4.1 Introduction

“In the case of elephant and man we have one of the best examples known of two superficially dissimilar animals sharing common biological needs, and therefore competing vigorously whenever they contact each other.”- Alistair Graham (1973).

The gradual loss of habitat coupled with changing land-uses and ever increasing human population, influences the degree of wildlife movement and thus the chances of frequent interactions with human being ensuing to a conflict situation. Large scale degradation of natural landscape due to human activities has resulted in the reduction of habitat of a wide range of species. Such habitat fragmentation and the ensuing interspersion of human habitation and cultivation brought wildlife into greater contact with humans, leading to an escalation in human-animal conflict (Sukumar, 1994; Hoare, 1999; Williams et al., 2001; Madhusudan, 2003; Sitati and Walpole, 2006). A wide range of species are responsible for conflict, with the principal wild animals being primates, rodents, ungulates, large herbivores like elephants and guar, and top carnivores like lions, leopards and tiger (Naughton, 1998; Naughton et al., 1998; Rodwell et al., 2000; Saj et al., 2001).

Conflict arises from a range of direct and indirect negative interactions between humans and wildlife. These can culminate in potential harm to all involved, and lead to negative human attitudes, with a decrease in human appreciation of wildlife and potentially severe detrimental effects for conservation (Boer and Baquete, 1998; Nyhus et al., 2000). The wide-ranging nature of elephants, the 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; Balasubrahmanian et al., 1995; Desai and Baskaran 1996;
Baskaran et al., 2007). Human-elephant conflicts are generally referred as negative interactions between elephants and human beings throughout existing ranges of the former.

Human-elephant conflict is a symptom of inappropriate land use practices such as permanent human settlements and growing irrigated food crops adjacent to elephant range lands (Choudhury, 1991; Johnsingh and Joshua, 1994; Sivaganesan and Johnisingh, 1995; Hoare 2001; Fernando et al., 2008). The underlying cause of human-elephant conflict is habitat loss (Desai, 2002). Human-elephant conflict occurs because humans and elephants have overlapping interests. Elephants tend to have large home ranges with traditional migration routes. According to Sukumar (2003), the average home range of a herd in India is 267 km². In south India the elephant home range extends up to 651 km² (Baskaran et al., 1995). But in south-western West Bengal the home ranges is amazingly vast and extend up to 3708 km² (Chowdhury, 1998n and Sukumar, 2003).

The large areas required by elephants are susceptible to a range of habitat related threats such as loss, degradation and fragmentation which lowers the capacity of that habitat to support previous densities of elephants (Williams et al., 2001; Johnsingh et al., 2008). When their home ranges are reduced by human encroachment, the elephant habitat becomes fragmented and the traditional migration routes become disrupted. This will restrict the access to forage, refuge areas, saltlicks, and water and the elephants are forced to move towards the human occupancy or human converted landscape elements. It is reported that they compensate for this loss by eating crops, while bulls in particular may take advantage of the easy availability of crops and stored grain (Sukumar, 1989). Furthermore an adult Asian elephant requires about 150 to 300 kg of forage per day (Fernando et al., 2008) and spend anywhere from 40 to 75% of their time feeding on a varied diet of grasses, forbs, aquatic plants, foliage, bamboo, roots, bark, dry twigs, pith of bananas and fruits (Sukumar, 2003).

During the dry season when grass became inadequate elephants used to browse on plants. The nutrient derived from browse is far more important than grasses (Sukumar and Ramesh, 1995). Elephants eat almost every food crop that humans do. They even eat parts of cash crops such as cotton, cocoa and timber.
trees (Hoare, 2001). Elephants are capable of surviving on low quality forage (Balasubrahmanian et al., 1995; Grant et al., 2008) while also taking advantage of high quality crops to supplement or compensate their diet during dry season.

The fragmentation of elephant habitat also results in pocketed herds, which may have to depend on crop raiding for its survival. When the forest fragmentation continues in an area, resident elephants become squeezed into an ever decreasing forest patch, thereby increasing their density beyond the carrying capacity and placing a strain on the available resources. Furthermore, human activities, like logging, usually give rise to secondary vegetation which can attract elephants, so drawing them closer to human settlements. Elephants habitually frequent in to the proximate human settlements and destroy crops, raid stored food grains, damage house and properties and occasionally in the process injure or kill people too. On the contrary, people retaliate by deliberate measures to keep elephants away and often in extreme, injuring or killing them.

These conflicts result when elephants damage crops or property or when they accidentally kill or injure people during their movement through increasingly fragmented modern landscapes. In these encounters, elephants are often shot or wounded by humans, either in self-defence or in retaliation. Besides endangering wildlife and conservation efforts, human-elephant conflicts are also a serious threat to rural populations as conflicts often threaten the lives and livelihoods of thousands of farmer families (Kumar et al., 2011).

4.1.1 Modes of negative interaction

a. Damage to agriculture crop

Damage to crop at the forest-agriculture interface is the greatest and most widespread form of human-elephant conflict (HEC) occurring around elephant habitats. Crop raiding by elephants has received much attention in the last few decades in both Asia and Africa. In Asia, HEC had been quite widely studied; especially in India (Sukumar, 1989; Sukumar et al., 1991; Zhang, 2007). Crop damage inflicted by elephants on such interface is widely concerned due to high crop loss through consumption and trampling (Sukumar, 1989; Thouless, 1994; Balasubrahmanian et al. 1995; Datye and Bhagwat, 1995).
Crops provide the same nutritional rewards for elephants as they do for humans, and elephants are known to raid crops either because natural food abundance in their habitat is not sufficient to support their population size, or because of their optimal foraging strategy (Sukumar and Gadgil, 1988; Sukumar, 1991; Osborn, 1998). Some studies indicate that despite the availability of abundant natural forage, relatively intact and extensive natural habitats, some elephants indulge in eating crops (Sukumar, 1989; Barnes et al., 1995; Naughton-Treves, 1998). Elephants are known to consume a variety of crops including rice, maize, sorghum, wheat, coconut, banana, and a variety of vegetables and fruits (Sukumar, 2003). Studies have shown that there is a great deal of variation on types of crop raiding by elephants and most of these tend to be site specific.

The study in South India by Sukumar, (1989) showed that the types of crops consumed by elephants are commonly analogous with elephant food in the wild. In Malaysia, wild elephants often damage oil palm and rubber plantations, and the economic loss of the damage is significant (Stuwe et al., 1998). Despite the large variety of crops damaged by elephants, major cultivated crops that are normally raided can be grouped based on the families, Graminea (grasses), Palmae (palms) and Leguminose (legumes) which are also known to serve as major food of elephants in the wild (Sukumar, 1989).

Bulls are known to utilize exclusive habitats, the bull areas, which are usually too marginal or poor in resources to be used by female herds (Sukumar, 2003). Bull elephants are more prone to eating crops because of its availability in high densities, and its higher nutritive value (Sukumar, 1985b; Chiyo et al., 2005; Sitati et al., 2005). Crops provide bulls with a distinct nutritional advantage (Sukumar, 1985b) to sustain longer periods of musth and still survive the long dry season (Seidensticker, 1984). It is these few elephants that cause the bulk of the damage. In a single night, a bull can travel up to 6 km through cultivated fields (Sukumar, 1986), while herds eat crops opportunistically, not venturing further than 1km from the forest boundary (Sukumar, 1989). If undithered, bulls can become habitual crop-raiders (Boominathan et al., 2008). By eating crops more frequently and ranging farther than herds, bulls are at an increased risk of being injured or even killed by crop-guarding farmers. crop-raiding bulls have larger home ranges (~400 km²) than other bulls (150-200 km²), they eat crops in a restricted area within their home range and for only part of the year.
(Williams et al., 2001). But when they succeed in eating crops, elephants receive enormous gains from the highly nutritious plants (“high-risk, high-gain”) (Sukumar and Gadgil, 1988). Solitary bulls try to minimize the risk by forming groups of 2 to 4 before entering cultivation (Sukumar, 1986). In fact, some bulls appear to be disturbance-tolerant, as they were consistently found closer to settlements than females (Hoare, 1999).

Crop raiding is also known to be seasonal (Osborn and Parker, 2002). Habitat factors are important in determining the nature and extent of crop raiding by elephants; thus the reduction of natural habitat or its fragmentation may leave elephants with little choice but to seek a part of their forage needs from cultivated fields (Sukumar, 1985b, 1989). Elephants that share habitat with humans have large home ranges (Weerakoon et al., 2004); elephants with large home ranges are likely to move some of it to agriculture (Williams, 2001); elephants that suffer from habitat loss are more prone to eating crops (Balasubrahmanian et al., 1995). At the same time, the increased fragmentation of habitat increases the frequency of such conflict over larger regional scales (Sukumar, 2003). Some factors considered being responsible for the seasonal pattern of crop raiding are rainfall (Hoare, 1999), elephant movement (Tchamba, 1996), high nutrient contents in ripe crops (Sukumar, 1990), and decline in the food quality in the elephant habitat (Osborn, 1998).

Yet, in Africa, variability in rainfall did not attract more elephants to better crops (better nutrition per unit area) (Hoare, 1999) but more productive farms were damaged to a greater extent than less productive farms (Boer and Ntumi, 2001). The relationship between habitat features and crop raiding by elephants has also been identified in Africa (Hoare, 1999). The study showed that elephant density, proximity to Protected Areas, area of human settlement, human density or local rainfall could not predict conflict spatially. Furthermore, these studies demonstrated that crop raiding is unpredictable because most of the raiding was by bull elephants, so the conflict incidents were strongly associated with behavioural ecology of individual elephants (Hoare, 1999). “Prime bulls” in the middle age class are known to restrict their movements to areas frequented by herds (Osborn, 1998). Presumably it is the younger bulls that eat crops more. In this case, to understand crop-raiding behaviour, probably need to understand the foraging strategy of bull elephants.
b. Damage to property

There is little published data on property damage caused by elephants across their range. Tea plantations dominate the Valparai plateau and property damage is the more prevalent form of conflict unlike other elephant conflict areas in India (Kumar et al., 2004). Elephants occasionally damage school kitchens, ration shops and houses. A one year study (2002-2003) recorded 117 incidents of building damage, 31 incidents of eating stored provisions and about 8 miscellaneous events involving office equipment and automobiles. Most of the damage was caused by herds. In similar, tea estate dominated parts of Sonitpur District (Assam), property damage was the main form of conflict. Bulls typically eat bamboo, bananas, grass, tubers that grow in kitchen gardens near houses which leads to incidental property damage. But they also deliberately break into houses looking for salt, stored grain, home brewed alcohol, wheat and maize flour (Williams et al., 2001; Lahkar et al., 2007). In the township of Masinagudi (Tamil Nadu), much of the conflict occurs near to water installations. Residents complain of water pipes being pulled up and water tanks being destroyed during the dry season. Elephants also tend to deliberately damage structures (Desai, 2002).

c. Human kills and injuries

Attack on humans and manslaughter by elephants usually occurs during direct encounter between elephants and human beings. A variety of direct interactions by elephants leading to human injury and killing have been widely reported from Africa and Asia. In Africa, Thouless, (1994) and Tchamba, (1996) studied the human kills by African elephants and observed that the changes in climatic conditions especially the occurrence of extreme drought has resulted a high rate of human casualties by the attack of elephants. In India, Sukumar, (1989) reported killing of 30-50 people every year in southern region containing largest elephant habitat and population. The study further analyzed killing of adult men (77%) constituting mostly farmers, grazers and laborers. While working in Kodagu district, South India, Nath and Sukumar, (1998) recorded average 6 human deaths by elephants per year. Dey, (1991) reported human deaths ranging between 28-59 per year, from fragmented habitats of North West Bengal between 1980-90, though this region has only 1% of the total wild elephant
population in India. Similar reporting by Barua and Bist (1993) from the same region accounts killing an average of 47 people per year since 1981. Datye and Bhagwat, (1995) reported a total of 208 human deaths between 1980 and 1991 from south Bihar (134) and south West Bengal (74) through pocketed elephants on a fragmented landscape. Occasional dispersal and straying of elephants to the unknown habitats has also taken toll of human lives in Andhra Pradesh, South India; Madhya Pradesh and south Bihar in Central India (Sukumar, 1991). Williams and Johnsingh, (1996a) recorded total death and injury of 115 human from three districts of Garo hills, Meghalaya during 1984 - 1995. From other Asian country in Sri Lanka Jayawardene, (1993a) and Santiapillai and Silva (1994) also have accounted killing of human being in Mahaweli Project area and Hadapanagala area in Sri Lanka respectively.

The encounter with elephants usually occurs with the people from the settlements which were in the fringe areas of forest and forest plantations. Mostly the farmers and the people engaged in fire wood collection, non-timber forest produce collection and cattle grazing. (Sukumar, 1989; Thouless, 1994; Datye and Bhagwat, 1995). Information available on types of elephants causing human killing is scanty. Several authors have accounted bulls more responsible for human killing (Sukumar, 1989; Thouless, 1994; Williams and Jhonsingh, 1996a; Chowdhury et. al. 1997) due to their bad temperament and boldness, while others also have reported the herd’s involvement (Thouless, 1994; Datye and Bhagwat, 1995; Kumar, 1995) particularly with young calves.

d. Impact on ecosystem

Various authors have documented selective damage to several tree species by elephants leading to alteration of habitat on a long-term basis (Savidge, 1968; Guy, 1976; Eltringham, 1980; Sivaganesan and Sathyanarayana, 1993). Elephants are known to feed more on smaller trees as the branches are at lower heights and the trees can be pushed down more easily (Wing and Buss, 1970; Eisenberg and Lokhart, 1972; Bhaskaran et al., 1995). The plant *Zizipus xyloprius* is a highly preferred species by elephants and had undergone a 15% annual mortality due to elephant use in Mudumalai (Daniel et al., 1995). Another species that had been nearly wiped out from Mudumalai is the *Boswellia serrata* which is now confined to inaccessible hills of Moyar gorge (Daniel et al., 1995). In dry
deciduous forest of South India *Grewia tiliaefolia* and *Zizyphus xylopyrus* have been severely damaged due to uprooting (Sivaganesan and Sathyanarayana, 1993). In Sri Lanka, Mueller-Dombois, 1972 reported damage of several tree species due to crown distortion in Ruhuna National Park. Among which *Feronia limonia* was recorded particularly most affected with crown distortion in thorny evergreen forest. In some areas of South India, it was observed that the elephants feeding on the bark of eucalyptus (Sukumar, 1990).

In Africa tree species like *Acacia albida*, *A. gerrardii*, *A. tortilis*, *A. Xanthophloea*, *Colophospermum mopane*, *Commiphra ugogensis* and *Baobabs* are particularly reported to damage due to debarking, pushing and uprooting (Savidge, 1968; Croze, 1974; Harrington and Ross, 1974; Sherry, 1975; Leuthold, 1977; Barnes, 1983). Thomson, (1975) has reported severe damage to Brachystegia woodland on Siamagogas Ridge in Chizarira Game Reserve, Zimbabwe due to excessive debarking.

