Chapter 6

Identification of Potential Elephant Corridor between Anamalai Tiger Reserve and Periyar Tiger Reserve, Southern Western Ghats: A Geospatial Approach

6.1 Introduction

The long term survival of all ecosystems, communities and species populations depends critically on the extent of habitat fragmentation. Habitat loss, degradation, fragmentation, conversion and over exploitation of natural resources in human dominated landscapes has resulted in alteration of the extent and spatial configuration of wildlife habitats, which have profound implications on the conservation of the biological diversity (Wilcox and Murphy, 1985). The extensive removal of native vegetation has resulted 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). The fragmentation of biotic community and 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 habitat 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 to 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 is required (Johnsingh et al., 1990).

Wildlife corridor is generally a linear landscape element and serves as a link between historically connected habitats or natural areas to facilitate the animal movement (Euen, 1993). This minimizes the risk of inbreeding, facilitate increase in genetic diversity and enhance overall meta population survival (Doak and Mills, 1994; Fahrig and Merriam, 1994). Wildlife corridors have thus become a significant factor in conservation management systems, as an attempt to reduce the isolation of spatially separated populations to allow re-colonization of extinct
patches and to potentially increase the total area of habitat available. Current wildlife corridor theorists place an increased emphasis on the need to design corridors specifically for native, conservation-priority target species. A target species may be any species that has the greatest need for a corridor to survive and whose protection will likely provide benefits to the greatest number of other species.

The target species may be passage species or corridor dwellers. Passage species include large herbivores like elephants and medium to large carnivores that need corridors to facilitate seasonal migration and home range connectivity between two larger habitats and dispersal of juveniles in discrete events of brief duration (Beier and Lo., 1992). Most of the landscape level studies of the corridors are generally linked to the movement of wildlife across their migration path (Beier, 1993; Dumortier et al., 2006), and in some cases exchange of genetic pools (Cowling and Pressey, 2001).

The anthropogenic impacts have fragmented once contiguous forest stretch of Southern Western Ghats into three forest complexes, Anamalai (5127km²) Periyar (3678km²) and Agasthyamalai (2112km²). The Anamalai-Periyar and Periyar-Agasthyamalai landscape are the two intervening human dominated landscapes which have witnessed extensive habitat loss and fragmentation over time (Pillay et al., 2011). There are considerable amount of works already been done on identifying and evaluating the areas of conservation value in the Western Ghats, (Gadgil and Meher-Homji, 1986; Karanth, 1986 and 1992; Rodgers and Panwar, 1988; Daniel, 1996; Nair, 1991; Ramesh et al., 1997c; Prasad et al., 1998, Rodgers et al., 2002; Venkatraman et al., 2002). In 2006, Das et al., identified areas of high conservation value and evaluated the existing protected area network in the Western Ghats using a systematic conservation planning approach and observed that the greatest concentration of unique evergreen ecosystems is distributed in Southern Western Ghats.

Southern Western Ghats an extremely fragile, with resource rich ecosystem - is one among the 34 global biodiversity hotspots with several endemic and endangered species. Urbanisation and conversion of forest lands to agriculture with increasing tourism have limited the wildlife habitats between Anamalai landscape and Periyar Tiger Reserves resulting in numerous isolated forest
patches (stepping stone corridor patches). These patches provide temporary shelter for wildlife especially for elephants resulting in high conflicts with the people. Current study attempts to identify potential elephant corridors between these two landscapes with knowledge of elephant habitat preference and impedances to the elephant movement using GIS techniques.

In the present study, efforts have been made to develop geospatial model for the identification of potential elephant corridor through the highly fragmented human dominated landscape between Anamalai and Periyar Tiger Reserve, Southern Western Ghats. In fragmented human transformed landscape, corridors ensure the nutritional, demographic and unhindered gene flows across the populations to ensure long term viability. The animal movements, exchange of materials and genetic information across landscape always follow the least resistance which is a function of ecological corridor (Roy et al., 2010). The elephant forage preferences in different vegetation classes and impedance to its habitat were used to develop a geospatial model for the identification of potential elephant corridor based on the least cost principles. A regional conservation strategy will have to identify locations where habitat community is being threatened as well as locate areas for re-establishing corridors where fragmentation has already happened in variable ecosystems (Nair, 1991). Fragmentation of the original elephant habitats between Anamalai and Periyar landscapes into 'stepping stones' for elephant movement and high conflict with people especially at Anayirangal valley and in the Munnar can be reduced by connecting these landscapes with potential elephant corridor.

