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

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Abstract
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 land 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 people. Current study attempts to identify potential elephant corridor between these two landscapes with knowledge of elephant habitat preference and impedances to the elephant movement using GIS techniques. A habitat preference raster is generated by using information on different foraging habitats outside the Protected Areas as well as distance from waterholes and is integrated with Impedance Raster, function of disturbances for generating Cost Surface Raster. Least cost path along this cost raster was generated with Chinnar Wildlife Sanctuary as source and Periyar Tiger Reserve as destination. The accuracy of the modeled corridor has been assessed using the information of present and past elephant movement and dung density. Management of this corridor can reduce the frequency of human-elephant conflicts especially at Anayirangal, one of the stepping stone for elephant movement.

1. Introduction

The long term survival of all ecosystems, communities and species population 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 (Gascon et al., 1999 and Saunders et al.,1991).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 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 are 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. This minimizes the risk of inbreeding, facilitate increase in genetic diversity and enhance overall metapopulation survival (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, 1993). Most of the landscape level studies of the corridors are generally linked to the movement of wildlife across their migration path (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 (5127km^2), Periyar (3678km^2) and Agasthyamali (2112km^2). The Anamalai-Periyar and Periyar-Agasthyamali landscape are the two intervening human-dominated landscapes which have witnessed extensive habitat loss and fragmentation over time (Pillay et al., 2011). There in considerable amount of work on identifying and evaluating the areas of conservation value in the Western Ghats, (Gadgil and Homji, 1986, Karanth, 1992, Daniels, 1992, Nair, 1991, Prasad et al., 1998 and 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 the greatest concentration of unique evergreen ecosystems distributed in Southern Western Ghats. In the present study, efforts have been made to develop geospatial model for the identification of potential elephant corridor between highly fragmented human dominated Anamalai and Periyar landscape of 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. Fragmentation of the original elephant habitats between Anamalai and Periyar landscapes into 'stepping stones' for elephant movement and high conflict with people can be reduced by connecting these landscapes with potential elephant corridor. 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.

2. Study Area

The study has been carried out in the landscape between Anamalai and Periyar of Southern Western Ghats which lies between E 76.95° to E 77.41° and N 9.27° to N 10.35° covering an area of 4714.25km^2 of which 1426.49 km^2 area fall under protected area including Tiger Reserve, National Parks, and Wildlife Sanctuaries and Reserve Forests (Figure 1). The terrain is undulating with slope varying between 4° to 71.4° and altitude ranging between 100m to 2659m with an average rainfall of 3000mm. 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 (90.44km^2), Idukki Wildlife Sanctuary (70km^2), Kurinjimala Wildlife Sanctuary (32km^2), Eravikulam National Park (97km^2), Shola National Parks (Anamudishola; 7.5km^2, Pampadumshola; 11.75km^2, and Mathikettanshola; 12.817km^2) 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).

3. Methodology

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 and not natality (Rosenberg et al., 1995). The present model is 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).

