Management of landscape ecosystem desires to ensure the long-term potential of the natural resource to sustain ecological, cultural and economic functions. Landscape ecosystems are valued both for their biodiversity, and for the ecosystem services and ecological functions they provide to sustain the life. Rising demographic driven demands of natural resources and diversion of forest areas for faster economic growth have caused ever increasing stresses on natural resource rich areas. Recent trends of anthropogenic developments augment the process of modifications/alterations of the natural landscape for obtaining goods and services, delivered by that landscape, which are of economic, social or ecological value to them (Hector et al., 2011). These alterations are the response of changing economic and social needs, without much care on the natural potential of the landscape (Linehan and Gross, 1998). Such human induced alterations, fragmentation and shrinkage of wildlife habitats are the major threats to the long-term conservation of species. Fragmentation of landscapes results reduced remnant patch sizes, created higher edge-interior ratios, increased patch isolation and reduced the connectivity between patches (Mcintyre and Hobbs, 1999; Kretser et al., 2008). The shrinkage and degradation of natural landscape due to anthropogenic pressures and commercialisation have witnessed substantial disruption of ecological services and alarming erosion of our natural heritages comprising rivers, aquifers, forests, grasslands, mountains, arid lands, deserts, wetlands, coastal and marine habitats. This has also affected natural phenomena such as breeding, ranging and migration of wildlife. All of these changes have major consequences on the viability of species population (Gehring et al., 2003).

The extensive removal of native vegetation from the natural landscape has resulted in the formation of habitat patches or ‘habitat islands’ around which most or all of the original vegetation has been removed (Saunders et al., 1991; Gascon et al., 1999). As wildlife habitat is fragmented, there is a concomitant increase in other land cover types in the intervening space between the remnant patches collectively referred to as matrix where the land-use practices are
opposed to the natural reestablishment of forest vegetation. Since the forest tracts become ‘islands’, in human transferred landscape may alter the spatial structure of wildlife habitat and survival of many species which depend on that particular ecosystem. In such a human transferred fragmented landscape, the remnant vegetation patches in the landscape matrix, to varying degrees, do allow animals to move through, act as ‘habitat sinks’ for dispersing individuals and are also suitable for colonization by species that can persist in such habitats (Johnsingh et al., 2008).

Habitat fragmentation has multiple effects on wildlife population, most of them tending to decrease the population viability and increase the probability of local extinction because of the persistence of many populations which depends on the ability of individuals to disperse between patches. The loss of habitat furthermore may reduce the absolute size of subpopulation, or may divide populations into several subpopulations (Begon et al., 1999). The dynamics of which may be governed by high levels of demographic, environmental and spatial uncertainty (Caughley and Sinclair, 1994; Begon et al., 1999). As the inter-patch distance increases, local populations within a patch become increasingly isolated and may suffer genetic decline, due to inbreeding depression or erosion of genetic diversity, which threaten long term persistence (Dudash and Fenster, 2000).

Habitat fragmentation may induce the patchiness for the availability of resources and cause aggregation of the animal population confined to the remnant patches in the landscape matrix. This will reflect in the demographical difference of the species in the landscape. For a given species, good quality habitats yield a demographic excess (natality > mortality), and are designated as ‘source’. Lower quality habitats yield a demographic deficit (mortality > natality), the ‘sink’, which may not persist without immigration from ‘sources’. The favourable good quality landscape unit (sources) may support relatively large populations, while unfavourable lower quality landscape unit (sinks) may support small populations (Pullin, 1988).

The demographic dynamics is balanced in each habitat, and in the whole population, by dispersal, with net emigration from the source and net immigration into the sink (Dias, 1996). In this manner species may occur as sets of local population (Fahrig and Merriam, 1994; Hanski, 1999; Gergel and Turner, 2002)
connected by inter-patch dispersal (Osborn and Parker, 2003). Such connectivity allow for immigration, as well as colonization after local extinctions, thereby buffering species against extinctions (Aarde and Jackson, 2007).

The fragmentation of biotic community, bio-geographic changes and its environmental consequences may invariably threaten the survival of many species. Mega herbivores like elephants, the long ranging species with extensive habitats and nutritional requirements are among the most affected species (Sukumar, 2006). This has lead to frequent conflict of the wildlife with the humans (Baskaran and Desai, 1996) resulting in damage and death on both the sides. There is a need to avoid and minimize these conflicts in the human encroached natural wilderness which had served as a migrating corridor for these mega herbivores. To enable the wildlife to migrate, identification and development of potential migrating corridors are required (Johnsingh et al., 1990). Corridors, which connect the two landscape units (the sources and sink) can facilitate the local movements of species and prevents isolation of small population.