6.2 Methodology

6.2.1 Study area

The study has been carried out in the landscape between Anamalai and Periyar Tiger Reserve of Southern Western Ghats which lies between E 76.95° to E 77.41° longitude and N 9.27° to N 10.35° latitude covering an area of 2820.43 km² of which 1127.26 km² area fall under protected area (including part of Anamalai Tiger Reserve and Periyar Tiger Reserve; National Parks (Eravikulam NP and Shola National Park; Wildlife Sanctuaries (Chinnar WLS, part of Idukki WLS,) Kurinjimala Sanctuary and Reserve Forests (Fig 6.1, Chapter 2). The
terrain is undulating with slope varying between 4° to 71.4° and altitude ranging between 1000 m to 2659 m with an average rainfall of 3000 mm. The area between the Anamalai Landscape and the Periyar Tiger Reserve has numerous patches of forest which act as ‘stepping stones’ instead of continuous belt of forest cover for the movement of wildlife though there exists network of protected areas like Chinnar Wildlife Sanctuary (90.44km²), Idukki Wildlife Sanctuary (70 km²), Kurinjimala Wildlife Sanctuary (32 km²), Eravikulam National Park (97 km²), Shola National Parks (Anamudishola; 39.48 km², Pampadumshola; 11.75 km², and Mathikettanshola; 12.817 km²) of Kerala and Reserve Forests of Kerala and Tamil Nadu.

The major vegetation types in these landscapes are the montane shola forests with mosaics of grasslands which occur above 1800m and evergreen forests and moist deciduous from 1800m down to 600m elevation. On the eastern slope is the dry deciduous forest and scrub jungle. Grasslands generally occur in the high elevation as well as medium elevation and in the catchments of the reservoirs. There have been extensive plantations of tea, coffee and cardamom in the high elevations of these landscapes since 19th century. These areas were originally covered by dense evergreen forest (Nair, 1991). The reservoirs, dams and associated structures and encroachments have also contributed to loss of wildlife habitats in these landscapes (Easa, 2005).

6.2.2 Geospatial modelling for identification of potential elephant corridor

Corridors, the linear landscape elements facilitate accelerated movements across habitat patches with least resistance and least conflicts with the humans. Preference for corridors is based on the availability of fodder, water in spatial context and provides survivorship of the species (Rosenberg et al., 1995). The present model was developed by least cost principle, which is a function of ecological corridor with the knowledge of elephant habitat preferences and impedances to elephant movement across the landscape (Roy et al., 2010). Chinnar Wildlife Sanctuary, which is a part of Anamalai Elephant Reserve, was used as a source and Periyar Tiger Reserve, part of Periyar landscape which support a huge number of elephant population was used as a sink to run the corridor model.
6.2.3 Preparation of vegetation cover map

Vegetation type map at 1:50000 was prepared using three season LISS III data of the year 2009 -2010 by onscreen digital interpretation (Chapter 2). 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 cultivated areas using GPS (Garmin 76 CSX with an accuracy of 2-3m). The obtained thematic class of
cardamom plantation was then superimposed above the hybrid classified satellite images of the year 2009 and 2010 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 vegetation type of the study area has been then stratified into six habitat types. The major fuel wood plantations have been grouped into vegetation class 1 and include the eucalyptus, wattle and pine plantations. The grassland, open scrub and scrub jungle have been grouped into vegetation class 2. The shola forest, evergreen forest and deciduous forest were grouped into vegetation class 3. Cardamom plantation, managed ecosystem and tea plantations were classified as vegetation class 4, 5 and 6 respectively.

6.2.4 Identification of human - elephant conflict areas in the landscape

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. 28 settlements which are in the elephant track have been extensively surveyed for getting information on human - elephant conflict for the years 2007 to 2009 (Chapter 4). In each settlement, the total number of farmers who involved in all types of crop cultivation, its extent and season of cultivation were obtained by questionnaire survey.

The major crops in each settlement were grouped into cash crops and food crops. The elephant visit and elephant raids were separately observed and raid frequency index (Sukumar, 1991) of crop raid, property damages and human casualties in each settlement have been calculated. The extents of damage of matured crop due to crop raiding by elephants were estimated by field visit whenever a raid was occurred.

Economic losses for cash crops and food crops due to crop raiding incident were estimated by multiplying the crop loss in metric unit with the average market value of the commodity and its normal productive period. The total number of property damage and human casualties in each settlement due to elephant were also estimated.
6.2.5 Creation of habitat preference raster

Habitat preference of elephant depend many environmental factors and ecological conditions. The availability of enough fodder, water, shade, terrain with least slope and access to nearby continuous stretch of forest were the most important factor which govern the preference of habitat. The presence of protected areas also influences the preference to a habitat for elephants. By considering these factors, preference raster for feeding, water and protected areas were created.