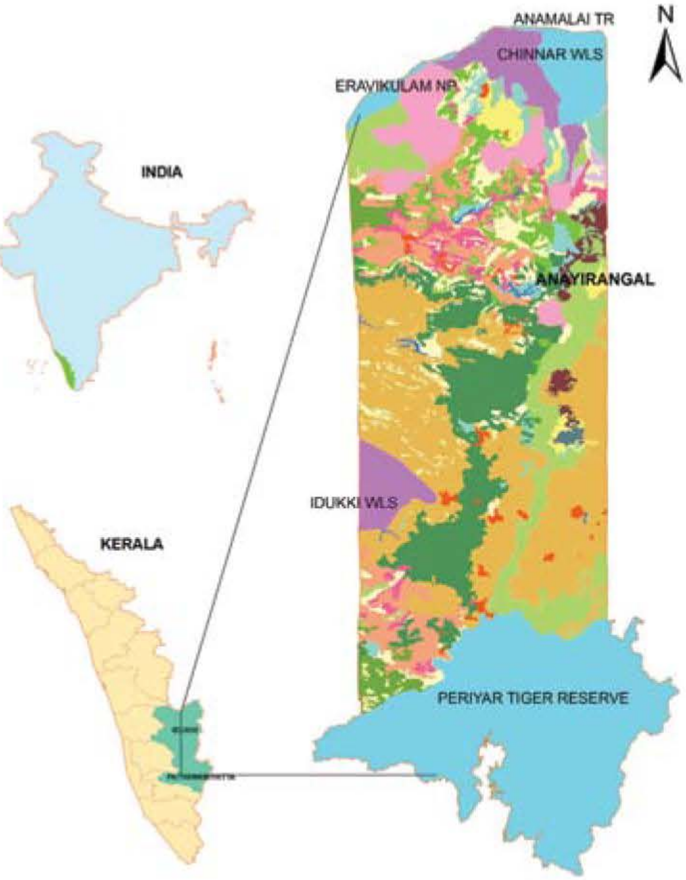

Figure 1: Study area location map on the LULC map of the study region

Chinnar Wildlife sanctuary, which is a part of Anamalai Elephant Reserve, is used as a source and Periyar Tiger Reserve, part of Periyar landscape which support a huge number of elephant population is used as a sink to run the corridor model. Vegetation type map at 1:50000 were prepared using three season LISS IV data of the year 2009-2010 by onscreen digital interpretation. To make distinct the cardamom plantations (an agriculture cash crop 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 3m). The obtained thematic class of cardamom plantation is 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. 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 eucalyptus, wattle and pine plantations. The grassland and open scrub have been grouped into vegetation class 2. The shola 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.

3.1 Human - Elephant Conflict

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. In each settlement, the total number of farmers who are 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 causalities 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 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 causalities in each settlement due to elephant were also estimated.

3.2 Habitat Preference Raster

To assess the habitat usage of elephants outside the protected areas, the elephant dung densities in six habitats were estimated by line transects method (Saunders et al., 1991 and Gascon et al., 1999). Elephant forage raster has been prepared by giving appropriate weightages based on Analytical Hierarchy Process (AHP) (Saaty, 2008) computed from percentage of elephant dung density in different foraging areas and waterbodies outside the Protected Areas (PAs). Euclidean distance raster of waterbodies and streams has been computed in order to get the minimum distance of elephants to permanent source of water. The same principle has also been used to generate protected area preference raster and the weighatges are given as per AHP based on the protection status computed as a function of minimum disturbance to elephant sighting (Table1). The Euclidean distance raster of water and protected area were added with the forage preference raster to generate a habitat preference raster in which maximum pixel values indicate the maximum preferred elephant habitat class.

3.3 Impedance Raster

The impedance raster, a function of anthropogenic and topographical disturbance to elephant movement is generated from the landscape elements such as road, settlements and slope. The settlements were classified into tribal colonies, tea estate colonies, rural village, medium town and large town; the weightages were given as per Saaty's AHP (2008) in the increasing order of disturbance with the assumption that forest dwellers and tribal colonies co-existing with wildlife are forcing least disturbance and the urbanized medium towns and large towns are 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. 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 and Road Impedance Raster was generated by converting feature to raster.

Table 1: Assigned weightages for different landscape elements

	Preference Layers	Weights assigned
Elephant forage Preference	**Vegetation Class 1** (Eucalyptus, Pine and Wattle Plantations)	55.05
	Vegetation Class 2 (Grassland and Open Scrub)	18.87
	Vegetation Class 3 (Shola Forest, Moist/ Dry Deciduous, Semi/ Evergreen Forest)	15.89
	Vegetation Class 4 Cardamom Plantation	9.09
	Vegetation Class 5 (Managed Ecosystem)	0.58
	Vegetation Class 6 (Tea Plantation)	0.52
PAs Preference	**Tiger Reserve** (Periyar Tiger Reserve)	9
	National Parks (Eravikulam and Shola National Parks)	9
	Wildlife Sanctuaries (Chinnar, Idukki, Kurinjimala)	7
	Reserve Forests (Anamudi, Palani, Theni, Kambam Valley, Nagarmapara)	5
	Impedance Layers	**Weights assigned**
Road	Village Road	5
	Rural Road	7
	State Highways	8
	National Highways	9
Settlements	Tribal Colonies and Tea Estate Colonies	5
	Village residential colonies	7
	Medium Town	8
	Large Town	9
Slope	0 to 30 degree	1
	30 degree and above	9

The major topographical barrier, slope was grouped in to two i.e. 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. Final impedance raster is generated by adding all the impedances.