A corridor allows target species to import new genetic material into isolated populations and also increases the area and diversity of habitats over and above the area of the two habitat patches that it connects. If the habitat of one area becomes unsuitable (e.g., because of climate change), organisms can move along corridors to reach more suitable habitat, and in a sense be ‘rescued’.

In a human dominated landscape, the long ranging with extensive habitat and nutrition required animals like elephants face huge stress to reach the favourable natural habitat units. Demographically stable populations of elephants in course of time is forced to live as sub population units due to the increasing rate of fragmentation, depletion of habitat area and nutritional requirements. Such populations are at the juncture of isolation and are less likely to be viable in the long term compared with the large population of elephants in the intact elephant habitats unless these patches are connected with corridor.

Anamalai landscape, the Project Elephant Range 9 (5700 km²), geographically include the Anamalai hills (meaning ‘elephant hill’), Nelliyampathy and Palani hill ranges, located to the south of the Palghat Gap in the Southern Western Ghats. This area, believed to harbour about 2000 elephants (Ramakrishnana et al.,
1998; Bist, 2002), has been identified as one of the potential landscapes for the long term conservation of the species (Santiapillai and Jackson, 1990; Leimgruber et al., 2003; Sukumar and Santiapillai, 1996). This population is genetically more diverse and distinct from the much larger elephant population exists further north in the Ghats (Vidya et al., 2005). This region is also known for its rich biodiversity (Subramaniam and Nayar, 1974; Kannan, 1998; Umapathy and Kumar, 2000; Gadgil and Homji, 2003; Kumar et al., 2004). On the other hand, this landscape has witnessed a variety of developmental activities such as commercial tea (Camellia sinensis (L.) Kuntze), coffee (Coffea arabica L.) and cardamom (Elettaria cardamomum (L.) Maton) plantations, several hydroelectric and irrigation projects with cut-open canals, and other forms of infrastructural development that impede the movement of elephants (Sukumar, 1989; Easa et al., 1990; Kumar et al., 2010). Urbanisation and conversion of forest lands for the cultivation of cash crops along with increasing tourism have limited the wildlife habitats as numerous isolated forest patches (stepping stone corridor patches) between Anamalai landscape and Periyar Tiger Reserve of Southern Western Ghats.

These forest patches provide temporary shelter for wildlife especially to elephants resulting in high and frequent conflicts with the surrounding people. In response to habitat loss and fragmentation, once continuous elephant population of Parambikkulam, Anamalai, Periyar and Agasthyamalai of Southern Western Ghats became relatively small and most of the remaining elephants presently confined to the protected areas (Varma et al., 2005).

The entire landscape of matrix with mosaics of cardamom, tea and coffee plantations and the increasing human occupancy create impedance for the free passage of these small populations of elephants to the protected areas and water sources. The increasing human-elephant conflict between these landscapes is an outcome of shrinkage, fragmentation and deterioration of elephant habitats along with the severe stress faced by the elephants to cross the mosaics of landscape matrices. This becomes a primary issue for the isolation of elephant population and its long term survival became an ambiguity. This is a crucial management issue, which needs to be addressed through innovative approaches.
The migration and conservation corridors concepts (Lesley et al., 2006) offer the hope of connectivity between Anamalai landscape and Periyar- Agasthyamalai landscape for the elephant population in Southern Western Ghats; will reinforce the dynamics of elephant metapopulation as an entity. The network of protected areas such as Chinnar Wildlife Sanctuary, Eravikulam National Park, Anamudishola National Park, Pampadumshola National Park, Kurinjimala Sanctuary, Mathikettanshola National Park, Idukki Wildlife Sanctuary and Periyar Tiger Reserve are situated in the landscape matrix of cash crop plantations such as tea, cardamom and coffee; the fuel wood plantations like eucalyptus, pine and wattle and ecologically fragile montane shola forests. Ecologically these protected areas probably function as singular units, thereby sharing the dynamics of elephant populations existing in the elephant reserves of Southern Western Ghats. The habitat distributional ranges of most of the elephant population in Southern Western Ghats stretches beyond the boundaries of protected areas and the consequent overlap in the resource need increase the chances of human-elephant conflict.

The land assignment for the landless people especially the landless tribes in the fuel wood plantations and grasslands of these landscape matrices along with the persistent tourism and population growth apparently compel to divert the forest land for settlements and other infrastructural developments. Such development fragments and destroys the natural elephant habitats; hence a few elephants are in stress to inhabit in the human dominated landscape units especially at Munnar and Anayirangal area.

