Identifying Habitat Connectivity for Isolated Populations of Lion-Tailed Macaque (Macaca silenus) in Valparai Plateau, Western Ghats, India

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Identifying Habitat Connectivity for Isolated Populations of Lion-tailed Macaque (*Macaca silenus*) in Valparai Plateau, Western Ghats, India

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Abstract: The endangered and endemic lion-tailed macaques (*Macaca silenus*) of the rainforest fragments of Valparai plateau in the Western Ghats Hotspot (India) are facing serious threats to their survival due to anthropogenic pressures and habitat degradation. In this study, we identify potential wildlife corridors between the rainforest fragments and adjacent more extensive forest areas so as to connect isolated lion-tailed macaque populations. Satellite datasets were used to delineate the forest fragments and assess the conditions of the surrounding landscape. The corridors were selected on the basis of minimal impact on human settlements, agricultural areas and other infrastructure, as well as to enhance ecosystem services. The results show that a minimum area of 156 ha is required to connect three isolated lion-tailed macaque populations to the adjacent forest area. This includes 54 ha of seasonal stream beds (low human-use areas), 99 ha of cultivated area (medium human-use areas) and 3 ha of roads, settlements and built-up areas (high human-use areas). This methodology for identifying wildlife corridors in highly fragmented landscapes of the Western Ghats can also be applied to other human-dominated landscapes, including biodiversity hotspots.

Key Words: Habitat fragmentation, lion-tailed macaque, wildlife corridors, remote sensing, India.

Introduction

Habitat fragmentation is a serious concern in landscape ecology and conservation (Pimm and Raven 2000), influencing numerous ecological patterns and processes, and negatively affecting most taxonomic groups, including birds and mammals (Andrén 1994; Zuckerberg and Porter 2010), reptiles (Richard and Jean-Baptiste 2006), amphibians (Stuart *et al.* 2004), invertebrates (Leidner and Haddad 2011) and plants (Hobbs and Yates 2003). Studies show that the persistence of populations is lower in fragmented than in intact habitats (Tilman *et al.* 1994). Populations are susceptible to demographic extinction as well as environmental stress (Quinn and Hastings 1987). In addition, large-scale movements of species such as seasonal migration or range shifts in response to climate change may also be affected by habitat fragmentation (Soulé *et al*. 2004).

The Western Ghats is one of the eight major biodiversity hotspots (Myers *et al.* 2000). While less than 6% of India's landmass, more than 30% of all plant and vertebrate species of the Indian sub-continent are found there. The Western Ghats are also listed as one of the 200 globally most-important ecoregions (Olson and Dinerstein 1998). In spite of these striking statistics, biodiversity in the Western Ghats is threatened. Menon and Bawa (1997) estimated that forest cover in the Western Ghats declined by 40% from 1920 to 1990, resulting in a four-fold increase in the number of fragments and an 83% reduction in the size of the remaining forest patches. This is unsurprising given that this region has the highest human population density of any of the biodiversity hotspots (Cincotta *et al.* 2000; Shi *et al.* 2005). The Valparai plateau in the southern region of the Western Ghats has undergone extensive fragmentation from the early 1900's because of forest clearance for tea, coffee, cardamom and eucalyptus plantations, and the associated infrastructural development (Joseph *et al.* 2009). Isolated remnants of rainforest in the middle of these plantations are known for their rich biodiversity. They harbour many endemic and endangered species including, for example, murid rodents and shrews (eight species), amphibians (40 species) and reptiles (40 species) (Umapathy and Kumar 2000).