3.4 Cost Raster and Corridor Generation

The preference raster is mathematically integrated to the impedance raster in order to generate cost surface raster in which each cell value is a function of elephant preference and disturbance to elephant movement (Gadgil and Homji, 1986, Nair, 1991, Daniels, 1992, Karanth, 1992, Prasad et al., 1998 and Venkatraman et al., 2002).

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. This cumulative cost distance path layer and the cost backlink layer computed from the destination will give the least cost path, the corridor which connects 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 (Figure 2). 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 to the generated corridor in order to assess its accuracy.

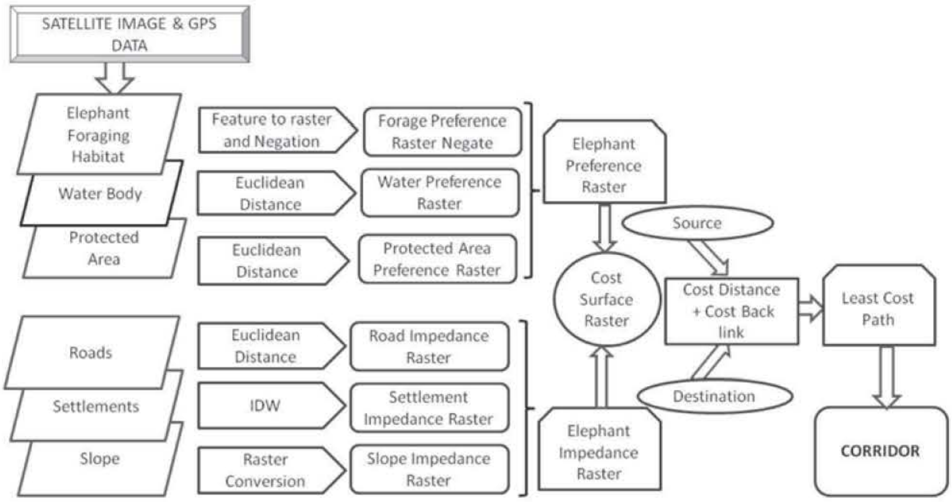

Figure 2: Model structure for generating potential elephant corridor

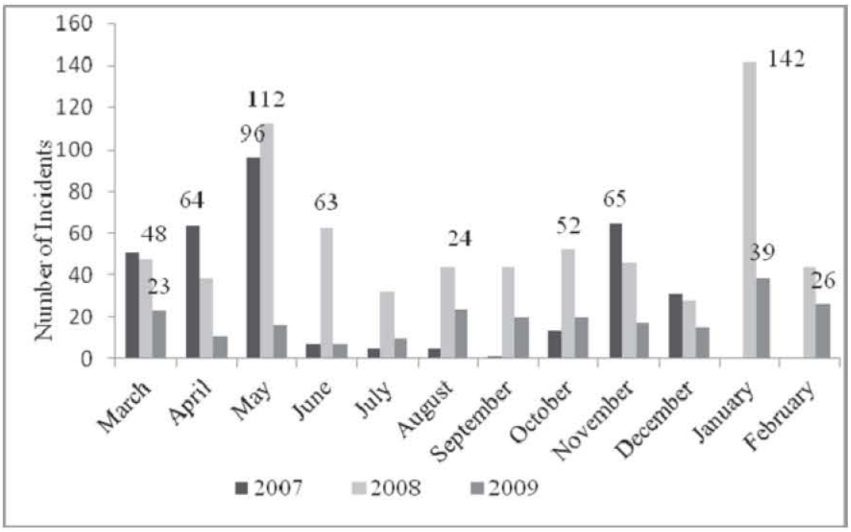

Figure 3: Raid Frequency Index: Elephant visit in settlements of Anayirangal per months