Even though there is a history of co-existence of elephants and people at Munnar and Anayirangal, the condition is now become topsy-turvy and one can see the frequent conflicting in the form of damage to property, agriculture loss and human casualties. The conversion of shola forest into cardamom plantations fragment the elephant habitats and may deplete their food sources as well as the usual movement paths. Commercially driven deforestation also may change elephant migration routes (Rood et al., 2008).

In the fragmented Munnar landscape most of the remaining elephant refuges in the matrix are on track of inhabitation by the people after the land assignment for landless while most of the protected areas are surrounded by cash crops and
anthropogenic interventions. The predicted continuing increases in human population growth and the associated transformation of the natural landscape and the consequent overlap in resource needs may enhance human-elephant conflict (Parker et al., 2007 and Dunham et al., 2010). When large elephant population becomes isolated into small population in such human dominated fragmented landscape, it may not meet the minimum size of a viable population (Sukumar, 1993) and concerns arise for the future persistence of these small fragmented units (Stacey and Taper, 1992; Barnes, 1999; Lacy, 2000). To prevent the inbreeding and thus its survival need, the consideration of the entire population in this landscape as a single unit and wants to create corridors to connect these ‘stepping stone’ populations.

Elephant management is complex and may need a regional scale perspective to be successful. It thus follows the elephant management may best be dealt with at a regional rather than local scale (Aarde et al., 2006). The development of an approach that integrates population and landscape ecology within the umbrella of metapopulation theory (Aarde and Jackson, 2007) can potentially contribute to a management plan for the conservation of elephants in Southern Western Ghats.

1.1 Focus of the thesis

The overall aim of the present study is to ecologically investigate the existing human-elephant interaction particularly the negative interactions leading to conflicts at Anayirangal in the fragmented Munnar landscape and to put forward landscape level management strategies in an environmental perspective to mitigate the conflicts and to conserve the magnificent Asian elephant (*Elephas maximus* Linnaeus), the National Heritage Animal. The available resources such as geospatial tools and remote sensing applications were also used for the completion of the present work.

The thesis is organized into eight chapters with the following objectives.

1. To study the status of elephant population and to evaluate the spatial and temporal extent of human-elephant conflicts in the settlements falling along the elephant corridor.

2. To identify the major reasons behind the human-elephant conflict and identification of conflict prone zones in and around Anayirangal area.
3. To study the status of landscape elements and to evaluate the extent of forest fragmentation.

4. To evaluate the habitat usage and distribution ranges of elephants in Munnar landscape,

5. To map the elephant movements and to develop a corridor between the Anamalai - Munnar landscape and Periyar Tiger Reserve using geospatial tools.

The study has been oriented in five phases. Initially the status and spatial extent of landscape elements between Anamalai and Periyar Tiger Reserve have been studied and the existing human-elephant conflicting areas have been identified. In the second phase, the status and family structure of elephant population, food resources availability and nutritional status of major elephant foraging species have been studied in the conflict recurrent areas. Ecological investigation and geospatial analysis of human-elephant conflicts have been studied during the third phase. In the fourth phase, habitat utilization, distribution pattern of elephants outside the protected areas of Munnar landscape have been studied in order to know the major viability of elephant population in its ranges. Finally a geospatial model has been developed by integrating the knowledge of elephant habitat preferences and impedances in order to identify the potential elephant corridor connecting the two large natural habitats viz the Anamalai and Periyar of Southern Western Ghats landscapes. Conservation and management strategies also have been formulated for the conservation of the magnificent endangered and flagship species and efforts have been taken by considering the livelihood of the people inhabitated in that area to have a co-existence between the people and elephants.

1.2 Study area

The present study has been carried out in the Munnar landscape and Cardamom Hill Reserve (E 76.95° to E 77.41° longitude and N 9.27° to N 10.35° latitude) between Anamalai Tiger Reserve and Periyar Tiger Reserve of Southern Western Ghats covering an area of 4717.47 km² of which 1230.97 km² falls under the protected areas including Tiger Reserve, National Parks and Wildlife Sanctuaries. In addition to this, there are Reserve Forests of Kerala and Tamil Nadu (Figure1.1). This landscape is a part of the Anamudi-Parambikkulam
Elephant Reserve of Anamalai Elephant Range - 9, which hold nearly 2,000 elephants in an area of 5700 km², within which, nearly 60% of the area were highly fragmented due to the development of transportation networks and human density (Kumar et al., 2011).