The lion-tailed macaque (*Macaca silenus*) is an endangered primate endemic to the rainforests in the southern part of the Western Ghats. It has a scattered distribution of 49 subpopulations across eight locations (Molur *et al.* 2003; Kumara and Singh 2004). The total number of mature

lion-tailed macaques is estimated to be less than 2,500, with no subpopulation of more than 250 individuals (Kumar *et al.* 2008). It has been estimated that the species will experience a population decline of 20% over the next 25 years (Kumar *et al.* 2008). The lion-tailed macaque is listed in Appendix I of CITES, and in Schedule I, Part I, of the Indian Wildlife (Protection) Act, 1972. The rainforest fragments in the Valparai plateau harbour subpopulations that are on the verge of extinction due to demographic and environmental stochasticity, diseases, natural catastrophes, and inbreeding depression (Umapathy and Kumar 2000; Singh *et al.* 2001, 2009; Hussain *et al.* 2013). Chapron *et al.* (2010) identified the preservation of the forests fragments of Valparai as one of the 100 top conservation priorities in Asia.

There are extensive studies on the ecology and behaviour of lion-tailed macaques in these rainforest fragments. Demographic studies have revealed reduced birth rates with correspondingly reduced numbers of immature individuals in the groups, an increase in the number of adult males, and considerable variation in group sizes and adult sex-ratios (Umapathy and Kumar 2000). Menon and Poirier (1996) pointed out that lion-tailed macaques in forest fragments spend more time ranging, and less time resting and feeding than is typical for groups in other regions. Forest-fragment size affects the demography, ranging patterns, feeding habits and reproductive rates of lion-tailed macaques (Kumar *et al.* 1995; Singh *et al.* 2001; Kumara and Singh, 2004). A recent study recommended the creation of dispersal corridors to facilitate male migration (Umapathi *et al.* 2011). Here we attempt to identify potential corridors between the fragments and the adjacent large forest area or nearby protected area.

Methods

Indian Remote Sensing Satellite data (IRS P6 LISS III and LISS IV) procured from the National Remote Sensing Centre was used to delineate the rainforest fragments in the Valparai plateau. LISS III images have a spatial resolution of 23.8 m, while for those of LISS IV it is 5.8 m. The LISS III data were geometrically corrected with respect to Enhanced Thematic Mapper (ETM+) satellite data based on 1st order polynomial regression between ground control points (RMSE<0.5 pixel) to compute the coefficients for two co-ordinate transformation equations, and registered to the UTM projection. Further to this, geometric correction of the LISS IV data was carried out with respect to LISS III data. The other data pre-processing techniques applied have been detailed elsewhere (Joseph *et al.* 2009, 2010, 2012). The rainforest fragments were delineated at a scale of 1: 10,000. Field surveys were conducted to find which isolated fragments harbored lion-tailed macaques. They were found in three, all owned by private enterprises in the Puthuthottam Estate, the Korangumudi Estate and the Tata Estate (hereafter the fragments are named with the name of the estate).

The following criteria were used in designing the corridors: 1) minimum impact on existing human settlements, agricultural areas, and infrastructure such as motorable tarred roads, tea factories, and other built up areas; 2) favorable logistics for afforestation; 3) the provision of ecosystem services to the area; and 4) maximizing potential for harnessing the natural capacity of the areas to revegetate.

Considering the above factors, we favored relatively intact, seasonal stream beds and their riparian zones for the construction of wildlife corridors, anticipating that the land-owners would perceive the advantages of the preservation and provision of additional ecosystem services such as improvement in ecohydrology, water purification, biodiversity conservation (specifically freshwater biodiversity), and enhancement of carbon stock. Afforestation along the banks of streams is less expensive compared with other areas in the landscape.

The seasonal streams that connect the rainforest fragments with the adjacent main forested land were delineated. A 50-m buffer was generated over the delineated corridors, assuming that a 100-m wide corridor would be sufficient for dispersal. A strip of 100 m also minimizes impingement by agricultural land. Settlements, built-up areas, and other forms of land use by humans were identified in the strip to identify the least used and disturbed seasonal streams to connect the fragments.