Table 2: Net economic loss due to human- elephant conflict- crop damage at Anayirangal

Year	2007	2008	2009
Net Loss for Cash Crops (Rs)	11,91,473	24,53,839	15,83,168
Net Loss for Food Crops (Rs.)	5,44,550	7,54,878	3,46,844
Grant Total (Rs)	17,36,023	32,08,717	19,30,012

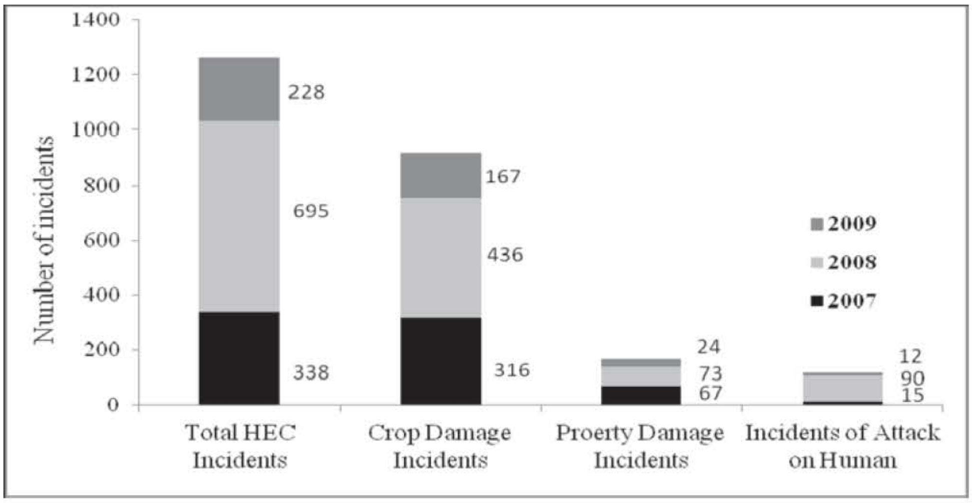

Figure 4: Human-elephant conflict incidents at Anayirangal

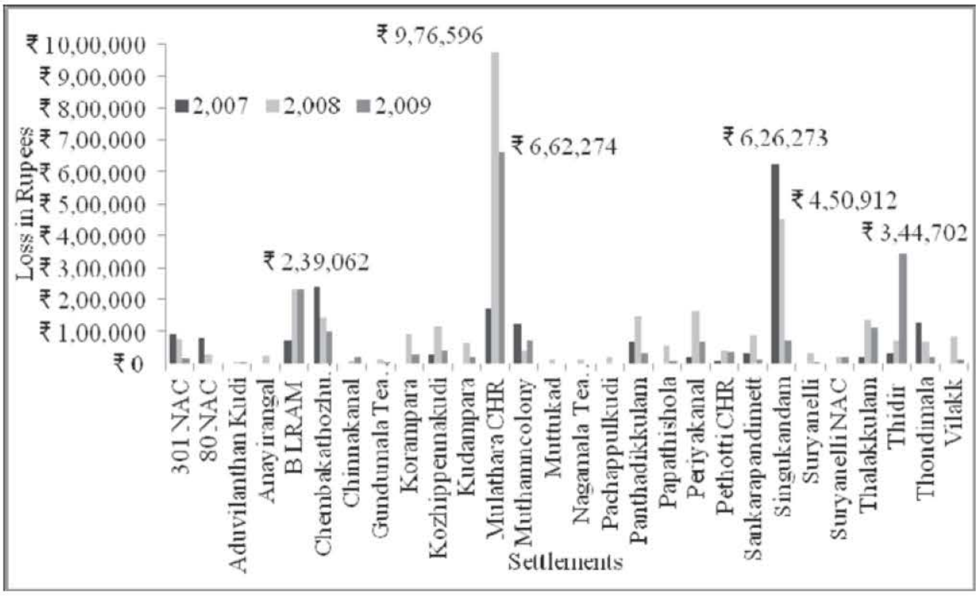

Figure 5: Net economic loss in various settlements due to human- elephant conflict- crop damage