### e. Retaliatory killing of elephants

In severe conflicting areas, the retaliatory killing of elephants by the inhabitants was observed to reduce the conflict. In India, Sukumar (1989), recorded death of at least 3-8% male and 17-19% female in crop protection measures out of the total elephant death from state of Tamil Nadu and Karnataka between 1975-87. Killings were done by gun shots or electrocution. Killing of elephants through electrocution has also been reported from Chittoor district of Andhra Pradesh, South India (Rao, 1993). Barua (1993), reports killing of at least 3 elephants in North Bengal during 1992 in crop protection measures possibly through gun shots.

Williams and Johnsingh (1996a), reports killing of 28 elephants in Garo hills, Meghalaya between 1984-1995 out of which 32% were killed by gun shots. Several cases of killing to problematic elephants after declaring rogue have been reported from North Bengal (Choudhury, 1980; Barua, 1993; Barua and Bist, 1993) and Haldwani, Uttaranchal (Nestrong and Smetacek, 1972). Barua (1993), also reported 13 cases of calf abandoning due to continuous stress in North Bengal between 1986-92, of which 12 died.
In other part of Asia elephant killing in conflict incidences has also been reported from Sri Lanka by several authors through gun shots (Kay, 1973; Jayawardene, 1993a and 1993b; Santiapillai, 1994; Santiapillai and Silva, 1994) and poisoning with insecticides. Jayawardene, (1994) and Santiapillai, (1994) gives a detailed account of elephant mortality in Sri Lanka between 1951-1969, showing that a total of 639 elephants were killed in defense of crop during that period.

4.1.2 Management of human-elephant conflict

The causes of conflict are often complex and difficult to resolve. As long as humans and elephants share the same landscape, human-elephant conflict can never be eliminated, it can only be reduced. The protection of elephant habitat and providing enough resources are the most important and effective measure of managing human - elephant conflict. The intensity of the conflict such as the distribution, frequency and severity of the raiding should be evaluated before implementing any mitigation measures (Hoare, 2001). Community based planning is essential for the management of HEC (Lee, 2002). The mitigation measures generally include the traditional methods ranging from land use planning, habitat enrichments, change in cultivation practices, demarcating protected areas and buffer zones, forming corridor to adjoining forests, elephant proof trenches, electric fences, guarding, use of repellents and removal and translocation of elephants. (Daniel, 1996).

4.2 Review on human-elephant conflicts

4.2.1 Human-elephant conflict perspective in Asia

Human-elephant conflict is one of the central conservation issues of elephant habitats across Africa (Thouless, 1994; Hoare, 1999; Dublin and Hoare, 2004) and in Asia (Blair et al., 1979; Sukumar, 1994; Williams et al., 2001). More scientific studies on human-elephant conflict for the development of management strategies are carried out in Africa (Naughton, 1998; Hoare, 1999; Sitati et al., 2003).

Human-elephant interactions have always had profound consequences on their respective distributions, but more recently conflict has generally led to the retaliatory killing of elephants (Parker and Graham, 1989; Hoare and Toit, 1999)
and represent the primary threat to the survival of the Asian elephant, a globally endangered species (Sukumar, 2006; Perera, 2009). The focal points of human-elephant conflict are usually the edges of protected areas (Hart and O’Connell, 1998). Mitigation of conflict demands a detailed investigation of the status and patterns of conflict.

The resident population of around 151 to 344 wild elephants in Bangladesh (Feeroz et al., 2004) are restricted to the south-eastern forested areas, which are shrinking due to pressure from human activities, leading to increasing incidents of HEC. The non resident elephant herds in Bangladesh which is migrating from Meghalaya, Assam and Myanmar cause serious damage to crops and houses. Feeroz et al. (2004) report that during a period of one year from June 2001 to May 2002, HEC occurred in 28% of the elephant range and resulted in 38 deaths and 94 injuries to humans, as well as 3 elephant deaths and damage to crops and households amounting to US$ 86,000.

According to Murdoch, (2008) though an elephant population of around 600 which is habituated in Bhutan along the Indian territorial border region, the intensity of HEC is low because of the low human population density in this region. The investigation of ecological studies on elephant in Cambodia shows, the HEC have usually occurred in the south and south-western regions with an elephant population of around 600 (Murdoch, 2008) have been increasing with crop raiding and damage to cottages reaching frequency of two per month in some areas (Hefferman, 2004). After the establishment of Seima Biodiversity Conservation Area (SBCA) in eastern Cambodia which is an important habitat for elephants, the forest administration with the support of local communities have implemented proper land-use planning and the enforcement of law brings down the incidence of HEC in the surrounding indigenous villages to a great extent.

In China the elephant exist only in the Upper Mekong Basin with a population of around 213 are distributed in six counties (Zhang, 2007). The intensity of conflict rate was increased from 1991 to 2004 (Luo, 2007). The general methods used for the conflict mitigation include electric fences, anti-elephant ditches and walls, relocating some of the villages falling inside the elephant habitats and improving elephant habitats to increase their natural feed availability and keep them away from farm lands. Hedges et al., (2005) studied the human-elephant conflict in
Sumatra and surrounding areas. The high degree of forest fragmentation, proximity of settlements to the remnant elephant habitat and the high human population density causes a high degree of human-elephant conflict.

The elephant population in Sumatra is around 2000-2500 (Hammatt et al., 2004) and are distributed in the provinces of South Sumatra and Lampung in the south, Aceh in the north and Riau in the east. A range of strategies are used for mitigating human-elephant conflict including habitat management, barriers, early warning systems, deterrents, driving away using “flying squads” of men and mahouts with captive elephants, and capture of problem animals followed by translocation or taming. Taming of captured animals is done in elephant training centres, but the survival rate of such animals appear to be very low, raising major concerns regarding its success (Hammatt et al., 2004).

According to Khounboline (2007), there were around 800-1000 elephant population in Lao PDR, ‘the land of a million elephants’ now faces lots of human anthropogenic pressure and are dispersed within and provincial protected and its adjoining areas (Khounboline, 2007). The villagers in rural areas practiced shifting cultivation within or near the network of protected areas. The establishment of several development projects in the elephant habitat further reduce habitats available to elephant and HEC are increasing and it is now become a social and economic issue. The retaliatory killing of elephants along with poaching for ivory also threatens the survival of elephants (William, 2008). The main mitigation methods include community based crop defence involving early warning systems and active as well as passive deterrents (Khounboline, 2007).

In Malaysia there are around 1220-1466 elephant (Perera, 2009) and the human-elephant conflict occurs in most areas around the elephant habitats. The mitigation measures used include erection of electric fences and translocation of problem animals to protected areas (Murdoch, 2008). In Myanmar 50% of the landmass is covered with forest and have an elephant population of around 4000-6000 (Kyaw and Cho, 2004). The number of incidents of crop raiding, damage to houses and human deaths is increasing, and the main methods of mitigation are driving elephants back to forest habitats and capture followed by translocation or taming (Kyaw and Cho, 2004). A study by Leimgruber et al.
Chapter 4: Ecological investigation of human-elephant conflict at Anayirangal, Munnar landscape, Southern Western Ghats

Hefferman (2004), reported that in Vietnam around 57 to 81 elephants are distributed in 11 different areas and the human-elephant conflict reached at crisis level. The fragmented nature of the present population and the continuing pressure on limited habitats, indicate the need for urgent action to prevent the extinction of Vietnam’s elephants. Thailand has an elephant population of around 3000 to 3500 elephants and are scattered over 60 protected areas (Stewart and Ritthirat, 2007). Human activities inside the forest cause considerable disturbance to elephants but the reforestation programme for the habitat improvement together with measures to improve the income and quality of life of the rural people, resulting in a marked reduction in HEC (Srikrachang and Srikosamatara, 2005).

Sri Lanka has around 3500-4000 elephants which constitute 10% of the wild Asian elephant population. The intensity of HEC in many rural areas adjacent to elephant habitats has been increasing rapidly. Between 1992 and 2001, 536 people were killed by wild elephants (75% men, 13% women and 12% children). On average, HEC results in deaths of 150 elephants and 50-70 humans each year. However, in spite of the severe hardships and economic losses suffered by rural people, many still have a positive attitude towards elephant conservation (Bandara and Tisdell, 2003). The mitigation measures used have been comprehensively reviewed by Fernando et al. (2008). The main activities include
habitat improvement, establishment of elephant corridors and conservation areas, capture and translocation of problem animals. The retaliatory killing of elephants by electrocution and poisoning, accidental falling into agricultural wells and abandoned gem pits and collision with trains are the major causes of higher elephant mortality.

4.2.2 Human-elephant conflict perspective in India

India which holds the largest Asian elephant (*Elephas maximus*) population in the wild with nearly 27,000-29,000 animals (MoEF, 2010) has ongoing developmental activities in all the elephant ranges with the exception of a part of the north-eastern region (Leimgruber et al., 2003). Elephant is one of the most conflict-prone wildlife species in India, causing large scale damage to crops and human lives. Each year, nearly 400 people and 100 elephants are killed in conflict related instances in India, and nearly 500,000 families are affected by crop damage (MoEF, 2010). The amount spent on control measures and ex-gratia payment towards human–elephant conflict runs to ₹15 crores annually (Bist, 2002). The major reasons behind the high rate of human-elephant conflict in the country are the habitat fragmentation, degradation of habitat quality, loss of forest cover, laxity in management of physical barriers (Sukumar, 1990, 1991; Johnsingh and Joshua, 1994; Williams et al., 2001; Jeyasingh and Davidar, 2003; Gubbi, 2009).

Conflicts between humans and elephants in North-Eastern (NE) India, however, are more serious and have become a major conservation issue in Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim, and the northern parts of West Bengal. This region covers approximately 274,680 km² and represents a global biodiversity “hotspot” (Myers et al., 2000) and is home to more than 10,000 wild elephants, around 25% of the world’s elephant population (Choudhury, 1999). The region is dominated by the Eastern Himalaya Mountains, the Meghalaya Plateau, Hill ranges, the plains of the Brahmaputra and the Barak rivers, and the Manipur valley.

North Eastern India contains diverse habitat including grassland, wetland, swamps, tropical evergreen and deciduous forest, subtropical and temperate forests and alpine tundra. Human population increases and development have
reduced and fragmented wildlife habitat. Human population growth, developmental activities and cultivation have dramatically encroached on natural habitat resulted loss of more than half of the elephant’s habitat since 1950 and increase the conflict between elephants and people. Crop raiding by elephants is a common occurrence throughout the region (Choudhury, 2004). Between 1980 and 2003, more than 1,150 humans and 370 elephants have died as a result of human–elephant conflicts in North Eastern India. Unlike parts of Africa (Thouless, 1994; Kiiru, 1995; Barnes, 1996; Bhima, 1998; Hill et al., 2002), however, there is little documentation of case studies in this part of India.

Assam holds approximately 20% of India's elephant population (Talukdar and Barman, 2004) and is considered a fundamental conservation area for the Asian elephant (Choudhury, 1980; Santiapillai and Jackson, 1990; Choudhury, 1991, 1999; Bist, 2002; Talukdar and Barman, 2004). The natural habitat of elephants in Assam is rapidly diminishing because of increased land clearance for cultivation and industrial use (Talukdar and Sushanta, 2006). Indeed, forest cover in Golaghat region has decreased by 85% between 1977 and 2004 due to such developmental activities (Talukdar et al., 2004). Human encroachment has forced elephants to forage in non-protected areas, thus augmenting the likelihood of disturbing local people (Talukdar and Sushanta, 2006).

The increased opportunity for human-elephant interactions has resulted in many elephants being killed both accidentally. According to Naughton-Treves et al. (1998) and Hoare (2000), conflict is usually highest closer to protected areas that act as elephant refuges. Studies carried out near Manas National Park (MNP) and in Golaghat district of Assam confirm these tendencies (Talukdar et al., 2004; Lakhar et al., 2007). Elephant raiding was found to peak during specific times of year when rice paddy (Oryza sativa) becomes more palatable and nourishing as it approaches harvesting (Sukumar, 1990).

The mitigation measures usually practised by the local people include community guarding, construction of temporary tree houses to watch the agriculture field and cultivating alternative crops. The traditional deterrents such as shouting, drum beating, bursting firecrackers, shining torch lights, setting fire to raw jute or tires fixed at the end of bamboo sticks, known as ‘bolem’ and driving the crop raiders
using domestic elephants and firing shots in the air by the forest department are practiced (Lahkar et al., 2007).

Garo Hills, Meghalaya is a major habitat of elephants (over 1,800 in 1993 and 1,200 in 2002). In this area, increased jhum (i.e., shifting cultivation), coal mining, logging, and poaching (for meat and ivory) significantly disturbed elephants (Williams and Johnsingh, 1996a; Gurung and Choudhury, 2000). Over 200 elephants descended on the Assam’s Goalpara district where none were recorded during the census of 1993 (small numbers used to be seen seasonally). Approximately 100 elephants currently live in the scattered forest blocks and damage surrounding houses and property. From 1990 to 1992, there were no human deaths as a result of conflicts with elephants, but a few people have been killed every year since 1993.

In Mizoram, Nagaland and in the hilly areas of Manipur, human-elephant conflict has had a different history. The elephants have almost always been persecuted for their flesh, which is a local delicacy. Around 10 -12 elephants are found in Mizoram (Choudhury, 2001b) and in the hills of Manipur, most are occasional/seasonal visitors. Elephants have vanished from most parts of Nagaland, but some (upwards of 200) are found in a few pockets where the area is contiguous with Assam.

The worst case of human-elephant conflict ever recorded was in the northern area of Darrang (now in Udalguri district, Assam) in October 1992 when 4,000 villagers belonging to 900 families fled their villages and took shelter in relief camps set up by the government (Choudhury, 1999a). A study by Choudhury (1998), in Assam found that an area between Karbi Anglong and Kaziranga National Park lost a third of its annual production of paddy to elephants. This area is located near an elephant migration route.

4.2.3 Human-elephant conflict in Kerala and Southern Western Ghats.

Conflict generally arises from economic losses to agriculture, including loss of cattle through predation and destruction of crops. In arid areas it often occurs over access to water and competition for resources.
Crop raiding by Asian elephant has been studied extensively almost all Asian countries. Studies on crop depredation by elephants are also well documented in India (Sukumar et al., 1995, Jayson and Christopher, 2008). But the studies on these aspects in the state of Kerala are scarce, where more than 4000 wild elephants are present in the forest areas of Western Ghats. A recent survey conducted by Veeramani and Jayson, (1995) reported that crop depredation by wild animals in Kerala is making heavy damage to the farmers.