1.2.1 Topography and climate

The terrain is undulating with a chain of rolling hills and forested valleys with slope varying between 4 degree to 71.4 degree and altitude ranging between 1000 m to 2690 m. There are generally three types of soils found namely alluvial soil, red soil and lateritic soil. The area falls within humid tropical climate zone with cool and humid climate. The altitudinal gradient across the landscape results in significant variation in the amount of precipitation with the western face and the crest-line of the Ghats receiving higher rainfall (mean annual rainfall up to 3500 mm) and the eastern rain shadow region of the Ghats receiving comparatively lower annual rainfall (mean rainfall about 800 mm) and having high rainfall of average 3500 mm annually. The area receives both the South-West monsoon and North-East monsoon with maximum rainfall during July and October. The rainfall gradient from east to west, along with the complex topography, results in heterogeneous vegetation types: from lowland tropical dry thorn forest mostly on the eastern side, mid-elevation tropical dry and moist deciduous forests, high elevation tropical semi-evergreen and evergreen forests to stunted montane forests (locally known as sholas) and grasslands (Subramanyam and Nayar, 1974).

The temperature varies between 14˚ C to 27˚ C with March- April being the hottest and December-January the coolest. The average humidity varies between 60% and 80% round the year and the lowest prevails during the month of February to May.

Agricultural land use patterns vary across this landscape depending on the extent and seasonality of rainfall; thus, the western part of the landscape supports perennial crops such as coffee (Coffea arabica L.), pepper (Piper nigrum L.), cardamom (Elettaria cardamomum (L.) Maton), rubber (Hevea brasiliensis (Willd. ex A.Juss.), banana (Musa acuminata Colla.) and coconut (Cocos nucifera L.), while the drier eastern part of the landscape with flat plains features annual crops.
such as paddy (*Oryza sativa* L.), maize (*Zea mays* L.), finger millet (*Eleusine coracana* (L.) Gaertn.) to a greater extent.

![Figure: 1.1 Study area location map](image)

**Figure: 1.1 Study area location map**
One of the most ecologically as well as economically significant area of the Munnar landscape is the Anayirangal, situated at the juncture of Kannan Devan Hills and Cardamom Hill Reserve of Devikulam Range, 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 covers an area of 107.04 km² surrounded by hills with an altitude ranging from 1010.87 m to 2444.6 m from which numerous streams originates and drains into the Anayirangal reservoir. The area falls within humid tropical climate zone with cool and humid climate, having a mean annual rainfall of 1705 mm. The area receives both the south-west monsoon and north-east monsoon with maximum rainfall at July and October (Figure 1.2). Usually high rainfall was observed during the month of October as the north-east monsoon become more prominent during this time. The area also got high rainfall during the months of June, July and August because of south west monsoon. There is least rainfall during the months of January and February. Based on the rainfall at Anayirangal there are two specific season viz. dry season and wet season. The months with average rainfall above 5 inches (>127 mm) are grouped as wet season and the average rain fall below 5 inches (<127 mm) are grouped as dry season.

![Figure 1.2 Rainfall pattern at Anayirangal from 1992 to 2009 (Source: Periyakanal Tea Estate, High Range Wildlife and Environment Preservation Association, Munnar).](image)

The valley has patches of varied habitats like montane shola grassland ecosystem, pine plantation, eucalyptus plantation, cardamom plantation, tea plantation, scrub and rocky areas. Two major anthropogenic interventions were intensified during recent past in this region - the increase of tourism activities and
the land assignments to the landless tribal. The undulating terrain of the tea estates in the background of the misty hills and the lumpy reservoir attracts a lot of tourists to this place, which is only 3 km from the Munnar - Bodi road (part of the Cochin - Dhanushkodi NH).

In the catchments of Anayirangal reservoir, extensive planting activities of eucalyptus and pine were done as resources for paper industries by Hindusthan News Print Ltd. a public limited undertaking under the control of Govt. of India. The land for this was leased out by the Kerala Land and Revenue Department. Lease was cancelled in some portions by the Govt. of Kerala during 2001 for the assignment of this land to the landless tribes when the tribal people of the state initiated a state-wide agitation demanding land.

There are nearly twenty eight settlements exist in the area out of which five settlements were established during 2002 as part of the land assignment programme for landless tribes by the Kerala Government. These villagers are under the Chinnakkanal, Pooppara and Shanthanpara villages of Chinnakkanal, Shanthanpara and Rajakumari Grama Panchayath. The new settlers of the area cultivate a variety of crops like ginger, pepper, cardamom, tapioca and banana.

Development activities for tourism and the human intrusion into the natural elephant habitat after the land assignment for landless tribes fragments and destroys elephant habitat. The small population of elephants in this region are pressured to inhabit in the human dominated landscape units. Once existed history of co-existence of elephants and people have become topsy-turvy and come up with frequent incidents of conflict in the form of damage to property, agriculture crop loss and human casualties in Anayirangal region.