Results

Lion-tailed macaques were found in three isolated rainforest fragments. 1. Puthuthottam fragment (123 ha) has evergreen trees in its upper storey and coffee plantations in its lower storey. A major road connecting the towns of Pollachi and Valparai passes through this fragment. The Puthuthottam fragment is surrounded by tea plantations, and Valparai is less than a kilometer from the fragment. The existing lion-tailed macaque population is highly exposed to human presence. 2. Tata Finlay fragment (78 ha) consists of relatively undisturbed evergreen forest, surrounded by tea and coffee plantations. 3. Korangumudi fragment (238 ha) is connected to another rainforest fragment (Pannimedu fragment) through a scattered chain of trees, and appears as a single fragment in the satellite data of 5.8-m resolution. It is surrounded by Upper Sholayar Reservoir on one side and extensive stretches of tea plantations on the other. The vegetation is relatively undisturbed evergreen forest.

Wildlife corridors: Puthuthottam fragment

There are two seasonal streams connecting the Puthuthottam fragment to the main forest area, the Indira Gandhi Wildlife Sanctuary (Fig. 1). The area statistics of delineated corridors along the streams are given in Table 1. The total area required for the first corridor is 38.82 ha while the second is 24.89 ha. In the first corridor, the cultivated area contributed 21.09 ha and motorable tarred roads 0.49 ha. There were no settlements and built up areas. In the second corridor, these land use categories represented 12.09 ha, 0.71 ha and 0.43 ha, respectively.