Human elephant conflicts in the adjacent states such as Karnataka have been extensively studied by Sukumar, 1989, 1991 and 1994 and Appayya, 1992). An estimate shows that human casualty in India is about 100-200 in a year due to human-elephant conflicts (Santiapillai and Jackson, 1990). In Kerala alone about 10-15 people are dying due to the attack of wild elephants and a heavy loss of crops to the farmers.

In India, especially in the south, better scientific assessments of HEC and compensation payments are required. There is little quantitative understanding on spatio-temporal patterns, intensity, extent of damage and determinants of HEC (Ogra, 2008; Gubbi, 2009; MOEF, 2010) that could help managers, although notable exceptions exist (Kumar et al., 2010; Bal et al., 2011; Varma et al., 2011).

In this study an attempt has been made to investigate the human-elephant conflicts in the Anayirangal area of Kerala, and to suggest possible measures needed for amelioration of the problem.

4.3 Geospatial analysis of human-elephant conflict at Anayirangal

4.3.1 Study area

One of the major landscape structures which is acting as ecological ‘stepping stones’ between the Anamalai landscape and the Periyar Tiger Reserve is Anayirangal valley with a mosaic of plantations (fuel wood and agriculture), shola forest and settlements. The area lies north to Mathikettanshola National Park and the south of Pampadumshola National Park in Devikulam Range of Munnar Forest Division (between 77.1534°E to 77.2729°E longitude and 10.0817°N to 9.9168°N latitude). It is a valley surrounded by hills with an altitude ranging from
1010.87m to 2444.6 m from which numerous streams originates and drains into the Anayiangal reservoir having an area of 4.6 km². The area acts as a home for elephants and human habitation. A detailed evaluation of human-elephant conflict has been done in the settlements in and around Anayirangal Area.

4.3.2 Background of the issue

The human-elephant conflict (HEC) in Anayirangal area has increased very recently. The main reasons for increase in human elephant conflict are the loss of habitat and habitat fragmentation. In 2002 Kerala Government assigned 410 ha pine plantation and 130 ha eucalyptus plantations for landless tribes in Chinnakkanal Grama Panchayath of Devikulam Thaluk. This plantation has been extensively utilized by the elephant for a long time for resting and feeding. It is also part of corridor between Mathikettanshola National Park and Munnar-Anamalai elephant reserves.

Elephants are coming towards Anayirangal valley from Mathikettanshola National Park because of the availability of water and fodder. The extensive cardamom plantation and the human habitation along this corridor are blocking the free movement of elephants. The growing tourism pressure results in emergence of large number of resorts in northern side of the area that is also acting as a manmade barrier for the elephant movement from Anayirangal towards Mattupetty-Gunderla. The encroachment of elephant habitat by people and their demographic influence are the other factors resulting in human-elephant conflict at Anayirangal region.

4.3.3 Spatial and temporal estimation of human – elephant conflict at Anayirangal

The study has been conducted during the period 2007 to 2009 in 28 settlements surrounding Anayirangal reservoir in which the human-elephant conflict exist. Out of these 28, five settlements (301 New Adivasi Colony, 80 New Adivasi Colony, Panthadikkulum New Adivasi Colony, Vilakk New Adivasi Colony, and Suryanelly New Adivasi Colony) are formed during 2002 under land assignment project for landless tribes by the Kerala Government. The settlements Chembakathozhu kudy and Kozhippennakudy are muduvan tribal settlements and settled here.
around 100 years back. The settlements Singukandam, BL Ram, Thidir Nagar, Shanmugavilasm, Mulathara, Muthaman Colony, Sundal, Thondimala and Thalakkulam are non-tribal settlements and settled 25-50 years back. These settlements are under Chinnakkanal, Pooppara and Shanthanpara revenue villages of Chinnakkanal, Shanthanpara and Rajakumari Grama Panchayath of Devikulam and Udumbanchola Thaluk.

The spatial and temporal human-elephant conflict data was collected through a questionnaire survey and direct observation by field visits. A questionnaire has been prepared covering different aspects of conflicts such as date and time of raid, geographic location (latitude and longitude) of crop raid incident, type of crop raided, extent of damage (crop loss, property loss and human injuries), distance to the natural vegetation and raided elephant (whether lone tusker or herd). In all the settlements an arrangement has been made with a person native of that village who will report whenever an elephant or a herd enters in to their respective settlement. A detailed record in the data sheet about the conflict incident was maintained after confirming the incident by direct field observation. With the GPS the geographic location of the conflict incident was marked. The nature of damage was assessed and the same was recorded separately into crop damage, property damage and human injuries.

4.3.3.1 Crop damage assessment

In each settlement, the total number of farmers involved in all types of cultivation, extent and season of cultivation were obtained through the questionnaire survey. Elephant entering the field was grouped into ‘visits’ and ‘raid’. ‘Visits’ are cases where elephants traverse the field and do little damage which may be due to trampling only, whereas ‘raids’ are cases where crops are fed upon (Osborn, 1998).

The major crops in each settlement were grouped into cash crops and food crops. Based on the nature of elephant raid, the crop damage was grouped into two categories viz. trampling the crops or crops eaten. Crops like banana, ragi, tapioca, cabbage and vegetables were usually raided by elephants for eating by entering the agriculture field or in the homestead garden. There were some crops especially the cash crops such as cardamom, ginger, pepper, coffee and tea...
which are usually trampled by the elephant while crossing in a highly stressed environment in human dominated landscape. In some cases the tender shoot of the cardamom plant was eaten by the elephant.

Whenever a crop raiding attempt occurred in an agriculture field or homestead garden, the information were collected by field visit. The geographic location of the crop raid incidents were taken by Garmin GPS 72 and 76 csx. Crop raid was confirmed by indirect evidences like presence of elephant foot print and fresh elephant dung piles. Efforts were made to collect maximum information on the raided elephant such as number of elephants and herd compositions were obtained by measuring the foot prints of all the elephants and dung pile circumferences. Based on the morphological features the elephants especially the lone tuskers were named by the local people.

Based on the herd composition and the morphological features of matriarchal female, the herds were also identified (Sukumar and Gadgil, 1988). This information was obtained from the owner of the affected crop or from the estate watchers who were being deputed during night in the agriculture field. The date and time of crop raid, name of the owner, name of the crop, crop type (seasonal crop or perennial crops), status of crop (immature or matured), extent of crop cultivation and the extent of crop damage were recorded from the field on a standardized data sheet (Hoare and Mackie, 1993; Hoare, 1999a; Hoare, 1999b) (Annexure VI).

Two methods were adopted to assess the extent of crop damage. For crops such as banana, cabbage, pepper, coffee and cardamom the total number of damaged (eaten or trampled) plants were counted and percentage of loss was assessed from the total number of that crop which was being cultivated by each affected farmer. Whereas for crops such as ragi, tapioca, ginger, beans and other vegetables the damaged (eaten/trampled) area was estimated by measuring the width and length with measurement tap and the same was converted into sq km and percentage of crop loss was assessed from the total area of the crop cultivation by individual affected farmer.

Economic loss of crop damage was also estimated. For seasonal annual crops such as ragi, banana, cabbage, ginger, tapioca, and vegetables the average yield
per square kilometer was estimated which was multiplied with the then existing average market value per kilogram of that commodity. For perennial crops such as cardamom, pepper and coffee the average lifespan, yielding period, average annual yield per square kilometer and then existed average market value per kilogram of each crop was obtained from the spices and coffee boards. While the mature crops were damaged, the information on first year of yield was obtained from the owner. The average annual yield of each crop was multiplied with the average market value. This is extrapolated into the remaining expected yielding period.

4.3.3.2 Property damage

Elephants used to destroy the obstacles existing along the path of their movement. There were different barriers such as solar power fence, walls, elephant proof trenches, pipe lines and buildings (houses or watch sheds). Property damage by elephants was classified into two categories viz. partial damage or complete damage based on the intensity of loss. When property damage incident occurred, the information like date, time, geographic location, name of the owner, property type, intensity of the damage were recorded on a standardized data sheet (Hoare, 1999b) (Annexure VI). The elephant group size and composition were also obtained (Sukumar and Gadgil, 1988).

4.3.3.3 Human casualties

Human casualties were categorized into minor injuries, major injuries and death. The incidents of elephant chase were also included in the minor injuries categories as the person may get some injuries while running away. Information like age, sex, date, time, geographic location and the reason for elephant attack were also recorded on a standard data sheet (Hoare, 1999b) (Annexure VI). The elephant group size and composition was also obtained (Sukumar and Gadgil, 1988).

4.3.3.4 Raid frequency index estimation

The elephant ‘visit’ and elephant ‘raids’ were separately observed (Osborn, 1998) in all the settlement for the period 2007 to 2009. Whenever such incidents occur, the date, time, the name of the settlement and the elephant details were recorded
on standardised data sheet and raid frequency index (RFI) of crop raid, property damages and human casualties in each settlement have been calculated. Raid Frequency Index gives the intensity of elephant visit and raid attempt in each settlement and is a measure of conflict intensity (Sukumar, 1991). This is the ideal method for assessing the real impact of elephants. Though it is logistically difficult over the large areas affected by elephants, it has been intensively applied in small areas of relatively high elephant challenge.

The frequencies of elephant visit in the settlements for the period 2007, 2008 and 2009 were categorized into visit by lone tuskers and herd separately. Using the geographic locations of the elephant visits separate maps were prepared for the elephant visit, as elephant herd and lone tuskers separately during the study period.

4.3.3.5 Spatial analysis of human - elephant conflict

The present study investigates the relationship between human-elephant conflicts and the specific spatial context in which they occur. The geographic locations of all elephant visit, crop raid, property damage and human casualties were imported in to the GIS platform and superimposed on the land use and settlement map. Spatial data for the environmental variables used for the present study includes the land uses, settlements, streams, water bodies, roads, slopes and altitude. Settlement boundaries were obtained by mapping in the field with GPS. The spatial data such as roads and streams were acquired by digitizing topographical sheets from the Survey of India using Arc GIS Version 9.3. A slope and altitude map of the study area was also prepared using the CARTOSAT DEM 1 arc data obtained from BHUVAN, open geospatial web based Eodata Achieves of National Remote Sensing Centre (NRSC).

4.3.3.6 Correlating the conflicts with environmental variables

The geographic locations of the elephant visits were superimposed over the land-use/land-cover map. The frequencies of elephant visit in the different settlements and different landuse were obtained by summarizing in each feature class using Arc GIS software.
The spatial analysis of human-elephant conflict data identifies the factors which have a significant effect on the patterns of conflict observed. These environmental variables may directly determine where human-elephant conflict incidents occur, but they may act instead as a surrogate for other unmeasured factors. For getting the correlation between conflicts and environmental variables, frequencies of elephant visits with respect to the distance from roads, settlements, streams, waterbody, eucalyptus plantations, pine plantations, grassland, shola forest and terrain were assessed.

The roads and streams present in the study area were reclassified into 40 classes at 25 m intervals for a distance of 1km using the Arc GIS software. Settlements and water-bodies present in the study area were reclassified into 80 classes at an interval of 50 m for a distance of 4 km. The slopes are grouped into 17 classes with an interval of 5 degree. The altitude ranges were reclassified into 20 equal classes at an interval of 69.3 m. The reclassified environmental variables were then converted into vector features using the raster to vector conversion tool of Arc GIS for the overlay operations.

The overlay function in GIS analysis tool was used to overlay multiple spatial feature classes to combine, erase, modify, and update spatial features in a new feature class. New information was created when overlaying one set of features with another. Overlay operations involve joining two existing sets of features into a single set of features to identify spatial relationships between the input features. The ‘identify’ overlay operations computes a geometric intersection of the input features and identity features. The input features or portions thereof that overlap identity features will get the attributes of those identity features. This tool combines the portions of features that overlap the identity features to create a new feature class.

In the present work the conflict incident locations were overlaid on to the each reclassified vector features of environmental variables by the ‘identify’ function using Arc GIS, so that the conflict incident feature class get the attributes of each reclassified environmental variables. By ‘summarising’ function the frequencies of conflict incident in all classes of each environmental variable were estimated.
Using SPSS software these environmental variables and the conflicts were correlated by *multivariate Pearson 2-tailed correlation* and assessed the *level of significance* of these factors which determine the human-elephant conflict.

**4.3.3.7 Identification of human - elephant conflict prone zone at Anayirangal**

The frequencies of human-elephant conflict in different *distance zones* of environmental variables were assessed by the ‘summarizing’ functions in the ArcGIS. Using these frequencies at different *distance zones*, all the environmental variables were subjected to *reclassification* and created *frequency-distance zone raster* for all the variables. These *raster* were mathematically *integrated* and created a human-elephant conflict prone *raster*. Human-elephant conflict prone zone *raster* gives the probable areas of conflicts with intensity. The *raster* was *reclassified* into five zones of possible areas of conflicts with intensity namely *very high conflicting prone areas*, *high conflicting prone areas*, *medium conflicting prone areas*, *low conflicting prone areas* and *very low conflicting prone areas*. The settlements falling under each prone zone were also identified.

**4.3.3.8 Social aspects of human - elephant conflict**

The settlements located in the elephant habitat of Anayirangal were surveyed to understand the socio-economic status of the families facing human-elephant conflict during the year 2008. A standard questionnaire was prepared by incorporating the family and community details, source of income, economic activities, and details of agriculture and forest dependency of the people. The information on socio-cultural history of Anayirangal was obtained by Participatory Rural Appraisal (PRA) with the traditional tribal community and community heads (traditional name *Kani*) of five old Muduvan tribal settlements (Chembakathozhukudi, Tankkudi, Pachappulkudi, Aduvilanthankudi and Kozhippennakudi), which were established in the Anayirangal valley during middle of 18th century.

**4.3.3.9 Assessment of impact of human activities on the elephant habitat**

The ever increasing human activities around forest areas resulting into shrinking of elephant habitat mainly due to encroachments, fragmentation by roads and degradation of habitats due to biotic pressures such as collection of non timber forest produces (NTFP), fuel wood collection and cattle grazing etc. All these
Biotic pressures may lead to stress in elephants' behaviour which will result into elephants entering the settlement areas causing human-elephant conflict. In the present study the intensity of cattle pressure and wood cuttings on elephant habitat was studied by line transect method.

To assess the impact of intensity of cattle grazing and wood cuttings for fuel wood collection from the settlements, separate transects were laid from the borders of settlements orienting towards the interior forest/plantation areas at Anayirangal valley.

4.3.3.9.1 Quantification of wood cuttings

A total of 9 km transects of 4 m (2*2 m) width were laid from three settlements in the fringe areas of elephant habitats (eucalyptus and pine plantations). All the cut trees by human per unit area at every 100 m intervals were counted and calculated the mean number of trees damaged (Ramkumar and Arumugam, 2004; Daniel et al., 2006). The average percentages of wood cuttings were then estimated at different proximities from village boundaries and identified the zone of maximum impact on elephant habitat.