1.3 Review of the distribution and abundance of Asian Elephant populations in India, Western Ghats and Eastern Ghats

The Asian and African elephants are believed to have diverged from a common ancestor in the African continent about 5–6 million years ago and migrated into Eurasia (Maglio, 1973; Sukumar, 2003). Despite the long and spectacular evolutionary history of the Proboscidea, extending back to the Eocene, there are only two living representatives; the African elephant (Loxodonta Africana B.) and Asian elephant (Elephas maximus L.) (Sukumar, 2006). Elephas maximus L. is
believed to have descended during the later Pleistocene from *Elephas hysudricus*, the fossil remains of which are found in the Siwaliks in the Indian Sub-Continent (Maglio, 1973). Both living species of proboscideans, the Asian elephant *Elephas maximus* L. and African elephant *Loxodonta Africana* B. are well adapted to live in diverse habitats by exploiting a wide spectrum of plant species. Their physiological adaptations like the large prehensile trunk, dentition and digestive system, helps to collect and process vast quantities of diverse plant food required to compensate for an extremely poor digestive ability and the nutritional demands of the elephant's large body mass, are undoubtedly critical to the survival of the species (Sukumar, 2003). The Asian elephant is considered to be among the largest living land mammals and is presently endangered (EN A1cd) according to the IUCN - The World Conservation Union red list data, 2008 and includes in Schedule-1 of the Indian Wildlife (protection) Act, 1972 (Choudhury et al., 2008).

The first comprehensive review of the status and distribution of the Asian elephant was that of Olivier (1978), made mainly based on then existing literature and questionnaire survey. The Asian elephant once possessed a vast kingdom that ranged across Southern Asia, from the Tigris–Euphrates basin in the West Asia to South East Asia (Olivier, 1978); Indian sub- continent into Indo-China, various islands in the southeast, and northward up to the Yangtze River and even beyond. However, the natural range of the Asian elephant is today confined to the Asian continent and distributed in Bangladesh, Bhutan, Myanmar, China, India, Indonesia, Cambodia, Laos, Malaysia, Nepal, Sri Lanka, Thailand and Vietnam (Santiapillai, 1987) (Figure 1.3). The distribution of the endangered Asian elephant has contracted over the past two to three millennia to approximately 6% of its historical range (Sukumar, 2003). The efforts of the Asian Elephant Specialist Group of the International Union for Conservation of Nature and Natural Resources, with the help of the World Wide Fund for nature have produced a more accurate picture of present distribution of elephants, especially in surveyed areas of Indian Sub-continent, Sri Lanka, Thailand and Sumatra. The number of Asian elephants in the wild is estimated to be about 44,000–56,000 and distributed in the following regions and countries (Sukumar, 1989).
i. Indian sub-continent: India, Nepal, Bhutan and Bangladesh.

ii. Continental Southeast Asia: China, Burma, Thailand, Kampuchea, Laos, Vietnam and Malaysia.

iii. Island Asia: Andaman Island (India), Sri Lanka, Sumatra (Indonesia) and Borneo (Malaysia and Indonesia).

Elephant populations in India were affected by habitat fragmentation, shrinkage and loss; human–elephant conflict and poaching for ivory and most often leading to highly skewed sex ratio (Easa, 2005). The present-day distribution of elephants in India is a fraction (about 3.5%) of its former range that extended from south of Himalayas to cover the entire subcontinent with the exception of the most arid tracts about six thousand years ago (Nair et al., 1980; Sukumar and Santipillai, 1996; Sukumar, 2011). The historical range of the elephant in India has shrunk, confining the elephants into distinct geographical zones (Jerdon, 1874; Ali, 1927; Daniel, 1980). Wild elephants are presently confined to the forested hilly tracts of four different regions: (i) the foothills of Himalayas in the north (ii) the north-eastern states (iii) the forests of east-central India, and (iv) the forested hilly tracts of Western and Eastern Ghats in southern India (Baskaran et al., 2011). A small population of feral elephants exists in the Andaman Islands, which are considered to be feral, and are the descendants of a captive stock. The Indian sub-continent has an estimated population of about
27,000–29,000 elephants, which is about 50% of the world population. These ranges in 26 (Baskaran et al., 2011) Elephant Reserves spread over about 110,000 km$^2$ forests in north-east, central, north-west and south India (Bist, 2002).

**North eastern India:** Elephant distribution in this region extends along the Himalayan foothills from northern West Bengal eastward into the states of Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. Some of these ranges are contiguous to Bhutan, Bangladesh and possibly Myanmar. The north-eastern elephant population was contiguous with that of Bhutan, Bangladesh, Nepal and Myanmar (Easa, 2005). The region is estimated to hold approximately 9,000-9,500 elephants, but figures from 1997, 2002 and 2007 show a decrease compared to 1978-83 and 1993 likely consequence of significant loss of habitat in states such as Assam and Meghalaya (Baskaran et al., 2011).