6.2.5.1 Forage preference raster

Relative uses of different habitat based on vegetation types were studied during the year 2008-2009. A systematic survey on dung pile density was carried out following line transects method covering 35% of the total area (Chapter 3) to find out the elephant density in six vegetation classes using DISTANCE programme (Barnes, 1993). The peak grass biomass in all the vegetation class were also estimated (Chapter 3). Using Arc GIS, elephant forage raster has been prepared by giving appropriate weightages based on Analytical Hierarchy Process (AHP) (Saaty, 2008) computed from percentage of elephant density and peak grass biomass in different vegetation class (Table 6.1).

6.2.5.2 Waterbody preference raster

All the permanent streams and water bodies of the landscape have been digitized from Survey of India Toposheets in GIS domain. Euclidean distance raster of water bodies and streams has been computed in order to get the minimum distance of elephants to permanent source of water. Euclidean distance calculates, for each cell, the euclidean distance to the closest source. Euclidean distance raster of water bodies and streams act as a function of water preference for elephants.

6.2.5.3 Protected area preference raster

Between Anamalai Tiger Reserve and Periyar Tiger Reserve there are three Wildlife Sanctuaries - WLS (Chinnar WLS, Kurinjimala Sanctuary, Idukki WLS), four National Parks -NP (Eravikulam NP, Anamudishola NP, Pampadamshola...
NP, and Mathikettanshola NP) and the Reserve Forests of Kerala and Tamil Nadu (Refer Chapter 2). The boundaries of all the protected areas were surveyed with the GPS (Garmin 76 CSX) during 2007-2008 and were exported into GIS platform. Personal geo-database of protected areas in the study area was prepared.

<table>
<thead>
<tr>
<th>Table: 6.1. Weightages assigned for different landscape elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preference Layers</strong></td>
</tr>
<tr>
<td>Vegetation Class 1 (Eucalyptus, Pine and Wattle Plantations)</td>
</tr>
<tr>
<td>Vegetation Class 2 (Grassland and Open Scrub)</td>
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<tr>
<td>Vegetation Class 3 (Shola Forest, Moist/ Dry Deciduous, Semi/</td>
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<tr>
<td>Evergreen Forest)</td>
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<tr>
<td>Vegetation Class 4 Cardamom Plantation</td>
</tr>
<tr>
<td>Vegetation Class 5 (Managed Ecosystem)</td>
</tr>
<tr>
<td>Vegetation Class 6 (Tea Plantation)</td>
</tr>
<tr>
<td><strong>Tiger Reserve</strong> (Periyar Tiger Reserve)</td>
</tr>
<tr>
<td><strong>National Parks</strong> (Eravikulam and Shola National Parks)</td>
</tr>
<tr>
<td><strong>Wildlife Sanctuaries</strong> (Chinnar, Idukki, Kurinjimala)</td>
</tr>
<tr>
<td><strong>Reserve Forests</strong> (Anamudi, Palani, Theni, Kambam Valley,</td>
</tr>
<tr>
<td>Nagarmapara)</td>
</tr>
<tr>
<td><strong>Impedance Layers</strong></td>
</tr>
<tr>
<td>Village Road</td>
</tr>
<tr>
<td>Rural Road</td>
</tr>
<tr>
<td>State Highways</td>
</tr>
<tr>
<td>National Highways</td>
</tr>
<tr>
<td>Tribal Colonies and Tea Estate Colonies</td>
</tr>
<tr>
<td>Village Residential Colonies</td>
</tr>
<tr>
<td>Medium Town</td>
</tr>
<tr>
<td>Large Town</td>
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<tr>
<td>0 to 30 degree</td>
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<tr>
<td>30 degree and above</td>
</tr>
</tbody>
</table>

Protected areas were classified into Tiger Reserve, National Parks, Wildlife Sanctuaries and Reserve Forest and weightages have been given based on Analytical Hierarchy Process (AHP) (Saaty, 2008) by considering the protection and legal status for conservation. Protected area preference raster was prepared.
based on the protection status computed as a function of minimum disturbance to
elephant sighting (Table 6.1).

The forage preference raster, water preference raster and protected areas
preference raster were added to get a final preference raster, a function of
elephant preference to a particular area. The maximum pixel values of the raster
indicate the maximum preferred elephant habitat class (Figure 6.2).

6.2.6 Impedance raster

Habitat preference of elephants depends on the anthropogenic impacts (such as
road and settlements) as well as the geographic barriers (such as slope and
terrain). Usually elephants do not prefer the areas with high anthropogenic
pressure and avoid high sloppy terrain. An impedance raster, which is a function
of anthropogenic and topographical disturbance to elephant movement, was
generated from the landscape elements such as road, settlements and slope
(Figure 6.3).