4. Results

Frequency of elephant visits in the settlements shows that the raid frequency index is maximum (694) for the year 2008, followed by the year 2007 (338) and is minimum (228) for the year 2009 (Figure 3). Human-elephant conflict intensity is high in the year 2008 (Figure 4). Net economic loss for agriculture damage due to elephant crop raid is high for the year 2008 (Rs. 9, 76,596) and 2009 (Rs. 6, 62,274) at Mulathara, where cardamom is the main crop used for cultivation. But in 2007 the net economic loss is maximum (Rs. 6, 26,273) for the settlement Singukandam, where both cash crops and food crops are cultivated (Figure 5 and Table 2). The intensity of property damage is high in Singukandam for the year 2007.

Table 3: Human causalities at Anayiranagal due to HEC

Injuries	Cases	♂	♀	Tribal community								Non tribal community			
				Urali		Mannan		Hillpulaya		Muduvan		Keralite		Tamilian	
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
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	2	0	1	1	6	0
Minor	101	80	21	1	0	20	8	7	0	7	0	39	5	6	8

Table 4: Spatial summary of impedance level and preference of elephant habitat

Elephant Habitat	Impedance Level (%)			Preferred habitat (%)
	Low	Medium	High	
Vegetation Class 1	**58.14**	33.81	8.04	3.50
Vegetation Class 2	38.82	47.21	13.97	17.45
Vegetation Class 3	**44.87**	45.05	10.08	35.67
Vegetation Class 4	6.44	**76.51**	**17.04**	12.39
Vegetation Class 5	7.50	**76.62**	**15.88**	23.31
Vegetation Class 6	**46.49**	40.44	13.07	7.68

But in 2008 and 2009 the intensity of property damage had become high at 301 New Adivasi Colony, which is a newly established tribal settlement during the year 2007-2008. In the case of human causalities, no cases of death is reported in the year 2007, but minor injuries by elephant attack is observed high (11 cases) at Singukandam and two cases of severe injury is observed at Mulathara (Table 3). In 2008 three cases of human death and seven cases of severe injuries were reported by elephant attack. Two cases of death were reported at 301 New Adivasi Colony and one case at Thalakkulam. Out of 5 cases of death, 3 were males and 2 females of tribal community. The minor injuries is also high (25 cases) at 301 New Adivasi Colony followed by Singukandam (22 cases). In 2009 one human death occurred due to elephant attack at Mulathara. Two cases of severe injuries were also reported for the year 2009, one case each at Pethotti and Thalakkulam. Even though the case of minor injuries by elephant were observed to be less compared to that for the year 2007 and 2008, the settlements Singukandam and 301 NAC faces elephant attack incidents. The elephant raid frequency in the settlements of Anayirangal is high in the month of January followed by May and November (Figure 3).

The corridor has been generated using a combination of preference and impedance layers to elephant movement. 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 show that eucalyptus, pine and wattle plantations (vegetation class 1) have the maximum area (58.14%) under low impedances followed by tea plantation (46.49%). The vegetation class 3 with shola forest, deciduous and evergreen forest has 44.87% area under low impedance and grasslands have 38.82% area under low impedance. The analysis of the elephant dung pile density shows that land cover which had high impedance to elephant movement is settlements. The spatial summary also shows that the managed ecosystem (Vegetation class 5) especially with settlements has 15.88% area under high impedance. Cardamom plantation has 76.51% area falls under medium impedance and 17.04% area under high impedance. The managed ecosystems like agricultural areas and orchards showed moderate impedances (76.62%) to elephant movements. The elephant movement preference raster generated showed high preference around the protected areas and in grasslands and fuel wood plantations. The spatial summary of the elephant preference generated by the integration of preference with respect to forage, water, protected area and terrain indicate the vegetation class 3 with shola forest, deciduous forest and evergreen forest has maximum area (35.67%) under high preference. The managed ecosystems with homestead gardens and orchards adjacent to protected areas are having 23.31% area with high preference followed by the grassland and open scrub. The highly preferred elephant habitat, the fuel wood plantations have only 3.50% area under high preference as these habitats does not have any protection status (Table 4).