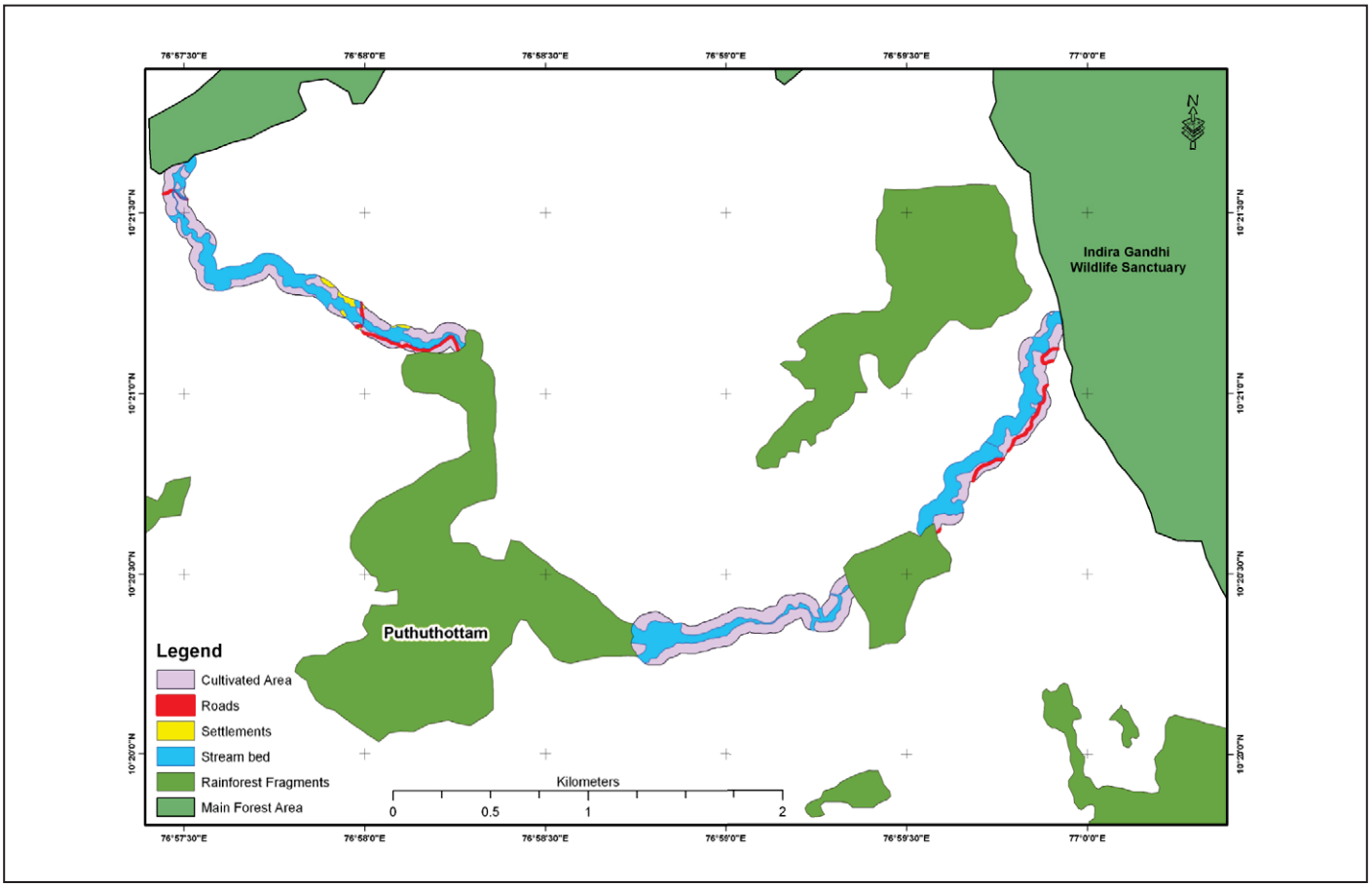

Figure 1. Potential wildlife corridors for the Puthuthottam rain forest fragment in the Valparai Plateau, Western Ghats, India.

Wildlife corridors: Tata Finlay fragment

A stream connects the Tata Finlay fragment with the Indira Gandhi Wildlife Sanctuary. The buffering and subsequent land-cover classification showed that an area of about 43.36 ha is required for the corridor, which includes 25.64 ha of cultivated land, 0.73 ha motorable roads, and 16.98 ha of stream bed (Table 2). There are no settlements or built-up areas in the assigned portion of the corridor (Fig. 2).

Wildlife corridors: Korangumudi Fragment

The Korangumudi fragment is almost in the center of the Valparai Plateau. A connection with the Indira Gandhi Wildlife sanctuary is not possible because of the Upper Sholayar Reservoir. The only way to connect this fragment with the main forest area is to link it with forest in the neighbouring state of Kerala. The area required for establishing this connection is 88.16 ha, which includes 61 ha of cultivated land, 0.51 ha of roads, 0.83 ha of settlements, and 25.82 ha of seasonal stream beds (see Fig. 3 and Table 3).

Table 1. Area required for establishing the wildlife corridors between the Puthuthottam rain forest fragment and the Indira Gandhi Wildlife Sanctuary in the Western Ghats, India.

No.	Land use	Corridor 1 (ha)	Corridor 2 (ha)
1	Cultivated land	21.09	12.03
2	Motorable asphalt roads	0.49	0.43
3	Settlements and built-up areas	0.00	0.71
4	Seasonal streambed	17.24	11.72
	Total	38.82	24.89

Discussion

Lion-tailed macaques are the most threatened of the primates endemic to the Western Ghats (Easa *et al.* 1997); habitat fragmentation is the primary reason (Singh et al. 2009). Many studies carried out in the Valparai Plateau have highlighted that habitat fragmentation and the subsequent increase in human disturbance could lead to the local extinction of the species (Umapathy and Kumar 2000; Kumara and Singh 2004; Kumar *et al.* 2008; Hussain *et al.* 2013). Two practical solutions to avoid such biological insults are to connect the fragments through corridors or translocate the primates into other contiguous areas. The success rate of the latter method is found to be low (Marsh 2003), and therefore less preferred. We therefore explored the possibility of establishing conservation corridors between fragments and adjacent larger forest areas.