4.3.3.9.2 Quantification of cattle grazing intensity

An index of the intensity of cattle grazing at different proximities from settlement boundaries towards elephant habitats (grasslands, eucalyptus plantations and pine plantations) was obtained through cattle dung abundance estimates using belt transects of 9 km with 4 m width (Daniel et al., 2006). The same transects used for quantification of wood cuttings were used for this purpose also. Dung piles observed within 2 m on either side of transects were recorded on standard data sheets (Annexure VII). From this arrived the mean number of cattle dung per unit area at every 100m interval from village towards elephant habitat.

4.3.3.9.3 Estimation of cattle dung density in elephant habitats

The herbivores pellets-group counts methods (Neff, 1968; Ramkumar and Arumugam, 2004) were adopted to estimate the cattle dung density in various elephant habitat at Anayirangal. Transects line made for estimation of elephant dung density estimation was used for the estimation of cattle dung density. All the
cattle dung pile found inside the 2 m width in either side of transect line were counted. Densities of cattle dung pile were estimated by using the following formula.

\[ D = \frac{N}{L} \times 2W \]

Where ‘D’ refers to density of dung piles; ‘N’ refers to number of dung piles counted along the transect line; ‘L’ refers to length of all the transect lines and ‘W’ refers to the width of transect line.

4.3.3.9.4 Forest fragmentation and human - elephant conflict

For detecting the land use land cover changes and the reduction in forest cover Landsat Multispectral Scanner (MSS) 1990 image, IRS-P6 (23.5m) LISS (Linear Imaging Self Scanner) - III image of January 2005-2006 and LISS III image of 2008-2009 and were subjected to supervised classification using Erdas - Imagine Version 8.7. To make distinct the cardamom plantations (an agriculture cash crops growing under the forest canopy) and the evergreen forest, ground surveys have been conducted separately and mapped the boundaries of cardamom plantation using GPS (Garmin 76 CSX with an accuracy of 2-3m). The thematic class of cardamom plantation obtained was then superimposed above the hybrid classified satellite images of the year 2008 and 2009 and final vegetation type map was prepared. The accuracy of the map was 90% as computed with ground control points taken at the boundaries of the transformed vegetation type map using GPS (Garmin 76). The changes that happened in the land use and forest cover between 1990 - 2009 were determined from these classified images.

4.4 Results

4.4.1 Elephant raid frequency index: spatial distribution of human - elephant conflict

The frequency of elephant sightings in various settlements of Anayirangal was maximum (697) during the year 2008, followed by the year 2007 (338) and was minimum (231) for the year 2009 (Table 4.1 and Figure 4.1, 4.2, 4.3 and Figure 4.11). During 2007 the frequency of herd sightings was maximum (185) than that of tusker (153) (Figure 4.5 and Figure 4.6). In 2008 at 430 locations herd was sighted and at 267 locations the tusker was sighted (Figure 4.7 and Figure
4.8). But in 2009 out of 228 elephant sightings outside the protected area, at 164 locations the herd was sighted and at 67 locations the tusker was sighted (Figure 4.9 and Figure 4.10).

**Table: 4.1. Elephant visits in the settlements during 2007 to 2009**

<table>
<thead>
<tr>
<th>Settlements</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>301 New Adivasi Colony</td>
<td>16</td>
<td>129</td>
<td>30</td>
</tr>
<tr>
<td>80  New Adivasi Colony</td>
<td>22</td>
<td>42</td>
<td>3</td>
</tr>
<tr>
<td>Aduvilanthan Kudi</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Anayirangal</td>
<td>0</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>B L Ram</td>
<td>11</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Chembakahozhukudi</td>
<td>57</td>
<td>61</td>
<td>17</td>
</tr>
<tr>
<td>Chinnakanal</td>
<td>0</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>Gundumala Tea Estate</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Korampara</td>
<td>0</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Kozhipennakudi</td>
<td>8</td>
<td>24</td>
<td>7</td>
</tr>
<tr>
<td>Kudampara</td>
<td>0</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Mulathara Cardamom Hill Reserve</td>
<td>9</td>
<td>59</td>
<td>20</td>
</tr>
<tr>
<td>Muthaman colony</td>
<td>13</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Muttukad</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nagamala Tea Estate</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Pachappulkudi</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Panthadikkulam New Adivasi Colony</td>
<td>21</td>
<td>44</td>
<td>12</td>
</tr>
<tr>
<td>Papathishola</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Periyakanal</td>
<td>2</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Pethotti Cardamom Hill Reserve</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Sankarapandimett</td>
<td>9</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Singukandam</td>
<td>153</td>
<td>118</td>
<td>24</td>
</tr>
<tr>
<td>Suryanelli</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Suryanelli New Adivasi Colony</td>
<td>1</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Thalakkulam</td>
<td>1</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Thidir</td>
<td>5</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>Thondimala</td>
<td>9</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Vilakk New Adivasi Colony</td>
<td>0</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>338</strong></td>
<td><strong>697</strong></td>
<td><strong>231</strong></td>
</tr>
</tbody>
</table>
Figure 4.1. Elephant sightings outside the PAs at Anayirangal during 2007 - 2009

Figure 4.2. Elephant sightings outside the PAs at Anayirangal during 2007
Figure: 4.3. Elephant sightings outside the PAs at Anayirangal during 2008

Figure: 4.4. Elephant sightings outside the PAs at Anayirangal during 2009
Figure 4.5. Elephant (Lone Tusker) sightings outside the PAs at Anayirangal during 2007

Figure 4.6. Elephant (Herd) sightings outside the PAs at Anayirangal during 2007
Figure 4.7. Elephant (Lone Tusker) sightings outside the PAs at Anayirangal during 2008

Figure 4.8. Elephant (Herd) sightings outside the PAs at Anayirangal during 2008
Figure: 4.9. Elephant (Lone Tusker) sightings outside PAs at Anayirangal during 2009

Figure: 4.10. Elephant (Herd) sightings outside the PAs at Anayirangal during 2009
In 2007, elephants visit was maximum (153) in Singukandam followed by Chembakathozhukudi (57). During 2008 elephant visit was observed maximum in 301 New Adivasi Colony (129) followed by Singukandam (118). In Chembakathozhukudi the frequency of elephant visit increased during the year 2008. Whereas in 2009 the frequency of elephant visit to the settlements were observed to be low but it was shifted to nearby settlements. The visit was high in 301 New Adivasi Colony (30), followed by Thidir (27) and B L Ram (26) (Figure 4.11).

The elephant raid frequency index for crop damage was observed to be high during the year 2008 (436), followed by 2007 (316) and 2009 (167). During the year 2007 and 2008 crop raid frequency was observed to be high in Singukandam followed by Chembakathozhukudi. In 2009 the crop raidings were maximum at Thidir and B L Ram (26) followed by Mulathara (20) (Figure 4.12).

The elephant raid frequency index for property damage was also observed to be high during the year 2008 (73), followed by 2007 (64) and 2009 (24). During the year 2007, the property damage index was high in Singukandam (26) followed by 80 New Adivasi Colony (9). During the year 2008 and 2009, frequency of property damage index was high in 301 New Adivasi Colony with 28 and 9 cases respectively. It was observed that after 2007, the frequency index of property damage was high in the newly established settlements such as 301 New Adivasi Colony, Chinnakanal New Adivasi Colony, Panthadikkulam New Adivasi Colony, Vilakk and 80 New Adivasi Colony which are in the middle of elephant habitat. In 2008, the 80 New Adivasi Colony erected solar power fences around their settlements, so that in 2009 the elephant frequency index becomes low in this settlement (Figure 4.13).

The elephant raid frequency index for human casualties was observed high (89) during the year 2008, followed by the year 2007 (15) and 2009 (12). In 2007, the settlement Singukandam got high frequency (9) followed by Mulathara Cardamom Hill Reserve (4). But during 2008 the frequency was increased to 28 in 301 New Adivasi Colony followed by Singukandam (23). In 2009 the frequency was decreased and the highest frequency of 3 was observed in Singukandam followed by 301 New Adivasi Colony (2). Moderate frequency indexes of human casualties were observed in the settlements 80 New Adivasi Colony, Chinnakanal...
New Adivasi Colony, Panthadikkulam New Adivasi Colony and Vilakk (Figure 4.14).

Figure 4.11. Frequency of elephant sightings in the settlements of Anayirangal

Figure 4.12. Raid frequency index for crop damage in various settlements
Figure: 4.13. Raid frequency index for property damage in various settlements

Figure: 4.14. Raid frequency index for human casualties in various settlements

The analysis of elephant raid frequency index of different months shows that the frequency was high in the months of April, May and November during 2007. During 2008 the elephant raid frequency was high in the months of January, May
and June. But in 2009, the elephant raid frequency was high during dry season, in the months of January, February and March (Figure 4.15).

![Figure: 4.15. Raid Frequency Index (Elephant Visits) in settlements per months](image)

**Table: 4.2.** Mean Raid Frequency Index in various months with respect to crop cultivation

<table>
<thead>
<tr>
<th>Season</th>
<th>Elephant palatable crop types cultivation</th>
<th>Months</th>
<th>Mean Raid Frequency Index (RFI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Banana</td>
<td>December</td>
<td>24.67</td>
</tr>
<tr>
<td></td>
<td>Tapioca</td>
<td>January</td>
<td>60.33</td>
</tr>
<tr>
<td></td>
<td>Jackfruit</td>
<td>February</td>
<td>23.33</td>
</tr>
<tr>
<td></td>
<td>Guava</td>
<td>March</td>
<td>40.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>April</td>
<td>38.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May</td>
<td>74.67</td>
</tr>
<tr>
<td>Wet</td>
<td>Banana</td>
<td>June</td>
<td>25.67</td>
</tr>
<tr>
<td></td>
<td>Ragi</td>
<td>July</td>
<td>15.67</td>
</tr>
<tr>
<td></td>
<td>Cabbage</td>
<td>August</td>
<td>24.33</td>
</tr>
<tr>
<td></td>
<td>Pigeon Pea</td>
<td>September</td>
<td>22.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>October</td>
<td>28.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>November</td>
<td>42.67</td>
</tr>
</tbody>
</table>

During the wet season, major elephant palatable crop species cultivated in the settlements are banana and tapioca. During this time jackfruit and guava were also ripened. It was observed that the habituated adult lone tuskers used to roam the settlements in search of jackfruit and guava. This was also a factor catalyses the intensity of conflict in these settlements. During wet season, elephant palatable crop cultivated in the settlements are ragi, cabbage, banana, pigeon...
pea and vegetables. The raid frequency index of the elephant herd was high during this period as these crops attract the elephant herds and they raid the crop (Table 4.2).

To get information on the influence of rainfall pattern at Anayirangal on the frequency of conflict incidents per months, the Pearson 2-tailed analysis was performed. The frequency of conflict was negatively correlated ($r=-0.436$ at 0.01 level) with the mean rainfall without significance (Table 4.3).

### Table 4.3. Pearson 2-tailed Analysis for rain fall and raid frequency Index

<table>
<thead>
<tr>
<th>Pearson 2-tailed Correlations</th>
<th>Mean Rainfall</th>
<th>RFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Rainfall</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Raid Frequency Index</td>
<td>-0.436</td>
<td>1</td>
</tr>
</tbody>
</table>

#### 4.4.2 Intensity of human - elephant conflict

The conflict incidents were classified into crop damage, property damage and attack on human beings. One conflict incident may either results in crop damage, property damage, and attack on human beings or with a combination of all these three types of conflicts. Out of 1266 elephant visits in various settlements of Anayirangal, 1200 incidents of conflicts have occurred.

In 2007 a total of 338 conflicts incidents have been recorded of which 316 incidents lead to crop damage, 67 incidents lead to property damage and 15 incidents were human attacks. In 2008 the conflict incidents increased and become 599 of which 436 incidents lead to crop damage, 73 incident lead to property damage and 90 incidents were attacks on human. Human-elephant conflict incidents decreased during the year 2009.

A total of 203 incidents were recorded of which 167 incidents resulted crop damage, 24 incidents of property damage and 12 incidents of attack on human beings (Figure 4.16).
4.4.2.1 Crop damage

Elephant raid in various settlements of Anayirangal had resulted with a net loss of ₹6874752. Net economic loss for agriculture damage due to elephant crop raid was estimated high for the year 2008 (₹32, 08,717) followed by 2009 (₹19, 30,012) and 2007 (₹17, 36,023). The major cash crops damaged by elephants were cardamom, coffee, pepper and ginger. Elephants mainly trampled these crops while crossing the plantation and agriculture area.

The cases of eating tender shoots of the cardamom were also noticed at Mulathara cardamom plantation. The main food crops damaged by elephants include ragi, banana, tapioca, cabbage, beans and pigeon pea. Elephants mainly eat the crops rather than trampling.

Net economic loss was observed maximum by the damage of cash crops for the year 2008 (₹24, 53,839) followed by 2009 (₹15, 83,168). The net loss occurred by the damage of food crops was also high in 2008 (₹7, 54,878) followed by the year 2007 (₹ 5, 44,550) (Table 4.4).
Table 4.4 Net economic loss for crop damage in various years.

<table>
<thead>
<tr>
<th>Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Loss for Cash Crops</td>
<td>₹ 11,91,473</td>
<td>₹ 24,53,839</td>
<td>₹ 15,83,168</td>
</tr>
<tr>
<td>Net Loss for Food Crops</td>
<td>₹ 5,44,550</td>
<td>₹ 7,54,878</td>
<td>₹ 3,46,844</td>
</tr>
<tr>
<td>Grant Total</td>
<td>₹ 17,36,023</td>
<td>₹ 32,08,717</td>
<td>₹ 19,30,012</td>
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</tbody>
</table>

The overall net economic loss due to crop damage by elephant was high in Mulathara (₹18, 10,801) followed by Singukandam (₹ 11, 51,070) followed by B L Ram (₹ 539601). The overall net economic loss due to crop damage in newly established tribal colony was very high at Panthadikkulam New Adivasi Colony (₹ 2, 44,701) followed by 301 New Adivasi Colony (₹ 1,82,156). Overall net economic loss in old tribal settlement was high at Chembakathozhukudi (₹4, 82,968) followed by Kozhippenakudi (₹1, 78,458).

During 2007 the economic loss due to crop damage was high at Singukandam (₹ 6, 26,273) followed by Chembakathozhukudi (₹ 239062) and Mulathara (₹171931). But in 2008 the net economic loss was very high at Mulathara (₹ 9, 76,596) followed by Singukandam (₹ 4, 50,912). Whereas in 2009 the net economic loss was lowered compared to that occurred in 2008. Mulathara has got the highest economic loss (₹ 6, 62,274) followed by Thidir Nagar and B L Ram (Figure 4.17).