The elephants of this region are spread across 32,600 km$^2$ but divided into perhaps as many as 14 sub-populations. The elephant habitats in this region have experienced tremendous pressure from legal and illegal logging, shifting cultivation, monoculture plantations and encroachments. (Williams and Johnsingh, 1996a and 1996b; Gurung and Choudhury, 2000; Marak, 2002) give the details of elephant conservation issues in the area.

**Northern India:** The elephant range is spread in a west-east direction along the foothill forests and floodplains of the Himalaya in the states of Uttarakhand and Uttar Pradesh, partly adjoining Nepal. The region is presently believed to support about 1,700 elephants and the numbers have shown an increasing trend over the years (Baskaran et al., 2011). The elephant habitats in the north-west have six Protected Areas, viz. Corbett National Park, Rajaji National Park, Sonanadi Wildlife Sanctuary, Dudhwa National Park, Kishanpur Wildlife Sanctuary and Katerniaghat Wildlife Division. The altitude varies from 200-1000 m. The vegetation in this tract is mostly moist and dry sal forests interspersed with northern tropical dry deciduous forests, northern tropical moist deciduous forest and bamboo thickets (Singh, 1978; Easa, 2005).
Currently the elephant occupies about 10,000 km² forests in the outer Himalaya and the Shivalik Hill ranges and parts of the Terai and Bhabar tracts. The crude density of elephants in the area is reported to be 1 per 10 km² with a sex ratio of 1:2.5 (Williams, 2002). After the independence large scale developmental projects in the form of irrigation and power generation projects, expansion of human settlement and cultivation along the major rivers and introduction of monoculture forest and commercial plantations have fragmented the habitat apart from creating bottlenecks to elephant movement at about twelve locations (Johnsingh et al., 1990; Singh, 1995). Sunderraj et al., 1995, Javed, 1996; Williams, 2002; Menon et al., 2003 and Johnsingh et al., 2004 have dealt with the conservation problems of the area.

**East-central India:** The elephants of eastern India are distributed over 23,500 km² mostly in the Chota Nagpur plateau across the states of Orissa and parts of Jharkhand (Shahi and Chowdhury, 1986; Sar and Varma, 2004). Since 1986 some of these elephants have also been moving into neighbouring states, in particular to southern West Bengal, Chhattisgarh and more recently to north-eastern Andhra Pradesh, where they are in serious conflict with people. Recent estimates (Synchronized Elephant Census 2002 and 2007, MoEF 2010) place the figure at around 2650 elephants, with elephants of Orissa constituting over 70% of them (1860 elephants) followed by Jharkhand (624 elephants), Chhattisgarh (122 elephants) and southern West Bengal (25 elephants resident).

The elephant habitats of this region were diffused to mosaic of natural forest, often degraded or fragmented village forest as well as cultivation and mining. The most viable habitat and population of this region is undoubtedly the Mayurbhanj Elephant Reserve (that includes the Simlipal Tiger Reserve) in Orissa. Other sizeable populations are also found in the Mahanadi and Sambalpur Elephant Reserves of the same state as well as the isolated Palamau Tiger Reserve in Jharkhand, where elephants were introduced by the Rajah of Sarguja during the early 20th century (Singh, 1989; Datye and Bhagwat, 1995; Tiwari, 2000; Nigam, 2002; Swain and Patnaik, 2002). Sar and Choudhury, 2002 and Singh et al., 2002 have dealt with conservation problems of elephants of this area. The central Indian habitat of elephant is one of the most fragmented and degraded because of encroachment, shifting cultivation and extensive mining especially of iron, manganese and chromate (Easa, 2005).
Southern India: The elephants in southern India range over forested hilly tracts of the Western Ghats and its adjacent Eastern Ghats in the states of Karnataka, Kerala and Tamil Nadu, and more recently in a small area of Andhra Pradesh, Maharashtra and Goa (Sukumar, 1989; Baskaran, 2011). Their distribution has shrunk to within the Ghats owing to increase in human population and its resultant opening of new forest land for the expansion of agriculture, commercial plantations and hydroelectric and irrigation dams (Sukumar, 1989). Most of the elephant ranges in this region are hilly with the tropical evergreen, semi-evergreen, moist deciduous, dry deciduous, dry thorn forests and forest plantations in addition to high altitude grasslands and montane shola forest. In total about 14,000 elephants (Synchronized Elephant Census 2007, MoEF, 2010) were found in southern India, with over one-fourth of the habitat falling in Protected Areas and signs of growing numbers in some population (Baskaran et al., 2007). This population has great conservation significance for the species. Elephants in the south could be considered to consist of eight populations based on habitat (Easa, 1989 and 1993). Sukumar, 1989; Sivaganesan, 1991; Syam and Reddy, 2002 describe various aspects of elephant conservation in the region.