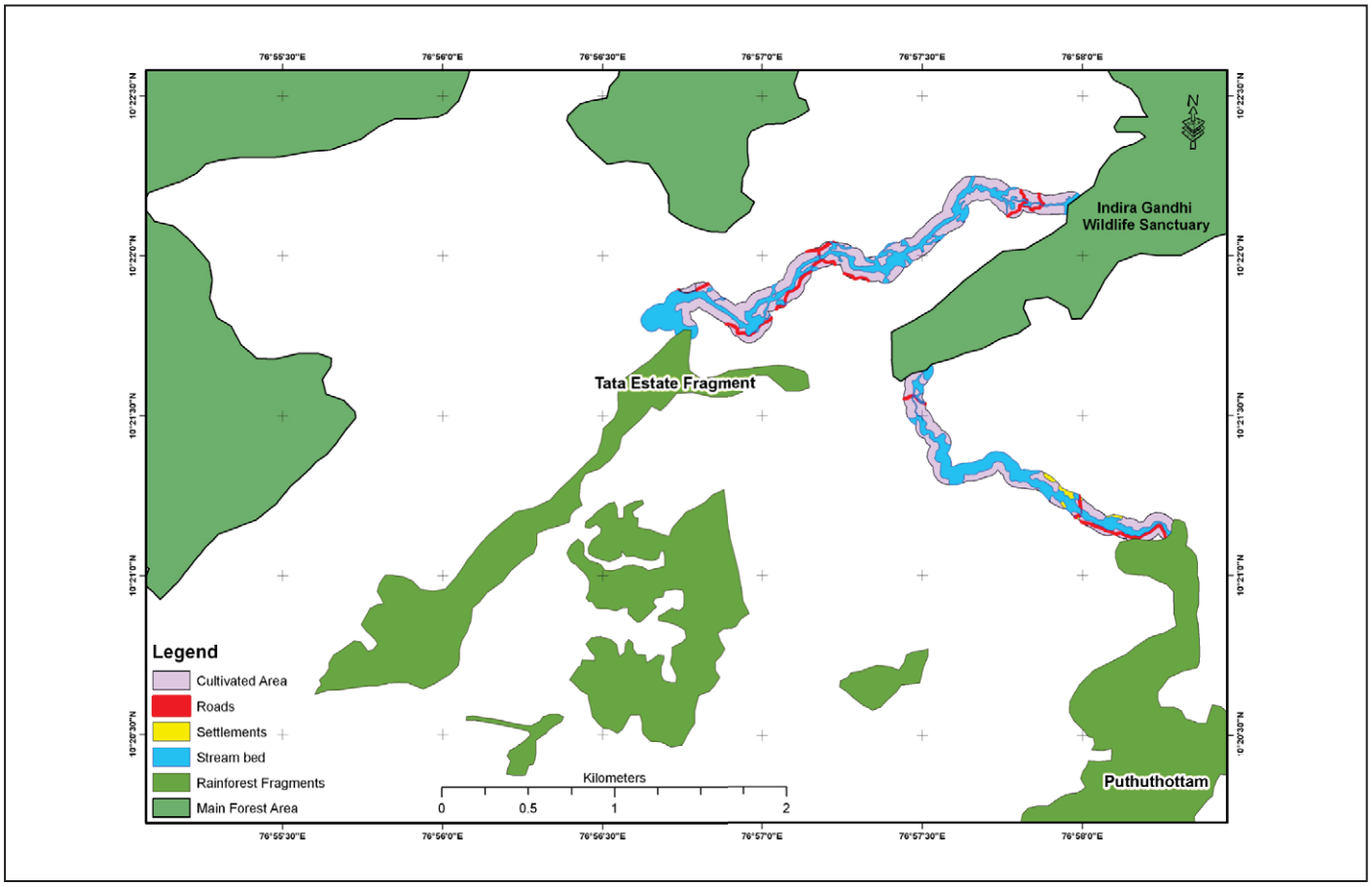

Figure 2. Potential wildlife corridors for the Tata Finlay Estate rainforest fragment in the Valparai Plateau, Western Ghats, India.

The next step we considered was to understand ways and means to acquire the land if we propose to establish a conservation corridor in private entities. The landscape is occupied mainly by plantations of tea, coffee, and cardamom, and the associated infrastructure (factories, settlements, motorable and muddy roads, community halls, religious places and small townships). Sharing land seems a challenging task in such areas, as seen from the recent increase in land disputes across India (Saikia 2011). Moreover, the overall terrain is highly undulating; elevations range from 550 to 1800 m, with intermittent steep slopes. We decided, therefore, to harness the utility of geological structures, and relatively less human-used areas such as the seasonal stream beds.