During the period 2007-2009 an average of 70% cardamom farmers of Singukandam, 66.67% farmers of Suryanelli New Adivasi Colony, 64% farmers of Mulathara Cardamom Hill Reserve, 61.67% farmers at Thidir Nagar, 50% farmers of Panthadikkulam were mainly affected because of elephant crop raid. A total of 18153 cardamom plants were trampled by the elephant during this period with a net economic loss of ₹ 47, 49107 (Figure 4.24, 4.26, Figure 4.28 and Annexure VIII).

Cardamom damage by elephants was observed very high during the year 2008 (9500 plants) followed by 2009 (4363 plants). During 2007, the high cardamom (1061 number of plants) loss was observed at Singukandam followed by
Mulathara (785), Thondimala (572) and Chembakathozhukudi (502). But the average loss of cardamom with respect to farmers per raid was observed high at 80 New Adivasi Colony (22%) followed by Thalakkulam (12%) and Chembakathozhukudi (8.69%). This is because the extent of cardamom cultivation per farmer was less compared to that in Mulathara and Singukandam where the extent of cardamom loss was high.

**Figure 4.17** Net economic losses for crop damage during the years 2007, 08 and 2009

**Figure 4.18** Net economic losses for crop damage in various settlements during 2007 - 2009
During 2008, the extent of cardamom damage by elephant was increased in most of the settlements except Singukandam, Thondimala, Chembakathozhukudi, 301 New Adivasi Colony and Muthaman colony. In Mulathara the cardamom damage was observed very high (4048) followed by BL Ram (828), Thalakkulam (566) and Korampara (309). Even though the overall percentage of cardamom damage was decreased during 2009, the percentage of cardamom loss with respect to farmer was increased in the settlements Chinnakanal New Adivasi Colony, Thidir Nagar and Vilakk (Figure 4.19, 4.20 and Figure 4.21).

In the case of pepper, the average percentage of farmers affected was high in the newly established tribal colonies were they started cultivation after 2006. The farmers of Panthadikkulam New Adivasi Colony (47.67%) and 301 New Adivasi Colony (41.67%) were the mostly affected because of elephant crop raid. A total of 238 pepper plants were damaged by elephant with a net economic loss of ₹ 40721. The average percentage of crop loss was high in the newly established tribal colonies Panthadikkulam New Adivasi Colony and 301 New Adivasi Colony followed by the old Muduvan settlement, Chembakathozhukudi (Figure 4.19, 4.22, 4.23, 4.24, 4.26 and Figure 4.28).

![Average percentages of farmers affected in various settlements](image)

**Figure: 4.19.** Average percentages of farmers affected in various settlements

The loss of coffee was only observed during the year 2007 and the percentage of farmers affected was high in Chembakathozhukudi (33.33%) and Singukandam.
(33%) followed by 301 New Adivasi Colony (22.22%). A total of 140 plants were damaged with a net economic loss of ₹ 2 25979.

A total of 1.35 km² of ginger was trampled by elephant during the period 2007-2009 with a net economic loss of ₹21 2674. Average percentage of ginger loss with respect to farmers per raid was high in the newly established tribal colonies 301 New Adivasi Colony (36.79%) and Panthadikkulam New Adivasi Colony (29.30%). The average percentage of farmers affected was also high in newly established tribal colonies 301 New Adivasi Colony (47.69%) and Panthadikkulam New Adivasi Colony (22.92%) (Figure 4.19, 4.24, 4.26, Figure 4.28 and Annexure IX).

The most damaged food crops at Anayirangal was banana. A total of 1867 banana was damaged by the elephant between the year 2007 and 2009 with a net economic loss of ₹ 12, 88,980. The damage was observed high during 2008 followed by the year 2007 and 2009. Extent of banana damage was high in the settlement Singukandam (776) followed by Periyakanal 342 and B L Ram (156). Even though the total loss was comparatively low at Muthaman colony, the average percentage of farmers affected was high (88.89%) followed by Sankarapandymett (77.78%) and Panthadikkulam (77.38%) (Figure 4.19, 4.25, 4.27, Figure 4.29 and Annexure X).

Cabbage was cultivated in Periya kanal, Chembakathozhukudi, B L Ram and 80 New Adivasi Colony. Between the year 2007 and 2009 a total extent of 0.56 km² was damaged by the elephant with a net economic loss of ₹ 33667.

The ragi cultivation was practiced by the old tribal (Muduvan) people and was especially cultivated in Chembakathozhukudi, Kozhipennakudi and Panthadikkulam New Adivasi Colony. A total of 2.76 km² of ragi was damaged by the elephant between the period 2007 and 2009 with a net economic loss of ₹ 1, 17,066. Crop damage was observed high during the year 2007 followed by 2008 and 2009. The extent of crop cultivation was less during the year 2008 and 2009 as compared to 2007.

An extent of 0.53 km² of pigeon pea and 0.26 km² of beans was damaged between the period 2007 and 2009. The net economic loss due to the crop
damage of beans (₹ 6835) and pigeon pea (₹ 2677) was comparatively low (Figure 4.19, Figure 4.25, 4.27 and Figure: 4.29).

**Figure: 4.20.** Extent of crop (cardamom) loss

**Figure: 4.21.** Average percentage of crop (Cardamom) loss with respect to farmers per crop raid
Figure: 4.22. Extent of crop (Pepper) loss

Figure: 4.23. Average percentage of crop (Pepper) loss with respect to farmers per crop raid
Figure: 4.24. Net economic losses for cash crops in various settlements of Anayirangal in 2007

Figure: 4.25. Net economic losses for food crops in various settlements of Anayirangal in 2007
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Figure: 4.26. Net economic losses for cash crops in various settlements of Anayirangal in 2008

Figure: 4.27. Net economic losses for food crops in various settlements of Anayirangal in 2008
Figure: 4.28. Net economic losses for cash crops in various settlements of Anayirangal in 2009

Figure: 4.29. Net economic losses for food crops in various settlements of Anayirangal in 2009
4.4.2.2 Property damage intensity

In Anayirangal area a total of 67 incidents of property damage have been reported during the year 2007. The property damage incidents increased (73) in the year 2008 and decreased (24) in 2009. A total of 33 houses and 35 sheds were destroyed by elephants in the year 2007 of which 12 houses and 18 sheds were completely destroyed.

The intensity of property damage was high in Singukandam followed by 80 New Adivasi Colony for the year 2007. In 2007 some of the families in 80 New Adivasi Colony started constructing houses and is the reason for high incidents of property damage in this colony. But in 2008 and 2009 the intensity of property damage had shifted to 301 New Adivasi Colony (26) and Singukandam (15). This is due to the construction of solar power fences around 80 New Adivasi Colony and the people in 301 New Adivasi Colony started house construction by clearing the pine plantation.

A total of 50 houses and 18 sheds were destroyed by the elephant during 2008 of which 6 houses and five sheds were completely damaged. A total of 11 houses and 8 sheds were destroyed by the elephant during 2009 of which 2 houses and 2 sheds were completely destroyed. In the newly established tribal colonies, the intensity of property damage was high in 301 New Adivasi Colony followed by 80 New Adivasi Colony, Panthadikkulam New Adivasi Colony, Suryanelli New Adivasi Colony and Chinnakanal New Adivasi Colony (Figure 4.30).

4.4.2.3 Attack on human beings

The human casualties resulted by the attack of elephant were classified into minor injuries, severe injuries and death. A total of 117 incidents of attack on human have been reported during the years 2007 to 2009. During this period 5 people were killed by the elephants, 11 were severely injured and 93 got minor injuries.
Figure: 4.30. Intensity of property damage by elephants in the settlements of Anayirangal during 2007-2009

Figure: 4.31. Property damage in the settlements of Anayirangal during 2007
No cases of death was reported in the year 2007, but 2 cases of severe injury at Mulathara and 15 cases of minor injuries were reported. The minor injuries by elephant attack was observed high (11 cases) at Singukandam. Attacks on human beings were observed very high during the year 2008. Four people got killed, 7 people were severely injured and 70 people got minor injuries by
elephants during the year 2008. Two cases of death were from 301 New Adivasi Colony, one from Thalakkulam and one from Suryanelli New Adivasi Colony. The minor injuries were high (25 cases) at 301 New Adivasi Colony followed by Singukandam (22 cases).

In 2009 one human death occurred by elephant attack at Mulathara. Two cases of severe injuries were also reported during the year 2009. Even though the cases of minor injuries by elephants were observed but the number of such incidents were less compared to that of the year 2007 and 2008, the settlements Singukandam and 301 NAC faces elephant attack incidents.

Out of five human deaths at Anayirangal, two were females with 44-45 years age and three were males with 33, 45 and 46 years age. Two deaths happened inside the cardamom plantation while they were returning home from the work place. Two people got killed inside the pine plantation and one from the eucalyptus plantation. The pine and eucalyptus plantations were the assigned land for the tribal people. Out of five people died three were from the newly established tribal families of the tribal groups Mannan and Hill Pulayas. The other two were basically native of Tamil Nadu who came here as cardamom estate workers (Table 4.5).

It was observed that the tribal groups of Mannans were mostly subjected to elephant attack. Out of 117 human injured cases 93 were males and 24 were females.

| Table: 4.5. Details of human casualties by elephant between 2007-2009 |
|----------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Injuries | Cases | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ |
| Death | 5 | 3 | 2 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Severe | 11 | 10 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 6 | 0 |
| Minor | 101 | 80 | 21 | 1 | 0 | 20 | 8 | 7 | 0 | 7 | 0 | 39 | 5 | 6 | 8 |

4.4.3 Spatial patterns of human - elephant conflict at Anayirangal

The analysis of the frequency of conflicts with respect to the distance from road shows high clustering near to the road within a range of 0-600m and was
maximum at 0 to 50 m zone (Figure 4.34). It was also observed that the frequency of conflicts decreases when the distance from road increases. Pearson 2-tailed correlation analysis shows the frequency of conflicts and distance from roads were negatively correlated and was highly significant ($r = -0.763^{**}$ at 0.01 level). The conflict incidents by elephant herd as well as tusker were negatively correlated with high significance (Table 4.6, 4.7 and 4.8).

The frequency of conflict was very high near to the streams within a range of 0-175m and was maximum at 0-50 m zone. The conflict intensity decreases with increasing distance from the streams (Figure 4.35). Pearson 2-tailed correlation shows the frequency of conflicts and distance from road was in negative correlation with high significance ($r = -0.549^{**}$ at 0.01 level). Frequency of conflicts by both the elephant herds and lone tuskers were negatively correlated with increasing distance with high significance (Table 4.6, 4.7 and 4.8).

The elephant conflict incidents were high near to the waterbody (Anayirangal reservoir) within a range of 0-600m and decrease with increasing distance (Figure 4.36). Pearson 2-tailed correlation also shows negative correlations with high significance ($r = -0.620^{**}$) (Table 4.6, 4.7 and 4.8).

It was observed that the slope of the area also act as a factor determining the frequency of conflicts. The conflict incident was high in a slope range of 0-5 degree and significantly ($r= -0.263^{*}$) decreased with increase in slope (Figure 4.37). In Anayirangal the elephant conflicts occurred within an altitude range of 1125 to 1350m. The conflicts decreases with increasing altitude and was significant ($r= -0.337^{**}$) (Figure 4.38). Most of the conflicts have occurred near to the settlements and was decreased significantly ($r = -0.327^{**}$) with increase in distance from the settlement (Figure 4.39 and Table 4.6, 4.7 and 4.8).

The major vegetation classes at Anayirangal are eucalyptus plantation, pine plantation, tea plantation, cardamom plantation, shola forest and grassland. The frequency of elephant conflict was observed high very near to pine plantation within a range of 0-50m and decreased with increase in distance from forest. But there was slight high in conflicts occurred at a range of 1000-1200m and 2000-2100m from the pine plantation (Figure 4.40). According to the Pearson 2-tailed analysis the frequency of conflicts was negatively correlated with the increase in distance
from pine plantation but not significant ($r = -0.173$). The conflict incident by elephant herd and lone tusker were negatively correlated with increase in distance from the pine plantation without any significance (Table 4.6, 4.7 and 4.8).

The conflict incidence was observed very high near to the eucalyptus plantation and was high within a range of 0-25m and decreased with increase in distance from the eucalyptus plantation (Figure 4.41). Pearson 2-tailed analysis also shows negative correlation without any significance ($r = -0.112$). But the conflict frequency by lone tusker and the distance from the eucalyptus plantation was negatively correlated with high significance (-0.485**) (Table 4.6, 4.7 and 4.8).

The frequency of conflict was observed high very near to cardamom plantation and was decreased with increase in distance from the cardamom plantation. The frequency of conflict was very high with a range of 0-50m (Figure 4.44). The Pearson correlation also shows negative correlation with high significance (-0.424**) (Table 4.6, 4.7 and 4.8). The frequency of conflict was also observed high near (0-100m) to the grassland and decreases with distance from the grassland (Figure 4.42). The Pearson 2-tailed analysis shows negative correlation with high significance (-0.467**). In the case of shola forest the frequency of conflict increases with increase in distance and was very high at the range of 2000-3000m (Figure 4.43). Pearson 2-tailed analysis shows a positive correlation with high significance ($r = 0.298**$ with 0.01 level) (Table 4.6, 4.7 and 4.8).

![Figure 4.34. Spatial analysis of conflict with environmental variable (distance from road)](image-url)
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Figure: 4.35. Spatial analysis of conflict with environmental variable (distance from streams)

Figure: 4.36. Spatial analysis of conflict with environmental variable (distance from waterbody)

Figure: 4.37. Spatial analysis of conflict with environmental variable (slope)
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Figure: 4.38. Spatial analysis of conflict with environmental variable (altitude ranges)

Figure: 4.39. Spatial analysis of conflict with environmental variable (distance from settlement)

Figure: 4.40. Spatial analysis of conflict with environmental variable (distance from pine plantation)
Figure 4.41. Spatial analysis of conflict with environmental variable (distance from eucalyptus plantation)

Figure 4.42. Spatial analysis of conflict with environmental variable (distance from grassland)

Figure 4.43 Spatial analysis of conflict with environmental variable (distance from shola forest)
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A study on human-elephant interaction in an environmental perspective

Figure 4.44 Spatial analysis of conflict with environmental variable (distance from cardamom plantation)

Table 4.6 Pearson 2-Tailed correlation of conflict with distance from environmental variables

<table>
<thead>
<tr>
<th>Distance</th>
<th>Road</th>
<th>Drainage</th>
<th>Pine Plantation</th>
<th>Eucalyptus Plantation</th>
<th>Grassland</th>
<th>Shola Forest</th>
<th>Cardamom Plantation</th>
<th>Waterbody</th>
<th>Settlement</th>
<th>Altitude</th>
<th>Slope</th>
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** Correlation is significant at the 0.01 level (2-tailed) & *Correlation is significant at the 0.05 level (2-tailed).