6.2.6.1 Settlement impedance raster

The geographic locations of all the settlements present in the landscape were
obtained by GPS survey. Geo-database for settlements was also prepared in GIS
domain. Attributes were given for the classified settlements based on the nature
of houses and living status of people such as tribal colonies, tea estate colonies,
rural villages, medium town and large town.
Figure: 6.2. Preference raster for protected area, streams, waterbody and elephant foraging habitats

Based on the Saaty’s AHP (2008) the weightages were given to these settlements in the increasing order of disturbance with the assumption that forest dwellers and tribal colonies, which has a history of co-existence with wildlife were forcing least disturbance and the urbanized medium towns and large towns which were mostly settled recently by converting the elephant habitat were acting big barrier for elephant movement. The settlement impedance raster has been
generated using the IDW (Inverse Distance Weighted) Interpolation technique for the given weights (Table 6.1).

6.2.6.2 Road impedance raster

Roads act as both a disturbance as well as benefit for elephants. The roads with heavy traffic and large cuttings of the landscape act as a barrier for elephant movement where as the small plantation roads and estate roads with least traffic density were chosen by elephant for its local movement (Desai and Baskaran, 1996; Desai, 2002; Ramkumar and Arumugam 2004; Daniel et al 2006).

The roads present in the study area were digitized from the Survey of India Toposheets. The newly constructed roads were surveyed by GPS tracking during the year 2008. The roads were classified into village roads, rural roads, state highways and national highways. The weightages were assigned proportional to the increasing order of disturbances as per Saaty’s AHP with the assumption that the roads with heavy traffic density were a big barrier for elephant movement than a least traffic estate and plantation roads. Road impedance raster was generated by converting feature to raster based on the weights assigned to them (Table 6.1).

6.2.6.3 Slope impedance raster

The major topographical barrier for elephant movement was slope and terrain. Many studies (Kay, 1973; Daniel et al., 1987; Sukumar, 1991; Areendran et al., 2011) have shown that elephants avoid steep slopes. The slope of the study area was grouped in to two: terrain with more than 30° slope, which is difficult for animal movement and below 30° slope which is suitable for elephant movement (Areendran et al., 2011). Slope Impedance Raster has been generated by reclassifying the slope raster with two classes by assigning weights (Table 6.1).
Final impedance raster, the function of disturbance was generated by adding the settlement impedance raster, road impedance raster and slope impedance raster using geospatial analysis tool (Figure 6.3).
6.2.7 Cost raster generation

The preference raster is mathematically integrated to the impedance raster in GIS platform and generated cost surface raster in which each cell value is a function of elephant preference and disturbance to elephant movement (Roy et al., 2010). Using the source as Chinnar Wildlife Sanctuary and sink as Periyar Tiger Reserve cumulative cost distance have been calculated to estimate the path of least resistance between the source and sink (Figure 6.4).

6.2.8 Least cost path - the corridor

This cumulative cost distance path layer and the cost back-link layer computed from the destination will give the least cost path, between the corridor which connect Chinnar Wildlife Sanctuary and Periyar Tiger Reserve. This raster is converted in to line feature and is buffered to get 50m width on each side which is then imported in to the habitat type map. The accuracy of the generated elephant corridor has been assessed with ground verification. The geographic locations of observed elephant dung piles and the direct and indirect evidences of the elephant usage are superimposed on the generated corridor in order to assess its accuracy.
6.3 Results

The forage preference raster, a function of feeding habitat of elephant shows a high preference in the vegetation class 1, comprising of eucalyptus, wattle and pine plantations. The availability of grass biomass was also high in grasslands and in vegetation class 1 (Chapter 3). Most of the highly preferred areas were in the fragmented Munnar landscape in the matrix of tea plantations and at Anayirangal valley (Figure 6.5).

The grasslands and shola forest present in the mosaic of tea and fuel wood plantations also act as highly preferred foraging areas. The major sources of water in the landscape were the Gunderle reservoir, Mattupetty reservoir, Lekshmi lake, Devikulam lake, Old Devikulam lake and Anayirangal reservoir. All these reservoirs and lakes were surrounded by either grasslands or fuel wood plantation. The elephant prefer these areas because of the availability of water and fodder.

The preference and impedance layers have differential distribution among the various land-use and land-cover classes. The impedance raster computed for elephant movement shows the maximum impedance in the regions near to the settlement and roads. Some of the impedances are also due to the high slope in the Western Ghats hills.

A spatial summary of the impedance layer with the land use and land cover classes (Table 6.2) show that eucalyptus, pine and wattle plantations have the maximum area under low impedances followed by grassland, open scrub, shola and tea plantation. Major disturbances to the elephant habitat were the human habitation inside the highly preferred vegetation classes especially at Anayirangal and in the Devikulam- Munnar area.
Figure: 6.5. Elephant forage preference map outside the protected areas between Anamalai Tiger Reserve and Periyar Tiger Reserve.
Figure: 6.6. Elephant habitat preference outside the Protected Areas in the Munnar landscape and Cardamom Hill Reserve.
The analysis of the elephant dung pile density and elephant density shows that land cover which had high impedance to elephant movement are settlements and reservoirs. The managed ecosystems like agricultural areas and orchards showed moderate impedances to elephant movements.