4.1 Evaluation of Elephant Corridor

The proposed elephant corridor passes through the rolling montane shola grasslands of Kurinjimala Wildlife Sanctuary, Anamudishola National Park, Mannavanshola, Pampadumshola National Park;

eucalyptus plantations of Chunduvarai, Mattuppatty and Devikulam; grasslands of Meesappulimala and Gundumala and shola forests of Silent Valley, Devimala and Sixty Acre shola of Chinnakanal and then the corridor reaches the Anayirangal valley, a stepping stone for elephant movement. All the 28 settlements at Anayirangal fall in elephant habitat. During 2007-2008 Kerala Government has assigned land for landless tribal people and five such settlements were established at Anayirangal. All the five settlements are in the middle of the elephant habitat. Out of five settlements, 80 New Adivasi Colony put solar power fence in the year 2008 around the settlement because of high human-elephant conflict that had occurred during the year 2007. This has shifted the conflict intensity to nearby settlements especially at 301 New Adivasi Colony, Chembakathozhukudi, Singukandam and Thidir. The eucalyptus and grasslands on the catchments of Anayirangal reservoir that has been assigned for the landless tribes falls along this track. From Anayirangal valley the corridors pass through the Cardamom Hill Reserves of Mulathara, Thondimala, Thalakkulam and move towards Mathikettanshola National Park. South of Mathikettanshola National Park is the rolling montane shola grasslands observed at Kudampara, Chathurangappara, Kottamalai, Ramakkalmedu and Chellarkovilmedu. The eastern slope of Western Ghats with deciduous forest and scrub jungle of Thevaram, Kombai and Kambam valley of Tamil Nadu also fall along this elephant track. The small evergreen forest patches near to the Kumali town bordering Periyar Tiger Reserve act as crucial link of the corridor, where the impedance due to the tunnel which was constructed as irrigation-cum-hydroelectric project of Tamil Nadu from Mullaperiyar Reservoir, is not making a hindrance to the elephant movement

5. Discussion

The highly fragmented and human transformed landscape between Chinnar Wildlife Sanctuary and Periyar Tiger Reserve is very crucial for elephant movement. Anayirangal area 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 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 during 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 this landscape and the behavior of habituated elephants of this landscape resulted high occurrence of human death 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 Munnar landscapes and remaining through the protected areas namely Kurinjimala Sanctuary, Anamudishola National Park, Mathikettanshola National Park and Theni Reserve Forest (Table 5, Figure 6). 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 narrow width of the corridor in places.

Table 5: Analysis of the identified elephant corridor

Vegetation Class in the corridor	Area		Inside Protected Areas		Outside Protected Areas	
	Proportion (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Vegetation Class 1	0.313	7.25	0.027	8.60	0.286	91.40
Vegetation Class 2	0.973	22.57	0.537	55.17	0.436	44.83
Vegetation class 3	2.183	50.67	1.875	85.90	0.308	14.10
Vegetation Class 4	0.171	3.97	0	0.00	0.171	100.00
Vegetation class 5	0.336	7.80	0.336	95.14	0.0172	4.86
Vegetation class 6	0.216	5.02	0	0.00	0.216	100.00
Settlements	0.018	0.42	0.001	3.45	0.018	96.55
Reservoir	0.094	2.20	0	0.00	0.0943	100.00
Total	4.304	100	2.776	65	1.546	35