Frequency of conflict intensity with distance from different environmental variables

Table 4.7 Pearson 2-Tailed correlation of conflict (by herd) with distance from environmental variables

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<tr>
<th>Distance</th>
<th>Road</th>
<th>Streams</th>
<th>Pine</th>
<th>Eucalyptus</th>
<th>Grassland</th>
<th>Shola Forest</th>
<th>Cardamom</th>
<th>Waterbody</th>
<th>Settlement</th>
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<th>Slope</th>
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<td>0.685**</td>
<td>0.949**</td>
<td>0.245</td>
<td>0.964**</td>
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<td>0.556**</td>
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<tr>
<td>Altitude</td>
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<td>0.378**</td>
<td>0.225</td>
<td>-0.011</td>
<td>0.135</td>
<td>-0.094</td>
<td>0.036</td>
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<tr>
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<td>0.432**</td>
<td>0.646**</td>
<td>0.932**</td>
<td>0.221</td>
<td>0.939**</td>
<td>-0.04</td>
<td>0.979**</td>
<td>0.567**</td>
<td>0.968**</td>
<td>0.037</td>
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</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed) & *Correlation is significant at the 0.05 level (2-tailed).

Frequency of Elephant (Herd) Conflict intensity with distance from different environmental variables
Table 4.8 Pearson 2-Tailed correlation of conflict (by tusker) with distance from environmental variables

<table>
<thead>
<tr>
<th>Distance</th>
<th>Road</th>
<th>Streams</th>
<th>Pine</th>
<th>Eucalyptus</th>
<th>Grassland</th>
<th>Shola Forest</th>
<th>Cardamom</th>
<th>Waterbody</th>
<th>Settlement</th>
<th>Altitude</th>
<th>Slope</th>
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<tr>
<td>Streams</td>
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<td></td>
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<td>Pine Plantation</td>
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<td>.713**</td>
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<td>-.003</td>
<td>.337**</td>
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<td>-.074</td>
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<td>Cardamom Plantation</td>
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<td>.643**</td>
<td>.610**</td>
<td>.639**</td>
<td>.903**</td>
<td>-.119</td>
<td>1</td>
<td>.307**</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Water Body</td>
<td>-.550**</td>
<td>.731**</td>
<td>.092</td>
<td>.377**</td>
<td>.409**</td>
<td>-.105</td>
<td>.307**</td>
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<td>.367**</td>
<td>.767**</td>
<td>.822**</td>
<td>.962**</td>
<td>-.045</td>
<td>.888**</td>
<td>.268*</td>
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<tr>
<td>Altitude</td>
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<td>.0163</td>
<td>.043</td>
<td>-.01</td>
<td>.167</td>
<td>.097</td>
<td>-.059</td>
<td>.121</td>
<td>.443**</td>
<td>.036</td>
<td>1</td>
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<tr>
<td>Slope</td>
<td>-.271*</td>
<td>.635**</td>
<td>.564**</td>
<td>.768**</td>
<td>.805**</td>
<td>.964**</td>
<td>-.038</td>
<td>.863**</td>
<td>.279**</td>
<td>.987**</td>
<td>0.001</td>
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</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed) &  * Correlation is significant at the 0.05 level (2-tailed).

4.4.4 Human - elephant conflict prone zone

The frequencies of occurrence of conflict incidents with respect to the distance zones from the environmental variables such as streams, waterbody, plantation, shola forest, altitude, slope, settlements, pine plantation, eucalyptus plantation, cardamom plantation, grasslands etc were used to prepare the conflict prone zone areas (Figure 4.45, 4.46 and 4.47. These raster data were mathematically integrated to produce a raster map which represents the possible areas of conflicts with its intensity. The raster map developed in such a manner was classified into five different conflict prone zones namely: very high prone areas, high prone areas, medium prone areas, low prone areas and very low prone areas (Figure 4.48). The area summary of the zones in different settlements was calculated using Arc GIS tools.

The analysis shows that 85% of the settlements at Anayirangal falls under high conflict prone zones except Pachapulkudi, Pethotti and Mulathara. Even though the conflicts inside these settlements are observed low, the surrounding areas of these settlements were under either very high conflict prone zone or high conflict prone zone. The percentage area of very high prone conflict zone was high in the settlements Kozhippennakudi (97%), Singukandam (96%) and Chinnakanal New Adivasi Colony (90%).

The newly established tribal settlements 301 New Adivasi Colony, 80 New Adivasi Colony, Chinnakanal New Adivasi Colony, and Panthadikkulam New
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Adivasi Colony falls under the very high conflict zone with a percentage area of above 75%. One among the newly established tribal settlement Suryanelli New Adivasi Colony cover 65.55% of very high conflict zone and 33.83% area was under high conflict prone zone. The old muduvan tribal settlements Kozhippenakkudi and Chembakathozhukudi falls under very high conflict zone covering percentage area of above 75%. The presence of low conflict prone zone was observed in the settlements Pachapulkudi, Aduvilanthankudi, Santhanpara and Pethotti. The settlement Thalakkulam, Thondimala, Thidir Nagar, B L Ram and Muthaman colony were observed at marginal to fall under very high conflicting prone zone with a percentage area less than 75 (Figure 4.49 and Table 4.9).

Table 4.9. Percentage area of human - elephant conflict prone zone in the settlements of Anayirangal.

<table>
<thead>
<tr>
<th>Settlement</th>
<th>Percentage Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very High</td>
</tr>
<tr>
<td>301 NAC</td>
<td>75.84</td>
</tr>
<tr>
<td>80 NAC</td>
<td>75.35</td>
</tr>
<tr>
<td>Chinnakanal NAC</td>
<td>90.14</td>
</tr>
<tr>
<td>Panthadikkulam NAC</td>
<td>86.46</td>
</tr>
<tr>
<td>Suryanelli NAC</td>
<td>65.55</td>
</tr>
<tr>
<td>Chembakathozhukudi</td>
<td>77.84</td>
</tr>
<tr>
<td>Aduvilanthan Kudi</td>
<td>12.87</td>
</tr>
<tr>
<td>Kozhippenakkudi</td>
<td>96.96</td>
</tr>
<tr>
<td>Singukandam</td>
<td>96.15</td>
</tr>
<tr>
<td>B L ram</td>
<td>74.74</td>
</tr>
<tr>
<td>Chinnakanal</td>
<td>44.50</td>
</tr>
<tr>
<td>Korampara</td>
<td>10.72</td>
</tr>
<tr>
<td>Mulathara</td>
<td>19.36</td>
</tr>
<tr>
<td>Muthaman colony</td>
<td>66.39</td>
</tr>
<tr>
<td>Pachapulkudi</td>
<td>1.27</td>
</tr>
<tr>
<td>Pethotti</td>
<td>0</td>
</tr>
<tr>
<td>Santhapara</td>
<td>0</td>
</tr>
<tr>
<td>Thalakkulam</td>
<td>59.72</td>
</tr>
<tr>
<td>Thidir</td>
<td>74.29</td>
</tr>
<tr>
<td>Thondimala</td>
<td>61.83</td>
</tr>
</tbody>
</table>
Chapter 4: Ecological investigation of human-elephant conflict at Anayirangal, Munnar landscape, Southern Western Ghats

Figure: 4.45. Conflict Prone Zone with respect to environmental variables (plantations and grasslands)
Chapter 4: Ecological investigation of human-elephant conflict at Anayirangal, Munnar landscape, Southern Western Ghats

A study on human - elephant interaction in an environmental perspective

Figure: 4.46. Conflict Prone Zone with respect to environmental variables (shola forest, settlements, water bodies and streams)
Figure: 4.47. Conflict Prone Zone with respect to environmental variables (Roads, altitude and slopes)
Figure: 4.48. Human-elephant conflict prone zone area of Anayirangal
Chapter 4: Ecological investigation of human-elephant conflict at Anayirangal, Munnar landscape, Southern Western Ghats

Figure: 4.49. Percentage area of human-elephant conflict prone zone in the settlements of Anayirangal.

4.4.5 Social aspects of human - elephant conflict

For about 150-200 years ago the Anayirangal area was known as Thalamala. A large extent of grasslands with mosaics of shola forest was spread across the valley from Bodimettu to Periyakanal tea estate holding a large number of Gaur and Elephants. Elephants were being habituated in the Anayirangal reservoir area, dense evergreen forest patch with little cardamom cultivation owned by Chettiyar and Ravuthar of Tamil Nadu. Elephants as a herd usually forage these grasslands and used to take water from a swampy structure called Nallathanni of the stream Suryanala. Now this swamp along with the dense evergreen forest wrapped up by the newly constructed Anayirangal reservoir.

Elephants from Mathikettanshola National Park, Shankarapandimettu grassland, Vetnamteri grassland, B L Ram-Bodimettu, Aramanappara-Papathichola and from Panduvanpara grassland used to came down to this swampy (Nallathanny) area for water. The then existed Muduvan called this area as Anayirangal, (Anayirangal in Tamil means ‘where elephants descent’). Once in every year usually at middle of January these muduvan people used to burn the grassland from Bodimettu to Periyakanal for regeneration of grass as well as for shifting cultivation practices.
The Muduvan people settled in this area from Tamil Nadu around 200 years back basically at Mulavara, above the now called Thidir Nagar. In order to look after the cultivation they lived in various places especially in the top of the hills in Thalamalai like Moolavara, Koluthanpara, Parakadav, Kanamugam, Kunchipetty, Vellathan, Pandavanpara, Parakkudy, Pachapulkudy, Aduvilanthankudy and Chembakathozhukudy. Around 25 families settled permanently at Chembakathozhukudy during 1955-1956, around ten families at Aduvilanthankudy and about five families at Pachapulkudy. Some families from Aduvilanthankudy split and settled at Kozhippennakuy during 1970s.

There are individual names for each place based on some cultural as well as ecological significances like Anakettythara (Anakkettythara meaning elephants mud bathing place in their language) for now called Panthadikkalam; Meenakshiyammantheriyam (meaning the holy place of God Meenakshy) and Parakkadavu (meaning place where historical stones were found) for now called 80 New Adivasi Colony; Peethundu, Kunhippetty, Poothodu, Koombsui and Eruvanthan (meaning where lot of honey combs are seen) are the places in 301 NAC; and the places in eucalyptus plantation are Ellampattam, Panthalam, Vellathanny (Elephant inhabiting places and take water from the swampliness areas) and Surinala for the stream. The muduvan people believed that these places are the home of elephants because of the enough availability of food and water resources. The mosaics of small forest patches were acting as the shade and resting habitat for elephant. The Muduvan people then and now (now seems to be some extend only) do not cause any threat and damages to these places and considered as sacred places. Core of the presently existing pine plantation has one Shankuthuky temple, the God of Elephants and Maladevatha.

They used to cultivate rice, ragi and some vegetables in the then existed swampliness areas especially at Kallumadam, Puyimkesham (South of Thidir Nagar and B L Ram, Vellakkaltheri, Anakkettythara, Karinkallady, Vannathipara, Vellathanny and Panniyar Kandam. In order to protect the crop from the elephant raid, community cultivation guarding had been practiced. Watch sheds were constructed in ten feet intervals for night guarding. For keeping away the elephants they used to smoke by putting fire on the cloth that is rolled and tied in a tree in the wind direction. The period of cultivation was March to December. After getting maturity
to the crop they harvest by cutting the tip portion of the plant with seed. The remaining will leave for elephants and gaur and the people leave that place.

During the time of Anayirangal dam construction the Muduvan families settled permanently in Chembakathozhukudy, as there is least wildlife problem. They were not ready to live near catchments area of reservoir because of disturbing elephant home places. According to the view of old tribal (Muduvan) people the gaur and the tigers habituated in the surroundings of Anayirangal move towards Mathikettanshola and towards Kolukkumala and Rajamala because of the disturbances caused by the dam construction activities. Some of the elephant herd move towards Mathikettanshola, Kallippara, Pappathishola area and towards Mattuppetty area. The remaining elephants occupied still in the surroundings of Anayirangal. Every year during the peak monsoon (June-August) and dry season (December-March) the descendant of those elephants, which moved out of this area, used to come to the grasslands surroundings of Anayirangal reservoir.

About 40 to 50 years back the people from different parts of Idukki and Kottayam districts migrated to Anayirangal and began to settle in the revenue lands adjoining to the Anayirangal reservoir. The settlements Singukandam, Thidir Nagar, Shanmugavilasm, B L Ram, Chinnakanal, Vilakk and Suryanelli were established during that period. Some people from Tamil Nadu came here as cardamom estate workers and they settled in small colonies inside the cardamom plantation. The settlements Mulathara, Muthaman Colony, Thalakkulam, Thondimala, Korampara, Pethotti and Kudampara were examples of such colonies inside the cardamom plantations.

Human - elephant conflict at Anayirangal has increased from the year 2005 onwards. Government of Kerala assigned land for about 704 families of landless tribes in the middle of the elephant habitat during the year 2002 and the people began to settle during 2005 onwards. This is the primary reason behind the conflict. The pine plantation and some portion of the eucalyptus plantation in the catchment areas of Anayirangal reservoir with an area of 3.72 km² was allotted for 589 families during 2002-2003 and constituted five New Adivasi colonies. Tribal families who got land at Anayirangal valley came from different places of Idukki district.
A part of pine plantation was assigned for 53 families and constituted 80 New Adivasi Colony of which about 34 families settled here during 2007-2008. These families were basically from Marayoor and Kovilkadav areas of Idukki. Most of them belong to Hill Pulayas community. The settlement was protected from human - elephant conflict by erecting the solar powered fence during the year 2008. The pine plantation at Panthadikkulam area was assigned to 77 families and constituted Panthadikkulam New Adivasi Colony. The main community of this settlement were Hill Pulayas from Marayoor–Kanthallur area, Mannans from Chemmannar, Udumbanchola and Kannampadi, Ulladans from Melukav-Erattupetta and Muduvans of Munnar area. Only 19 families settled during the year 2008 because of human elephant conflict.

The pine plantation near to Singukandam non tribal settlement was assigned to 301 families and constitutes the 301 New Adivasi Colony. This colony mainly constituted people from Kumali, Marayoor Thodupuzha, Mankulam, Munnar, Adimali, Idukki and Kozhimala belongs to the community Hill Pulayas, Ulladans, Uralis, Mannans and Muduvans. The human - elephant conflict in this settlement was very high and only 6 families settled permanently during the year 2008. Eucalyptus plantation near to Suryanelli was assigned for 92 tribal families and form Suryanelli New Adivasi Colony. About five families settled permanently during the year 2008. These people belong to the community Mannans and native of Kumali and Kozhimala area of Idukki district. Human elephant conflict in this settlement was also very high. The part of eucalyptus plantation near to Chinnakanal was assigned for 66 families and constituted Chinnakanal New Adivasi Colony. Only six families of Mannans were settled during the year 2008 (Table 4.10).