The elephant habitat preference raster generated showed high preference around the protected areas and in the grasslands and fuel wood plantations. The spatial summary of the elephant preference with respect to the land-use and land-cover classes indicated the following order of priority the shola forests followed by the managed ecosystems and grassland/scrubland (Figure 6.6 and Table 6.2).

<table>
<thead>
<tr>
<th>Elephant Habitat</th>
<th>Impedance Level</th>
<th>Preferred habitat (Percentage area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation Class 1</td>
<td>58.14% Low, 33.81% Medium, 8.04% High</td>
<td>3.50%</td>
</tr>
<tr>
<td>Vegetation Class 2</td>
<td>38.82% Low, 47.21% Medium, 13.97% High</td>
<td>17.45%</td>
</tr>
<tr>
<td>Vegetation Class 3</td>
<td>44.87% Low, 45.05% Medium, 10.08% High</td>
<td>35.67%</td>
</tr>
<tr>
<td>Vegetation Class 4</td>
<td>6.44% Low, 76.51% Medium, 17.04% High</td>
<td>12.39%</td>
</tr>
<tr>
<td>Vegetation Class 5</td>
<td>7.50% Low, 76.62% Medium, 15.88% High</td>
<td>23.31%</td>
</tr>
<tr>
<td>Vegetation Class 6</td>
<td>46.49% Low, 40.44% Medium, 13.07% High</td>
<td>7.68%</td>
</tr>
</tbody>
</table>

The corridor has been generated using a combination of preference and impedance layers to elephant movement (Figure 6.7). The proposed elephant corridor has a length of 88.4 km and a width of 50 m. The corridor passes through the highly fragmented Munnar landscape. The remnant shola forest and eucalyptus plantation inside the tea estates and the grasslands of Kurinjimala Sanctuary and the Mannanmala, Meesappulimala, Thondimala, Njandar, Chathurangappara, Kottamala area play great role in the movement path. Anayirangal valley, Mathikettanshola National Park and the deciduous forest and scrub jungle of Theni and Kambam Valley RF in eastern slope of Western Ghats act as a crucial link of the corridor between Chinnar Wildlife Sanctuary and Periyar Tiger Reserve. About 31 km (35%) of the corridor pass through the
highly fragmented and fragile landscape elements outside the protected areas and remaining through the protected areas namely Kurinjimala Sanctuary, Anamudishola National Park, Mathikettanshola National Park and the Reserve forests of Theni and Kambam Valley of Tamil Nadu (Figure 6.7).

The summary analysis of the identified corridor has been performed to find out the area of each vegetation class and its protection status. The vegetation class 3 forms 50.67% of the corridor area of which 85.90% has got protection status. Shola forest, evergreen and deciduous forest constitutes this class. This indicates that corridor along with the remnant ecosystems of montane shola grasslands and the stepping stones influences decision on the conservation action. The second major constituent (22.57%) of the area of corridor was the vegetation class 2. The grasslands and scrub jungle forms this class. Nearly half of it (44.83%) lies outside the protected area that is in the revenue land. Agriculture land with an area of 0.336 km² of tribal community inside the protected area especially at Anamudishola National Park was falling along the corridor (Table 6.3).

<table>
<thead>
<tr>
<th>Vegetation Class in the corridor</th>
<th>Area (km²)</th>
<th>Inside Protected Areas</th>
<th>Outside Protected Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proportion (km²)</td>
<td>Percentage (%)</td>
<td>Area (km²)</td>
</tr>
<tr>
<td>Vegetation Class 1</td>
<td>0.313</td>
<td>7.25</td>
<td>0.027</td>
</tr>
<tr>
<td>Vegetation Class 2</td>
<td>0.973</td>
<td>22.57</td>
<td>0.537</td>
</tr>
<tr>
<td>Vegetation Class 3</td>
<td>2.183</td>
<td>50.67</td>
<td>1.875</td>
</tr>
<tr>
<td>Vegetation Class 4</td>
<td>0.171</td>
<td>3.97</td>
<td>0</td>
</tr>
<tr>
<td>Vegetation Class 5</td>
<td>0.336</td>
<td>7.80</td>
<td>0.336</td>
</tr>
<tr>
<td>Vegetation Class 6</td>
<td>0.216</td>
<td>5.02</td>
<td>0</td>
</tr>
<tr>
<td>Settlements</td>
<td>0.018</td>
<td>0.42</td>
<td>0.001</td>
</tr>
<tr>
<td>Reservoir</td>
<td>0.094</td>
<td>2.20</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4.304</td>
<td>100</td>
<td>2.776</td>
</tr>
</tbody>
</table>