Northern Karnataka is the northern-most limit of elephant distribution in south India and elephants were distributed mainly in the forests of Dandeli and Belgaum districts. About 40–60 elephants including a few elephants that move into Maharashtra and Goa occur in the moist and dry deciduous forest mainly in the Dandeli Wildlife Sanctuary.

The crestline of the Karnataka portion of the Western Ghats has a population, which occurs as small scattered groups in the forest of South Kanara, Mangalore, Shimoga and Chickmangalur. The total number of elephants was estimated to be less than 60. The Malanad plateau, in particular the Bhadra Wildlife Sanctuary, to the east of the Ghats holds an isolated population of about 250 elephants. The Malanad plateau on the east of the Ghats has been separated from the rest of the tract by coffee plantations and other cultivations. The elephant habitat of the Bhadra Wildlife Sanctuary of about 827 km² was considered to have tenuous links with the Pushpagiri and Brahmagiri Range.
The Brahmagiri–Nilgiri–Wayanad–Mysore landscape with the Nagarahole, Bandipur, Wayanad and Mudumalai complex of reserves harbours one of the highest elephant densities (about 2 individuals/km$^2$) in Asia, followed by significant numbers in the Biligirirangans and the hilly tract along the Cauvery river of the Eastern Ghats. This landscape is estimated to support over 8800 elephants. Nagarhole National Park, Bandipur Tiger Reserve and Mudumalai Tiger reserve in the Nilgiris have densities in the range of 1-3 elephants/km$^2$ (Sukumar and Santiapillai, 1996). The large extent of habitat with diverse vegetation types and a number of cash crop cultivated areas and human settlements within also makes it one of the most complex regions in terms of conservation challenges. Maintenance of habitat contiguity through existing corridors or through consolidation of habitat while mitigating the ill-effects of human–elephant conflict and control of poaching, fire and other degradation factors would help in maintaining the integrity of habitat (Easa, 2005). The diversity in vegetations ranging from dry thorn forest to the montane shola grasslands make it one of the best Elephant Reserves in the country with a demographically and genetically viable population. This is the largest population of elephants in the country and possibly in Asia as well.

A small population of elephants that dispersed from here in the 1980s now ranges as scattered groups over isolated hills to the east in Andhra Pradesh and Tamil Nadu. About seven elephants appeared in Andhra Pradesh in 1984 and established in the dry deciduous forests of Koundinya Wildlife Sanctuary. A second herd of 22 joined the first in 1986 (Syam and Reddy, 2002). The population is reported to be on the increase and occupies an area of about 356 km$^2$ (Easa, 2005).

The Nilambur-Silent Valley-Coimbatore elephant population is connected to the Nilgiris through the high altitude mountainous portions of Silent Valley and Mukurthi National Park. It is also distributed within the forests of Nilambur South and North Forest Divisions, Mannarkad Forest Division and Silent Valley National Park. The vegetation types include evergreen, semi-evergreen, moist deciduous, dry deciduous, dry thorn scrub and montane shola grasslands. Though a large stretch of virgin forest is found in the area, a portion of it is being subjected to forestry operations, cash crop cultivation and pressures from human habitations. There are a few connections through which the elephants move either throughout
the year or in certain seasons. Maintenance of these corridors through appropriate measures, relocations of selected private holdings and stringent protection measures can ensure the long-term survival of this otherwise viable population (Easa, 2005).

Anamalai-Nelliampathy-High Ranges landscape (Elephant Range 9) with Anamalai, Parambikulam, Malayattur and Vazahchal Forest Divisions being the most important elephant habitats supporting over 3000 elephants, includes around 225 isolated elephants in Idukki Wildlife Sanctuary and Kothamangalam Forest Division (Figure 1.4). Elephants in these landscape range over Tamil Nadu and Kerala. The Anamalai Tiger Reserve and the Palani Hills and part of Theni, Dindugal Forest Division form the Tamil Nadu part of the habitat. Parambikulam, Chinnar, Thattekad, Peechi and Chimmoni Wildlife Sanctuaries, Eravikulam National Park, Pampadumshola National Park, Anamudishola National Park, Mathikettanshola National Park and the forests of Chalakudy, Nemmara, Vazhachal, Malayattur, Munnar and Mankulam Forest Divisions form the Kerala part of the elephant habitat. The vegetation types range from dry thorn scrub forest to high altitude shola grasslands with evergreen and moist deciduous forests equally dominating. Though vast and varied in habitats, the area also has the largest number of reservoirs for irrigation and electricity generation, tea, cardamom estates and forest plantations in addition to extraction of forest produce (especially reeds). The population is also under pressure because of shrinkage of forest, loss of habitat and corridor patches especially in Munnar landscapes.