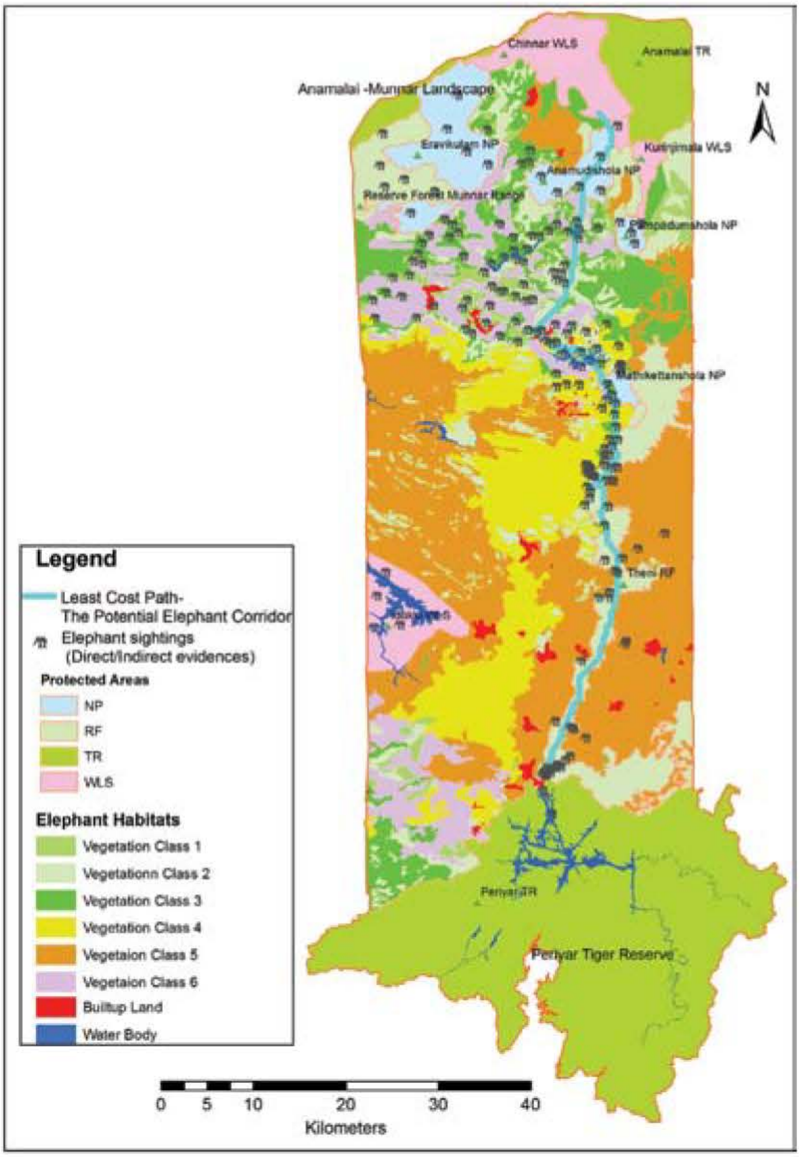

Figure 6: Potential elephant corridor between Anamalai-Munnar landscape and Periyar Tiger Reserve

In the present study the remnant natural vegetation patches is utilized for foraging and other requirements of the elephants during their migration. The width of the identified corridor joining the natural patches which will act as stepping stone has been proposed to be 50m. 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 matches quite accurately with the study by Menon et al., 2005. Vegetation class 1, which has got moderately high elephant dung density (640 dung piles per km²) 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 which appeared to provide cover and fodder for elephants. About 44.83% area of the grasslands and open scrub which contribute 22.6% area of the corridor are in the revenue land. In grassland the observed elephant dung pile density was 478 dung piles per km². Though Vegetation class 3 contributes a major portion of the corridor (50.67 %), around 14.1% of the area falls in the revenue land especially the shola forests. This indicates that corridor along with the remnant ecosystems of monatne shola grasslands and the stepping stones influences decision on the conservation action. The remnant shola forest, grasslands and eucalyptus plantations in the Munnar landscape acts as steeping 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 create 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 forest 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 create hindrance to elephant movement and leading high conflict with adjacent habitation.

The elephant dung pile density is observed as maximum (707 dung pile per km^2) in cardamom plantations. 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 windmill constructions in the crest of Western Ghats at Chathurangappara acts as hindrance to elephant movement between the 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 which connects the Periyar Tiger Reserve and the Reserve Forest of Theni 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 reserve 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 PAs thereby increasing the habitat available to elephants on the fringe areas of the Protected Areas (Menon et al., 2005).

6. 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 landscape through the highly fragmented and human transformed Munnar landscape unless 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-Mattuppetty, 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 50m 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 50m along the identified corridor will reduce and ensure further entry of elephants to the crop land of farmers. For long term management of human-elephant conflict, these areas have to convert gradually to natural vegetation and 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 Wildlife 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 acts 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.

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