The geospatial analysis of the conflict with environmental variables shows that all the five New Adivasi Colony were falling under the very high conflict prone zone. Because of high elephant conflict, the remaining families were hesitating to settle here. During 2008 the human-elephant conflict was observed very high as the people began to settle during this period. These tribal people were introduced into an area which was not familiar to them both landscape point of view as well as elephant’s behavioural point of view. This was the main reason for high rate of human casualties by elephant attack in these settlements.
Table: 4.10. Socio economic details of Settlements facing human - elephant conflict at Anayirangal

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<tr>
<td></td>
<td>Community</td>
<td>Total Family</td>
<td>Human population (2008)</td>
<td>Wage labour (%)</td>
<td>Farmers: own land (%)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pachapulkudi</td>
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<td>144</td>
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<td>27</td>
<td>95.00</td>
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<td>80 New Adivasi</td>
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<td>134</td>
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<td>92.31</td>
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<td>20</td>
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<td>0</td>
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<td>Chinakanal New</td>
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<td>0</td>
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<td>Adivasi Colony</td>
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<tr>
<td>B.L.Ram</td>
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<td>574</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singukandam</td>
<td>Non Tribal</td>
<td>56</td>
<td>216</td>
<td>47.37</td>
<td>40.79</td>
</tr>
<tr>
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<td>Non Tribal</td>
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<td>75</td>
<td>43.48</td>
<td>56.52</td>
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<td>Non Tribal</td>
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<td>43</td>
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<tr>
<td>Chinnakanal</td>
<td>Non Tribal</td>
<td>22</td>
<td>81</td>
<td>95.00</td>
<td>0</td>
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<td>Tribal (Muduvan)</td>
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<td>140</td>
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<td>Non Tribal</td>
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</tbody>
</table>
4.4.5.1 Economic activities

The socio-economic survey of the settlements facing human - elephant conflict at Anayirangal shows an average of 77.61% of the people are wage labours, 18.86% of people are farmers in their own marginal lands and about 3.53% people engaged in other activities including government jobs and own business. The people under the category of wage labours are engaged in the daily wages activities in cardamom plantation, tea estates and the construction activities. Among the agriculturists, the marginal to small farmers grow mainly ginger, tapioca, banana, ragi, cabbage, vegetables like beans in the homestead gardens and some extent of cardamom, pepper and coffee in the nearby areas.

4.4.6 Biotic pressure on elephant habitat

The information of status and distribution of biotic pressure on the elephant habitat was necessary for the preparation of long term management of human elephant conflict at Anayirangal area. In Anayirangal area fuel wood collection and livestock rearing were the two major anthropogenic pressures on the elephant habitat.

4.4.6.1 Intensity of wood cutting

One of the major cultivation at Anayirangal was cardamom. After each harvest, the seed was dried before selling using drier. They were using the dead trees and small branches of the tree as a source of fuel. They used to collect the fuel wood from nearby eucalyptus plantation, pine plantation and cardamom plantation. The average fuel wood consumption per family was 19 kg per day. The people also put fire in the settlement during night to keep away the elephants entering into settlements.

From the transect data it was observed that the wood cuttings was higher near to the settlement (around 100-200 m) and away from the settlement (1 km away) (Figure 4.50). Most of the settlements are very adjacent to the fuel wood plantation. They collect fuel wood from the fringe areas and inside the plantation. The Pearson 2-tailed analysis shows the average percentage of wood cuttings and distance from settlement were positively correlated but no significance (Table 4.11 and Table 4.12). The fuel wood collection during day time inside the
plantations give more stress to the elephant habitat and also the chances of encountering with elephants inside the plantation during the time of fuel wood collection was also high.

![Figure 4.50. Percentage of average wood cuttings with respect to distance from settlements](image)

**Table 4.11.** Percentage of average wood cuttings with respect to distance from settlements

<table>
<thead>
<tr>
<th>Distance (m) from settlements</th>
<th>Percentage of average wood cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-100</td>
<td>5</td>
</tr>
<tr>
<td>101-200</td>
<td>13</td>
</tr>
<tr>
<td>201-300</td>
<td>9</td>
</tr>
<tr>
<td>301-400</td>
<td>12</td>
</tr>
<tr>
<td>401-500</td>
<td>8</td>
</tr>
<tr>
<td>501-600</td>
<td>12</td>
</tr>
<tr>
<td>601-700</td>
<td>8</td>
</tr>
<tr>
<td>701-800</td>
<td>9</td>
</tr>
<tr>
<td>801-900</td>
<td>12</td>
</tr>
<tr>
<td>901-1000</td>
<td>12</td>
</tr>
</tbody>
</table>
Table: 4.12. Pearson 2-tailed analysis of average percentage of wood cuttings with respect to distance from settlements

<table>
<thead>
<tr>
<th>Pearson 2-tailed Correlations</th>
<th>Distance from settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from settlement</td>
<td>1</td>
</tr>
<tr>
<td>Average Percentage of Wood Cutting</td>
<td>0.32178</td>
</tr>
</tbody>
</table>

4.4.6.2 Livestock rearing

Livestock rearing is one of the major economic activities in the settlements of Anayirangal. During 2008 a total of 160 cows were reared for milk production in the settlements adjacent to the elephant habitat of shola forest, eucalyptus and pine plantation. It was observed that there were no families practising stall fed rearing of cows. All of them send the cattle in fallow lands and grasslands inside the eucalyptus and pine plantations during day time for grazing as the availability of enough fodder.

The cattle population was high in B L Ram (60) followed by Sigukandam (32) during the year 2008. In addition to this the people from outside the settlements used to bring large number of buffalos (about 75 to 100 per period) from Tamil Nadu and used to graze them in the eucalyptus, pine and grasslands for a short period of nearly two months by constructing temporary shelter in the immediate catchments of Anayirangal reservoir before sending them to the meat shops. Within two months these group of buffalos were send to meat shop and was replaced by another set of buffalos. So the buffalo population remains almost constant throughout the year.

The average density of cattle dung piles was observed highest (10.66 dung piles/100m²) at a distance of 100-200 m away from the settlements followed by 700–800m distance from the settlement (Table 4.13, Figure 4.51). According to the Pearson 2-tailed analysis, cattle dung density and distance from settlements was negatively correlated without any significance (Table 4.15). The density of cattle dung was high in the grasslands (8.3 dung piles/100m²) followed by pine plantation (6.4 dung piles/10m²) and eucalyptus plantation (2 dung piles/100m²) (Table 4.14).
Cattle grazing inside the grasslands and plantations may lead to competition for fodder as well as forage place between elephant and cattle. The chances of encounter of people with elephants were also high leading to human injury or even death. During 2009, in Chinnakanal New Adivasi Colony one cow was severely injured by elephant attack and got died. One human death also occurred in 301 New Adivasi Colony by elephant attack while the person was going to graze the cattle inside the pine plantation. Fuel wood collection and cattle grazing activities act as a stress to the free movement of elephant inside the elephant habitat which may lead to conflict with people.

<table>
<thead>
<tr>
<th>Distance from settlement (m)</th>
<th>Average cattle dung density/100 m²</th>
<th>Percentage of average cattle dung density/100 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-100</td>
<td>9.33</td>
<td>11.97</td>
</tr>
<tr>
<td>101-200</td>
<td>15.33</td>
<td>19.66</td>
</tr>
<tr>
<td>201-300</td>
<td>13.33</td>
<td>17.09</td>
</tr>
<tr>
<td>301-400</td>
<td>4.0</td>
<td>5.13</td>
</tr>
<tr>
<td>401-500</td>
<td>2.0</td>
<td>2.56</td>
</tr>
<tr>
<td>501-600</td>
<td>1.33</td>
<td>1.71</td>
</tr>
<tr>
<td>601-700</td>
<td>10.67</td>
<td>13.68</td>
</tr>
<tr>
<td>701-800</td>
<td>14.00</td>
<td>17.95</td>
</tr>
<tr>
<td>801-900</td>
<td>5.33</td>
<td>6.84</td>
</tr>
<tr>
<td>901-1000</td>
<td>2.67</td>
<td>3.42</td>
</tr>
</tbody>
</table>

**Table: 4.14** Average cattle dung density in various elephant habitat

<table>
<thead>
<tr>
<th>Land use</th>
<th>Average Cattle dung density/100 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>8.3</td>
</tr>
<tr>
<td>Eucalyptus plantation</td>
<td>2.0</td>
</tr>
<tr>
<td>Pine plantation</td>
<td>6.4</td>
</tr>
<tr>
<td>Cardamom plantation</td>
<td>1.4</td>
</tr>
<tr>
<td>Shola forest</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table: 4.15** Pearson 2-tailed analysis of percentage of average cattle dung density with respect to distance from settlements.

<table>
<thead>
<tr>
<th>Pearson 2- tailed Correlations</th>
<th>Distance from settlements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from settlement</td>
<td>1</td>
</tr>
<tr>
<td>Average cattle dung density</td>
<td>-0.367</td>
</tr>
</tbody>
</table>
4.4.7 Human – elephant conflict and forest fragmentation

Forest cover change analysis of Anayirangal area between the period 1990 to 2008-2009 shows distinct changes in the vegetation classes. There was a considerable increase in the extent of settlement, resort area, cardamom plantation and tea plantation between the year 1990 and 2008-2009. The area of the settlement increased from 2.5 km² to 6.88 km² and the resort area increased from 0 to 0.93 km² between the period 1990 to 2008-2009.

During this period the area of cardamom plantation increased from 34.53 km² to 36.12 km² with an extent of 1.59 km². The area of tea plantation also increased to an extent of 1.19 km² between 1990 and 2008-2009. Even though the extent of grassland increased from 20.25 km² (during the year 1990) to 22.68 km² (2005-06) but subsequently it decreased and remains almost stable (20.63 km²) during the year 2008-2009.

A considerable decrease in the area of shola forest was observed between the year 1990 and 2008-2009. During 1990 the shola forest has an extent of 25.44 km² but in 2008-2009 the area decreased to 20.49 km² (Table 4.16, Figure 4.52 to 4.54).
Table: 4.16. Analysis of land-use/land-cover changes during 1990 to 2009

<table>
<thead>
<tr>
<th>Land use Classes</th>
<th>Area (km²) 1990</th>
<th>Area (km²) 2005-2006</th>
<th>Area (km²) 2008-2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterbody</td>
<td>3.74</td>
<td>3.74</td>
<td>3.46</td>
</tr>
<tr>
<td>Shola Forest</td>
<td>25.44</td>
<td>21.22</td>
<td>20.49</td>
</tr>
<tr>
<td>Cardamom Plantation</td>
<td>34.53</td>
<td>35</td>
<td>36.12</td>
</tr>
<tr>
<td>Tea Plantation</td>
<td>17.34</td>
<td>18.53</td>
<td>18.53</td>
</tr>
<tr>
<td>Eucalyptus Plantation</td>
<td>5.69</td>
<td>5.04</td>
<td>5.04</td>
</tr>
<tr>
<td>Pine Plantation</td>
<td>4.88</td>
<td>4.88</td>
<td>2.29</td>
</tr>
<tr>
<td>Grassland</td>
<td>20.25</td>
<td>22.68</td>
<td>20.63</td>
</tr>
<tr>
<td>Settlement</td>
<td>2.5</td>
<td>3.16</td>
<td>6.88</td>
</tr>
<tr>
<td>Coffee Plantation</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Moist Deciduous Forest</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Resort Area</td>
<td>0</td>
<td>0.12</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Total Area</strong></td>
<td><strong>114.56</strong></td>
<td><strong>114.56</strong></td>
<td><strong>114.56</strong></td>
</tr>
</tbody>
</table>

During the year 2005 an area of 2.59 km² of pine plantation, 0.87 km² of eucalyptus plantation and 0.25 km² of grasslands were used for the land assignment for landless tribes at Anayirangal. The scenic beauty and climatic conditions attracts the tourists and numerous settlements were constructed at Chinnakanal area by converting nearly 1 km² of grassland. The extensive conversion of shola forest to cardamom plantation was observed especially at Papathishola, Periyakanalshola and fringe areas of Mathikettanshola National Park.

The conversion of eucalyptus plantation, pine plantation and grasslands to settlements and resort areas from the year 2005 onwards along with the conversion of shola forests to cardamom plantation resulted into the loss of suitable habitats for elephants as well as blocking the usual movement paths of elephant. The shrinkage of elephant habitat and blocking of usual movement paths and corridor had resulted the elephants to enter into human habitation and leading to a conflict condition.
Figure 4.52. Land-use/land-cover of Anayirangal (1990)
Figure: 4.53. Land-use/land-cover of Anayirangal (2006)
Figure: 4.54. Land-use/land-cover of Anayirangal (2008-2009)
4.5 Discussion

Elephant visits and human-elephant conflict in the settlements of Anayirangal was high during the year 2008. The habit shrinkage and blocking of the usual elephant movement was the prime reason behind the increase in conflict at Anayirangal. About 3.72 km² of elephant habitat including grassland, eucalyptus and pine plantation surrounding the Anayirangal valley has been converted to settlement by the land assignment programme of Govt. of Kerala for the landless tribal families during the year 2002-2003. The land assignment in the middle of the elephant habitat along with the encroachments especially in Chinnakanal area leads to the shrinkage of major elephant habitat at Anayirangal and block the usual movement paths. Habitat loss or degradation through deforestation and conversion results pocketing effect and loss of corridor to adjoining forest tracts indirectly increases the conflicting condition (Wing and Buss, 1970; Sukumar, 1986; and Daniel et al., 1995).

During 2007, the frequency of elephant sightings was high in the settlement Singukandam followed by the old tribal Muduvan settlement. The tribal people who got land by land assignment programme at Anayirangal valley began to construct the houses and start cultivation in the homestead gardens by clearing the vegetation inside the pine, eucalyptus and grasslands since 2005 onwards. The presence of human and the anthropogenic influences in the elephant habitat induces stress on the elephants and they started entering in to the settlement and nearby areas and started destroying the crops, property and attack on human beings. The human casualties were also high in Singukandam which is located in the juncture of newly established tribal colonies.

Out of 589 tribal families who got land as part of land assignment programme, only about 75 families occupied in the settlements because of the fear of elephant during 2007-2008. These families started cultivating the crops such as tapioca, banana, ginger etc in the settlements. The shrinkage of elephant habitat along with the cultivation of elephant palatable food species induces intrusion of the elephants and in 2008, it was observed that the elephant sightings were high in these settlements.
In 2008 property damage was very high in newly established 301 New Adivasi Colony. During 2008, more number of houses was being constructed in the newly established tribal colonies. Elephants destroyed most of the houses and shed constructed by these families during 2008. Even though the pine and eucalyptus plantations were allotted for the tribal families, the elephants utilized these areas as temporary places for feeding and resting as well as moving paths. But at the beginning of 2008, one of the newly established tribal colony (80 New Adivasi Colony) erected solar power fences around their settlements with a perimeter of 6 km. This resulted in permanent blocking of elephant movement paths as well as loss of habitat. This was the major reason behind high conflict in the adjacent settlements during 2008.