Encroachments of the natural vegetation by the people for economic activities, ever increasing tourism and land assignment for landless people have reduced the effective habitat and depriving of the traditional movement paths of elephants resulted high human–elephant conflict. Major such conflicting locations are concentrated around the Valparai and Anayrangal areas (Easa et al., 1990, Rameshan et al., 2011). The maintenance of the traditional paths through the elephant corridors, resettlement of some of the human habitations for consolidation of elephant habitat, improvement of degraded habitat and monitoring for prevention of poaching are the most crucial measures for long-term conservation of this population.
The Periyar-Srivilliputhur population is spread over Kerala and a small portion of Tamil Nadu. Periyar Tiger Reserve with adjoining Gudrical, Ranni, Konni, Achankovil, Punalur and parts of Thenmala Forest Divisions form the elephant habitats in Kerala where as Srivilliputhur, High Wavies and parts of Theni Divisions of Tamil Nadu form the habitat in Tamil Nadu. In Periyar Tiger Reserve 379 elephants were reported having a density of 0.50/km² (Easa et al., 1997). The diverse vegetation type - evergreen forest, deciduous forest and thorn scrub available to elephant, within a small area are the factors that support these high elephant densities (Sukumar et al., 1996).

Figure 1.4 Map showing elephant distribution and Elephant Reserve (MoEF) in South India (Source: AERCC, ANCF)
The vast stretch of evergreen forests is the uniqueness of the area. The dry deciduous forest along the foothills of Varashunad Hills is also prominent. There are extensive plantations of tea and eucalyptus especially in the southern part. There are about 1500 elephants in this area. Though the large-scale poaching of elephants has resulted in the reduction of a number of tuskers, this is probably one of the compact elephant habitats in the south without much human habitations. One of the major issues in the area is the disturbance caused by the Sabarimala pilgrimage, which attracts millions of people within a short period. Stringent anti-poaching activity, measures to improve the degraded habitats and reducing the pressure on the area from pilgrims are the priorities for conservation (Easa, 2005).

Agastyamalais is the southernmost elephant population in the country and consists of Kalakkad-Mundanthurai Tiger Reserve, Neyyar, Peppara and Shendurney Wildlife Sanctuaries and Reserve Forests of Thiruvananthapuram Forest Division. This form the part of the Agastyamalai Biosphere Reserve and the habitat supports about 300 elephants.

1.4 Conservation initiatives

1.4.1 Project Elephant

Project Elephant was launched in February 1992 by Govt. of India for conservation of elephant and its habitat. The programme envisaged (i) ecological restoration of existing natural habitats and migratory routes, (ii) development of scientific and planned management of habitats and viable population, (iii) promotion of measures to mitigate man and elephant conflict, (iv) moderating human pressures in elephant habitats and (v) research on elephant management related issues. It aims at addressing the threats to the survival of elephant in our country on account of loss of its habitat, migration path and poaching for tusks and issues arising out of elephant depredation in villages. It also aims at maintaining an appropriate size of the population in any habitat to safeguard it against extinction and maintaining genetic continuity of isolated populations, which are otherwise susceptible to inbreeding.
The project aims

- To conserve and protect elephant populations and to ensure healthy population and viable within its ecosystem.
- To conserve and protect the habitat and to reverse its deterioration.
- To conserve, protect and open up traditional migration corridor linking the different habitats.
- To continue eco-development activities, welfare measures and mitigation of elephant depredation.
- To take measures to check poaching and other threats.
- To create facilities for research and veterinary care.
- To educate people about the ecological significance of conservation.

Elephant Range areas falling under each state have been notified as Elephant Reserves (Bist, 2002). There are presently 11 Elephant Ranges and 26 Elephant Reserves in 12 states, spread across 58,000 km², supporting more than 20,000 elephants or about two-third of the elephant population of the country (Project Elephant - 2004). Elephants in India although enjoying protection in Elephant Reserves, are threatened with ever increasing pressure on the habitat. Conservation efforts should be focused mostly to consolidate the habitat especially by reducing or removing biotic pressure through site-specific programmes. The central Indian population is perhaps the most fragmented one and the habitat has been further threatened due to the mining activities. However, some of the sub-populations, especially in the north-east were also highly vulnerable. The skewed sex ratio due to selective removal of tuskers, human elephant conflicts leading to intolerance among the affected people and the policies for economic development in elephant habitats are also of great concern. An integrated approach involving all the stakeholders could probably ensure the long-term conservation of this magnificent animal.