The vegetation class 1 with eucalyptus, pine and wattle plantation constitute 7.25% of the corridor of which 91.40 % is in revenue land; only 8.60% has got protection status. This indicates that the highly preferred vegetation outside the protected area are significant for the elephant movement.
6.3.1 Evaluation of the identified potential elephant corridor

The proposed potential elephant corridor passes through the high altitude (2040m - 2070 m) rolling montane shola grasslands of north western part and fringe areas of Kurinjimala Sanctuary bordering the Anamudishola National Park (Figure 6.7). The corridors move downwards to an altitude of 1450m -1800m and enter into Pullaradi shola of Anamudishola National Park. The cultivation area of the settlement Kudal Ar kudi inside the Anamudishola National Park was also fall along the corridor. Then the corridor passes through the valley of shola forest at the east of Madavarimala and west of Jhandamala and enters into the revenue land at (the Kannan Devan Hills) Chunduvarai tea estate.

Eucalyptus planted inside the Chunduvarai tea estate as a source of fuel for the tea manufacturing was acting as a movement paths for the elephants. From Chunduvarai, the corridor goes towards the Gundala reservoir through the eucalyptus plantation. The remnant shola forest existing in the tea estates of Ellappaty acts as a crucial link of the proposed corridor. From Ellappatty with an altitude of about 1800 m the corridor moves towards the montane grasslands of Mannamala and Meesappulimala with an altitude of about 2500 m though a fragile track of shola forest existing in the fringe areas of Kerala-Tamil Nadu interstate border. From Meesappulimala the corridors come down towards the Silent valley though the shola ecosystem.

From Silent Valley the proposed corridor moves towards the Gundumala montane shola ecosystem and enters into the Anayirangal valley through 60 Acre shola forest above Chinnakanal tourism zone. Anayirangal valley acts as ‘stepping stone corridor’ for the movement of elephant. The corridor moves towards the Anayirangal reservoir through the grasslands, eucalyptus and pine plantation. The resort areas at Chinnakanal and the school zones of Chinnakanal and Vilakk acts as major impedances to the movement of elephants through the proposed corridor. During 2007-2008 Government of Kerala has assigned this area for landless tribal people and five such settlements were established in this valley, which intensify the human-elephant conflict. All the five settlements are in the middle of the elephant habitat. From Chinnakanal, the corridor passes through the settlements Vilakk, Chinnakanal New Adivasi Colony, Singukandam, 301 New Adivasi Colony, 80 New Adivasi Colony, Panthadikkulam New Adivasi
Colony and enters into the Cardamom Hill Reserve at Anayirangal, Mulathara, Thondimala and Thalakkulam.

One of the tribal settlements, the 80 New Adivasi Colony put solar power fence in the year 2008 around the settlement because of high human-elephant conflict that had been occurred during the year 2007. This has shifted the conflict intensity to nearby settlements especially at 301 New Adivasi Colony, Chembakathozhukudi, Singukandam and Thidir Nagar (Chapter 4). From the cardamom plantation the proposed corridor enters into Mathikettanshola National Park. The shola forests in the fringe areas of Mathikettanshola National Park especially at Thalakkulam, Korampara, Pethotti and Njandar are highly significant link in the corridor for elephant movement.

From Njandar the identified corridor moves towards the eastern slopes of Western Ghats through the montane shola grassland ecosystem. The continuous stretch of cardamom plantation in the western part of Western Ghats acts as major impedance to the elephant movement. The terrain in the eastern part of the Western Ghats near the Mathikettanshola National Park was having high slope.

Scrub jungle and deciduous forests in the eastern slope of Ghats acts as habitat for the elephant movement. This falls under the reserve forests (Theni Forest Division) of Tamil Nadu Forest department. The cultivation of agriculture crops in lower reaches of the Western Ghats and in the fringe areas of Theni Forest Division tempts the elephant for crop raiding. In Theveram area crop raiding by elephants was also observed.

Further, the corridors move towards Chathurangappara, a montane grassland ecosystem in the crest of Western Ghats. The grassland ecosystem which acting as a crucial link in the corridor was under threat because of the construction of windmills on the crest of the Western Ghats at Chathurangappara by the Tamil Nadu state government.

Along the ridges of Western Ghats, the corridors pass through the shola forests of Kottamalai. From the Kottamalai the corridor again move towards the eastern slope and at the lower reaches of Ghats near to Kombai the corridor goes towards the Ramakkalmedu, a montane grassland ecosystem with scrub jungle on its eastern slope. The windmills and tourism in this area act as an impedance
to elephant movement. The western side of this stretch was converted into human habitation.