Our argument to use seasonal stream beds is valid in many ways. First of all there is no cultivation in the seasonal stream beds and their riparian zones, as they are saturated or filled with water at least half of the year. Revegetation of the riparian zones will enhance the water-holding capacity of the soil, and thereby increase water availability for agriculture. The riparian zones also act as water purifiers; the water is contaminated by the extensive use of pesticides and fertilizers in the plantations. Revegetation of riparian zones and the provision of better-quality water will further enhance the local biodiversity of the area, especially that of freshwater. The streams are part of the Chalakudy River basin, which harbors an exceptional diversity of fishes, including several endemic and threatened species (Raghavan *et al.* 2008). Biophysically, the revegetation and afforestation programs could contribute to climate change mitigation by enhancing the carbon stock of the area (Joseph *et al.* 2012).

Table 2. Area required for establishing a wildlife corridor between the Tata Finlay rain forest fragment and the Indira Gandhi Wildlife Sanctuary, Western Ghats, India.

No.	Land use	Corridor (ha)
1	Cultivated land	25.64
2	Motorable asphalt roads	0.73
3	Settlements and built-up areas	0.00
4	Seasonal streambed	16.98
	Total	43.36

Though there are several such direct and indirect benefits, we have limited our proposal for revegetation to 50 m either side of the stream beds, in order to minimize pressure on cultivated land and other areas occupied by people. A marginally good portion of the land is available from the stream bed itself (47% in the case of Puthuthottam, 39% for Tata Finlay and 29% for Korangumudi). We have not carried

