) Dehradhun.

Walpole, M., N.Sitati, B. Stewart-Cox, L. Niskanen & P.J. Stephenson. "Mitigating human-elephant conflict in Africa: a lesson-learning and network development meeting." *Pachyderm 41*, July-December 2006: 95-99.

Woodroffe, R., S. Thirgood and A. Rabinowitz (2005), The impact of human-wildlife conflict on natural systems, in Woodroffe, R., S. Thirgood and A. Rabinowitz (eds.), *People andWildlife. Conflict or Coexistence? ,* 1–12. Conservation Biology 9. The Zoological Society of London. Cambridge University Press, U. K.

Zhang, L., Wang, N., 2003. An initial study on habitat conservation ofAsian elephant (Elephas maximus), with a focus on human elephantconflict in Simao, China. Biological Conservation 112, 453–459.

## Appendix 1. Human–elephant conflict questionnaire used for rapid survey

**General details**

| | | |
|---|---|---|
| 1 | Date | |
| 2 | Division Name | |
| 3 | Range Name | |
| 4 | Village Name | |
| 5 | Village Location | Peripheral / Enclave / Corridor |
| 6 | Farmer's Name / Religion/ living since how long? | Hindu/Muslim/Christian<br>Many generation / Second generation /Recently settled |
| 7 | Location | Latitude: Longitude |
| 8. | Distance from RF / Adjoining habitat type | …….. km / DEGF/MDF/DDF/DTF Others if any:_____ |
| 9 | Types of damage | Crop / House /Stored grains/ Infrastructure / Live stock / Human casualty (Injury/ Death)<br>Month & year of casualty:<br>Caused by: Herd / Bull |
| 10 | Area owned | _____ Acres |

**Human casualty & elephant mortality details:**

| | | |
|---|---|---|
| 12 | Human casualty details | Victim's Sex: M / F Age:<br>Incident location: Crop field/ House/Forest:<br>Lat: Long:<br>Compensation: Clamed: Yes/No<br>Received: Rs. _____ |
| 13 | Elephant mortality due to HEC | Month & Year:<br>Nature of mortality: Electrocution / Gunshot / Poisoning<br>Lat: Long: |

**Human casualty & elephant mortality details:**

| | | |
|---|---|---|
| 12 | Human casualty details | Victim's Sex: M / F Age:<br>Incident location: Crop field/ House/Forest:<br>Lat: Long:<br>Compensation: Clamed: Yes/No<br>Received: Rs. _____ |
| 13 | Elephant mortality due to HEC | Month & Year:<br>Nature of mortality: Electrocution / Gunshot / Poisoning<br>Lat: Long: |

**Mitigation measures & compensation details:**

| | | |
|---|---|---|
| 14 | Crop protection type | Ordinary fence / Electric Fence / Trench / Other's in any_____ |
| 15 | Efficacy | Successful / Failure |
| 16 | Crop protection measure established by | Self / Govt<br>Which Dept._____ |
| 17 | Crop compensation claimed/ received during last three years | 2006-07: Claimed: Yes/ No. Rs.<br>2007-08: Claimed: Yes/ No. Rs.<br>2008-09: Claimed: Yes/ No. Rs. |
| 18 | Farmer's opinion about the causes of HEC | Habitat loss & Fragmentation / Habitat degradation / Increase of elephant population / Lack of water sources / Others if any_____ |