The proposed elephant corridor crosses the Kambam Mettu-Kambam Ghats road at Kambam valley reserve forest. This road acts as impedance to elephant corridor. The dry deciduous forest and the scrub jungle of Kambam valley Reserve Forests in the eastern slope of the Ghats act as crucial link of the proposed corridor and it passes through the Chellarkovil medu towards the destination (Periyar Tiger Reserve).

Adjacent to the Periyar Tiger reserve, there are two major impedances, the Kollam - Theni NH road and the tunnel made for irrigation-cum- hydro electric project of Tamil Nadu from Mullaperiyar reservoir. It was observed that the elephants cross the NH very near to the Kerala - Tamil Nadu interstate border. The small evergreen forest patches in this region act as crucial link of the corridor, where the impedance due to the tunnel was not making a problem.

The accuracy assessment of the proposed elephant corridor shows that out of 100 randomly selected elephant sightings, 92 observations fall within the corridor while the rest fall within a buffer zone of having 100 m width (Figure 6.8). The terrain and elevation based analysis shows that the corridor passes through an undulating terrain with the valley, crest, western and eastern slopes of the Western Ghats (Figure 6.9).
Chapter 6: Identification of potential elephant corridor between Anamalai Tiger Reserve and Periyar Tiger Reserve, Southern Western Ghats: A geospatial approach

Figure 6.7. Potential Elephant Corridor between Anamalai Tiger Reserve and Periyar Tiger Reserve.
Figure: 6.8. Elephant sightings along the proposed potential Elephant corridor between Anamalai Tiger Reserve and Periyar Tiger Reserve.
6.4 Discussion

The highly fragmented and human transformed landscape between Anamalai and Periyar Tiger Reserve is very crucial for elephant movement. Anayirangal valley is acting as vital elephant habitat and the elephants habituated in this landscape unit are struggling with people for their existence leading high conflict with people. The raid frequency index and economic loss due to crop damage is observed maximum for the year 2008. This is because the newly assigned tribal people began to settle in the usual elephant habitat by removing the vegetation and start cultivation from 2008 onwards. Most of the tribal people were far away from Anayirangal and got the land as part of the land assignment practice of the Government. So the non residential tribal people, who got their land at Anayirangal, are novel to the area, the landscape and the behaviour of habituated elephants of this landscape resulted high occurrence of human death by elephant attack during the year 2008.

The proposed elephant corridor has a length of 88.4 km of which about 35% (31 km) pass through the highly fragmented and fragile landscapes outside the protected areas and remaining through the protected areas namely Kurinjimala Sanctuary, Anamudishola National Park, Mathikettanshola National Park and the Reserve Forest of Theni and Kambam valley in the eastern slope. According to Menon et al., 2005, approximately 65% of the land is under protected area and/or Reserve Forest and remaining jointly under Reserve forest, Revenue land and
private land in the areas used as corridors by elephants. Due to the limited resources and encroachment on the wilderness coupled with increased residency period of the elephants in the corridor leads to conflict with humans from the adjoining settlements. To reduce the incidence of conflicts between humans and elephants, there is a need of stepping stone areas in order to provide temporary shelter for the elephants to move over the hindrance (Cimprich et al., 2005) due to high human pressure in the narrow width of the corridor in some places.

In the present study the remnant natural vegetation patches utilizes for foraging and other requirements of the elephants during their migration. The width of the proposed corridor joining the natural patches which will act as stepping stone has been proposed to be 50 m. An analysis of the proposed corridor shows that 65% of the different vegetation classes are under protected area and remaining 35% in the revenue lands, this match quite accurately with the study by Menon et al. (2005). Vegetation Class 1, which has got moderately high elephant dung density and maximum forage preference value (43.57) are under revenue land covering an area of 0.29 km² (91.4%). According to Kumar et al. (2010), the major reason behind high preferences of fuel wood plantations especially the *Eucalyptus* is the availability of tree canopy along with secondary vegetation and grass growth appeared to provide cover and fodder for elephants.