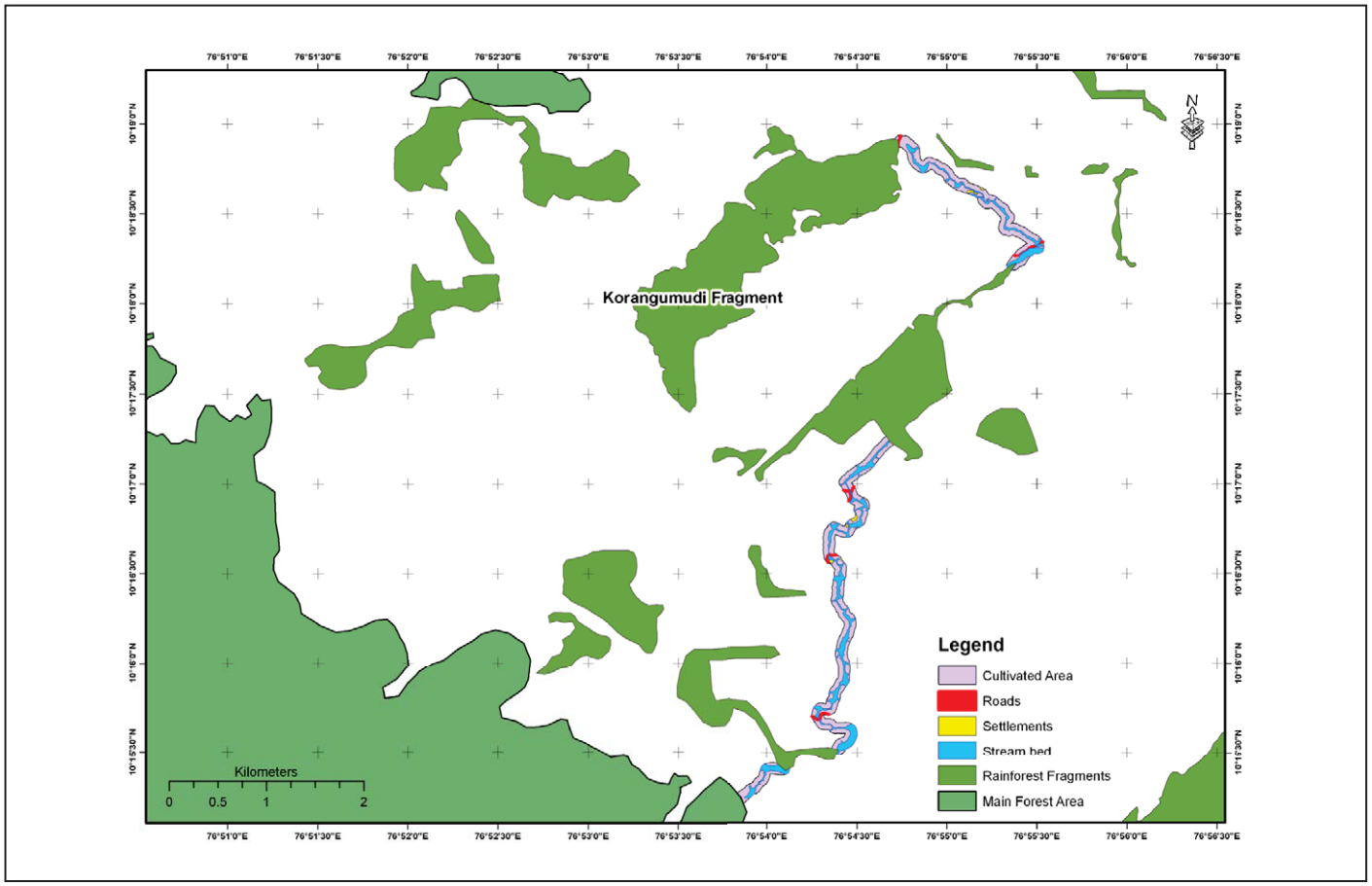

Figure 3. Potential wildlife corridors for Korangumudi rain forest fragment in the Valparai Plateau, Western Ghats, India.

out any simulation study to assess whether a 100-m stretch would be enough for lion-tailed macaques to disperse through these corridors. Our previous field experience, however, and the literature (Kumar *et al.* 2001; Joseph *et al.* 2010) reveal that lion-tailed macaque populations have undergone drastic behavioral changes in these fragments, and are not shy to human presence, unlike those observed in protected areas.

With respect to addressing the concerns of the various stakeholders, our studies showed that all the three fragments, especially Puthuthottam fragment, support the local communities existing around them in terms of provisioning firewood and other minor forest products (Kanagavel *et al.* 2013). Our previous study also indicated that the key stakeholders (plantation owners) may be unwilling to participate in legally-binding initiatives such as a Conservation Reserve on their leased lands, due to a perceived devolvement of power over their leased land that could curb further land use. Plantation enterprises such as Tata and Parry Agro, however, have already collaborated with local NGO's to restore disturbed rainforest fragments (<http://www.ncf-india.org/restoration>). Hence informal, non-binding collaboration may be the way forward in this landscape, especially as some of the land owners are interested in supporting conservation. Further work is required to identify funding opportunities in the context of recent financial mechanisms such as REDD+ (Reducing Emissions from Deforestation and Degradation) (Estrada and Joseph, 2012).

Table 3. Area required for establishing a wildlife corridor between the Korangumudi rain forest fragment with the main forest area in Kerala, Western Ghats, India.

No.	Land use	Corridor (ha)
1	Cultivated land	61.00
2	Motorable asphalt roads	0.51
3	Settlements and built-up areas	0.83
4	Seasonal streambed	25.82
	Total	88.16

The present study has wider implications for global conservation efforts. Habitat fragmentation is a serious issue, happening on a day-to-day basis for numerous reasons with varying impacts from a minor change in habitat quality to local extinction. Our study used a simple methodology for corridor construction after considering the biophysical and socio-economic conditions of the landscape. The scope of the study was limited to geospatial analysis only as there was extensive information available on the ecology, behavior, distribution, and population size and structure of the lion-tailed

macaque groups in these forest fragments (Menon and Poirier 1996; Umapathy and Kumar 2000; Kumar *et al.* 2001; Singh *et al.* 2001, 2002, 2009; Umapathy *et al.* 2011; Hussain *et al.* 2013). We therefore project the present study as a model to highlight the implementation of simple conservation practices with minimal impact on existing conditions and the livelihood profiles of local communities.

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