Both the tuskers as well as the elephant herd were equally causative to the conflict. The net economic loss due to crop damage was high in Mulathara, where the main cash crop cardamom was extensively cultivated. Cardamom was the major cash crop damaged by elephants. It was observed that elephants usually move through the cardamom plantations without causing any damage to the cardamom plants. But under stressed environmental condition such as when the people were trying to keep away the elephant by making noise with crackers or when the elephant was chased by some people, elephants usually trampled the cardamom plant in a huge extent.

The main food crop damaged by elephant was the ragi, banana, tapioca and cabbage. Ragi is being cultivated by the Muduvan tribal people for their subsistence in the fringe areas of pine plantations especially in Chembakathozhukudi and Kozhippennakudi. According to Sukumar (1986) and Daniel et al. (1995), crop fields and villagers bordering forest will face more human-elephant conflict due to suboptimal resources. First time in their history the food crop, ragi was raided by elephants in huge extent during 2008. Habitat loss by erecting solar power fence in the nearby newly established tribal colony was the prime reason behind this. According to them, they were practising community farming and shifting cultivation of ragi for more than 100 years.

Before the year 2002-2003, elephants will not enter their agriculture field during the cultivation period. They were practising community guarding and kept the elephant away by smoking in air with a twine of coir or cloths. After harvesting
they left the place for elephants to eat the shoots of the ragi. This becomes topsi-
turvy after 2003. Elephants are interested to crop raid since cultivated species 
are highly nutritious and palatable and less toxic than their wild counterpart. They 
require less effort due to single species dominance (Albl, 1971; Sukumar, 1985a, 
1989, 1990). Though not much highlighted in studies, crop raiding could be 
related to requirement of grass in the diet than other factors, taking this into 
account that Poaceae species such as finger millet (ragi) are more preferred 
species during crop raid. Such agriculture crops offer bulk and nutritious forage 
and easier to feed to the elephants (Sukumar, 1990).

The frequency of crop raiding inside the ragi field was higher by herd than that by 
lone tusker. The range and intensity of crop raiding inside the settlement area by 
lone tusker was high than that of herd. It was observed that lone tusker roam in 
large area in search of palatable agriculture crops like banana, cabbage and 
tapioca. Bulls are well known to raid crop more frequently than family herds 
(Sukumar, 1989, 1991; Santiapillai and Jackson, 1990; Appayya, 1995; Daniel et 
al., 1995). According to Balasubrahmanyam et al. (1995), though the frequency 
of raids by males was more the extent of damage caused by bulls and herds was 
not statistically different as the damage caused by a herd collectively was more 
than that by a lone tusker.

The human casualties were also high during 2008. The frequency of 
manslaughter incidents was high in the newly established tribal colonies along 
with Singukandam. Most of the people in the newly established tribal colonies 
came from different parts of Idukki districts, their knowledge on the behaviour of 
elephants at Anayirangal was very poor and they were not much familiar with the 
geography of this landscape. This was the reason for increase in number of 
human casualties and manslaughter in the newly established tribal colonies 
during the year 2008. During 2007-2009, five people got killed by elephant of 
which 3 people were from newly introduced tribal families belonging to Mannanas 
(2) and Hill Pulaya (1). Out of five manslaughter incidents at Anayirangal by 
elephants, two cases were by tusker elephant and the remaining three cases by 
elephant herd. According to Sukumar (1991), the trend of manslaughter incidents 
in South India was by bulls though they constitute less than 10% of the total 
population.
Out of two manslaughter incidents by lone tusker one case happened when the tusker elephant was under musth condition. Some bulls are inherently aggressive (especially during musth) and turn into habituated killers (Sukumar, 1989; Chandrashekaran et al 1992; Cheeran, 2008). The intensity of minor injuries by adult lone tusker at Anayirangal was high compared to herd elephants. It was observed that the frequency of encounter with elephants was high in males than females as men were actively involved in cutting of trees and collection of fire woods.

The spatial analysis of human - elephant conflict with the environmental variables shows the frequency of conflict was high in the settlements and adjoining areas near to the roads, streams, water bodies and low altitude ranges having fewer slopes. Pearson 2-tailed analysis of the frequency of conflict and distance from these variables shows negative correlation with high significance. It was observed that elephants extensively use the village roads and estate roads in tea, eucalyptus, pine, and cardamom plantations at Anayirangal area as a local movement path between various patches of elephant habitat. Elephants usually preferred the least disturbed trek paths and even transect lines which were made inside the forest and plantation as its movement paths (Desai and Baskaran, 1996; Desai, 2002; Ramkumar and Arumugam 2004; Daniel et al., 2006).

Water and saltlicks are the two important factors that govern the movement and distribution of elephants (Eisenberg and Lockhart, 1972; Willamson, 1975; Seidensticker, 1984). The general scarcity of water in forest areas in summer and its availability in irrigation tanks near human settlement acts as catalysts for crop raiding. Many of the check dams and reservoirs attracts elephants as a source of water, in such situation crop raiding occurs in the settlements adjoining to these reservoirs (Seidensticker, 1984; Sukumar 1989; Sukumar, 1990). The major source of permanent water for elephants in the Anayirangal valley was the Anayirangal reservoir. Most of the conflicting incidents occurred in the settlements near to the Anayirangal reservoir. Pearson 2-tailed analysis of the frequency of conflict and distance from the streams and water bodies shows negative correlation with high significance. In many places such as different regions of Eastern Ghats, the competition for water between people and elephants were prevalent (Sukumar, 1986).
Many studies (Kay, 1973; Daniel et al., 1987; Sukumar, 1991; Areendran et al., 2011) have shown that elephants avoid steep slopes. Hills were also probably avoided as they are more open in nature and offer less shade.

The spatial analysis of the frequency of conflict and the distance from major elephant habitat were negatively correlated and the intensity was high in the settlements very near to such elephant habitat except shola forest. The intensity of conflict was high very near to pine plantation, eucalyptus plantation, cardamom plantation and grasslands. It was observed that the frequency of conflict was high in the settlements away from the shola forest. Elephants can occur in high densities in monoculture plantations and they also feed on the bark of the eucalyptus in some areas pointing to its adaptability (Sukumar, 1990; Nair and Jayson, 1992). Most of the settlements facing human - elephant conflict were situated in the fringe areas and inside the eucalyptus, pine and grasslands. Grass is an important component in the diet of elephants and could determine their movements in some areas (Kay, 1973; Sivaganesan and Johnsingh, 1995; Sukumar, 1990). Other than food, an important role of vegetation for elephants is in providing shade. Asian elephant need access to shade much of the day (Wing and Buss, 1970 and Seidensticker, 1984). During day time, elephant spend grazing in the grasslands, eucalyptus and pine plantations. Most of the crop raiding was observed in evening and late night.

Human - elephant conflict at Anayirangal was observed high during January, March, April and May in summer season and during June, October and November in rainy season. During the wet season, major elephant palatable crop species cultivated in the settlements are banana and tapioca. During this time jackfruit and guava were also ripened. It was observed that the habituated adult lone tuskers used to roam the settlements in search of jackfruit and guava. This was also a factor catalyses the intensity of conflict in these settlements. During wet season, elephant palatable crop cultivated in the settlements are ragi, cabbage, banana, pigeon pea and vegetables. The raid frequency index of the elephant herd was high during this period as these crops attract the elephants herd and they used to attempt to raid the crop.

The Pearson 2-tailed analysis of mean rain fall and frequency of conflict was showed negative correlation without significance. More number of elephant
sightings was observed adjoining to the Anayirangal reservoir during the summer season as the scarcity of fodder and water in high altitude areas and shola forest. The conflicting incidents were also observed high in the settlements surrounding the Anayirangal reservoir. The agriculture cycle and the drought have influence for inducing the conflict as the availability of forage and water shall be affected. During drought, the artificially maintained water sources attract elephants (Sukumar, 1990; Sutton, 1998; Thouless, 1994).

Using the multi-criterion analysis, the conflict prone zone area was identified with most probable conflicting areas. The newly established tribal settlements were in the high prone area. The old muduvan tribal settlements Chembakathozhzukudi, Kozhippennakudi were also fall under high conflict prone zone. The non tribal settlement Singukandam was in very high conflict prone zone. The spatial nature of conflict intensity was varying at Anayirangal in each year and was mainly depending on the anthropogenic impacts on elephant habitat and barriers to the usual elephant moving paths.

The major anthropogenic impacts on the elephant habitat were the wood cuttings, fire wood collection and cattle grazing inside the elephant habitat adjoining to Anayirangal reservoir. The intensity of wood cutting was observed high in the fringe areas of plantations as well as in deep forest plantation areas. Pearson 2-tailed analysis also shows a positive correlation of wood cuttings and distance from settlements. Average fuel wood requirement for the families at Anayirangal was 19 kg per day. The high fuel wood consumption was due to the fuel requirement for drying up the cardamom as well as to put fire during night time to keep away the elephants.

Livestock rearing was also contributing as a biotic pressure to the various elephant habitat at Anayirangal. In Anayirangal area there were around 160 domestic cows and about 100 buffalos. Because of the availability of grass as a fodder, the farmers were not practising stall fed rearing of cattle and send them in the fallow lands, grasslands and plantation areas. Cattle dung pile was observed highest in grasslands and pine plantations with maximum in the fringe areas and away from the settlement. Grazing by domestic cattle and fire wood collection became serious habitat threats degrading forest conditions (Beadle and Mishra, 1995).
The degradation of habitats brought about by grazing and fuel wood cutting opens up spaces that facilitate the proliferation of weeds like *Lantana camera*, *Clidemia hirta* (L.) D. Don and *Eupatorium* (Deepamol et al., 2012). These weeds suppress the growth of grass and other natural vegetation, which in turn results in reduced food resources for elephants (Baskaran and Venkatesh, 2009). The studies by Varma et al. (2009), in the Bannerghatta National Park and adjoining landscape, shows that the major reasons for human-elephant conflict was due to the ever increasing human activities around forest areas, shrinking habitat due to encroachments, fragmentation by roads and degradation of habitat due to biotic pressures such as fire wood collection cattle grazing and poaching of trees in the elephant habitat. The biotic pressure due to cattle grazing and wood cuttings decreased the quality of elephant habitat of Mudumalai according to Silori and Mishra (1995) and the elephant corridors of Nilgiri north forest division (Ramkuar and Arumugam, 2004).

Anayirangal area has a history where the people especially the Muduvan tribal and the elephants live in harmony with each other. Community farming and community guarding was practiced at that time. The main food source ragi, and rice were extensively cultivated by the muduvan tribal people since then. The rate of forest fragmentation and conversion was observed high between 1990 and 2008 at Anayiranagal. About 4.95 km² of shola forest had been converted to cardamom plantation and fuel wood plantations. The elephant habitat in the valley was fragmented by the conversion of forest plantations to settlements. About 4.38 km² of crucial elephant habitat was converted to settlement.

The ever increasing tourism activities endorse the construction of resorts about an area of 1 km² in the elephant corridors. It was estimated that prime elephant ranges have shrunk by 20-25% in South India within a century and fragmentation has brought elephant closer and conflict with people. The prime elephant habitats have already been converted to agriculture lands and the existing elephant population was trapped (Sukumar, 1989, 1990). The improper land assignment for the landless tribes in the middle of the elephant habitat along with the erection of solar power fence around the tribal settlement and the encroachment of the eucalyptus plantation by the outsiders resulted the shrinkage of crucial elephant habitat and loss of usual movement paths for elephant.
4.6 Conclusion

Once existed harmony of people living with elephants in the Munnar landscape has now become topsy-turvy. The over exploitation and habitat conversion into stepping stone habitats leads the local abundance of elephants and high conflicts with people at Anayirangal.

Unscientific land allotment for landless tribal triggers the rate of conflicts. A total of 1200 incidents of conflicts occurred either in the form of crop damage, property damage or attack on human beings between 2007 and 2009. Elephant raid in various settlements of Anayirangal had resulted with a net loss of ₹874752. The percentage of farmers affected is high in the settlements where the farmers having small scale cultivation of both cash crops and food crops. A total of 164 property damage incidents occurred at Anayirangal valley and was high in 2008 as the newly established tribal settlements started constructing their sheds and houses during this time. A total of 117 incidents of attack on human have been reported between 2007 and 2009.

Lack of awareness about the knowledge on the behaviour of elephants at Anayirangal and the geography of landscape influencing the reasons for increased incidents of human casualties due to conflict. During this period 5 people were killed by the elephant, 11 people were severely injured and 93 got minor injuries. Out of five human deaths two were females. Most of the human casualties occurred among the tribal people and are novel to this region, who got their land as part of land assignment programme by the Govt.

The erection of solar power fences around one of the newly established tribal colony increases the rate of conflicts and the conflicting incidents were shifted to nearby settlements during 2008.

The intensity of conflict was high in the settlements of Anayirangal during the dry season as the scarcity of water in the hilly areas of Western Ghats during peak summer. The elephant palatable crop cultivation in the settlements also influences the rate of conflicts. Cultivation of tapioca, banana, and the availability of jackfruits and guava is influencing the conflicting intensity during the dry
season and the cultivation of ragi, cabbage, pigeon pea and other vegetables influence the crop raiding during the wet season.

Lone tuskers are found to be taking high risk for the crop raiding attempt than the herd. Lone tuskers very frequently used to travel a long distance through the settlements in search of jackfruits, banana and guava. The bulk damage due to the crop raiding is by the elephant herd. They usually raid the crops such as ragi, cabbage and banana cultivated in the settlements occupying in the fringe areas of forests and forest plantations. The cash crop, cardamom got damaged due to the trampling especially while the elephants passing through the cardamom plantations to nearby elephant habitat.

The analysis of the frequency of conflicts with respect to various environmental variables reveals that the conflict decrease with increase in distance from road, streams, water bodies, settlements, fuel wood plantations, cardamom plantations and grasslands and increases with decrease in altitude, slope and increase in distance from shola forest. The geospatial analysis of conflicts shows 85% of the settlements at Anayirangal fall under high conflict prone zones except Pachapulkudi, Pethotti and Mulathara.

The rate of forest fragmentation and conversion of shola forest, grasslands and fuel wood plantations was high between 1990 and 2008, which leads shrinkage of crucial elephant habitats as well as blocking the usual movement paths of elephant resulted high conflict condition. Over exploitation of elephant habitat by conversion of natural vegetation to settlements, resort areas and agriculture land along with other biotic pressure such as looping of trees, fire wood collection and cattle grazing inside the elephant habitat resulted the elephants to live in a stressed and fragmented habitat which intern increase the conflicting condition at Anayirangal. Unscientific construction of solar power fences around the cardamom plantation will further amplify the trapping of elephant population at Anayirangal and will enhance the rate of conflicts.