The remnant shola forest, grasslands and eucalyptus plantations in the Munnar landscape acts as stepping stone and provide temporary shelter for elephants to move over the hindrance of settlements, roads and cash crop plantations. The elephant has to cross five major roads and several village roads. Even though the village roads in the plantations are used by the elephants as their local movement paths, the major roads with heavy traffic especially the Munnar - Mattuppetty road, Munnar - Suryanelli Road, Kochin - Dhanushkodi NH, Kambam mett - Kambam Ghat road and Kollam - Theni NH make impediment to the elephant movement. The vegetation type in particular the grasslands, open scrubs, eucalyptus plantations, permanent water source and the proximity to protected Mathikettanshola National Park make Anayirangal area as one of the highly preferred area for elephant habitat. But the settlements and upcoming resorts at Chinnakanal and the newly assigned tribal colonies at Anayirangal area, a major tract of elephant corridor make hindrance to elephant movement, leading high conflict with adjacent people inhabited here.
Cardamom plantations along the elephant corridor from Anayirangal reservoir to Mathikettanshola National Park and further south up to Chathurangappara at the western slope of Western Ghats are critical areas to be protected. The quarrying activities and the windmill constructions in the crest of Western Ghats at Chathurangappara acts as hindrance to the elephant movement between these landscapes. The eastern slopes of Western Ghats from Mathikettanshola National Park to Periyar Tiger Reserve have to be preserved as this is the only forest patch which connects these two landscapes.

Even though the canals and hydro electrical pipe line from Mullaperiyar Reservoir to Lower camp and plains of Tamil Nadu along with the Kollam - Theni NH are big human constructed barriers for elephant movement, the least cost path analysis and field evidences reveal that elephants are crossing this area especially along the narrow patch of forests in the eastern part of Kumali town very near to the Kerala - Tamil Nadu interstate border, which connects the Periyar Tiger Reserve and the Reserve Forest of Kambam valley Forest Division, Tamil Nadu. Thus the identified elephant corridor connects fragmented ‘stepping stones’ between these two landscapes which in turn interlink two elephant reserves, the Anamalai and Periyar of Southern Western Ghats and thus the protection of viable elephant population.

An ecological corridor provides a network of unconnected patches of forests or stepping stone remnants to facilitate the persistence of populations and the exchange of materials and genetic information across landscape always follows theory of least resistance (Walker and Craighead, 1997). In the present study, connecting these two elephant reserves through highly fragile and fragmented landscapes encourages the creation of viable elephant populations with proper genetic mixing. Corridor becomes more vital when they connect Protected Areas or are close to Protected Areas thereby increasing the habitat available to elephants on the fringe areas of the Protected Areas (Menon et al., 2005).

6.5 Conclusion

The present geospatial model with the application of least cost principle, a function of ecological corridor becomes highly practical in this study with the knowledge of elephant habitat preference and impedance to elephant movement. The evaluation of the identified potential elephant corridor reveals the exigency of
taking regional conservation strategies for the protection of crucial narrow link that connect the two elephant landscapes through the highly fragmented and human transformed Munnar landscape otherwise the elephant population in the Munnar landscape will soon become isolated.

The remnant forest patches, grasslands and fuel wood plantations in the Munnar landscape acts as stepping stone and provide temporary shelter for elephants. In order to reduce the risk for elephant to cross the major roads (Munnar-Mattupetty, Kochin-Dhanushkodi NH, Kambam mett-Kambam Ghat road and Kollam-Theni NH) the Government has to take initiatives to control the vehicle movements during night, construction of speed breaks and putting sign boards along the roads especially at major elephant crossing areas.

One of the major disturbances, the quarrying activities along the crest of Western Ghats especially at Chathurangappara and in the fringe areas of Mathikettanshola National Park should cease. There should be prior ecological studies for any construction or development activities such as windmill constructions or road construction along this part of Western Ghats. The government also should take initiatives to relocate the tribal families especially from 301 New Adivasi Colony, Chinnakanal New Adivasi Colony and Panthadikkulam which are along the tract of elephant corridor and there should not be any further land assignment for the landless people at Anayirangal.

By leaving the cardamom cultivation especially along the corridor with a minimum width of 50 m in the cardamom plantations of Mulathara, Thondimala, Thalakkulam and Kudmapara will further reduce the conflict with people. Erecting solar power fences in proper and scientific manner in the cardamom plantations by leaving a strip of having a minimum width of 50 m along the identified corridor will reduce further entry of elephants to the crop land of farmers. For long term management of human-elephant conflict, these areas have to be converted gradually to natural vegetation thus improving the elephant habitat.

The Shola National Parks, fuel wood plantations at Mattuppatty and Devikulam, Anayirangal valley, Cardamom Hill Reserve in the western slopes of Western Ghats and the rolling grasslands of Kurinjimala Sanctuary, Meesappulimala, Chathurangappara, Kudampara, Kottamalai, Ramkkalmedu and Chellarkovilmedu at the crest and the attenuating scrub jungle in the eastern slopes of Western
Ghats which are along the track of elephant corridor and act as the vulnerable links between Anamalai and Periyar landscapes. Developing a regional conservation strategy with the aspiration of managing these entire landscape as a matrix supporting the whole biotic community will ensure the conservation of Asian elephants which intern reduce the conflicts especially at Anayirangal and nearby areas.